
SOCIO-ECONOMIC IMPACTS OF ROAD DEFICIENCY

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EXECUTIVE SUMMARY

BACKGROUND AND APPROACH

The Legatus Group is the trading name of the Central Local Government Region of South Australia (SA), established under the Local Government Act. The Region covers the area from north of metropolitan Adelaide to the Flinders Ranges, including 15 member Councils and covering an area of 42,262 km².

The current Road Deficiency Plan outlines over \$81 million in upgrades required, which member Councils have included in their respective forward works programs pending availability of appropriate funding. A further \$22 million in upgrades are identified as required but not currently included in Council forward works plans. Thereby, even without consideration of any new/ expansion works, Councils will require at least \$103 million in road upgrades over the next five to ten years. Currently the 15 Councils (in aggregate) are allocated approximately \$2.5 to \$3 million per annum via the Special Local Roads Program, which is the main source of funding for these projects. While there are also other funding programs, these other programs are often required to fund other capital works projects. The Special Local Roads Program typically covers two-thirds of the cost of projects with the rest funded by Council, with around \$4 million per annum currently invested in regional roads across the 15 Councils (\$40 million over 10 years), leaving a shortfall of around \$63 million over the next decade.

AEC Group Pty Ltd (AEC) has been engaged to develop this report assessing (qualitatively and quantitatively, where possible) the economic, social and environmental impacts/ costs from not being able to upgrade major roads to a fit for purpose standard due to insufficient funding. This report is to be used to support advocacy efforts of the Legatus Group and its member Councils for securing required funding.

KEY FINDINGS

Research of the economic, social and environmental impacts of insufficient investment in road infrastructure suggests a strong link between a lack of infrastructure investment and costs to users, the local community, businesses and the environment. This assessment found that a deterioration in road quality, as a result of insufficient maintenance investment, would result in increased costs particularly in terms of:

- **Increased vehicle operating costs:** The degree of roughness of the surface of the road from degradation of the road surface, in conjunction with others, can result in additional costs to road users.
- **Travel time costs:** The travel time costs associated with business-related and commuter travel, freight transport and efficiencies and private vehicle travel are all impacted by degradation of the road surface.
- **Risk of accidents and crashes:** Most accidents on Australian roads are caused by driver based contributing factors, however, a number of defects in road surface can contribute towards increased risk of road accidents.
- **Impact to Council:** Insufficient investment in the maintenance of road infrastructure is likely to result in further deterioration of the road surface and higher future costs of maintenance.
- **Residual asset values:** Degradation of the road surface will result in a lower residual value (benefit) at the end of the cost benefit analysis assessment period, due to an increased rate of depreciation.
- **Access to services:** The impact of vibration on service delivery and the need for emergency vehicles to slow their speeds on local roads can impact on access to emergency services for local residents.
- **Air Pollution:** The degree to which air pollution is dispersed can be influenced by road-specific factors such as congestion, roughness and the presence of obstructions.
- **Green House Gas emissions:** Vehicle fuel consumption and emissions will be impacted by the surface quality of the road, particularly roughness.

Of the above factors, quantification of the impact of a deterioration in road surface was able to be quantified for vehicle operating costs, travel time costs, costs of accidents, air pollution and greenhouse gas emissions. A hypothetical example has been used to demonstrate the impact of insufficient road maintenance investment.

Demonstrative Example

A number of key data points are required to undertake a quantitative assessment of the impact of insufficient road maintenance investment, including traffic counts (annual volumes by vehicle types), and measures of roughness and skid resistance. At the time of writing this information was unavailable and, hence, throughout this document, a hypothetical example has been used to demonstrate the potential impact of insufficient investment and funding in maintaining road infrastructure.

For the purposes of this assessment, it is assumed that the road has the following qualities:

- Is approximately 1km in length.
- Has a speed limit of 60km per hour.
- Is described as a MRS 10 Sealed road of 7.01 to 7.6 metre width.
- Experiences a daily traffic count of 500 vehicles, of which:
 - 100 are heavy vehicles (e.g., 5-axle articulated trucks).
 - 400 are light vehicles (e.g., medium sized cars), 50% of these vehicles are on business-related travel.
- Insufficient funding of the road has resulted in an increase in the roughness of the road, from an International Roughness Index (IRI) of 2 to an IRI of 4.
- Insufficient funding of the road has resulted in a reduction in the skid resistance of the road, from a Skid Number (SN) of 60 to a SN of 40.

Findings

Quantification of the costs associated with a road deterioration was conducted for the following costs:

- Additional vehicle operating costs: \$6,182 per annum.
- Additional travel time costs: \$14,242 per annum.
- Additional cost of road accidents and crashes: \$9,384 per annum.
- Additional cost of air pollution: \$67 per annum.
- Additional cost of greenhouse gases: \$1,721 per annum.

The total impact is estimated at a cost of \$31,596 per annum per kilometre.

For comparison, an estimated cost of road maintenance (to maintain roads in a good condition) has been developed assuming an annual vehicle maintenance cost of 4.5 cents per vehicle kilometres travelled by cars and a cost of 16.78 cents per vehicle kilometres travelled by 5 axle articulated trucks (Transport for New South Wales, 2020). This resulted in an estimated annual maintenance cost of the road of \$12,760.

This suggests a significant cost saving associated with maintenance of road infrastructure compared to the associated costs of insufficient road maintenance, with the example above indicating under the road conditions and traffic volumes assumed, the annual cost of the road's condition deteriorating from an IRI of 2 to an IRI of 4 would be approximately 2.5 times the cost of maintaining the road to a good condition.

RECOMMENDATIONS

Future assessment of the cost of insufficient investment in road infrastructure maintenance for the Legatus region is likely to be focused on the quantification of the full cost associated with the estimated \$63 million shortfall in investment over the next decade.

Investigation into and collation of a number of key datapoints for the region will be required to facilitate such an assessment. In particular, annual traffic counts by vehicle type, IRI and SN estimates for local roads are identified as prominent data gaps. At the time of writing, quotes for obtaining IRI and SN information for key roads in the

Legatus region are being investigated by Legatus officers. It is expected traffic counts data will be obtained from each of the Councils within the region.

An assessment of the total cost of insufficient investment in road infrastructure in the Legatus region would require investigation into local IRI and SN levels and estimation of the potential lift in IRI/ reduction in SN for each road as a result of deferred or insufficient road maintenance investment.

Most commonly, cost benefit analysis is conducted on a project-by-project basis, rather than across large geographical areas. A selection of key roads known to be problem zones within the region could be identified and analysed individually. These assessments would enable the quantification of a baseline (a scenario in which infrastructure maintenance investment is sufficient over the assessment period, and the quality of the road is maintained) and a scenario of insufficient road infrastructure investment (in which the quality of the road deteriorates over time) which can be compared. Such an assessment would limit the scope and scale of the required data gathering exercise, whilst providing proof of concept case studies for other roads in the region. Development of a cost-benefit analysis for each identified case study would be estimated to cost approximately \$10,000.

Contextual information regarding social impacts or perceptions of the state (or future state) of road infrastructure in the region could be collected (via a community and business survey) to develop a more comprehensive understanding of costs unable to be quantified.

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1. INTRODUCTION

1.1 BACKGROUND

The Legatus Group is the trading name of the Central Local Government Region of South Australia (SA), established under the Local Government Act. The Region covers the area from north of metropolitan Adelaide to the Flinders Ranges, including the Adelaide Plains, Barossa Valley, Clare Valley, Southern Flinders and Yorke Peninsula, covering an area of 42,262 km². There are 15 member Councils of Legatus Group: Adelaide Plains, Barossa, Barunga West, Clare and Gilbert Valleys, Copper Coast, Flinders Ranges, Goyder, Light, Mount Remarkable, Northern Areas, Orroroo-Carrieton, Peterborough, Port Pirie, Wakefield and Yorke Peninsula.

The Legatus Group has developed a Regional Transport Plan to 2030 outlining the regional transport needs and priorities across the 15 member Councils of Legatus Group over the next decade. This includes an outline of specific roads and routes considered to be “deficient” and anticipated to need investment over the period.

The current Road Deficiency Plan outlines over \$81 million in upgrades required, which member Councils have included in their respective forward works programs pending availability of appropriate funding. A further \$22 million in upgrades are identified as required but not currently included in Council forward works plans. Thereby, even without consideration of any new/ expansion works, Council’s will require at least \$103 million in road upgrades over the next five to ten years. Currently the 15 Councils (in aggregate) are allocated approximately \$2.5 to \$3 million per annum via the Special Local Roads Program, which is the main source of funding for these projects. While there are also other funding programs, these other programs are often required to fund other capital works projects. The Special Local Roads Program typically covers two-thirds of the cost of projects with the rest funded by Council, with around \$4 million per annum currently invested in regional roads across the 15 Councils (\$40 million over 10 years), leaving a shortfall of around \$63 million over the next decade.

Without securing this additional funding, either the needed road upgrades will not occur (leading to increased road degradation and deficiencies, with associated economic, social and environmental costs) or funds will need to be diverted from other important capital works or Council service funding (which would result in other adverse economic, social and environmental outcomes for the local community).

The 15 member councils of the Legatus Group are seeking to gain a better understanding of the impacts to their communities, businesses and industry through not addressing the major road deficiencies of the roads to assist with both advocacy and funding considerations.

1.2 PURPOSE OF THIS REPORT

AEC Group Pty Ltd (AEC) has been engaged to develop this report assessing (qualitatively and quantitatively, where possible) the economic, social and environmental impacts/ costs from not being able to upgrade major roads to a fit for purpose standard due to insufficient funding. This report is to be used to support advocacy efforts of the Legatus Group and its member Councils for securing required funding.

This report does not attempt to value the specific economic costs from insufficient funding to upgrade some or all of the roads identified in the current Road Deficiency Plan. To undertake such an analysis would require significant levels of detail regarding existing and future usage, road conditions/ degradation rates, and the marginal implication of degradation on a range of factors. This level of detailed analysis was not deemed possible within the budget and timeframes for this study.

Rather, this report provides a more generalised understanding of the different types of economic, social and environmental impacts that may be expected from poorly maintained roads (relative to well maintained roads) as well as information to assist in quantifying and valuing these impacts in future (where possible) for any specific projects that may be proposed by the Legatus Group and its member Councils for future funding. The information presented is based on case studies, benchmarks and evaluation standards/ guidelines for road infrastructure assessment.

1.3 APPROACH

Desktop research and review of assessments of road infrastructure has been used to identify the range of economic, social and environmental impacts that may typically be experienced as a result of insufficient investment and funding in maintaining road infrastructure. Relevant approaches for quantifying/ valuing impacts for specific projects are also outlined where appropriate.

The remainder of this report is structured as follows:

- Chapter 2: Examines the potential economic impacts arising from insufficient investment in maintaining roads.
- Chapter 3: Examines the potential social impacts arising from insufficient investment in maintaining roads.
- Chapter 4: Examines the potential environmental impacts arising from insufficient investment in maintaining roads.

Demonstrative Example

A number of key data points are required to undertake a quantitative assessment of the impact of insufficient road maintenance investment, including traffic counts (annual volumes by vehicle types), and measures of roughness and skid resistance. At the time of writing this information was unavailable and, hence, throughout this document, a hypothetical example has been used to demonstrate the potential impact of insufficient investment and funding in maintaining road infrastructure.

Wherever possible in this document, the impact of the deterioration of the road surface and quality has been quantified through this example.

For the purposes of this assessment, it is assumed that the road has the following qualities:

- Is approximately 1km in length.
- Has a speed limit of 60km per hour.
- Is described as a MRS 10 Sealed road of 7.01 to 7.6 metre width.
- Experiences a daily traffic count of 500 vehicles, of which:
 - 100 are heavy vehicles (e.g., 5-axle articulated trucks).
 - 400 are light vehicles (e.g., medium sized cars), 50% of these vehicles are on business-related travel.
- Insufficient funding of the road has resulted in an increase in the roughness of the road, from an International Roughness Index (IRI) of 2 to an IRI of 4.
- Insufficient funding of the road has resulted in a reduction in the skid resistance of the road, from a Skid Number (SN) of 60 to a SN of 40.

2. ECONOMIC IMPACTS

This chapter outlines the likely economic impacts associated with the maintenance of roads.

2.1 IMPACTS TO USERS

2.1.1 Vehicle Operating and Fuel Costs

Description of Impact

Vehicle operating costs (VOC) are the ongoing costs incurred through the ownership of cars and other vehicles. Commonly cited VOCs include fuel, oil, tyres, vehicle maintenance and repair costs and vehicle depreciation (Transport and Main Roads, 2011). VOCs will vary between vehicle types, with higher costs generally incurred by larger vehicles.

