FINAL REPORT

Project Title: A27 Harmonisation of Pavement Impact Assessment: Updates and Extended Marginal Cost Values (Year 1 - 2015/16)

ARRB Project No: PRA16023

Author/s: Tyrone Toole, Ron Roper and Lory Noya

Client: Queensland Department of Transport and Main Roads

Date: June 2017

AN INITIATIVE BY:

SUMMARY

The Queensland Department of Transport and Main Roads has produced a new guideline to assess the transport impacts of development, which will replace the 'Guidelines for Assessment of Road Impacts of Development' (GARID), which was published by the Department in 2005.

The new guideline, named the 'Guide to Traffic Impact Assessment' (GTIA), requires that impacts on the state-controlled road network are identified and measures are implemented to avoid, reduce or compensate for the effects on the asset life of state-controlled roads.

For marginal standard axle repetitions (SAR) impacts, i.e. in cases where the pavement life is not consumed during the loading period, there is a need to identify the relevant marginal cost (MC) rate per SAR-km of road wear from the Department's marginal cost database for each state-controlled road section, and calculate the contribution required to offset pavement impacts.

This report describes the basis and outcomes of a study tasked with producing updated long run MC road wear values for sealed roads by using the results of Traffic Speed Deflectometer (TSD) surveys undertaken on a substantial proportion of sealed roads which contribute to the state-controlled road network. The outcomes are available to support the application of the GTIA.

The report also describes the background to the load-wear cost model and the Freight Analysis and Mass Limits Tool (FAMLIT) and its application within this study, the data assembly processes and technical models employed, and a summary of the marginal costs determined for sealed roads.

.

This page is intentionally left blank

CONTENTS

TABLES

FIGURES

1 INTRODUCTION

1.1 Background

The Queensland Department of Transport and Main Roads (TMR) has produced a new guideline to assess the transport impacts of development which will replace the '*Guidelines for Assessment of Road Impacts of Development*' (GARID), which was published by the Department in 2006 (Queensland Department of Transport and Main Roads 2006).

The new guideline, named the '*Guide to Traffic Impact Assessment'* (GTIA) (Queensland Department of Transport and Main Roads 2017), requires that impacts on the state-controlled road network are identified and measures are implemented to avoid, reduce or compensate for the effects on the asset life of state-controlled roads.

The GTIA requires a pavement impact assessment report to be produced for roads in the impact assessment area (IAA), according to the following process:

1. Determine the existing SARs for each section of the state-controlled road (SCR) on all affected SCRs in accordance with Section 3.4 (of the GTIA).
2. Determine the number and types of vehicles that will be generated by the development in both the construction and operational phases, and determine the sections of the SCR network where pavement assessment is required based on the SAR thresholds defined in Section 10.3.2 (of the GTIA).
3. Determine if the development-generated construction or operational SARs will consume the remaining pavement SAR capacity during the impact mitigation period on any section of the SCR network, then prepare a pavement design for that section to return the pavement to its pre-development SAR capacity at the end of the impact mitigation period. The design should be submitted to TMR's nearest regional office for approval, and the development will be required to construct the pavement upgrades before pavement failure occurs.
4. For marginal SAR impacts, defined as cases where the remaining pavement SAR capacity will not be consumed during the impact mitigation period, identify the relevant marginal cost rate per SAR-km from TMR's marginal cost database for each SCR section in the impact assessment area. Calculate the contribution required to offset pavement impacts using the following formula (reproduced directly from the GTIA):

- $\text{Pavement contribution} = \sum_{i=1}^{n}[(C+O)_i \times MC_i \times L_i]$

Where: i is each road segment triggered
C is construction period SARs
O is operational period SARs for the impact mitigation period
MC is the relevant marginal cost (per SAR-km) prescribed in the department's database for each road segment
L is the length of road section in km
n is the number of road segments triggered in the impact assessment area

Source: Queensland Department of Transport and Main Roads (2017).

The GTIA describes the source of the marginal cost database as being based on an analysis performed using the Freight Axle Mass Limits Investigation Tool (FAMLIT)[1] in a study completed in 2014. The FAMLIT was produced by ARRB and is published by Austroads, with the latest versions of the user guide and technical report published in 2015 (Austroads 2015a & 2015b).

The GTIA further states that for assessments which involve road or pavement categories not defined above, or where the increased loading is more intensive and is applied over a short period and pavements are known to be very weak in relation to the task, the FAMLIT software is to be used. This, however, is not a standard calculation using the published Austroads tool, and requires a first principles approach to its calculation which allows the impact of step changes in loading and the period of elevated loading to be defined and analysed. This is because the standard FAMLIT analysis assumes that the increased load applies throughout the development period and beyond, i.e. it offers an MC based on the long run marginal cost of road wear, with the marginal cost calculated for each one kilometre road section and reported in cents per SAR-km.

1.2 Scope and Structure of this Report

This report describes the basis and outcomes of a study tasked with producing updated long run MC values for sealed roads by using the results of Traffic Speed Deflectometer (TSD) surveys undertaken on a substantial proportion of sealed roads which contribute to the state-controlled road network.

The outcomes of this study are available to support the application of the Department's new guidelines on the impact of road transport from development, with a focus on road pavement impacts.

The contents of this report are organised as follows:

- Section 1, this section, provides background information including the aim of the current study and the planned application of the results.
- Section 2, Quantifying Pavement Impacts, describes the background to the load wear cost model, as well as the FAMLIT and its application within this study.
- Section 3, Data Assembly and Technical Models, describes the basic input, models and section classification data, comprising network categorisation information, determination of pavement strength, road deterioration and works effects models employed, unit costs, intervention criteria, etc. used for the study.
- Section 4, Long Run Marginal Costs for Sealed Roads, includes the presentation and discussion of the results.
- Section 5, Conclusions and Recommendations, contains the conclusions and recommendations drawn from this study.

The report is also accompanied by the following appendix and an electronic copy of the study data:

- Appendix A – Example Calculation of the Charge per Trip

---

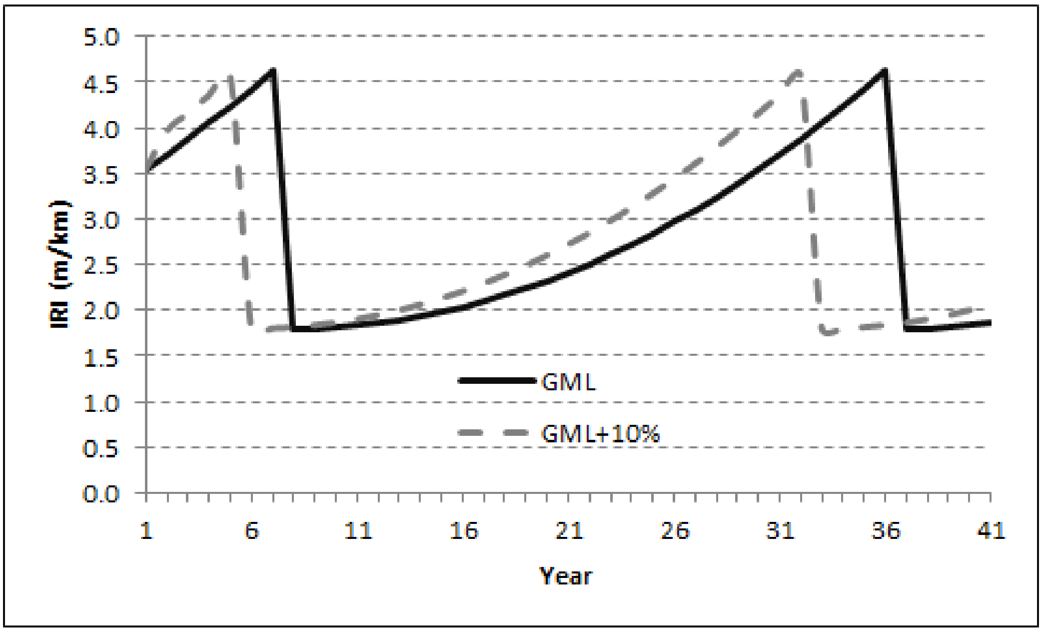
[1] This study replaces the results for sealed roads produced in a study completed in 2014 and reported in ARRB Contract Report 008661-1, Harmonisation of Pavement Impact Assessment: Technical Report (Toole & Sen 2014). The 2014 study also included a preliminary study of unsealed roads, and these have not been updated under this study.