How Degradation of the Road Surface can Contribute to this Impact

A number of factors contribute to the operating costs of a vehicle (Booz Allen & Hamilton, 1999; Litman 2009; Polzin, Chu and Raman, 2008), including:

- **Size and type of the vehicle:** Larger vehicles (e.g., trucks) tend to record higher operating costs than smaller vehicles.
- **Vehicle speeds:** Considered to be the most dominant factor impacting on vehicle operating costs, costs typically decrease with increasing speed to a certain point, and then begin to increase with increasing speed thereafter.
- **Speed changes:** Changes in speed can result in higher incurred vehicle operating costs.
- **Gradient:** Positive grades (uphill) are more strenuous for vehicle engines and result in greater fuel consumption. Conversely, negative grades (downhill) result in lower levels of fuel consumption but will increase wear on brakes.
- **Curvature:** Increased curvature of the road results in additional wear on vehicle's tyres and fuel consumption.
- **Road surface:** Rough road surfaces result in lower speeds, greater fuel consumption, increased wear on tires and increased maintenance costs.

The relationship between roughness of the road and the additional cost of maintenance is considered to be linear. The roughness of a road surface can be measured through the use of the International Roughness Index (IRI), a standardised measurement generally reported in either metres per kilometre (m/km) or millimetres per metre (mm/m). A lower score correlates with a smoother surface, as outlined in the following table. In general, Australian VOC measurement guidelines are based on an IRI of 2.0 (ATAP, 2016). A source of IRI estimates for most Australian roads may be accessed through a subscription from HERE¹ or, can be developed by engineers for each road in question.

Table 2.1. Speed-related IRI Thresholds at Different Speeds

Ride Quality Level	IRI Thresholds at Different Speeds (m/km)					
	20	40	60	80	100	120
Very Good	<5.72	<2.86	<1.90	<1.43	<1.14	<0.95
Good	5.72-8.99	2.86-4.49	1.90-2.99	1.43-2.24	1.14-1.79	0.95-1.49
Fair	9.00-11.39	4.50-5.69	3.00-3.79	2.25-2.84	1.80-2.27	1.50-1.89
Mediocre	11.40-16.16	5.70-8.08	3.80-5.40	2.85-4.05	2.28-3.24	1.90-2.70
Poor	>16.16	>8.08	>5.40	>4.05	>3.24	>2.70

Source: Chen et al. (2020)

¹ <https://www.here.com/>

In keeping with the different cost structures for different vehicle types, the impact of roughness of the road on VOC differs between vehicle types also. For example, for articulated trucks versus medium cars, as the IRI increases from 2.0 to 4.0, the VOC would be expected to increase as follows (Austroads, 2018):

- From 112 cents per vehicle km to 130 cents per vehicle km for a 6-axle articulated truck (i.e., 18 cents per vehicle km)
- From 28 cents per vehicle km to 30 cents per vehicle km for a medium car (i.e., 2 cents per vehicle km).

Measurement

Measurement of estimated VOC is based on km travelled by vehicle types. In a cost benefit analysis, this would involve:

- Estimating the total km travelled (i.e., vehicle km) by vehicle types
- Applying a cost estimate to the resulting number of vehicle km by vehicle type to ascertain the total Base VOC.
- Applying a degree of lift to the Base VOC based on the IRI of the road.

An approach for each of these stages is outlined below.

Step 1: Estimate Total Vehicle Km by Vehicle Type

Estimating the total vehicle km by vehicle type is conducted using traffic count estimates (by vehicle type) and length of road estimates.

Traffic counts data, by vehicle type, can be collated from Councils or State Government agencies and applied to the length of the road (in km), to understand the total vehicle km travelled per annum on each road. Traffic counts may be held constant over the analysis timeframe, if projected traffic counts are not available.

Step 2: Estimate Base VOC

Estimates of Base VOC (i.e., excluding road roughness and conditions) are based on applying detailed cost variables to the estimated vehicle km. The most generally accepted cost variables applied in these instances are outlined below. The outcomes of these estimates can be aggregated to the total Base VOC.

Table 2.2. Vehicle Repairs and Maintenance Costs

Vehicle Type	Vehicle Repair and Maintenance c/km
Cars	
Small	6.35
Medium	7.39
Large	5.94
Average	6.56
Utility Vehicles	
Courier Van Utility	6.98
4WD Mid Size Petrol	8.54
Rigid Trucks	
Light Commercial (2 axle, 4 tyre)	6.35
Medium (2 axle, 6 tyre)	13.64
Heavy (3 axle)	14.58
Bus	
Heavy Bus	13.64
Articulated trucks	
4 axle	19.89

Vehicle Type	Vehicle Repair and Maintenance c/km
5 axle	23.12
6 axle	23.74
Combination Vehicles	
Rigid (3 axle) + dog trailer (5 axle)	26.24
B-Double	27.59
Twin steer (4 axle) + dog trailer (5 axle)	28.32
A-Double	29.47
B-Triple combination	36.76
A B combination	36.13
A-Triple	37.80
Double B-Double combination	40.82

Source: ATAP (2016)

Table 2.3. Fuel Consumption Assumptions, South Australia (2020)

Vehicle Type	Consumption (L/km)
Passenger vehicles	0.11
Light commercial vehicles	0.29
Rigid trucks	0.55
Heavy Vehicles	0.44

Source: ABS (2020)

Fuel prices should be updated for each assessment, based on local prices. Ideally, where a time series of petrol price data is available, this information should be used, otherwise a daily spot price can be inserted (as per the below example). In this process, the GST and fuel excise rates should be removed from the cost:

- GST can be estimated by multiplying the raw petrol price by 10 and dividing by 110 (e.g., $((111.90 \text{ c/l} \times 10)/110) = 10.17 \text{ c/l}$)
- Fuel excise rates can be estimated based on data from the Australian Taxation Office. At the time of writing this excise was 42.7 c/l.
- If a state subsidy is in place, this should be removed from the final net tax estimate. The below example assumes no subsidies are in place.

In this example, the total net tax estimate is 52.87 c/l, resulting in an average petrol price for use in the assessment of 59.03 c/l for both unleaded and diesel.

Table 2.4. Fuel Prices^(a), cents per litre, Assumptions

Resource Type	Retail Petrol Price	GST	Excise Rate	Subsidy	Net Tax ^(b)	Average Resource Price
Unleaded	111.90	10.17	42.70	0	52.87	59.03
Diesel	111.90	10.17	42.70	0	52.87	59.03

Notes: (a) Based on petrol prices at Port Wakefield on 1 February 2021. (b) Net Taxes = (GST + Excise Rate - Subsidy).
Source: Petrolspy (2020), ATO (2020)

Step 3: Estimate VOC Associated with Road Roughness

Once the Base VOC has been estimated (on a cents per kilometre basis), a treatment can be undertaken to lift this estimate based on the degree of road roughness. This is done through the application of the below equation.

$$VOC = BaseVOC * (k_1 + \frac{k_2}{V} + k_3 * V^2 + k_4 * IRI + k_5 * IRI^2 + k_6 * GVM)$$

Where:

VOC = vehicle operating costs in Cents/km

BaseVOC = lowest VOC point in curve from the Australianised version of the World Bank's Highway Development and Management Model (HDM-4)

V = Vehicle speed in km/h

IRI = International Roughness Index in m/km

GVM = Gross vehicle mass in tonnes

k₁ to k₆ = model coefficients.

Model coefficients associated with this estimation model will vary depending on road width, gradient (RF) and curvature of the road. They include estimated fuel costs. A set of example coefficients are provided in the table below, with more detailed coefficient tables provided in an Excel Appendix.

Table 2.5. Example Model Variable Inputs, Cents per Km, (Refer to Excel File for More Details)

Vehicle Type	Base VOC (cents/km)	K ₁	K ₂	K ₃	K ₄	K ₅	K ₆
Small Car	22.54934	0.68257	8.92663	0.00002	0.02925	0.00081	0.04068
Medium Car	29.76668	0.68913	10.27355	0.00001	0.02714	0.00095	0.03045
Large Car	38.77133	0.71454	10.81935	0.00001	0.02398	0.00103	0.02068
Courier Van-Utility	33.47361	0.67199	8.08566	0.00002	0.03960	0.00249	0.02385
4WD Mid-Size Petrol	36.95751	0.70409	7.16007	0.00001	0.03458	0.00210	0.01630
Light Rigid	46.55381	0.69041	5.57112	0.00002	0.04239	0.00188	0.01311
Medium Rigid	53.84039	0.64653	8.31013	0.00002	0.03753	0.00176	0.01092
Heavy Rigid	67.00040	0.45218	10.40255	0.00003	0.08201	0.00023	0.00659
Heavy Bus	104.32046	0.59927	9.03981	0.00001	0.06603	0.00105	0.00444
Artic 4 Axle	90.03155	0.44366	9.16907	0.00004	0.08746	0.00026	0.00645
Artic 5 Axle	99.60035	0.48678	8.85121	0.00003	0.08393	0.00040	0.00441
Artic 6 Axle	107.87829	0.49192	8.58642	0.00003	0.08524	0.00037	0.00408
Rigid + 5 Axle Dog	114.22683	0.50733	7.40323	0.00003	0.08119	0.00011	0.00394
B-Double	126.42036	0.48366	7.87634	0.00002	0.09105	0.00015	0.00357
Twin steer + 5 Axle Dog	125.39283	0.50106	7.60681	0.00002	0.08578	0.00019	0.00359
A-Double	153.06636	0.47756	7.54018	0.00002	0.09615	0.00009	0.00299
B Triple	177.39500	0.48833	7.86430	0.00002	0.09784	0.00033	0.00258
A B Combination	173.23396	0.47581	7.00604	0.00002	0.09811	-0.00005	0.00267
A-Triple	194.57790	0.48014	6.88429	0.00002	0.09925	-0.00002	0.00239
Double B-Double	197.53761	0.47994	6.57904	0.00002	0.09898	-0.00013	0.00236
Small Car	22.54934	0.68257	8.92663	0.00002	0.02925	0.00081	0.04068

Source: ATAP (2016)

Hypothetical Example – Base Cost (IRI = 2)

Total vehicle kilometres per annum:

- Cars: (400 cars x 1km x 356 days) = 146,500
- Trucks: (100 trucks x 1km x 365 days) = 36,500

Base Vehicle Operating Costs:

- Cars (Medium passenger vehicle): (146,000 vehicle kilometres x 7.39 c/km repair and maintenance cost) + (0.11 litres fuel consumption per kilometre x 146,000 vehicle kilometres x 59.03 c/l fuel price) = Operating cost of \$20,308 (a per vehicle kilometre cost of \$0.14).
- Truck (5 axle articulated truck): (36,500 vehicle kilometres x 23.12 c/km repair and maintenance cost) + (0.44 litres fuel consumption per kilometre x 365,000 vehicle kilometres x 59.03 c/l fuel price) = Operating cost of \$17,836 (a per vehicle kilometre cost of \$0.49).

Total Cost: \$38,144.

Hypothetical Example – Deteriorated Cost (IRI = 4)

- Cars (Medium passenger vehicle): Following application of the equation (on the total VOC identified above, including repair and maintenance), a per kilometre VOC cost of 15 c/km was achieved. Applied to average vehicle kilometres resulted in VOC estimated of \$21,895.
- Truck (5 axle articulated truck): Following application of the equation, a per kilometre VOC cost of 61 c/km was achieved. Applied to average vehicle kilometres resulted in VOC estimated of \$22,430.

Total cost = \$44,326.

Impact of Lack of Investment

The difference in total VOC as a result of the lift in IRI is estimated at \$6,182.

2.1.2 Time Costs

Description of Impact

Road users will adjust their travelling speeds in response to the quality of the road infrastructure. Adjustments in speed will impact upon the total time travelled by road users – with higher speeds taking shorter time frames.

Time travel impacts are generally considered to be the one of the most important component of transport project assessment. Generally, these impacts are analysed from the following perspectives (Transport and Main Roads, 2011):

- Travel time costs/ benefits associated with freight transport and efficiency
- Travel time costs/ benefits associated with business-related commuter travel (e.g., lost productive time for employees commuting)
- Travel time costs/ benefits associated with private (i.e., non-work related) travel (e.g., lost leisure time for non-work-related travel).

Freight and business-related travel are typically considered economic impacts, while private travel is typically considered a social cost. While time costs include both economic and social costs, it has been included under the economic impacts section as this is typically the higher cost of travel time.

How Degradation of the Road Surface can Contribute to this Impact

Travel time has been demonstrated to hold a statistically significant negative linear relationship with the roughness of the road, defined by the IRI (i.e., as the roughness of the road increases, the average speed on the road decreases) (Austroads, 2018). This relationship holds in both urban and rural environments. Austroads (2018)

estimate an increase in IRI from 2 to 4 on an urban road with a speed limit of 80 kilometres per hour would be anticipated to increase the travel time:

- From an average travel time of 0.87 minutes per vehicle kilometre to 0.95 minutes per vehicle kilometre in off peak hours
- From an average travel time of 0.89 minutes per vehicle kilometre to 0.97 minutes per vehicle kilometre in peak hours (despite the presence of congestion impacts on low IRI roads in this period).

Measurement

Measuring travel time cost is conducted based on the average trip time, average occupancy rate (i.e., the number of drivers and passengers in the vehicle), the value of time per occupant (for non-freight related travel), freight travel time costs and the average daily traffic rate (Transport and Main Roads, 2011). In a cost benefit analysis, this would involve:

- Estimating the total hours of vehicle travel time by vehicle type (per annum)
- Estimating the total number of occupants and the value of their travel time
- Estimating the cost associated with freight travel times (for freight vehicles only).

An approach for each of these stages is outlined below.

Step 1: Estimate the total hours of private vehicle travel time (per annum)

Travel time estimates can be estimated using the following equation:

$$Travel\ Time = \frac{Road\ Length}{Operating\ Speed}$$

IRI will influence the operating speed achieved on the road, as outlined in Table 2.6.

Table 2.6. IRI and Average Speed Recorded, by Speed Limit, South Australia, Non-Peak, 2013-2017

IRI	Speed Limit (km/hr)			
	50	60	80	100
1	-	-	72	92
2	42	55	70	90
3	40	53	67	87
4	37	51	65	85
5	35	49	62	78
6	32	48	60	75

Source: Austroads (2018)

Step 2: Estimate the Total Value of Travel Time

The value of a business related and/ or private road users time travelling is measured in terms of the opportunity cost of that travel to the vehicle occupant(s):

- For business-related road users, this is measured in terms of the lost productivity of that individual due to travel (i.e. as a cost to business), which is valued based on the wage of the individual. This value is typically estimated based on the seasonally adjusted full time average weekly earnings at the national level.
- For private road users, this is measured as the foregone value (or enjoyment) the traveller would have had from spending this time on an alternative activity (such as leisure). This value is typically estimated as approximately 40% of the seasonally adjusted full time average weekly earnings at the national level.

Hourly values of time for occupants by vehicle and user type are provided in the table below.

Table 2.7. Value of Occupants in Vehicles (2021 dollars), \$/hour

Vehicle Type	Non-Urban		Urban	
	Occupancy Rate	Value Per Occupant	Occupancy Rate	Value Per Occupant
Cars				
Private	1.7	\$18.57	1.6	\$18.57
Business	1.3	\$60.25	1.4	\$60.25
Utility Vehicles				
Courier Van Utility	1.0	\$31.48	1	\$31.48
4WD Mid Size Petrol	1.5	\$31.48	1.5	\$31.48
Rigid Trucks				
Light commercial (2 axle, 4 tyre)	1.3	\$31.48	1.3	\$31.48
Medium (2 axle, 6 tyre)	1.2	\$31.87	1.3	\$31.87
Heavy (3 axle)	1.0	\$32.45	1.0	\$32.45
Buses				
Heavy Bus (Driver)	1.0	\$31.87	1	\$31.87
Heavy Bus (Passenger)	20.0	\$18.57	20	\$18.57
Articulated Trucks				
4 axle	1.0	\$33.22	1.0	\$33.22
5 axle	1.0	\$33.22	1.0	\$33.22
6 axle	1.0	\$33.22	1.0	\$33.22
Combination Vehicles				
Rigid (3 axle) + dog trailer (5 axle)	1.0	\$33.70	1.0	\$33.70
B-Double	1.0	\$33.70	1.0	\$33.70
Twin steer (4 axle) + dog trailer (5 axle)	1.0	\$33.70	1.0	\$33.70
A-Double	1.0	\$34.67	1.0	\$34.67
B-Triple combination	1.0	\$34.67	1.0	\$34.67
A B combination	1.0	\$34.67	1.0	\$34.67
A-Triple	1.0	\$35.25	1.0	\$35.25
Double B-Double combination	1.0	\$35.25	1.0	\$35.25

Source: ATAP (2016)

The total value associated with travel time is estimated by the following formula:

$$\text{Value of Travel Time} = \text{Annual Traffic Count} \times \text{Occupancy Rate} \times \text{Travel Time} \times \text{Value per Occupant}$$

Hypothetical Example – Base Cost (IRI = 2)

Travel time = 1km road length / 55 km speed = 0.018 minutes

Value of occupants' time:

- Cars (Private): 73,000 traffic count x 1.7 occupants x 0.018 minutes x \$18.57 value per hour = \$41,900
- Cars (Business): 73,000 traffic count x 1.3 occupants x 0.018 minutes x \$60.25 value per hour = \$103,958
- Heavy Vehicles: 36,500 traffic count x 1 occupant x 0.018 minutes x \$33.22 value per hour = \$22,046

Total Cost: \$167,905

Hypothetical Example – Deteriorated Cost (IRI = 4)

Travel time = 1km road length / 51 km speed = 0.020 minutes

Value of occupants' time:

- Cars (Private): 73,000 traffic count x 1.7 occupants x 0.020 minutes x \$18.57 value per hour = \$45,187
- Cars (Business): 73,000 traffic count x 1.3 occupants x 0.020 minutes x \$60.25 value per hour = \$112,113
- Heavy Vehicles: 36,500 traffic count x 1 occupant x 0.020 minutes x \$33.22 value per hour = \$23,775

Total Cost: \$181,074

Impact of Lack of Investment

The difference in the value of time as a result of the lift in IRI is estimated at \$13,169.

Step 3: Estimate the Total Value of Travel Time for Freight

The value of freight time associated with road travel can be estimated in addition to that of the drivers and passengers in associated vehicles. This value takes into account the additional cost incurred from associated with the delayed delivery of goods.

Table 2.8. Value of Freight Time Costs (2021 dollars), \$/hour

Vehicle Type	Non-Urban	Urban
Cars		
Private	-	-
Business	-	-
Utility Vehicles		
Courier Van Utility	-	-
4WD Mid Size Petrol	-	-
Rigid Trucks		
Light commercial (2 axle, 4 tyre)	\$0.81	\$1.59
Medium (2 axle, 6 tyre)	\$2.20	\$4.32
Heavy (3 axle)	\$7.52	\$14.79
Buses		
Heavy Bus (Driver)	-	-
Heavy Bus (Passenger)	-	-
Articulated Trucks		
4 axle	\$16.17	\$31.85
5 axle	\$20.62	\$40.62
6 axle	\$22.24	\$43.80
Combination Vehicles		
Rigid (3 axle) + dog trailer (5 axle)	\$31.79	\$65.59

Vehicle Type	Non-Urban	Urban
B-Double	\$32.76	\$67.59
Twin steer (4 axle) + dog trailer (5 axle)	\$30.72	\$63.40
A-Double	\$43.02	\$88.77
B-Triple combination	\$43.91	\$90.60
A B combination	\$52.89	\$109.13
A-Triple	\$63.40	\$130.83
Double B-Double combination	\$64.13	\$132.34

Source: ATAP (2016)

The total value associated with travel time is estimated by the following formula:

$$\text{Value of Travel Time} = \text{Annual Traffic Count} \times \text{Travel Time} \times \text{Dollars per Vehicle Hour}$$

Hypothetical Example – Base Cost (IRI = 2)

Travel time = 1km road length / 55 km speed = 0.018 minutes

Value of freight time: 36,500 traffic count x 0.018 minutes x \$20.62 value per hour = \$13,684

Hypothetical Example – Deteriorated Cost (IRI = 4)

Travel time = 1km road length / 51 km speed = 0.020 minutes

Value of freight time: 36,500 traffic count x 0.020 minutes x \$20.62 value per hour = \$14,757

Impact of Lack of Investment

The difference in the value of time as a result of the lift in IRI is estimated at \$1,073.

Note:

The above approach for assessing impacts to freight is applicable where the road infrastructure project is not anticipated to result in a shift in the type of vehicles being used to transport freight. However, where a project (for instance) is expected to result in increased capacity for higher productivity vehicles to use a road (resulting in a shift in modal share of road freight) the approach for valuing the freight cost saving should be based on the cost per tonne kilometre for each modal type and the number of tonne kilometres travelled for each vehicle with and without the project.

2.1.3 Cost of Road Accidents and Crashes

Description of Impact

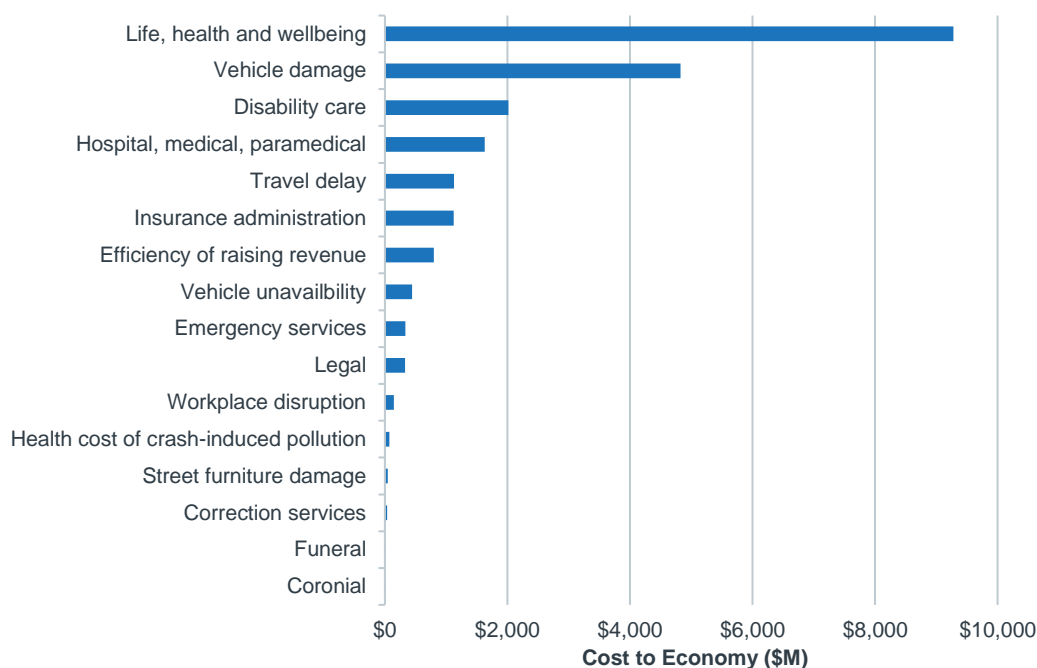
Road crashes are a significant issue in Australia. In 2019, 1,195 people were killed in road-related deaths, which equates to over 3 people per day. The most recent annual count of hospitalised injuries due to road crashes (in 2017) was 39,330, with 24.9% classified with a high threat to life (BITRE, 2020).

The Australian Automobile Association (AAA) commissioned a study in 2017 to quantify the cost that the Australian community incurs each year as a result of road crashes (using 2015 calendar year figures). The study uses a methodology known as the willingness-to-pay (WTP) approach to calculate the value of a statistical life, which estimates amounts individuals are willing to pay for reduced risks to life. Whilst this method is more likely to produce higher estimates than other traditional methods, it is widely used among OECD countries as an approach to valuation. Other financial costs to society due to the crash are also included, such as emergency costs. These additional costs are included as the WTP to avoid crashes by the individual do not factor in these other costs to society. Overall, the study reported that in 2015:

- The total cost of road trauma is estimated at \$22.2 billion.
- The economic cost of each road fatality was \$4.34 million.
- The cost per hospitalisation caused by road injury was \$239,000.
- The cost per non-hospitalised injuries was \$12,000.