2 QUANTIFYING PAVEMENT IMPACTS

2.1 Load-wear Cost Model Background

Whereas a number of practical options for quantifying pavement impacts exist, the adopted approach is based on the application of marginal cost principles, this having been widely accepted at an Australian Government, state and local government level as a reasonable basis for cost attribution (Austroads 2012b). This is because it aims to capture the performance impacts and full life-cycle costs of maintaining and rehabilitating road infrastructure over an extended period as illustrated in Figure 2.1. This illustration shows a difference in the frequency of major work from approximately 30 years to 27 years, which is typical of a long-term policy change such as allowing a change from gross mass limits (GML) to higher mass limits (HML) or to a concessional mass loading (CML) arrangement.

Figure 2.1: Impact of increasing axle load on road rehabilitation intervention timing



Source: Austroads (2012a).

The marginal cost of road wear, which is the metric used in road cost attribution, is defined as the difference in the cost of maintaining a road in a serviceable condition arising from an increase in traffic loading above current or base traffic. Algebraically, it is the rate of change of the cost resulting from the incremental change (increase) in the freight task.

Analysis has shown that the marginal cost is mostly dependent on the magnitude and duration of the additional load, the structural strength of the road and its variation, and the additional cost of road maintenance activities to fulfil performance requirements.

Consequently, a standard marginal cost based on a network average for all roads is inadequate compensation for the majority of roads as this does not reflect the variation between the design strength and in-service pavement strength. For example, many rural roads have relatively weak structures in relation to the additional traffic loads they may be subjected to, whereas freeways and highways, which are designed, built and maintained to higher standards, possess significantly higher strengths.

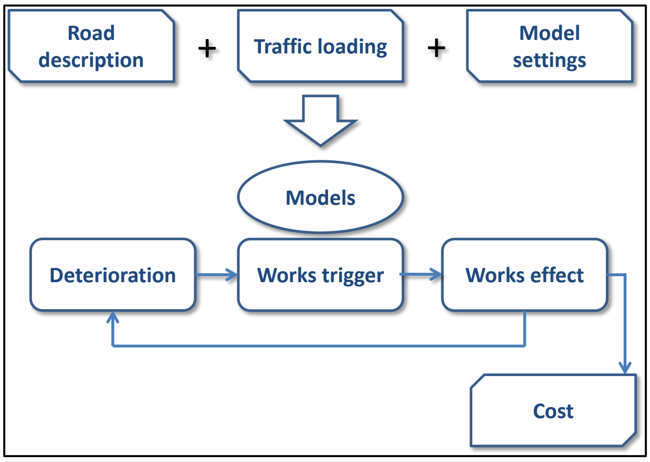
2.2 The FAMLIT model

The FAMLIT has been developed under various Austroads and National Transport Commission (NTC) supported projects to offer asset managers a ready means to determine the marginal cost of road wear. The tool evolved from state-based studies (Michel & Toole 2005) and then national studies with a national approach published in 2012 (Austroads 2012b). Further updates have taken place and a new version was released in 2015 (Austroads 2015a & 2015b).

FAMLIT is a network-level pavement life-cycle costing analysis tool that has been specifically tailored to produce load-wear cost (LWC) relationships suitable for estimating the marginal cost of road wear with increased axle loads.

FAMLIT produces road wear costs in the form of equivalent annual uniform cost (EAUC), based on road and traffic input data. The EAUC is based on the discounted present value of the road agency maintenance and rehabilitation work costs over the defined analysis period used for each road segment analysed. The tool uses a combination of road deterioration models, works effects models and road condition triggers to run a year-by-year analysis over 50 years that computes the effects of increasing axle group mass or an increased task (Figure 2.2). FAMLIT allows both single and multiple axle group loads to be modelled to produce LWC curves that are the basis for developing marginal cost relationships. The process of setting up the road network for analysis and estimating the marginal costs occurs outside the FAMLIT software, and is described in Section 3.2.

Figure 2.2: Flow chart of FAMLIT life-cycle cost model



FAMLIT assists asset managers in assessing the wear and cost implications of changes in traffic loading at a route or network level. Whereas the approach is not intended as a substitute for road maintenance planning and programming, the road wear modelling approach used by FAMLIT is available for road agencies to assess network-level road wear costs by using whole-of-life cycle costing principles to determine the required interventions for the various traffic levels on a range of functional road classes, while maintaining an acceptable level of service on each road class.

FAMLIT is designed to support road asset managers in tasks such as:

- assessing the financial impacts associated with changes in the heavy vehicle fleet, and either changes in the transport task caused by additional road use or incremental increases in mass limits
- assessing variations in road agency costs under different loading scenarios for different pavement types, with different structural capacities and conditions in different environments
- assessing the capacity of each link in the network to support a change in axle mass or the freight task

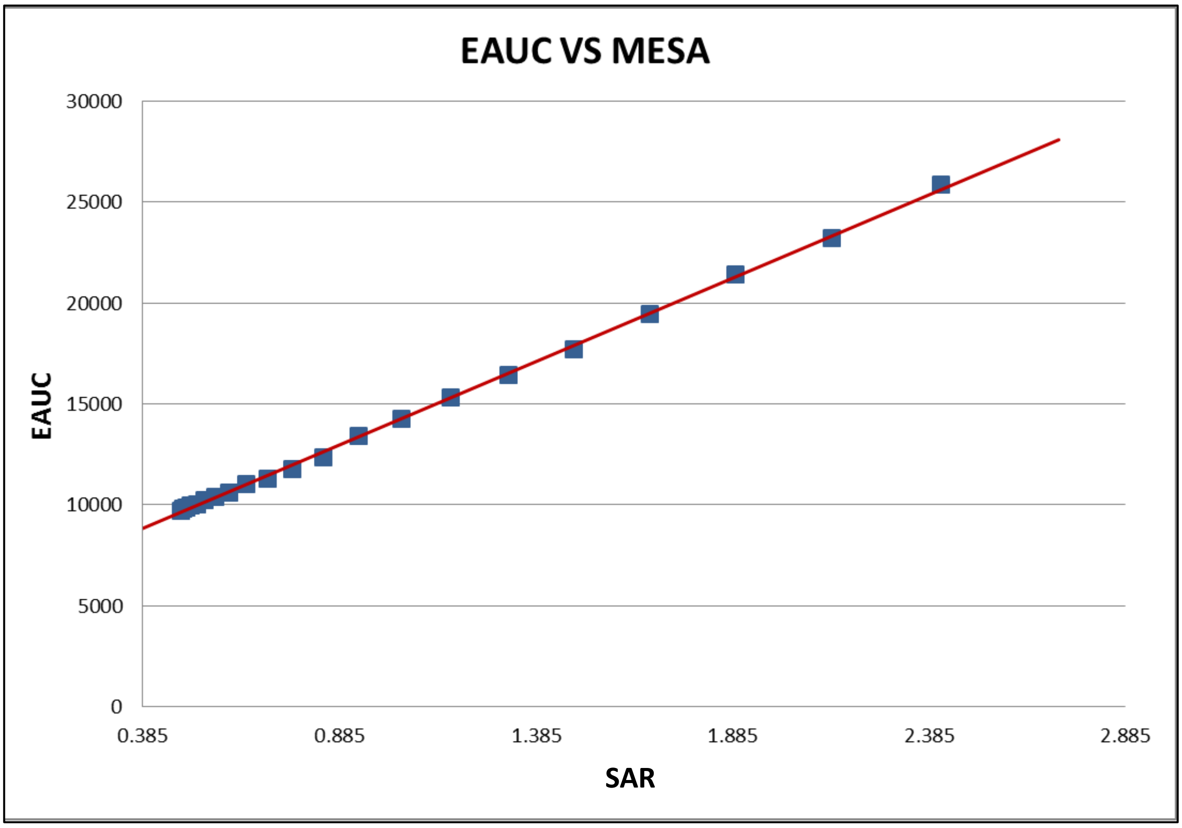
- setting different axle mass limits for each link in the network.

For each assessment, FAMLIT requires pavement condition information, traffic loading, typical maintenance practices and maintenance costs. The input data required is described in Section 3.2. It then uses this information to generate a simulated works program for that segment over 50 years using Austroads pavement deterioration and works effects models (Austroads 2010a & 2010b) for each loading scenario. A road pavement maintenance cost per SAR-km is then derived from the cost of the simulated works program.

2.3 Determination of Load-wear Cost Relationships

The aim of a FAMLIT analysis is to produce sufficient results based on a number of realistic loading scenarios to enable a LWC relationship to be determined based on the full analysis period using: a) the loading in terms of the cumulative number of SAR; and b) the commensurate road wear costs, EAUC. This then provides the basis for deriving the MC (in cents per SAR-km, being the slope of the relationship) for each physical or representative length of road as shown in Figure 2.3. The relationship between SAR and EAUC is linear, and this considerably simplifies the application of the approach, noting that the derivation is based on evaluating the effect of increased axle loads without overstressing the pavement and surfacing layers.

Figure 2.3: Example relationship between SAR and EAUC based on changing the loading on a single axle group



However, in practice, the approach to defining loading scenarios can vary, and the following methods have been applied in different cases:

1. The typical approach to producing LWC relationships has been to fix all axle group loads at the general mass limits (GML) (National Transport Commission (Road Transport Legislation — Mass and Loading Regulations) Regulations 2006), and then change the loading on a

single axle group to determine the effect that a specific axle load has on maintenance (road wear) costs. This is the method used to populate the example in Figure 2.3.

2. Another approach is to calculate the actual annual SAR per physical road section and to vary this between 60% and 140% of the total transport task in annual SAR, and determine the effect that this has on maintenance (road wear) costs measured in EAUC. The results are then employed to produce a unique SAR-EAUC relationship for each road section.

While either of the above approaches is suitable for the main purpose of this study, method 2 was chosen as it can be applied directly to data from the physical sections which form the basis for the analysis. An alternative to the above is where a specific change in the transport task has been specified in terms of the total tonnage and duration, in which case a comparison between the current (base) loading and the alternative loading needs to be done on a case-by-case basis.

3 DATA ASSEMBLY AND TECHNICAL MODELS

3.1 General

Whereas earlier studies involving the determination of marginal costs applied the concept of representative road sections, due primarily to the lack of structural data for the greater proportion of TMR's network of physical road sections, the current study had access to comprehensive pavement strength data from the Traffic Speed Deflectometer (TSD) surveys undertaken on approximately 17,673 km of TMR's sealed road network.

This enabled a database of physical road segments (each 100 m in length) to be developed and populated with road condition and other data drawn from TMR's ARMIS database for approximately 60% of the sealed road network. The remaining network was then populated by creating a new suite of representative sections using a number of characteristics and measured data available from ARMIS, and by assigning the TSD data. In this way, the representative road sections cover the scope of physical sections within the Queensland state road network in terms of different road classes, pavement types, traffic levels, environments (both soil and climate) and pavement ages and strength. The data used to populate the representative sections employed the full database of information available, including making use of the TSD data and applying it to segments not measured in the surveys, but which possess similar characteristics in other respects.

3.2 Data and Network Population

3.2.1 Required FAMLIT Input Data

The required network data includes attributes relating to road identification, pavement construction and material type (GN, AC and CS)[2], climate (Thornthwaite Moisture Index (TMI) (Thornthwaite 1948)), pavement/subgrade strength (modified structural number (SNC)), surface condition (roughness and rutting), and pavement age. Road deterioration (RD) and works effect (WE) model calibration factors, maintenance intervention data, and unit cost rates for maintenance and rehabilitation works are also required.

Table 3.1 contains a list of the road specific input variables for FAMLIT, a brief description of each one and the source of the input used for the physical road segments analysed in this study

---

[2] The pavement type nomenclature used in this report differs from TMR nomenclature (Queensland Department of Transport and Main Roads 2013) and is based on that used in FAMLIT. A suggested translation into TMR nomenclature is shown below. For high load intensity low intervention (HILI) pavements, the nearest equivalent pavement type should be chosen. A common set of functional (rutting and roughness) deterioration models were employed for each pavement type, whereas separate structural deterioration models were employed. See Austroads (2010a) and Austroads (2010b) for further details.

TMR pavement type	FAMLIT pavement type	Load damage exponent
SG (Sprayed seal granular pavement)	GN	4
AG (Asphalt over granular pavement)	AC	5
ACst (Asphalt over cement stabilised pavement)	CS	12

Table 3.1: List and description of road input parameters

Parameter name	Description	Source
Rd no.	Unique road identification number.	Defined for this study
Road name	Unique road/pavement identification name.	Defined for this study
Road class	The sub-group that the road belongs to for allocating traffic loading.	TMR ARMIS
Pavement type	The type of pavement material; GN = granular pavement with a spray seal, AC = asphaltic concrete, CS = cement stabilised. The pavement type selected will influence the deterioration model.	Derived for this study based on ARMIS data
Discount rate	The discount rate (%) used to calculate the lifecycle cost.	Defined for this study. 5% applied
TMI	Thornthwaite Moisture Index (Thornthwaite 1948) climate variable.	Defined for each district
Overlay IRI trigger	The road roughness level in IRI (m/km) that will trigger an overlay.	Defined for this study, see Table 3.5
Overlay SNP ratio trigger	The ratio of SNC to SNC_0 that will trigger an overlay.	Defined for this study, see Table 3.5
Overlay IRI reset	The road roughness level in IRI (m/km) that the road is reset to after an overlay.	Defined for this study, see Figure 3.1, Table 3.7 and Table 3.8
Overlay min interval	The minimum time in years between overlays.	Defined for this study. 3 years applied.
Overlay max interval	The maximum time in years between overlays.	Defined for this study. 100 years applied.
Material coefficient	A coefficient used to convert the thickness of a material in millimetres into a structural number measure of strength.	Coefficient selected based on pavement type, with 0.14 applied for granular overlays and 0.4 applied for asphalt overlays
Min. overlay thickness	Minimum overlay thickness (mm) the model will use.	Not used, with actual thickness based on model calculation.
Max. overlay thickness	Maximum overlay thickness (mm) the model will use. Optional input.	No value supplied.
Min. pavement strength	Minimum pavement strength (SNC) post-treatment that the model will tolerate. Optional input.	Defined for this study. SNP 3 applied.
Overlay design life	Design life used to calculate the thickness of an overlay treatment (years).	Defined for this study. 30 years applied.
Fixed overlay thickness	The thickness (mm) applied to all overlays, regardless of design life.	No fixed thickness applied.
Overlay design traffic	The expected traffic for the road of this design.	Calculated for each section.
Overlay design traffic growth	Traffic growth used when calculating new overlay thickness based on the design life (%/year).	Defined for this study. 0% applied.
Reseal cost ($\$/m^2$)	Reseal works cost ($\$/m^2$).	Defined for this study, see Table 3.9
Overlay1 ($Cost/m^3$)	Overlay works cost for the minimum thickness of a mill and replace overlay or the total thickness of a non-mill and replace overlay ($\$/m^3$).	Defined for this study, see Table 3.9
Overlay2 ($Cost/m^3$)	Overlay works cost for a mill and replace overlay where the mill depth required is between the minimum thickness and 300 mm ($\$/m^3$).	Defined for this study, see Table 3.9

Parameter name	Description	Source
Overlay3 (Cost/m^3)	Overlay works cost for a mill and replace overlay where the mill depth required is greater than 300 mm (\$/m^3).	Defined for this study, see Table 3.9
Direction factor	Proportion of the traffic assigned to the lane being modelled (e.g. 1 for all traffic, 0.5 for 50%).	Factor of 1 applied.
Traffic growth	Traffic growth for the vehicle count or SAR loading applied to the road (%/year). Does not have to be the same as the Overlay design traffic growth.	Defined for this study. 0% applied.
SNP	Pavement modified structural number at the start of the analysis.	Derived from TSD data.
RI_0	Roughness in IRI (m/km) at the start of the analysis period.	TMR ARMIS
AADT	Annual average daily traffic (vehicles per day) for the road. Optional input. This variable is not used in the model and is just a guide for when reviewing results.	TMR ARMIS
TSRS	Time (years) since last reseal.	TMR ARMIS
TSOVL	Time (years) since last overlay.	TMR ARMIS
TSRE	Time (years) since last reconstruction or since construction.	TMR ARMIS
Road length	Length of road section (m).	TMR ARMIS
Road width	Width of road section (m).	TMR ARMIS
Initial SNP	Pavement modified structural number at construction or zero pavement age.	Derived by back calculation from Austroads (2010b)
ME constant	Annualised pavement maintenance expenditure (\$/lane-km/year). It is an input to the roughness deterioration model and part of the routine maintenance cost.	Derived from the following equation multiplied by a factor of 1.88 to account for cost escalation between 2002 and 2016. $me = \alpha + 0.00309 \times$ ESA/lane/year
IRI_0	Initial roughness, IRI (m/km), at zero pavement age for the roughness deterioration model, typically has the following default values for the range of road classes/types: IRI_0 = 0.8–1.0 (m/km) freeways IRI_0 = 1.0–1.2 (m/km) major arterial highways IRI_0 = 1.2–1.5 (m/km) main arterial highways IRI_0 = 1.5–1.8 (m/km) minor arterial roads IRI_0 = 2.0–2.5 (m/km) local collector roads IRI_0 = 2.5–3.0 (m/km) local access roads.	Defined for this study.
Drut K-fact	Delta rut calibration factor for the roughness deterioration model.	Defined from 2012 FAMLIT study (Hore-Lacy, Thoresen & Martin 2012), see Table 3.10