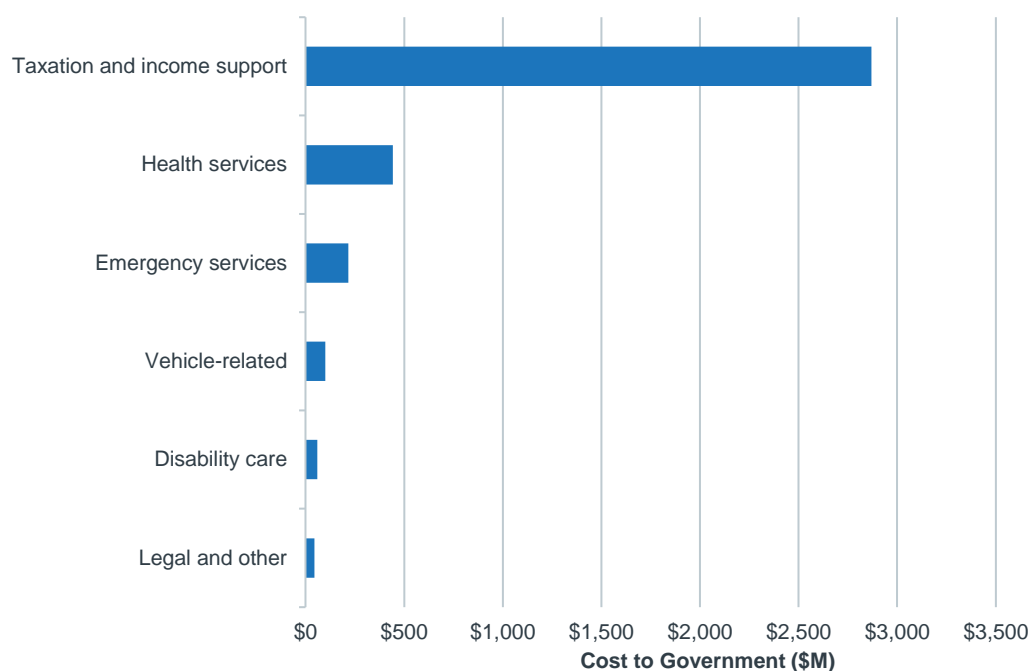
The largest cost relates to the loss of life, health and wellbeing, accounting for approximately 41.7% of total economic costs of road trauma. This is followed by vehicle damage at 27.1%, with an average damage cost per vehicle estimated at \$3,001.

Figure 2.1: Cost to Economy for 2015 Road Trauma (\$ Million)



Source: AAA (2017).

The study also identified that the direct cost of road trauma in 2015 to government was valued at \$3.7 billion. This is made up of the immediate costs related to road crashes, as well as the lasting impacts such as forgone taxation, additional income support payments, and long-term disability care and support costs.

Figure 2.2: Cost to Total Government (Local, State and Federal) for 2015 Road Trauma (\$ Million)

Source: AAA (2017).

In the years between 2015 and 2019 (inclusive), South Australia recorded approximately 72,006 road accidents, involving 153,854 vehicles (Department for Infrastructure and Transport, 2020), of which 71,404 accidents were allocated to a local government area and the remainder were unallocated. Of the 71,404 accidents which were allocated to a local government area, 3,796 (5.3%) occurred within the Legatus region. On average, accidents occurring within the Legatus region are more likely (than those outside the region) to involve fatalities, as well as serious and minor injuries. Whilst accidents occurring in the region were most likely to occur on sealed roads (85.6% of total accidents), accidents occurring on unsealed roads (14.4% of total accidents) were more likely to involve fatality and injuries within the region.

Table 2.9. Road Accident Comparison, Legatus Region vs Rest of South Australia, 2015 to 2019

Indicator	Number of Accidents				
	Total Accidents	Involving Casualties	Involving Fatalities	Involving Serious Injuries	Involving Minor Injuries
Number					
Legatus	3,796	1,610	87	356	1,291
Non-Legatus	67,608	23,382	340	2,590	21,012
Total	71,404	24,992	427	2,946	22,303
Proportion of Total					
Legatus	5.3%	6.4%	20.4%	12.1%	5.8%
Non-Legatus	94.7%	93.6%	79.6%	87.9%	94.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Legatus Accidents (Number)					
Sealed	3,248	1,375	77	295	1,107
Unsealed	548	235	10	61	184
Total	3,796	1,610	87	356	1,291
Legatus Accidents (Proportion of Total)					
Sealed	85.6%	85.4%	88.5%	82.9%	85.7%
Unsealed	14.4%	14.6%	11.5%	17.1%	14.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Department for Infrastructure and Transport, 2020

Using Transport for NSW (2020) values for the cost per crash (provided below), which applies the same WTP based approach used by AAA, it is estimated that local accidents between 2015 and 2019, resulted in a total cost of \$1.2 billion (or approximately \$248 million per annum). It is further estimated that accidents in the rest of South Australia cost approximately \$6.9 billion over this time frame, equating to a cost of \$1.4 billion per annum). Based on these estimations, it is inferred that the Legatus region comprised 15.2% of the total cost of accidents in South Australia over this timeframe, higher than the region's contribution to South Australia's total population of 7.4% (ABS, 2020). This is reflective of the higher prominence of fatalities and serious injuries in accidents occurring within the Legatus region, by comparison with the rest of South Australia.

Table 2.10. Road Accident Cost Comparison (per accident), Legatus Region vs Rest of South Australia, 2015 to 2019 (2021 Dollars)

Indicator	Property Damage Only	Total Fatalities	Total Serious Injuries	Total Minor Injuries	Total
Number					
Legatus	2,186	87	356	1,291	-
Non-Legatus	44,226	340	2,590	21,012	-
Total	46,412	427	2,946	22,303	-
Associated Cost (Total)					
Legatus ⁽¹⁾	\$23,154,112	\$823,837,365	\$255,371,972	\$136,876,984	\$1,239,240,433
Non-Legatus ⁽²⁾	\$468,441,792	\$2,991,164,620	\$1,523,854,990	\$1,922,724,072	\$6,906,185,474
Total	\$491,595,904	\$3,815,001,985	\$1,779,226,962	\$2,059,601,056	\$8,145,425,907

Notes: 1. Rural cost per accident applied. 2. Average costs per accident applied.

Source: Department for Infrastructure and Transport (2020), Transport for NSW (2020)

How Degradation of the Road Surface can Contribute to this Impact

There are a broad range of factors which contribute to the occurrence of road accidents. Monash University (2020) estimates driver-based contributing factors (driver error, driving task behaviour, inattention, health and state factors, and non-compliant behaviors) were contributing factors in 99.5% of accidents involving serious injury.

Whilst not a main contributing factor towards car accidents, a number of defects in road surface can contribute towards increased risk of road accidents and crashes:

- **Skid resistance:** Skid resistance describes the degree of friction provided by the road surface during braking or turning (Austroads, 2018). There are two aspects of skid resistance, including the degree to which the road surface enables vehicle tyres to grip the road surface (the macrotexture of the road) and the degree to which the road surface is able to drain water from the surface (the macrotexture of the road). International studies (NZTA, 2016; Bennett and Greenwood, 2003) indicate roads with higher skid resistance record lower vehicle accident rates than roads with low skid resistance.

Skid resistance is particularly important (Austroads 2017, Pratt et al. 2014):

- In wet weather, as most roads will provide a relatively consistent degree of skid resistance in dry weather.
- For roads with horizontal curves (as opposed to straight roads).

International studies suggest the relationship between skid resistance and crash rates are not linear, but that once the skid resistance of a road (measured by a Skid Number) reduces below 60 (from a maximum of 100), there is an exponential increase in crash rates (Long et al, 2013). The Crash Rate Ratio (CRR) is used to identify the relationship between skid resistance and crash risk. For example, a road with a CRR of 2.0 would be expected to record twice as many crashes as a road with a CRR of 1.0 (Austroads, 2018).

- **Hazards:** The presence of potholes and other hazards along the road surface contributes to road accidents and crashes due to the driving activity undertaken by road users to avoid them (Gould et al, 2003).
- **Rutting:** Repeated traffic along the road, particularly from heavy vehicles, can eventually lead to deformation of the road surface (Austroads, 2018). The impact of rutting is most problematic during wet weather periods, where water accumulates in the road deformations and the skid resistance of the road is reduced and the risk

of hydroplaning is increased. When rutting of a road surface exceeds 20mm, the risk of road accident increases by 25% (Austroads, 2008).

- **Road Shoulders:** Road shoulders are provided to enable road users to recover or correct their driving if they accidentally drive off the main lanes of the road (Austroads, 2018). Road shoulders gradually slope away from the road which will assist the driver in correcting their direction. If the shoulder is inadequately maintained, the degree of slope can gradually increase, and can result in increased severity of road accidents. Similarly, unmaintained vegetation growth on the road shoulders can result in increased severity of road accidents. The placement of fencing or barriers along the road shoulder can assist in reducing the severity of accidents along road shoulders.
- **Structure failure:** catastrophic structural failure of infrastructure is an extreme result of lack of road maintenance activities which could result in a significant lift in road accidents (Transport Research Laboratory, 2012).
- **Dust:** Adverse weather conditions, including dust, have been associated with higher road accident risk due to obstruction of the driver's vision (Bhattachan et al, 2019).
- **Sealed and unsealed roads:** Sealed roads tend to record higher accident rates than unsealed (gravel) roads (Austroads, 2012).

Measurement

Measurement of the cost of road accidents is undertaken through the application of a cost multiplier per accident, injury or fatality applied to relevant road accident data. In a cost benefit analysis, this would involve:

- Estimating the number of accidents per annum
- Estimating the number of injury and fatalities as a result of the estimated accidents
- Applying a cost multiplier to the resulting number of crashes, injuries (by severity) and fatalities.

An approach for each of these stages is outlined below.

Step 1: Estimate the Likely Number of Road Accidents

Estimating the number of future road accidents is conducted using traffic count estimates, length of road estimates and road accident rates.

Traffic counts data can be collated from Councils or State Government agencies and applied to the length of the road (in kilometres), to understand the total kilometres travelled per annum on each road. Traffic counts may be held constant over the analysis timeframe, if projected traffic counts are not available.

Road accident rates can be separated into two components:

- The average accident rate: the average number of accidents per annum compared to the number of kilometres travelled per annum
- The CRR: the degree to which accidents are more likely to occur in instances of high Skid Numbers (SNs).

The average road accident rate can be developed from historical road accidents data where available, or, can be based on average road accident rates outlined in the table below (Austroads, 2012).

Table 2.11. Non-Urban Accident Rates (per 100 million km of travel)

Road Description	Total Accidents
Undivided Roads (Gravel)	
MRS 1 Natural surface	107.00
MRS 2 Formed roads	107.00
MRS 3 Gravel <= 4.5m	126.00
MRS 4 Gravel >= 4.5m	126.00

Road Description	Total Accidents
Undivided Roads (Sealed)	
MRS 5 Sealed <= 4.5m	104.00
MRS 6 Sealed 4.51m - 5.2m	97.00
MRS 7 Sealed 5.21m - 5.8m	94.00
MRS 8 Sealed 5.81m - 6.4m	87.00
MRS 9 Sealed 6.41m - 7.0m	70.00
MRS 10 Sealed 7.01m - 7.6m	58.00
MRS 11 Sealed 7.61m - 8.2m	52.00
MRS 12 Sealed 8.21m - 8.8m	49.00
MRS 13 Sealed 8.81m - 9.4m	46.00
MRS 14 Sealed 9.41m - 10.0m	55.00
MRS 15 Sealed 10.01m - 11.6m	55.00
MRS 16 Sealed 11.61m - 13.7m	55.00
MRS 17 Sealed > 13.7m	55.00
Divided Roads	
MRS 18 Sealed <= 7.6m	52.00
MRS 19 Sealed 7.61m - 8.2m	52.00
MRS 20 Sealed 8.21m - 8.8m	52.00
MRS 21 Sealed 8.81m - 9.4m	50.00
MRS 22 Sealed 9.41m - 11.6m	50.00
Freeways	
MRS 24 Sealed (4 lane) <= 9.4m	20.00
MRS 25 Sealed (6 lane) 9.41m - 11.6m	20.00
MRS 26 Sealed (8 lane) > 11.6m	20.00

Source: Austroads (2012)

The CRR can be used to lift the average accident rate to account for the level of skid resistance of the road, defined by the SN. This number can be estimated by engineers for each individual road under analysis. The CRR is a relative measure, and considers the data for all roads at or below a certain SN compared to all roads in the region to provide guidance on the increased risk of accident on roads at or below a certain SN level.