Parameter name	Description	Source
DIRI K-fact	Delta roughness calibration factor for the roughness deterioration model.	Defined from 2012 FAMLIT study (Hore-Lacy, Thoresen & Martin 2012), see Table 3.10
B	Factor for estimating the field layer thickness (FLT) of bitumen binder (only applicable if cracking is implemented).	Not implemented
S	Nominal maximum size (mm) of seal aggregate (only applicable if cracking is implemented).	Not implemented
SN	Structural number of the pavement layers excluding the subgrade. Optional input. This variable is not used in the model and is just a guide for when reviewing results.	Determined as difference between computed SNP and subgrade contribution (based on Hodges, Rolt & Jones 1975)
CBR	California Bearing Ratio of subgrade.	Defined for this study. CBR 10 applied
Year	Analysis start year.	2016
RS year	Year of last reseal.	Calculated from TMR ARMIS data
OVL year	Year of last overlay.	Calculated from TMR ARMIS data
RE year	Year of last reconstruction or the year of construction.	Calculated from TMR ARMIS data
Low Vol Rd Model	Logical value to select low volume road strength deterioration model (1) or not (0).	Austroads models applied. 0 selected.
Mill and replace	Logical value to select mill and replace overlay treatment (1) or not (0).	Defined for this study. Applied to urban roads only.

3.2.2 Network Characterisation

Both physical road segments and representative sections were required to be classified based on the following characteristics, with the number of categories identified in brackets:

- functional class (6)
  - inter-regional
  - major through
  - regional distributor and connector
  - rural land access
  - urban arterial
  - urban sub-arterial
- pavement type (3)
  - asphaltic concrete, AC
  - unbound granular, GN
  - cement treated, CS
- traffic level (4)
- sub-grade reactivity (2) and subgrade strength (3)
- pavement age (5)
- climate (TMI, three each for urban and for rural).

These were used for assigning specific attributes which may vary by road class, pavement type, or other reasons for which typical values are required. They also provided a framework for the categorisation of the entire network, including physical segments and representative sections. The information used to assign labels is provided in Table 3.2.

Table 3.2: Criteria for creating bins during network setup

Parameter	Range/logic	Bin number
AADT	<= 1,500	1
	> 1,500 <= 5,000	2
	> 5,000 <= 10,000	3
	> 10,000	4
Pavement age	<= 10 years	1
	> 10 <= 20 years	2
	> 20 and <= 30 years	3
	> 30 and <= 40 years	4
	> 40 years	5
Reactivity	Zone = Wet reactive or Dry reactive	1
	Zone = Wet non-reactive or Dry non-reactive	0
TMI	Urban and < 0	1
	Urban and 0 to +20	2
	Urban and +20 to +60	3
	Rural and < –25	1
	Rural and –25 to +15	2
	Rural and +15 to +80	3

A summary of the length of sealed roads defined by location and pavement type is presented in Table 3.3. Derivation of the length information was drawn from the ARMIS database supplied for the project. The information presented highlights the relative coverage of different pavement types by location, with GN pavements dominant in a rural setting and AC pavements dominant in an urban setting.

Table 3.3: Length (km) of sealed road by location and pavement type

Location	GN (km)	AC (km)	CS (km)	Total (km)
Rural	24,205	865	1,011	26,081
Urban	2,239	2,869	346	5,454
All	26,444	3,734	1,357	31,535

3.2.3 Assigning Road Segment Attributes

The process of assigning segment attributes to physical segments drew on the data available in TMR's ARMIS database, and involved applying a series of look-up tables with examples of the assignment rules employed, which are shown in Table 3.4, with specific examples described below.

Table 3.4: Criteria used to assign test section attributes

Attribute group	Road functional class and AADT	Road functional class, pavement type and sub-grade type	Road functional class, surface type and overlay thickness	Location and pavement type
Treatment intervention criteria	✓			
After works conditions			✓	
Treatment costs				✓
Deterioration model factors		✓		

Intervention Criteria

In order to emulate the cycle of maintenance and rehabilitation works that occurs over a pavement life-cycle, the FAMLIT model requires external provision of intervention triggers to determine when treatment should take place.

The current model uses two sets of externally set triggers based on roughness or strength. These interventions represent the minimum level of service needed for each pavement and road type. There is also a further rutting intervention trigger, but this is internal to the model and is not adjustable by the user. The roughness intervention trigger comprises a maximum roughness level measured in IRI (international roughness index units (m/km)). This was adjusted to employ the rehabilitation intervention criteria in Table 3.5. The roughness triggers were developed specifically for application in South East Queensland under the TMR Road Asset Maintenance Contracts and applied in TMR's Pavement Management System (Kadar 2014). The strength intervention trigger uses a strength ratio of 0.59, i.e. SNC_i/SNC_0 (Austroads 2010b), based on Austroads studies and is also user defined.

Table 3.5: Rehabilitation intervention criteria

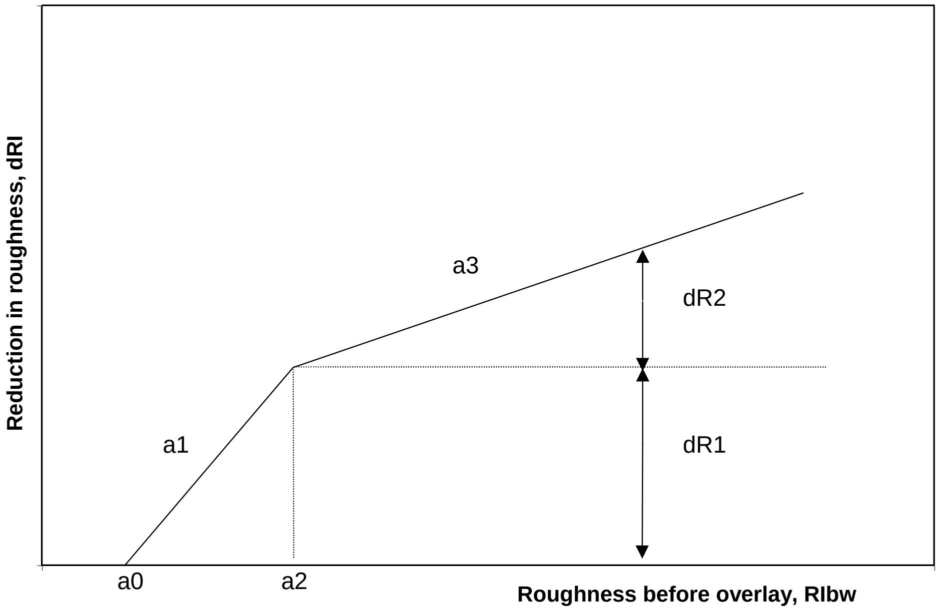
Road class	AADT bin	Rehabilitation roughness trigger (IRI)	Rehabilitation strength trigger (SNC_i/SNC_0)
Inter-regional	1	5	0.59
Inter-regional	2	4	0.59
Inter-regional	3	3.6	0.59
Inter-regional	4	3.3	0.59
Major through	1	5	0.59
Major through	2	4	0.59
Major through	3	3.6	0.59
Major through	4	3.3	0.59
Regional distributor and connector	1	5	0.59
Regional distributor and connector	2	4	0.59
Regional distributor and connector	3	3.6	0.59
Regional distributor and connector	4	3.3	0.59
Rural land access	1	5	0.59
Rural land access	2	4	0.59
Urban arterial	1	5	0.59
Urban arterial	2	4	0.59
Urban arterial	3	3.6	0.59
Urban arterial	4	3.3	0.59

Road class	AADT bin	Rehabilitation roughness trigger (IRI)	Rehabilitation strength trigger (SNC_i/SNC_0)
Urban sub-arterial	1	5	0.59
Urban sub-arterial	2	4	0.59
Urban sub-arterial	3	3.6	0.59
Urban sub-arterial	4	3.3	0.59

Works related assumptions and effects

These were estimated based on user specified minimum after works roughness values and use of a bi-linear roughness reduction relationship employed in HDM-4 (Morosiuk, Riley & Odoki 2009) and calibrated to Australian conditions (Toole & Michel 2005)[3]. The form of the relationship is illustrated in Figure 3.1.

Figure 3.1: Form of the generalised bi-linear roughness reduction relationship



Source: Morosiuk, Riley & Odoki (2009).

The relationship requires the user to define a minimum after works roughness (Table 3.6) and a number of coefficients, which for bituminous overlays, vary depending on the overlay thickness as specified in Table 3.7. The assumptions used for design and service lives are shown in Table 3.8.