If historical road accident data and SNs are available for all local roads, the local CRR can be estimated through the following equation (long et al., 2013):

$$CRR = \frac{\text{Cumulative percentage of total crashes below a specific SN}}{\text{Cumulative percentage of total kilometers travelled at or below a specific SN}}$$

Where road specific data is not available, the degree of lift required to be applied to the general accident rate to account for skid resistance is estimated using the following equation (Austroads, 2018).

$$CRR \text{ at each SN} = 3.894 \times \text{EXP}(-0.04605 \times \text{SN}) + 0.9205$$

Once the above datapoints have been determined, the total number of accidents can be determined using the following equation:

$$\text{Number of Accidents: } CRR \times \text{Average Accident Rate} \times \text{Annual Kilometers Travelled}$$

Step 2: Estimate the Number of Injuries and Fatalities

Historical data (Department for Infrastructure and Transport, 2020) can be used to understand the historical rate of minor injuries, serious injuries and fatalities as a result of road accidents within the region. The historical composition of accidents by these injuries can be applied to future levels of accidents, as identified in Step 1.

Where data is not available, the following injury and property damage rates can be applied to the future level of accidents identified in Step 1.

Table 2.12. Contribution to Non-Urban Accident Rates, by Person and Property Outcomes

Road Description	Accident Category			Total
	Fatal	Injury	Property Damage Only	
Undivided Roads (Gravel)				
MRS 1 Natural surface	1.4%	26.6%	72.0%	100.0%
MRS 2 Formed roads	1.4%	26.6%	72.0%	100.0%
MRS 3 Gravel <= 4.5m	1.4%	26.4%	72.2%	100.0%
MRS 4 Gravel >= 4.5m	1.4%	26.4%	72.2%	100.0%
Undivided Roads (Sealed)				
MRS 5 Sealed <= 4.5m	1.4%	27.4%	71.2%	100.0%
MRS 6 Sealed 4.51m - 5.2m	2.0%	38.2%	59.8%	100.0%
MRS 7 Sealed 5.21m - 5.8m	2.1%	40.4%	57.4%	100.0%
MRS 8 Sealed 5.81m - 6.4m	1.9%	35.5%	62.6%	100.0%
MRS 9 Sealed 6.41m - 7.0m	1.8%	33.9%	64.3%	100.0%
MRS 10 Sealed 7.01m - 7.6m	1.9%	36.9%	61.2%	100.0%
MRS 11 Sealed 7.61m - 8.2m	2.0%	38.8%	59.1%	100.0%
MRS 12 Sealed 8.21m - 8.8m	2.0%	38.8%	59.2%	100.0%
MRS 13 Sealed 8.81m - 9.4m	2.3%	43.9%	53.8%	100.0%
MRS 14 Sealed 9.41m - 10.0m	1.9%	35.6%	62.5%	100.0%
MRS 15 Sealed 10.01m - 11.6m	1.8%	34.5%	63.6%	100.0%
MRS 16 Sealed 11.61m - 13.7m	1.8%	33.5%	64.8%	100.0%
MRS 17 Sealed > 13.7m	1.9%	36.7%	61.4%	100.0%
Divided Roads				
MRS 18 Sealed <= 7.6m	1.2%	37.3%	61.5%	100.0%
MRS 19 Sealed 7.61m - 8.2m	1.2%	37.3%	61.5%	100.0%
MRS 20 Sealed 8.21m - 8.8m	1.2%	37.3%	61.5%	100.0%
MRS 21 Sealed 8.81m - 9.4m	1.2%	38.8%	60.0%	100.0%
MRS 22 Sealed 9.41m - 11.6m	1.2%	38.8%	60.0%	100.0%
Freeways				
MRS 24 Sealed (4 lane) <= 9.4m	2.0%	26.8%	71.3%	100.0%
MRS 25 Sealed (6 lane) 9.41m - 11.6m	2.0%	26.8%	71.3%	100.0%
MRS 26 Sealed (8 lane) > 11.6m	2.0%	26.8%	71.3%	100.0%

Source: Austroads (2012)

Step 3: Estimate the Cost of Accidents

There are two generally accepted sources for cost of accident data. However, the method of application of these sources is the same, multiplying the estimated number of accidents or casualties by the cost multiplier.

Transport for NSW (TfNSW, 2020) provides estimates of the average cost per road crash, based on the same WTP approach as used in the AAA study above (including other costs to society not captured through WTP of the individual). Transport for NSW estimates of the average WTP to avoid crashes, as well as other social costs, are higher than those estimated by AAA, and are as follows (in 2021 dollar terms). These are the preferred multipliers applied in AEC Research.

Table 2.13. Average Cost of Crash and Casualty

Accident Type	Urban	Rural	Average
Costs per Casualty			
Fatality	\$7,607,821	\$8,329,954	\$7,943,090
Serious injury (injury requiring hospitalisation)	\$456,462	\$604,334	\$508,046
Moderate injury (attendance at an emergency department)	\$70,233	\$90,064	\$79,374
Minor injury (not requiring attendance at an emergency department or hospital)	\$70,233	\$90,064	\$79,374
Unknown injury type	\$200,908	\$256,567	\$221,383
Costs per Crash			
Fatal crash (at least one person killed)	\$8,000,446	\$9,469,395	\$8,797,543
Serious injury crash (at least one person hospitalised, but no fatalities)	\$520,012	\$717,337	\$588,361
Moderate injury crash (at least one person attended emergency, but no serious injuries or fatalities)	\$87,390	\$115,372	\$99,906
Minor injury crash (at least one person received a minor injury, but no moderate / serious injuries or fatalities)	\$80,313	\$106,024	\$91,506
Unknown injury type crash	\$181,615	\$249,065	\$215,984
Property damage only	\$10,592	\$10,592	\$10,592

Source: TfNSW (2020)

As an alternative to the TfNSW valuation, some jurisdictions may prefer the use of Australian Transport Assessment and Planning Guidelines (formerly Austroads) (ATAP, 2016) values, which uses a Human Capital approach to valuing the impact of crashes. The Human Capital approach aggregates various identifiable costs, such as: loss of income, medical expenses, long term care, insurance cost, vehicle repair, property damage, travel delays and policing. The value of a statistical life or a fatality is the discounted present value of these costs over a period of up to 40 years. However, the Human Capital approach is generally considered to likely under-value the cost of crashes.

ATAP (2016) Guidelines indicate the following costs per crash (in 2021 dollar terms) using the Human Capital approach:

- Fatal crash: approximately \$2.72 million per crash.
- Crash resulting in a spinal cord injury: approximately \$8.96 million per crash.
- Crash resulting in quadriplegic/ paraplegic injury: approximately \$13.83 million per crash.
- Crash resulting in serious injury: approximately \$609,972 per crash.
- Crash resulting in minor injury: approximately \$21,552 per crash.
- Crash resulting in property damage only: approximately \$10,586 per crash.

AEC recommends only using the ATAP approach where specifically directed by funding agencies/ guidelines for specific funding programs.

Hypothetical Example – Base Cost (SN = 60)

Number of accidents: $(182,500 \text{ vehicle kilometres} / 100,000,000) \times 58 \text{ accidents per 100 million km of travel} = 0.11 \text{ accidents per annum.}$

Types of accidents:

- Fatal accidents: $(0.11 \text{ accidents by } 2.00\% \text{ fatal accident rate}) = 0.002 \text{ per annum}$
- Injury accidents: $(0.11 \text{ accidents by } 38.20\% \text{ injury accident rate}) = 0.039 \text{ per annum}$
- Property damage only accidents: $(0.11 \text{ accidents by } 59.80\% \text{ property damage only accident rate}) = 0.65 \text{ per annum}$

Cost of accidents:

- Fatal accidents: $(0.002 \text{ per annum} \times \$9,469,395) = \$19,044$
- Injury accidents: $(0.039 \text{ per annum} \times \$249,065) = \$9,728$
- Property damage only accidents: $(0.065 \text{ per annum} \times \$10,592) = \$686$

Total cost: \$29,459

Hypothetical Example – Deteriorated Cost (SN = 40)

CRR lift = CRR at SN of 40 (1.53) / CRR at SN of 60 (1.17) = 1.32

Number of accidents: $(182,500 \text{ vehicle kilometres} / 100,000,000) \times 58 \text{ accidents per } 100 \text{ million km of travel} \times 1.32 \text{ CRR} = 0.14 \text{ accidents per annum.}$

Types of accidents:

- Fatal accidents: $(0.14 \text{ accidents by } 2.00\% \text{ fatal accident rate}) = 0.003 \text{ per annum}$
- Injury accidents: $(0.14 \text{ accidents by } 38.20\% \text{ injury accident rate}) = 0.052 \text{ per annum}$
- Property damage only accidents: $(0.14 \text{ accidents by } 59.80\% \text{ property damage only accident rate}) = 0.085 \text{ per annum}$

Cost of accidents:

- Fatal accidents: $(0.003 \text{ per annum} \times \$9,469,395) = \$25,111$
- Injury accidents: $(0.052 \text{ per annum} \times \$249,065) = \$12,827$
- Property damage only accidents: $(0.140 \text{ per annum} \times \$10,592) = \$905$

Total cost: \$38,842

Impact of Lack of Investment

The difference in the cost of accidents as a result of the decline in skid resistance is estimated at \$9,384.

2.2 IMPACTS TO BUSINESSES

Vehicle operating and fuel costs (section 2.1.1) and travel time costs (section 2.1.2) are examined in previous sections and both can impact on the overall cost of doing business and productivity of employees. These impacts can be felt by any business, but will be especially impactful on industries and businesses highly reliant on roads for their business operations such as:

- Freight and logistics (as well as businesses that rely heavily on this industry for access to goods and services as well as for transporting goods to market)
- Passenger transport services and vehicle rental services
- Any business that requires employees to undertake significant volumes of road travel for their work
- Any business that pays for or reimburses employees for travel
- Emergency services.

This section examines other potential costs to business from the quality of roads and road maintenance, including impacts in terms of access to labour and impacts specifically to the tourism industry.

2.2.1 Access to Labour

Description of Impact

Access to labour (i.e., the extent to which businesses can access workers with suitable educational attainment, experience, and skill development for the intended role) is a key component of business operations and longevity.

Due to its importance, the Department of Employment has conducted research to identify where access to labour is impeded (i.e., shortages are present) in the Australian labour market. Shortages exist when employers are:

- Unable to fill vacancies
- Have considerable difficulty filling vacancies
- Need specialised skills within an occupation.

Labour shortages have been identified as an issue for various areas within the Legatus Region, namely Yorke and the Mid North where shortages are evident in the areas of aged care, viticulture, and the meat (abattoir) industry (Regional Development Australia, 2019).

Approximately 97.1% of commuters in the Legatus Region access their place of employment via road infrastructure (ABS, 2017), highlighting the importance of road infrastructure for providing access to workers for local business.

How Degradation of the Road Surface can Contribute to this Impact

With approximately 97.1% of commuters in the Legatus Region accessing their place of employment via road infrastructure this suggests the degradation of road surface infrastructure is likely to impact negatively upon their commuting experience and has the potential to deter workers from commuting to/ within the region. The following implications of poor road surface infrastructure are likely to contribute to this impact:

- Increased vehicle operating and fuel costs
- Increased journey times due to reduced speeds at which vehicles can safely travel
- Reduced safety and increased risks provided by the roughness, hazards, rutting, etc.
- Increased congestion levels afforded by the lower speed at which cars can travel due to poor road surface conditions
- Reduced comfort due to roughness of the road surface.

Measurement

While measures for valuing how road surface quality may impact on vehicle operating costs (section 2.1.1), journey times (section 2.1.2) and safety (section 2.1.3) for employees are available, a measure for quantifying the impact of road quality on user comfort or the ability to access labour by business is not currently available. It is, however, reasonable to consider workers within the region are experiencing some degree of discomfort due to poor road surface conditions present in the Legatus Region, and that poor road conditions may deter some workers from commuting to/ within the region.

2.2.2 Tourism

Description of Impact

Tourism is a key industry for the Legatus Region, with 26 primary tourism destinations including the Barossa Valley, Clare Valley, Flinders Ranges, and Yorke Peninsula (Legatus, 2020). While tourism visitation is typically reliant on factors other than roads and road quality (i.e., it is typically based on the tourism attractions and overarching amenity of the region itself), roads are a crucial facilitator of tourism by providing visitors with the requisite access to and within a region and its tourist attractions. Tourism Research Australia (2020a, 2020b) data indicates that road transportation is the primary form of access to and around the Legatus Region, with 96.2% of visitors having utilised road transportation methods on their stay in 2019. Currently, there are approximately 570 kilometres of road identified as regionally significant tourism routes, which facilitate access to key tourism sites, activities, and accommodation. Without adequate access to a region's tourism attractions, visitors will be unable and/ or disincentivized to travel to the region.