---

[3] A number of studies of post-works conditions have been undertaken in Australia. However, a general relationship which covers a sufficiently wide range of conditions has been difficult to establish. The relationship employed herein aims to overcome this having been tested on a range of conditions in Tasmania (Toole & Michel 2005), and having been validated against observations in Queensland, reported by Austroads (2007). Coefficients are reported in Table 3.7 and Table 3.8.

Table 3.6: Design and service lives and minimum roughness values

Road functional class	IRI min (a0 in Figure 3.1)	
	Sprayed seal	Asphalt
Inter-regional	1.5	1.2
Major through	1.5	1.2
Regional distributor & connector	1.8	1.5
Rural land access	1.8	1.5
Rural special function	1.8	1.5
Urban arterial	1.5	1.2
Urban sub-arterial	1.8	1.5

Table 3.7: Model coefficients for the bi-linear roughness reduction model for bituminous overlays

Thickness (mm)	a0 (minimum)	a1 (slope 1)	a2 (inflection)	a3 (slope 2)
15	User specified by road functional class & surface type	0.38	2	0.18
25	User specified by road functional class & surface type	0.5	2	0.33
30	User specified by road functional class & surface type	0.54	2	0.4
35	User specified by road functional class & surface type	0.59	2	0.48
40	User specified by road functional class & surface type	0.65	2	0.55
50	User specified by road functional class & surface type	0.75	2	0.7
60	User specified by road functional class & surface type	0.80	2	0.8
70	User specified by road functional class & surface type	0.90	2	0.9
80	User specified by road functional class & surface type	1	2	1

Table 3.8: Design and service lives and minimum roughness values

Road functional class	Design life (yrs) for structural reset/thickness	Service life for structural deterioration
Inter-regional	30	50
Major through	30	50
Regional distributor & connector	20	40
Rural land access	20	40
Rural special function	20	40
Urban arterial	30	50
Urban sub-arterial	30	50

Treatment costs

Unit costs were adapted from the basic unit rates for GN re-sheets and AC overlays, AC mill and replace and GN reseal activities. The values were originally provided by TMR in 2012 and are reproduced in Table 3.9. Additional treatment types were calculated from these base rates using ratios developed from previous work.

Table 3.9: Road work unit cost rates for the Queensland network (2011 prices)

Road type	Overlay (\$/m^3)	Mill and replace(1) depth 1 (\$/m^3)	Mill and replace depth 2 (\$/m^3)	Mill and replace depth 3 (\$/m^3)	Reseal (\$/m^2)	Double seal (\$/m^2)
Rural AC	1,057	(1)	(1)	(1)	4.50	8.50
Rural CS	1,057	(1)	(1)	(1)	4.50	8.50
Rural GN	423	(1)	(1)	(1)	4.50	8.50
Urban AC		1,386	1,455	1,525	4.50	8.50
Urban CS		1,386	1,455	1,525	4.50	8.50
Urban GN		879	923	967	4.50	8.50

Note: Mill and replace depths are as follows:

- Depth 1 – Minimum practical thickness
- Depth 2 – Between minimum thickness and 300 mm
- Depth 3 – Greater than 300 mm.

1 Mill and replace treatments are not applicable to rural roads.

Network attributes – pavement deterioration sub-model calibration

A necessary precursor to applying the FAMLIT model to the Queensland data was the calibration of its rutting and roughness road deterioration (RD) sub-models to match observed Queensland pavement performance. This was undertaken during the 2012 study with the same results also applied in this study. The model structure is based on the Austroads RD functional (roughness and rutting) and structural models (Austroads 2010a and Austroads 2010b) and includes adjustment (or calibration) factors, which when applied adjust the predicted rutting and roughness progression rates to the observed rates. These adjustment factors are referred to as K factors and were computed for both the rutting and roughness sub-models.

Table 3.10 contains the estimated values of the rutting and roughness K factors (referred to as Drut K-fact and DIRI K-fact), which are set out for a sample of 18 road types defined by road class, pavement type and subgrade reactivity.

Table 3.10: Calibration of rutting and roughness road deterioration models estimation of K factors and associated information

Road type	Pavement type	Reactive subgrade	Drut K-fact	No. of points	r^2	DIRI K-fact	No. of points	r^2
Inter-regional	GN	Non-reactive	2.4	2,393	0.814	0.8	2,622	0.64
Inter-regional	GN	Reactive	2.5	1,368	0.858	0.9	1,602	0.717
Inter-regional	CS	Non-reactive	1.6	418	0.595	0.3	403	0.571
Inter-regional	CS	Reactive	4.4	142	0.774	0.3	165	0.745
Major through	GN	Non-reactive	2.3	1,401	0.848	0.9	1,470	0.688
Major through	GN	Reactive	2.5	758	0.845	1	823	0.689
Major through	CS	Non-reactive	2.9	88	0.737	0.2	99	0.583
Regional distributor and connector	GN	Non-reactive	2.3	221	0.86	0.9	234	0.683
Regional distributor and connector	GN	Reactive	2.3	34	0.922	0.6	36	0.768
Regional distributor and connector(1)	CS	Non-reactive	1.6	525	0.602	0.3	514	0.568
Rural land access(1)	GN	Non-reactive	2.4	4,118	0.83	0.8	4,450	0.653
Rural land access(1)	GN	Reactive	2.5	2,179	0.854	0.9	2,482	0.705

Road type	Pavement type	Reactive subgrade	Drut K-fact	No. of points	r^2	DIRI K-fact	No. of points	r^2
Urban arterial	GN	Non-reactive	3.3	77	0.877	0.8	88	0.752
Urban arterial	AC	Non-reactive	3.7	252	0.834	0.5	330	0.619
Urban arterial	AC	Reactive	4.2	18	0.893	0.6	27	0.746
Urban arterial	CS	Non-reactive	1.4	16	0.758	0.3	14	0.602
Urban sub-arterial	GN	Non-reactive	3.3	25	0.921	1.3	35	0.742
Urban sub-arterial	AC	Non-reactive	4.3	30	0.801	0.7	35	0.65

1 Rows in grey used the general pavement type regression results.

3.2.4 Calculating Pavement Strength-SNC

Initial pavement strength immediately post-construction (SNC_0) in combination with traffic, other pavement characteristics and climatic variation affect the requirement for and scheduling of pavement maintenance and rehabilitation activities and costs. Pavement strengths were allocated to each physical road segment and to representative road segments and road types based on measured TSD data for the physical segments. This data was used to derive representative strength values for the representative sections assigned to those physical segments where TSD measurements were unavailable.

The maximum deflection from the TSD ($D_{0\text{-TSD}}$) was used in the calculation of the modified structural number (SNC). The conversion of the estimated TSD deflection to the equivalent Falling Weight Deflectometer (FWD) values ($D_{0\text{-FWD}}$) followed the relationship established in NACOE project P40 for TMR (Lee 2016) as expressed in Equation 1, whereas the derivation of the $D_{0\text{-TSD}}$ employed the area under the curve method developed by Muller and Roberts (2012).

$$D_{0\text{-FWD}} = 0.9D_{0\text{-TSD}} + 13.8 \qquad 1$$

The in-service pavement strength values were converted to values of SNC (modified structural number of the pavement/sub-grade) as defined by Hodges, Rolt & Jones (1975) using the following relationship (Equation 2) developed by Paterson (1987):

$$SNC_i = 3.2 \times (D_0)^{-0.63} \qquad 2$$

where

SNC_i = modified structural number for pavement/sub-grade at pavement age AGE_i, corresponding to the measurement date

D_0 = FWD deflection (mm) under test plate centre

Whereas Paterson offered an alternative conversion relationship for cement stabilised pavements, the above equation was retained because of its use in analysing the Austroads Long Term Pavement Performance (LTPP) data (Austroads 2010a & 2010b).

The resulting SNC_i was then employed to back-calculate SNC_0 as input to the RD models, using Equation 3 (Austroads 2010b):

$$SNC_0 = k_s \text{ x } (SNC_i / \{0.9035 \times [2 - EXP(0.0023 \times TMI_i + 0.185 \times AGE_i / DL)]\}) \tag{3}$$

where

SNC_0 = modified structural number at the time of the pavement construction (AGE = 0)

SNC_i = modified structural number at year *i*

k_s = local calibration factor for strength (default = 1.0)

TMI_i = Thornthwaite Moisture Index at year *i*

AGE_i age of pavement at year *i* (number of years since construction or last rehabilitation)

DL[4] = service life of pavement (years) (assumed = 50, or user specified)

Recent analysis on behalf of the Commonwealth Bureau of Transport and Regional Economics (BITRE) (Toole & Roper 2014) has highlighted the need to represent the distribution of strength, i.e. by not applying an average, on the justification that for network-level analysis, averaging underestimates the variation in performance which exists in reality and which drives treatment needs and costs. This approach was adapted for the 2014 study where the distributions of SNC for each representative section were employed. These were then used to define ranges of low, moderate and high SNC values. This means that the analysis size was increased three-fold. However, for this study, the TSD data provided the means to supply data for each physical 100 m segment where it was available. For segments where TSD data was unavailable, the TSD data was matched with each representative section, and a 50th percentile value applied.

---

[4] Whereas the published model and report uses the term design life, in practice this is understood to represent the service life of a typical pavement being of the order of 50 years, as opposed to a structural design life of 20 years to 30 years.

4 LONG RUN MARGINAL COSTS FOR SEALED ROADS

4.1 General

The results of the analysis used to determine the long run marginal costs for sealed roads are presented in this section, as follows:

- results for measured physical segments, with the calculation of the MC based on a regression relationship for each measured 100 m segment, as explained in Section 2.3
- the basis for creating representative segments, which involved employing a combination of different key attributes and producing MC values based on these by identifying physical sections with similar attributes
- presentation of results in maps, showing the spatial distribution of MC
- presentation of a selection of results to illustrate the effect of specific combinations of factors on MC, such as functional road class, pavement type and traffic level.

4.2 Results for Measured Physical Segments

The results from the application of FAMLIT were produced and presented as follows:

1 as individual FAMLIT analysis files representing each district and a selection of road classes

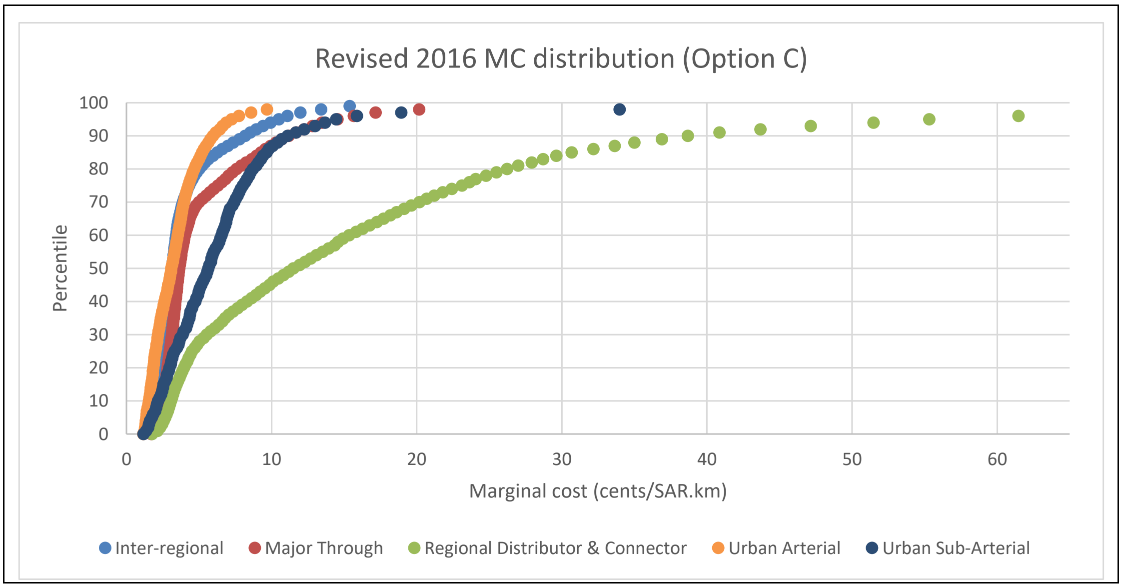
2. as combined results files including regression results by 100 m segment, look-up tables used to classify the physical segments for later application in the creation of representative sections, and to classify analysis sections based on a selection of input attributes

3. as an extract of the combined analysis files, including the presentation of cumulative MC distributions for each road class

4. mapping of results at 1 km resolution for illustrative purposes by aggregating consecutive 100 m segments.

The final analysis results were employed to produce the cumulative distribution of marginal costs for each road class, as illustrated in Figure 4.1. Option C, in this figure and elsewhere, refers to the final analysis run performed using the 2010 Austroads structural deterioration model and new resets for design life by road class and the estimation of post-works conditions as described in Section 3.2

Figure 4.1: Distribution of marginal cost for TSD measured physical segments by road class



4.3 Assigning Results to Non-TSD Measured Segments

Results were developed for non-TSD measured segments by assigning each to a representative section, and deriving MC values based on the population of measured segments with similar characteristics.

To achieve this, a number of ‘groups’ were defined, each with different sets of attributes included or excluded, but with the aim to retain as many key attributes as possible so that the representative section was as close as possible to the characteristics of the physical segments it represented.

A number of different rules were used to create applicable groups for all physical segments, and these are described in Table 4.1, with group ‘S’ representing the ideal case where a physical segment is populated solely by measured data. Four groups were defined to allow physical segments to be populated. However, a solution could not be found using this method for 156 urban special function sections. These roads primarily comprise busways and unformed roads, and assigning an MC value to these roads may not be relevant given their specific purpose.

Table 4.1: Basis for creating representative sections for MC purposes

Group code	Description	No. of unique IDs	Attributes included	Attributes excluded
S	Discrete 100 m TSD surveyed sections. MC assigned directly if available.	176,729	District ID, LGA, Road number, Carriageway code, Locale, Functional road class, Start chainage, Surface type, Pavement type, AADT bin, Reactivity bin, Pave age bin, TMI bin	
G1	First choice representative group. Highest detail except for discrete sections.	4,785	District ID, LGA, Road number, Carriageway code, Locale, Functional road class, Surface type, Pavement type, AADT bin, Reactivity bin, Pave age bin, TMI bin	Start chainage
G2	Second choice representative group if first choice cannot be assigned.	2,086	District ID, LGA, Locale, Functional road class, Surface type, Pavement	Road number, Carriageway code, Start chainage

			type, AADT bin, Reactivity bin, Pave age bin, TMI bin	
G3	Third choice representative group if second choice cannot be assigned.	689	District ID, LGA, Locale, Functional road class, Surface type, Pavement type, AADT bin, Reactivity bin	Road number, Carriageway code, Start chainage, Pave age bin, TMI bin
G4	Final choice representative group if third choice cannot be assigned.	21	Functional road class, Pavement type	District ID, LGA, Locale, Road number, Carriageway code, Start chainage, Surface type, AADT bin, Reactivity bin, Pave age bin, TMI bin

4.4 Combined Results for Sealed Roads

The combined results, where each 100 m physical segment is assigned an MC, was derived by combining the results from the 176,729 measured segments and assigning an MC based on the closest match found by choosing the best ‘group’ using the options in Section 4.3. The result was a fully populated set of 315,350 100 m segments, each containing 68 fields representing the entire sealed road network.

The list of fields are contained in Table 4.2, and the MC results represent the following:

- For Group S, a single value is given which is based on the calculated value for a physical segment with TSD measured data.
- For all other groups
  - three percentile values (10, 50 and 90) were reported based on the distribution of MC values for the relevant representative section
  - this data was then used to derive a weighted MC for each non-measured segment, as follows
    - Weighted MC (cents/SAR-km) = $0.15^* MC_{10} + 0.70^*MC_{50} + 0.15\ MC_{90}$.

Table 4.2: List of fields accompanying final MC values for all measured and non-measured segements

General data	Condition, pavement and surfacing data	Traffic data	MC classification and calculated MC data
APRoad100mID	IRI	AADTRoad	AADT_Bin
CARRIAGEWAY_CODE	RoughnessSurveyDate	AADTCWay	Unique_ID
SUPERSET_CWAY	SNC	TRAFFIC_PERCENT_HEAVY	Group_ID_1
TDIST_START	FORMATION_DATE	TRAFFIC_YEAR	Group_ID_2
TDIST_END	PavementTypeDescription	HVAADTRoad	Group_ID_3
SurfType	PAVEMENT_WIDTH	HVAADTCWay	Group_ID_4
PavType	PAVEMENT_DEPTH	AADT	MC Origin
ROAD_NAME	PAVEMENT_DATE	AADT_YEAR	Average MC
SEGMENT_LENGTH	SEAL_FLAG	AADT_CLASS_2A	10Pctile MC
CWAY_TYPE	SEAL_TYPE	AADT_CLASS_2B	50Pctile MC
LaneCount	SealClass	AADT_CLASS_2C	90Pctile MC
RoadClass	SealTypeGroup	AADT_CLASS_2D	Key
STATE_ROAD_NETWORK_ID	SEAL_WIDTH	AADT_CLASS_2E	
STATE_ROAD_NETWORK_NAME	SEAL_DATE	AADT_CLASS_2F	
LGA_ID	LAYER_1_DESCRIPTION	AADT_CLASS_2G	
DISTRICT_ID		AADT_CLASS_2H	
GENERAL_TERRAIN		AADT_CLASS_2I	
ZONE		AADT_CLASS_2J	
RURAL_OR_URBAN		AADT_CLASS_2K	
FUNCTIONAL_CLASS_NAME		AADT_CLASS_2L	
Road_Section		FUNCTIONAL_CLASS_NAME	

4.5 Variation in MC based on Location and Specific Factors

4.5.1 Spatial Distribution

Input data to represent the spatial distribution of MC was derived from the database representing each physical 100 m road segment based on Section 4.4. This involved aggregating values to determine a 1 km value for mapping purposes.