The perceived characteristics of these tourism routes (by visitors) will influence visitors' initial decision making regarding where to travel as well as their overall experience once traveling. These considerations are similar to those in relation to access to labour for businesses (see section 2.2.1), however, have been considered in the context of tourism as below:

- **Access:** Ease of access to destinations, through the provision of adequate and reliable infrastructure and services between key points (i.e., airports to accommodation, accommodation to key tourism sites), is an essential requirement for generatively tourism activity (Marek Wieckowski et al, 2014).
- **Travel Distance/ Journey Time:** Travel distance/ time is directly related to visitors' decision to visit a destination as well as their behavioral patterns once arrived (Xue & Zhang, 2020). Greater distances between points of interest can discourage tourists from travelling to a destination, as greater distances result in higher costs, longer travel times, greater risks, and uncertainty in reaching the destination within desired timeframes.
- **Safety:** The perceived safety of visitors at destinations/ sites visited is essential in deciding where to travel and is determinant of trip success. Whilst road safety depends on a variety of factors including human/ driver behavior, vehicle safety and the regulatory framework, the quality of infrastructure is specific to the tourism destination. The quality of road surface infrastructure refers to the skid resistance, hazards, rutting, road shoulders, structure failure, dust, and sealed/ unsealed roads (see section 2.1.3), all which impact upon the safety of operating vehicles on the road.
- **Amenity:** Amenity generally refers to 'the pleasantness or attractiveness of a place' or 'the desirable or useful features of a facility or place' (ATAP, 2018). Key determinants of infrastructure amenity typically include the pleasantness/ attractiveness of the surrounds, the safety, comfort and convenience, and the accessibility/ connectivity. For visitors, amenity may be derived from smoothness of the road, linkages/ ease of access to key tourism destinations, and pleasantness of the surrounds.

The perceived views of visitors regarding the above characteristics will influence the level of visitation to the Legatus Region. The level of visitation will, in turn, impact upon tourism-oriented businesses operating in the region. Various tourism businesses rely on road infrastructure in conducting their business, including tour guides, taxis, activity shuttle services, and hotel shuttle services. A variety of other tourism businesses rely on road infrastructure in providing access to the visitor market, including food and beverage operators, accommodation providers, and tourism activity providers.

How Degradation of The Road Surface Can Contribute to This Impact

The above factors all contribute to the sustainability of the tourism industry in the Legatus Region; however, the degradation of road surface quality is likely to negatively impact upon these. In particular, the safety risk and increased journey times are the key impediments to visitation resulting from the degradation of road surface infrastructure.

Of the 570 kilometres of road identified as regionally significant tourism routes in the Legatus Region, 118 kilometres (or 20.3%) have been assessed as having at least one major deficiency, and a further 238 kilometres (or 41.8%) of roads assessed as having minor deficiencies.

Degradation of the road surface can increase the risk of accidents, particularly those caused by skidding and those actions taken by road users in avoiding hazards. Low maintenance budgets mean the necessary initiatives for improving road surface safety cannot be funded. Discussion groups held in New Zealand regarding general perceptions of road surfaces, indicated that safety was the primary consideration for tourists in terms of the impacts of road surface quality (Symonds Travers Morgan (NZ) Ltd, 1997). Tourists believed the roughness of the road surface was more strongly correlated with safety, followed by degree of grip, number of loose stones, and level of dust generated.

Deterioration of road surface conditions is likely to cause longer travel durations for visitors (as outlined in section 2.1.2), as vehicles (particularly those driven by people unfamiliar with the road conditions) travel at lower speeds on roads with poor conditions. As outlined in section 2.1.1, lower speeds will also result in higher vehicle operating costs. This may deter visitors from travelling to certain destinations in the Legatus Region.

Measurement

Whilst approaches for measuring and valuing the impact of an increase/ decrease in tourism activity are available, an approach for measuring the change in visitation (and associated expenditure) specifically due to road conditions was unable to be identified in research.

In order to measure the change in visitation (and thereby expenditure) due to road conditions, a specific research project (likely including primary research such as surveying) would be required.

Where estimates of the change in visitation are able to be developed, the general approach for valuing an increase/decrease in tourism activity involves:

- Applying average visitor spend per day/ night to the change in visitation to identify the total change in visitor spend induced. Tourism Research Australia is a key source for visitation and expenditure estimates for various geographical areas around Australia.
- Disaggregating the expenditure across expenditure items based on national averages of expenditure by items (using data from Tourism Research Australia).
- Allocating expenditure items to relevant industries in an Input-Output model to estimate the direct impact on Gross Regional Product (GRP) and employee incomes. Labour incomes are then subtracted from the GRP estimate to produce a gross operating surplus estimate, reflecting the change in producer surplus supported by the change in visitor expenditure (i.e., change in profits to the producer for selling goods and services in the market).

2.3 IMPACTS TO COUNCILS

2.3.1 Operating and Maintenance Costs

Description of Impact

Insufficient investment in the maintenance of road infrastructure is likely to result in further deterioration of the road surface and higher future costs of maintenance (Gould *et al.*, 2013). The costs of recovering from a deterioration in infrastructure quality far exceed the cost of retaining existing quality levels (Transport Research Laboratory, 2012).

How Degradation of the Road Surface can Contribute to this Impact

In periods of resources constraint, Councils and other bodies need to consider the best allocation of funds for road maintenance activities. Some of the options available include (Cambridge Systematics, 2011):

- **Performing no maintenance:** An extreme scenario in which roads are not maintained and the road surface deteriorates significantly. This could result in the road infrastructure reaching a state of disrepair – requiring significant investment to be returned to a high-quality level.
- **Performing only inexpensive maintenance:** For example, light resurfacing might be undertaken to improve the smoothness of the road as a short-term measure rather than performing more costly, but effective, solutions such as milling and resurfacing, which address the cause of the surfacing issue and will be cost-efficient over the long term.
- **Maintaining only priority assets:** Funds may be focused on maintenance of key road infrastructure assets, resulting in a greater degree of diversity of road quality in the region. This is likely to attract greater traffic levels to the maintained roads, resulting in increased maintenance costs for these roads.
- **Perform Maintenance only in reaction to failed infrastructure:** Focusing funding on road infrastructure which have fallen into disrepair and cannot be avoided. This scenario would pose increased costs to both Councils and local users.

Measurement

Several studies have focused on the cost impact of delayed investment in road maintenance (Cambridge Systematics, 2011):

- A study of bridge washing maintenance determined the delaying washing of painted steel on bridges for a period of eight years would cost transport agencies an additional US\$20,000 per bridge due to the impact of corrosion.

- A study regarding culverts replacement determined the cost of unplanned (emergency) replacement of culverts was significantly higher than the cost of maintenance of the culverts over their life.

However, a comprehensive relationship between the degree of degradation and the corresponding increase in future cost, by maintenance type, has not been identified.

2.3.2 Residual Asset Values

Description of Impact

Residual value is typically defined in one of the following two ways:

- 1 The value of infrastructure at the end of its project lifetime and the value that the asset generates from then on. It represents the capacity of the asset to accrue benefits past the end of the cost benefit analysis evaluation period.
- 2 The net value of the asset in the market if it is recycled at the end of its useful life (i.e., the value of the recycled materials minus the costs of removal and recycling).

The definition selected will be dependent on the specific situation.

How Degradation of the Road Surface can Contribute to this Impact

Degradation of the road surface will result in a lower residual value (benefit) at the end of the cost benefit analysis assessment period, as it reduces the useful life of the asset. Various factors can influence the residual value, including:

- Usage of asset
- Maintenance
- Depreciation
- Expected life span
- Disposal performance
- Recent market trends.

Degradation of road surface infrastructure will increase the rate of depreciation and hence decrease the residual value remaining at the end of the cost benefit analysis period.

Measurement

There are various approaches to estimating the residual value of an asset, including:

- The straight-line method
- The condition-based method

These methods are outlined in more detail below.

Approach 1: Straight Line Method

The straight-line method assumes that capital costs incurred are depreciated at a constant rate during the estimated asset life for the whole project without discounting. The residual value under this method can be calculated using the below formula:

$$\text{Residual Value} = \frac{\text{Useful Life Remaining (years)}}{\text{Total Useful Life (years)}} * \text{Value of Asset}$$

Where an asset is periodically renewed (e.g., resealing of a road) prior to complete degradation of the asset, the 'useful life' is the average time to renewal (e.g., reseal). Austroads can provide the service lives for various road asset categories, including both sealed roads and unsealed roads, as applied or recommended by various State and Federal Government Agencies.

Approach 2: Condition Based Method

The actual service life of a particular asset can vary significantly from the average service life for that asset type, Reasons for this include:

- Quality of construction supervision
- Variability of geological conditions
- Variability in climatic conditions
- Variability in usage
- Variability in maintenance regime.

The above factors influence the overall condition of the asset; asset condition is key in determining remaining useful life. As such, the condition-based method assumes that capital costs incurred are depreciated according to its condition. Estimating the residual value using this method involves finding the cost of restoring the asset to the original condition; the residual value is then the difference between the original value of the asset and the cost involved in restoring the asset.

To estimate this, the following should be carried out:

- Capture of data surrounding the condition of assets
- Assessment of costs involved in restoring asset condition
- Development of conditions models to provide an understanding of the lifecycles and deterioration of the entity's physical assets.

This method is generally the preferred method for road pavement infrastructure, due to the variability in road conditions around Australia.

3. SOCIAL IMPACTS

This chapter outlines the likely social impacts associated with the maintenance of roads.

3.1 USER SATISFACTION AND AMENITY

Description of Impact

The quality of road infrastructure will influence users' satisfaction with the road from an amenity perspective. Generally, users' satisfaction with the quality of road infrastructure will consider two aspects (Austroads, 2018):

- **The quality of the ride:** Users' experience of travel along local roads will inform their perception of the quality of the road, regardless of the actual condition of the road (Austroads, 2018). Generally, users mention the following conditions when associated with poorly maintained roads:
 - Potholes
 - Roughness
 - Narrowness.
- **The pleasantness of the road environment:** General cleaning and appearance of the road to users (i.e., the presence of graffiti, etc.)

The presence of congestion and timeliness of the journey undertaken on road infrastructure (including delays) is also likely to be a key consideration for users' satisfaction. This aspect of user satisfaction is outlined in detail in section 2.1.2 and is not covered in any further detail in this section.

Data relating to satisfaction with South Australian roads is not readily available. However, a survey of consumer and business satisfaction with South Australian government services suggests major roads comprise 2% of all consumer complaints regarding South Australia government services and 6% of all business complaints. Major roads are the 6th highest ranking government service in terms of business complaints (SA Department of Premier and Cabinet, 2020).

How Degradation of the Road Surface can Contribute to this Impact

The presence of potholes and roughness of the roads are considered by users to reflect the quality of the road infrastructure (Austroads, 2018). International customer service surveys indicate road users consider roads in poor condition to be amongst the highest detractors in rating their journey and that the conditions in local road infrastructure is a key contributing factor to reduced satisfaction with local government services (Transport Research Laboratory, 2012). Studies found a correlation between increased road maintenance expenditure and reduced volumes of complaints regarding local roads.

Measurement

Measuring the value of the benefit to users of high quality and pleasant ride has been conducted in a handful of international studies, primarily focusing willingness to pay approaches. Outcomes from a willingness to pay approach will tend to be reported as a total outcome, capturing the users' own perceived benefit which is likely to include other benefits outlined in this document, including safety, time and operating costs. It is, therefore, not appropriate to use these outcomes within a detailed cost benefit analysis, however, the outcomes below demonstrate the degree to which users may place a value on improved roads which is, in some instances, considerably higher than the outcomes of other benefits associated with road infrastructure maintenance costs.

A study in Sweden (Olsson, 2002) identified users were willing to pay:

- 10 cents per kilometre to avoid roads that were fully cracked
- 17 cents per kilometre to avoid roads with deep rutting
- 34 cents per kilometre to avoid rough roads.

The same study found the estimated VOC associated with IRI decreases by just 4 cents when the IRI declines from 6 to 2 (Austroads, 2018). However, the findings of the assessment undertaken in section 2.1 suggests travel time estimates and crash costs associated with a similar level of deterioration in road surface considerably exceed those of VOC. A difference in willingness to pay and VOC in this instance might reasonably be considered to encapsulate these other, quantifiable benefits. It is recommended this benefit not be included in valuation to avoid potential double counting.