Example maps are presented for illustrative purposes covering:

- all roads with MC assigned to TSD measured and non-measured segments (Figure 4.2)
- TSD measured segments only (Figure 4.3)
- all regional distributor and connector roads with MC assigned to TSD measured and non-measured segments (Figure 4.4)
- regional distributor and connector roads for TSD measured segments only (Figure 4.5).

The legend used in the maps is based on the classification in Table 4.3.

Table 4.3: Marginal cost ranges within various bands

MC value (cents/SAR-km)	MC band
0–1.5	1
1.5 - 3	2
3–6	3
6–12	4
12–30	5
> 30	6

In the 2014 study, results were presented in the lower five bands, with the fifth band incorporating all values greater than 12 cents/SAR.km.

Figure 4.2: Spatial distribution of MC for all state-controlled roads

Figure 4.3: Spatial distribution of MC for TSD measured segments only

Figure 4.4: Spatial distribution of MC for all regional distributor and connector roads

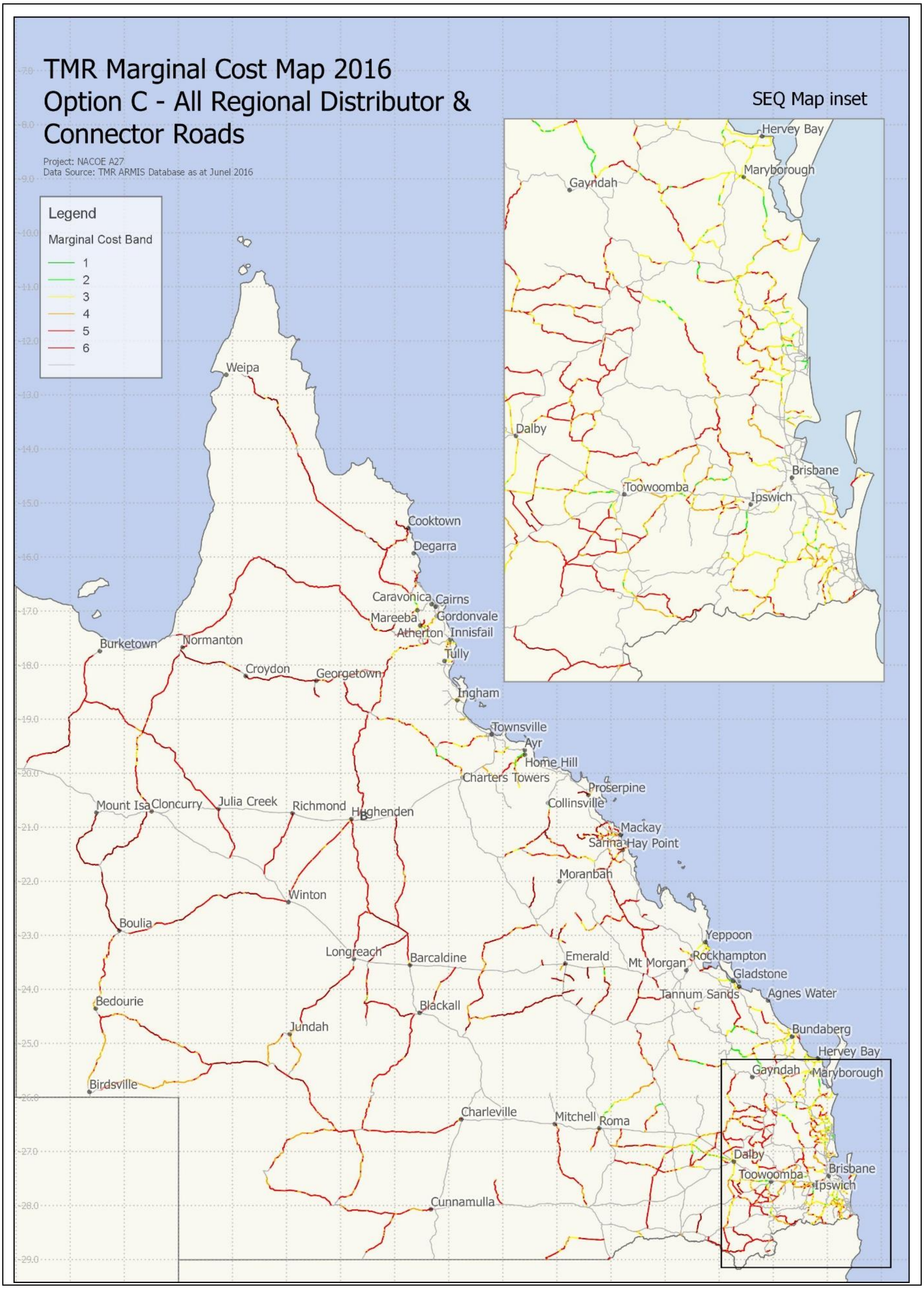


Figure 4.5: Spatial distribution of MC for regional distributor and connector roads for TSD measured segments only

4.5.2 Variations in MC Estimates

Various parameters affect MC estimates, with a selection of those examined listed and illustrated below:

- functional road class and pavement type (Figure 4.6)
- traffic range and pavement type (Figure 4.7) for a single road class.

Figure 4.6: Average MC trend for different functional road classes and pavement types

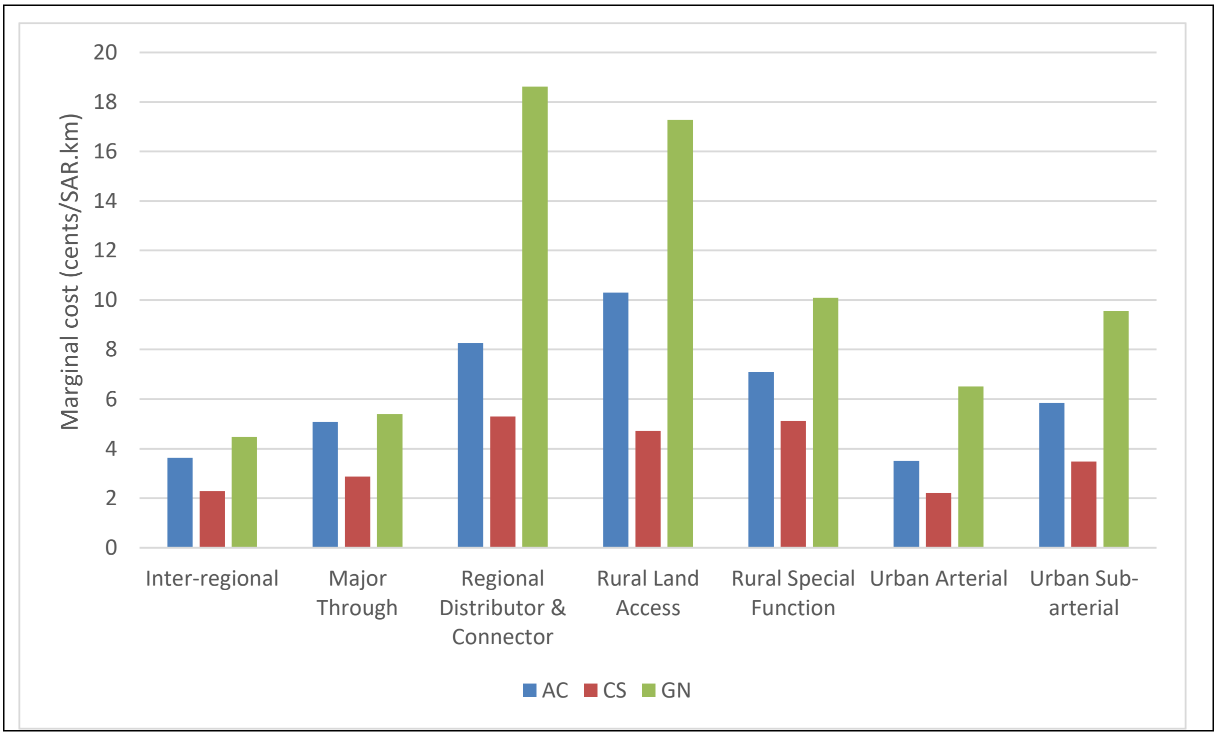
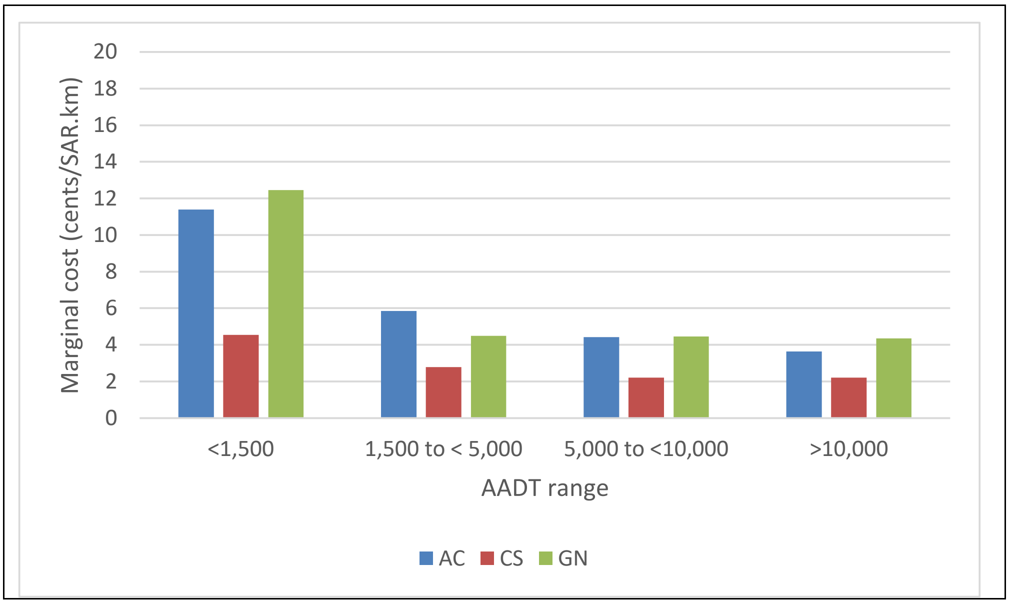