3.2 HEALTH OUTCOMES

Description of Impact

Long-term exposure to ride vibration (whole body vibration experienced whilst in contact with a vibrating surface) has been linked to many health risks, most commonly back disorders (lumbago, sciatica, generalized back pain, and intervertebral disc herniation and degeneration), but also cardiovascular diseases (Granlund, J., 2008).

The quality of the road surface, including roughness, is also a key contributor to road accidents (and associated health impacts and costs). Further details on this aspect of health impacts are outlined in greater detail in Section 2.1.3, and is not explored in further detail in this section.

How Degradation of the Road Surface can Contribute to this Impact

As surfaces deteriorate, the likelihood of potholes and other surface discontinuities increase. Road users travelling along the road are likely to experience increased vibrations. Road users who drive on roads for considerable periods, such as truck drivers, are at a risk of health impacts from experiencing these vibrations (Transport Research Laboratory, 2012). Whilst the level of vibration experienced by road users is a result of many factors, including vehicle properties and driving behaviours, road condition (including roughness, megatexture, potholes and other defects) is the most decisive factor for in-vehicle vibration (Granlund, J., 2008).

Some users are more vulnerable to the degree of bumpiness of the road, such as (Granlund, J., 2008):

- Persons with certain disabilities, diseases of injuries
- Pregnant women and unborn babies
- Injured ambulance patients.

Whole Body Vibrations (WBV) can be measured in terms of acceleration and are reported as metres per second (m/s^2). As a general rule, a level of WBV at or below 0.315 m/s^2 is considered “not comfortable”, while a measure above 0.5 m/s^2 is “fairly uncomfortable” (Granlund, J., 2008). Some vehicles are also more likely to expose their occupants to higher levels of WBV than others, due to varying degrees of suspension. For example, passengers in a passenger car may experience WBV of between 0.1 to 1 m/s^2 on a route, whilst a driver of a heavy truck might experience WBV of between 0.2 to 1.6 m/s^2 on the same route.

Truck drivers tend to record higher levels of WBV than other vehicles due to a combination of factors, including their driving position in the vehicle (further away from the vehicle’s centre of gravity), the high amount of dry friction and the greater dynamic activity of trucks (Granlund, J., 2008).

Measurement

Whilst measures can be identified to quantify the degree of WBV experienced by vehicle occupants along roads, a measure for quantifying the health cost is currently unavailable. It is, however, reasonable to consider heavy vehicle operators within the region as experiencing some degree of additional health cost as a result of the lack of investment in maintaining local road infrastructure.

3.3 ACCESS TO SERVICES

Description of Impact

Roads facilitate access to services for users. In particular, access to emergency and health care services is generally realised through road infrastructure. In the period between 2012-13 and 2016-17, the South Australian Ambulance Service transported an average of 220,358 patients per annum (SAAS, 2020a). Approximately 45% of

these transports were emergency incidents, 30% were urgent incidents and 25% were non-emergency incidents. Over this timeframe, the South Australian Ambulance Service received an average of 71 complaints per annum regarding access and 26 complaints regarding driving (which has the potential to be influenced by the quality of the road surface and infrastructure) (SAAS, 2020b).

Timeliness of receiving medical treatment is particularly critical for health outcomes of patients in emergency situations, in particular for acute conditions (e.g., stroke and heart attack) and severe trauma injuries (BHI, 2012). Similarly, timeliness of other emergency services (e.g., fire and police) can be expected to be critical in minimizing and successfully resolving emergency situations.

How Degradation of the Road Surface can Contribute to this Impact

The degradation of road infrastructure, particularly once the quality of the ride is impacted (see section 3.1), can result in delayed access to emergency services by users. The degree of degradation can also impact on the ability for emergency service workers to perform their duties:

- Vibration of the road may result in dislodgement of care equipment, changes in settings or disturbances in monitors and equipment in ambulances (Granlund, J., 2008).
- Vibrations have also been suggested to reduce the ability of care worker to perform duties whilst the ambulance is in motion.

In addition, in a health care context, vibrations can also impact on patient outcomes and experience:

- Patients travelling in ambulances have identified the pain experienced during relocation in an ambulance as being the “worst in their life” (Granlund, J., 2008, p. 15).
- A study of neonatal outcomes identified high-risk premature infants who travelled by ambulance to receive specialist care were more than twice as likely to record severe brain injury than those who did not undergo a transfer. It is considered the environment experienced in transit (stopping and starting, changes in noise levels, exposure to vibration) were, at least to some degree, contributing factors (Partridge, T., *et al.* 2020). Recommendations of methods to determine the smoothest route (and avoid risk of further impact) were provided.

Though not specifically mentioned in research regarding road quality, it is likely that the quality of road infrastructure has an impact on emergency vehicle response times and transport times, due to the need to travel at a slower pace (refer to 2.1.2). It is also likely this impact impedes upon delivery of all forms of emergency service provision, including fire and police emergency services. The South Australian Bushfire Regulations require all new dwelling and tourism accommodation facilities to have “access roads and tracks that are appropriately designed and built for entry and exit of vehicles, including fire fighting vehicles during a fire” (South Australian Government, 2020).

Measurement

Whilst measures can be identified to quantify the degree of roughness and vibration experienced by vehicle occupants along roads, a measure for quantifying the impact of restricted or uncomfortable access to services is not available. It is, however, reasonable to consider residents within the region as experiencing some degree of additional discomfort or reduced satisfaction with access to services.

3.4 REDUCED HOUSE PRICES

Description of Impact

The level of road amenity, access and environmental factors can all influence the enjoyment (or utility) of owning a property (Transport Canada, 1994). Where these factors impact negatively on homeowners’ enjoyment (or utility), house prices within the vicinity may decline.

In addition to amenity impacts, changes in accessibility result in significant impacts on the price of housing (Levkivich, O., *et al.*, 2015). All forms of accessibility (vehicle, public transport and walkability) are influencing factors on demand for housing and house prices (Grace, R., Saberi, M., 2018). Of these three forms, vehicle

accessibility has been demonstrated to have the most significant impact, with a 10 percentage point lift in accessibility² associated with a 6.8% lift in house value sales in Melbourne (Grace, R., Saberi, M., 2018).

How Degradation of the Road Surface can Contribute to this Impact

The degree of investment in road infrastructure has been demonstrated to be a key input in the user satisfaction outcomes (these are covered in detail in section 3.1) as well as environmental impacts (refer to Section 4). Investment in road infrastructure, of deficiency in, can also result in increased risk of severe accidents and vehicle operating costs (refer to section 2.1). These factors have the potential to impact on the demand for housing along roads, the degree of utility experienced by residents living in properties on local roads and, as a result, the price of properties. Noise is also a key factor, with noise pollution (such as traffic noise, trucks and exhaust braking) impacting on the amenity provided by a dwelling, and thereby on demand and prices for housing.

Measurement

An examination of property price sales in the vicinity of road improvements and improved quality of road infrastructure in Brazil found a considerable positive correlation between road quality improvements in residential house prices (Inter-American Development Bank, 2017). The diversity of road quality in Brazil is likely to be greater than that of the Legatus region (where road quality is likely to be relatively homogenous), as a result the degree of influence of road quality on house prices will be more muted in the Legatus region.

Insufficient data was available to quantify and value the impacts on property prices in the Legatus region. However, it is expected that inclusion of this impact in analysis would result in some double counting of benefits, as benefits to house prices from quality roads would likely include consideration of other factors such as user satisfaction/amenity, safety and time savings.

² Measured through the ARRB accessibility metric (AAM) which incorporates costs and time to access opportunities from a given location.

4. ENVIRONMENTAL IMPACTS

This chapter outlines the likely environmental impacts associated with the maintenance of roads. The factors considered in this chapter are considered to be externalities – when parties not directly involved in a transaction or action are impacted upon by that transaction or action.

4.1 AIR POLLUTION

Description of Impact

Air pollution refers to the quality of air close to the ground, which can impact on the health of living organisms including humans, animals and plants, as well as visibility. Road impacts on air pollution are primarily focused on exhaust emissions from travelling vehicles, however, air pollution impacts can also include fuel vapours, and emissions resulting from the contact between vehicles' tyres and the road surface. This can particularly be an issue for unsealed roads where the dispersal of road dust is more prevalent, though dust covered sealed roads can also generate air pollution through dispersal of road dust (Khan and Strand, 2018). Emissions will vary considerably between vehicle, fuel types and the type of road surface (Austroads, 2018).

Air pollution impacts of road infrastructure can affect human health, forests and agricultural activities at a local or broader geographical scale. However, in general, the impacts of vehicles on air pollution is predominantly an urban issue, and as a rule of thumb the parameter values for air pollution for a passenger car in a rural area is approximately 1% of the value in an urban area (TfNSW, 2020).

In addition to impacting on air pollution, emissions of vehicles include carbon monoxide, hydrocarbons and nitrogen oxide, which are all greenhouse gases. The impact of roads on greenhouse gas emissions is examined separately in section 4.2.

How Degradation of the Road Surface can Contribute to this Impact

The principal factors for the degree to which air quality is impacted by traffic include (Department of Transport and Main Roads, 2014):

- Traffic volume
- Average traffic speed
- Traffic composition (i.e., vehicle types)
- Road gradient
- Driving conditions (i.e., congestion)
- Individual vehicle emissions (contributed by engine types, fuel systems and braking systems and wheel systems)
- Driver behaviour and vehicle operating conditions (including factors such as: maintenance of the vehicle, air conditioner use).

The degree to which air pollution is dispersed can be influenced by road-specific factors, including road configuration, surface roughness and the presence of obstructions, as well as meteorological conditions. Road defects (including roughness, potholes, etc.) also impact directly on vehicle speeds and fuel consumption, lifting the level of emissions experienced (Gould et al, 2013).

Measurement

Measuring air pollution is based on a value per kilometres travelled by vehicle type. A method for calculating kilometres travelled by vehicle type is outlined in Section 2.1.1.

Applicable values (in terms of cents per kilometres travelled) for estimating air pollution emissions by vehicle type, specifically for rural areas, are provided in the following table. These can be applied to the kilometres travelled estimates to determine a total air pollution impact.

Table 4.1. Air Pollution Values

Vehicle Type	Cents per Kilometre Travelled
Car	0.04
Bus	0.43
Light Commercial Vehicle	-
Rigid Truck	0.16
Articulated Truck	0.67

Source: Austroads (2012)

Studies regarding the degree of influence of road roughness (specifically, IRI) and the level of vehicle emissions have produced mixed results, with some studies finding a linear relationship (i.e., as the roughness of the road increases, the level of emissions also increases), and others finding the relationship to be non-linear (Qing et al, 2017). One study identified the most advantageous IRIs, with regards to air pollution, being above 1.99 and below 6.00 (Qing et al, 2015) with limited difference in air pollution outcome within this range, however both smoother and rougher roads outside this range would be anticipated to increase emissions.

Most commonly, studies which identified a linear relationship between air pollution and IRI ascertained that the amount of pollutant released through motor vehicle operation is proportionate to the amount of fuel consumed. As a result, the equation provided in section 2.1.1 can be applied in this instance also.

Hypothetical Example – Base Cost (IRI =2)

Car air pollution: (146,000 vehicle kilometres x 0.041 c/km) = \$59.8

Truck air pollution: (36,500 vehicle kilometres x 0.067 c/km) = \$243.1

Total impact = \$302.9

Hypothetical Example – Deteriorated Cost (IRI = 4)

Applying the equation in section 2.1.1 to the base cost of air pollution per kilometre resulted in cost values of 0.044 c/km for cars and 0.84 c/km for trucks.

Car air pollution: (146,000 vehicle kilometres x 0.044 c/km) = \$64.5

Truck air pollution: (36,500 vehicle kilometres x 0.084 c/km) = \$305.6

Total impact = \$370.2

Impact of Lack of Investment

The difference in the cost of air pollution as a result of the increase in IRI is estimated at \$67.3.

4.2 GREENHOUSE GAS EMISSIONS

Description of Impact

Greenhouse gases are those which trap heat in the atmosphere and are primarily comprised of carbon dioxide, methane, nitrous oxide and fluorinated gases (EPA, 2020a). In Australia, transport accounts for 15% of national greenhouse gases, driven by the direct combustion of fuels in transportation (State of the Environment, 2020). Greenhouse gases are considered to have a global impact as they contribute towards warming of the planet.

How Degradation of the Road Surface can Contribute to this Impact

Vehicle fuel consumption and emissions are affected by the characteristics of the road surface, primarily the roughness of the road and, to a lesser extent, the degree of macrotexture (refer to section 2.1.3). An improvement in the quality of the road surface (measured by IRI) is thought to have an immediate impact on the level of greenhouse gases emitted. As a result, cumulative effects of improvement/ deterioration in road surface for greenhouse gases can be substantial (Wang, T. *et al*; 2014).

Measurement

Measuring greenhouse gas emissions is based on a value per kilometres travelled by vehicle type. A method for calculating kilometres travelled by vehicle type is outlined in Section 2.1.1.

Applicable values (in terms of cents per kilometres travelled) for estimating air pollution emissions by vehicle type, specifically for rural areas, are provided in the following table. These can be applied to the kilometres travelled estimates to determine a total greenhouse gas emission impact.

Table 4.2. Greenhouse Gas Values (2021 Dollars)

Vehicle Type	Cents per Kilometre Travelled
Car	2.73
Bus	15.99
Light Commercial Vehicle	2.41
Rigid Truck	3.74
Articulated Truck	15.00

Source: Austroads (2012)

Due to the commonalities between air pollution and greenhouse gas emissions, the same method for lifting the cost associated with air pollution can be applied for greenhouse gas emissions.

Hypothetical Example – Base Cost (IRI =2)

Car greenhouse gas: (146,000 vehicle kilometres x 2.73 c/km) = \$3,979.

Truck greenhouse gas: (36,500 vehicle kilometres x 15.00 c/km) = \$5,475.

Total impact = \$9,454.

Hypothetical Example – Deteriorated Cost (IRI = 4)

Applying the equation in section 2.1.1 to the base cost of greenhouse gas emissions per kilometre resulted in cost values of 2.94 c/km for cars and 18.86 c/km for trucks.

Car greenhouse gas: (146,000 vehicle kilometres x 2.94 c/km) = \$4,290.

Truck greenhouse gas: (36,500 vehicle kilometres x 18.86 c/km) = \$6,885.

Total impact = \$11,175.

Impact of Lack of Investment

The difference in the cost of greenhouse gas as a result of the increase in IRI is estimated at \$1,721.

4.3 WATER

Description of Impact

Contamination of water bodies (lakes, rivers, oceans, groundwater) by transport-related activities is considered as water pollution. This impact is not isolated to roads contiguous to a water body, as it also includes the cost associated with fuel or oil run-off from the road surface and particulate matter washing into waterways (Transport and Main Roads, 2011).

How Degradation of the Road Surface can Contribute to this Impact

The degree of dilapidation of the road, resulting in additional roughness and road defects as well as vibration, has the potential to increase the degree of wear and tear on local vehicles, and the potential for increased matter to be washed into waterways. However, the impact of reduced road maintenance on biodiversity is considered to be marginal.

Measurement

Measuring water impacts from transport activities is based on a value per kilometres travelled by vehicle type. A method for calculating kilometres travelled by vehicle type is outlined in Section 2.1.1. The values applied are based on a willingness to pay methodology and mitigation costs, care must be taken to prevent double counting of these values with other externality costs.

Applicable values (in terms of cents per kilometres travelled) for quantifying water impacts by vehicle type, specifically for rural areas, are provided in the following table. These can be applied to the kilometres travelled estimates to determine a total water impact.

Table 4.3. Water Impact Values (2021 Dollars)

Vehicle Type	Cents per Kilometre Travelled
Car	0.05
Bus	0.06
Light Commercial Vehicle	0.01
Rigid Truck	1.01
Articulated Truck	4.05

Source: Austroads (2012)

Details regarding the degree of impact upon water and IRI correlation was not able to be identified through research, though is broadly considered to be marginal. In a cost benefit analysis, qualitative discussion regarding a potential impact of road surface on water resources should be included, noting the impact is not anticipated to be significant.

The below demonstrates an example of how the impact upon water is calculated.

Hypothetical Example – Base Cost (SN = 60, IRI =2)

Car water impact: (146,000 vehicle kilometres x 0.05 c/km) = \$75.

Truck water impact: (36,500 vehicle kilometres x 4.05 c/km) = \$1,477

Total impact = \$1,552.

Hypothetical Example – Deteriorated Cost (SN = 40, IRI =4) (No Measurable Change Due to Road Surface Condition)

Car water impact: (146,000 vehicle kilometres x 0.05 c/km) = \$75.

Truck water impact: (36,500 vehicle kilometres x 4.05 c/km) = \$1,477.

Total impact = \$1,552.

Impact of Lack of Investment

Difference in impact not able to be quantified.

4.4 NATURE AND LANDSCAPE

Description of Impact

Nature and landscapes surrounding the road infrastructure refer to the geology, biodiversity, agriculture, and soils. The primary impacts caused by the presence of road infrastructure include habitat loss, fauna and flora disturbances, and fauna mortality.

How Degradation of the Road Surface can Contribute to this Impact

The degradation of the road surface may result in a multitude of impacts to the surrounding nature and landscape, including:

- The spread of dust, splash, and spray from the road surface

- The spread of wear particles such as asphalt, tyres, etc.
- Greater noise disturbances to fauna (noise generated by vehicles is louder on roads in poor condition)
- Vibrations may disturb fauna and cause damage to surrounding geological objects
- Increased road accidents resulting in damage to surrounding flora and fauna (Roadex Network, 2021).

The impacts highlighted above may cause loss of fauna and flora, encourage relocation of fauna, and ultimately modify the community structures, population dynamics and biodiversity of the area.

Measurement

Measuring the impact on nature and landscapes is typically based on a value per kilometres travelled by vehicle type. A method for calculating kilometres travelled by vehicle type is outlined in Section 2.1.1.

Applicable values (in terms of cents per kilometres travelled) for estimating the costs by vehicle type, specifically for rural areas, are provided in the following table. These can be applied to the kilometres travelled estimates to determine a total impact upon nature and landscapes.

Table 4.4. Nature and Landscape Values (2021 Dollars)

Vehicle Type	Cents per Kilometre Travelled
Passenger Cars	0.64
Buses	1.76
Light Commercial Vehicles	0.01
Rigid Trucks	0.78
Articulated Trucks	11.27

Source: Austroads (2012)

Details regarding the degree of impact upon the nature and landscapes (i.e., geology, biodiversity, agriculture, and soils) and IRI correlation was not able to be identified through research. In a cost benefit analysis, qualitative discussion surrounding the potential for road surface quality to impact on nature and landscape should be included.

The below demonstrates an example of how the impact upon nature and landscapes is calculated.

Hypothetical Example – Base Cost (SN = 60, IRI =2)

Car nature and landscape impact: (146,000 vehicle kilometres x 0.64 c/km) = \$927.

Truck nature and landscape impact: (36,500 vehicle kilometres x 11.27 c/km) = \$4,114.

Total impact = \$5,041.

Hypothetical Example – Deteriorated Cost (SN = 40, IRI =4) (No Measurable Change Due to Road Surface Condition)

Car nature and landscape impact: (146,000 vehicle kilometres x 0.64 c/km) = \$927.

Truck nature and landscape impact: (36,500 vehicle kilometres x 11.27 c/km) = \$4,114.

Total impact = \$5,041.

Impact of Lack of Investment

Difference in impact not able to be quantified.

5. KEY FINDINGS AND RECOMMENDATIONS

5.1 KEY FINDINGS

Insufficient investment in maintenance of road infrastructure presents significant economic, social and environmental costs.

Degradation of the road surface (potholes, defects and roughness) is a common physical manifestation of deficient road infrastructure maintenance investment. The roughness of a road surface is commonly measured using the International Roughness Index (IRI). Through this study, the impact of an increase in IRI from 2 to 4 was able to be quantified for the following impacts:

- Vehicle operating costs – with the per kilometre cost increasing by approximately 8% for cars and 26% for trucks.
- Travel time costs – with the rate of speed achieved on the road decreasing from 55kmph to 51 kmph.
- Air pollution levels – with the per kilometre cost increasing by approximately 8% for cars and 26% for trucks.
- Greenhouse gas emissions – with the per kilometre cost increasing by approximately 8% for cars and 26% for trucks.

Degradation of the road surface can also impact on the roads skid resistance. Roads with lower levels of skid resistance have been demonstrated to result in increased numbers and severity of accidents. In a worked example, the risk of accident associated with a decline in skid resistance from a level of 60 to a level of 40 was associated with a 32% lift in the number of accidents.

Some impacts have been shown to have a direct link to changes in IRI but were not able to be quantified in this assessment. These impacts include:

- Increased in-car vibration levels – posing additional health risks to heavy vehicle operators and ambulance passengers.
- Reduced access to services.

In addition to the measures and impacts outlined above, a broad range of other impacts associated with insufficient infrastructure in road maintenance were identified, but either had insufficient information available regarding the link between road surface quality and impacts or were not valued due to potential double counting of impacts. These include:

- Lower levels of tourism attraction than might otherwise occur.
- Difficulties in accessing labour.
- Reduced house prices.
- Potential for reduced user satisfaction and amenity.
- Increased impacts on water, nature and landscapes.

Whilst Local Councils may, in the short term, experience a financial benefit of deferring expenditure on road maintenance, the continued physical degradation of the road infrastructure is likely to result in additional and higher maintenance costs in the long-run.

Hypothetical Example Results

A hypothetical example of a poorly maintained road has been used throughout this document to demonstrate the potential costs of a lack of road infrastructure investment and the resulting deterioration in the road surface from an IRI of 2 to an IRI of 4 and the decrease in SN from 60 to 40. The details of the traffic volumes and road parameters are provided in Section 1.3.

Quantification of the costs associated with the road deterioration was conducted for the following costs:

- Additional vehicle operating costs: \$6,182 per annum.
- Additional travel time costs: \$14,242 per annum.
- Additional cost of road accidents and crashes: \$9,384 per annum.
- Additional cost of air pollution: \$67 per annum.
- Additional cost of greenhouse gases: \$1,721 per annum.

The total impact is estimated at a cost of \$31,596 per annum per kilometre.

For comparison, an estimated cost of road maintenance (to maintain roads in a good condition) has been developed assuming an annual vehicle maintenance cost of 4.5 cents per vehicle kilometres travelled by cars and a cost of 16.78 cents per vehicle kilometres travelled by 5 axle articulated trucks (Transport for New South Wales, 2020). This resulted in an estimated annual maintenance cost of the road of \$12,760.

This suggests a significant cost saving associated with maintenance of road infrastructure compared to the associated costs of insufficient road maintenance, with the example above indicating under the road conditions and traffic volumes assumed, the annual cost of the road's condition deteriorating from an IRI of 2 to an IRI of 4 would be approximately 2.5 times the cost of maintaining the road to a good condition.

5.2 RECOMMENDATIONS

Future assessment of the cost of insufficient investment in road infrastructure maintenance for the Legatus region is likely to be focused on the quantification of the full cost associated with the estimated \$63 million shortfall in investment over the next decade.

Investigation into and collation of a number of key datapoints for the region will be required to facilitate such an assessment. In particular, annual traffic counts by vehicle type, IRI and SN estimates for local roads are identified as prominent data gaps. At the time of writing, quotes for obtaining IRI and SN information for key roads in the Legatus region are being investigated by Legatus officers. It is expected traffic counts data will be obtained from each of the Councils within the region.

An assessment of the total cost of insufficient investment in road infrastructure in the Legatus region would require investigation into local IRI and SN levels and estimation of the potential lift in IRI/ reduction in SN for each road as a result of deferred or insufficient road maintenance investment.

Most commonly, cost benefit analysis is conducted on a project-by-project basis, rather than across large geographical areas. A selection of key roads known to be problem zones within the region could be identified and analysed individually. These assessments would enable the quantification of a baseline (a scenario in which infrastructure maintenance investment is sufficient over the assessment period, and the quality of the road is maintained) and a scenario of insufficient road infrastructure investment (in which the quality of the road deteriorates over time) which can be compared. Such an assessment would limit the scope and scale of the required data gathering exercise, whilst providing proof of concept case studies for other roads in the region. Development of a cost-benefit analysis for each identified case study would be estimated to cost approximately \$10,000.

Contextual information regarding social impacts or perceptions of the state (or future state) of road infrastructure in the region could be collected (via a community and business survey) to develop a more comprehensive understanding of costs unable to be quantified.

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