Figure 4.7: Average MC trend for different pavement types for inter-regional roads



It is evident that:

- inter-regional and major through roads possess the lowest MC values, followed by urban arterial and sub-arterial roads (Figure 4.6).
- regional distributor and connectors, and rural land access and rural special function roads possess the highest MC values (Figure 4.7).
- a trend decrease in MC against AADT is evident for inter-regional roads for all pavement types (Figure 4.7), with granular and asphalt pavements possessing higher MC values than cement stabilised pavements.

Factors such as soil reactivity and TMI have previously been shown to affect total costs and not marginal costs, i.e. the effects are not load related, but environment related, and have not been examined further in this study.

5 CONCLUSIONS AND RECOMMENDATIONS

3. The marginal costs of road wear using a ‘long run’ cost approach has been determined for approximately 17,673 km of state-controlled roads based on ARMIS data and TSD measurements. The remaining 13,862 km were assigned representative values based on a set of key characteristics.

4. Changes to the model set up and a number of attributes have been made in the following areas. As a result, comparisons with previous estimates will display differences.

   (a) Limits were placed on the maximum initial and minimum initial pavement strength attribute (SNC) to ensure the values were applied within the envelope from which they were derived.

   (b) Corrections to the post-treatment condition were made, with lower after works roughness values having been applied in 2014 than would be reasonable for lower standard sprayed seal pavements.

   (c) Escalation of the annual maintenance expenditure (ME) component to 2016 prices was accounted for in the cost calculations, with this being dependent on the annual rate of traffic loading.

   (d) Further differences include the use of the TSD, with an acceptance that this can produce meaningful data in terms of equivalent (FWD) deflections, and the deterioration of the network over the three to four-year period since the data was first collected and analysed for marginal cost purposes.

5. A regular update should be initiated to track the changes in input parameters and calculated MC. This is particularly important given the recent introduction of the TSD technology and the ongoing work on the calibration and refinement of Austroads road deterioration models for application in Queensland.

REFERENCES

Austroads 2007, *Interim works effects models*, AP-R300-07, Austroads, Sydney, NSW.

Austroads 2010a, *Interim network level functional road deterioration models*, AP-T158-10, Austroads, Sydney, NSW.

Austroads 2010b, *Predicting structural deterioration of pavements at a network level: interim models*, AP-T159-10, Austroads, Sydney, NSW.

Austroads 2012a, *Guide to pavement technology: part 2: pavement structural design*, 3rd edn, AGPT02-12, Austroads, Sydney, NSW.

Austroads 2012b, *Preliminary methodology for estimating cost implications of incremental loads on road pavements*, AP-R402-12, Austroads, Sydney, NSW.

Austroads 2015a, *Deploy and refine the road wear modelling methodologies: FAMLIT final report*, AP-R501-15, Austroads, Sydney, NSW.

Austroads 2015b, *Freight Axle Mass Limits Investigation Tool (FAMLIT) user guide*, AP-R502-15, Austroads, Sydney, NSW.

Hodges, JW, Rolt, J & Jones, TE 1975, *The Kenya road transport cost study: research on road deterioration*, laboratory report 673, Transport and Road Research Laboratory (TRRL), Crowthorne, Berkshire, UK.

Hore-Lacy, W, Thoresen, T & Martin, T 2012, ‘Estimating the marginal wear costs of increased axle masses on Queensland roads: final report’, contract report 003491-2, for Queensland Department of Transport and Main Roads, ARRB Group, Vermont South, Vic.

Kadar, P 2014, ‘dTIMS documentation for TMR SEQ RAMC’, contract report 006570-1, for Queensland Department of Transport and Main Roads, ARRB Group, Vermont South, Vic.

Lee, J 2016, ‘Benefit of traffic speed deflectometer data in pavement analysis’, contract report 010554, for Queensland Department of Transport and Main Roads, ARRB Group, Vermont South, Vic.

Michel, N & Toole, T 2005, ‘Freight analysis and maintenance costs estimation tool: part 1: overview’, contract report VC71393-1, ARRB Group, Vermont South, Vic.

Morosiuk, G, Riley, M & Odoki, JB 2009, ‘HDM-4 modelling road deterioration and works effects: review draft version 1.1: vol. 6’, World Road Association (PIARC), Paris, France & World Bank, Washington, DC, USA.

Muller, WB & Roberts, J 2012, ‘Revised approach to assessing traffic speed deflectometer data and field validation of deflection bowl predictions’, *International Journal of Pavement Engineering*, vol. 14, no. 3-4, pp. 388-402.

Paterson, WDO 1987, *Road deterioration and maintenance effects: models for planning and management*, Highway Design and Maintenance Standards Series, John Hopkins University Press, Baltimore, USA.

Queensland Department of Transport and Main Roads 2006, *Guidelines for assessment of road impacts of development*, TMR, Brisbane, Qld.

Queensland Department of Transport and Main Roads 2013, *Supplement to ‘Part 2: Pavement Structural Design’ of the Austroads Guide to Pavement Technology*, TMR, Brisbane, Qld.

Queensland Department of Transport and Main Roads 2017, *Guide to traffic impact assessment*, TMR, Brisbane, Qld.

Thornthwaite, CW 1948, ‘An approach toward a rational classification of climate’, *Geographical Review*, vol. 38, no. 1, pp. 55-94.

Toole, T & Michel, N 2005, ‘Consolidation of HDM-4 applications in Tasmania (phase 3): part 2: improved works effects models’, contract report RC3809-2-1, for Department of Infrastructure Energy and Resources Tasmania, ARRB Group, Vermont South, Vic.

Toole, T & Roper, R 2014, ‘Case study of the maintenance needs of the non-urban road corridors of the National Land Transport Network in Victoria’, contract report 007959-1, for Bureau of Infrastructure, Transport and Regional Economics, ARRB Group, Vermont South, Vic.

Toole, T & Sen, R 2014, ‘Harmonisation of pavement impact assessment: technical report’, contract report 008661, for Queensland Department of Transport and Main Roads, ARRB Group, Vermont South, Vic.

APPENDIX A EXAMPLE CALCULATION OF THE CHARGE PER TRIP

An example of a typical permit request was provided by TMR and the resulting charge per trip was estimated. The hypothetical task involves a 9 axle B-double travelling on Warrego Highway 18A Ipswich to Toowoomba, seven trips a week for 200 days of the year at HML loading.

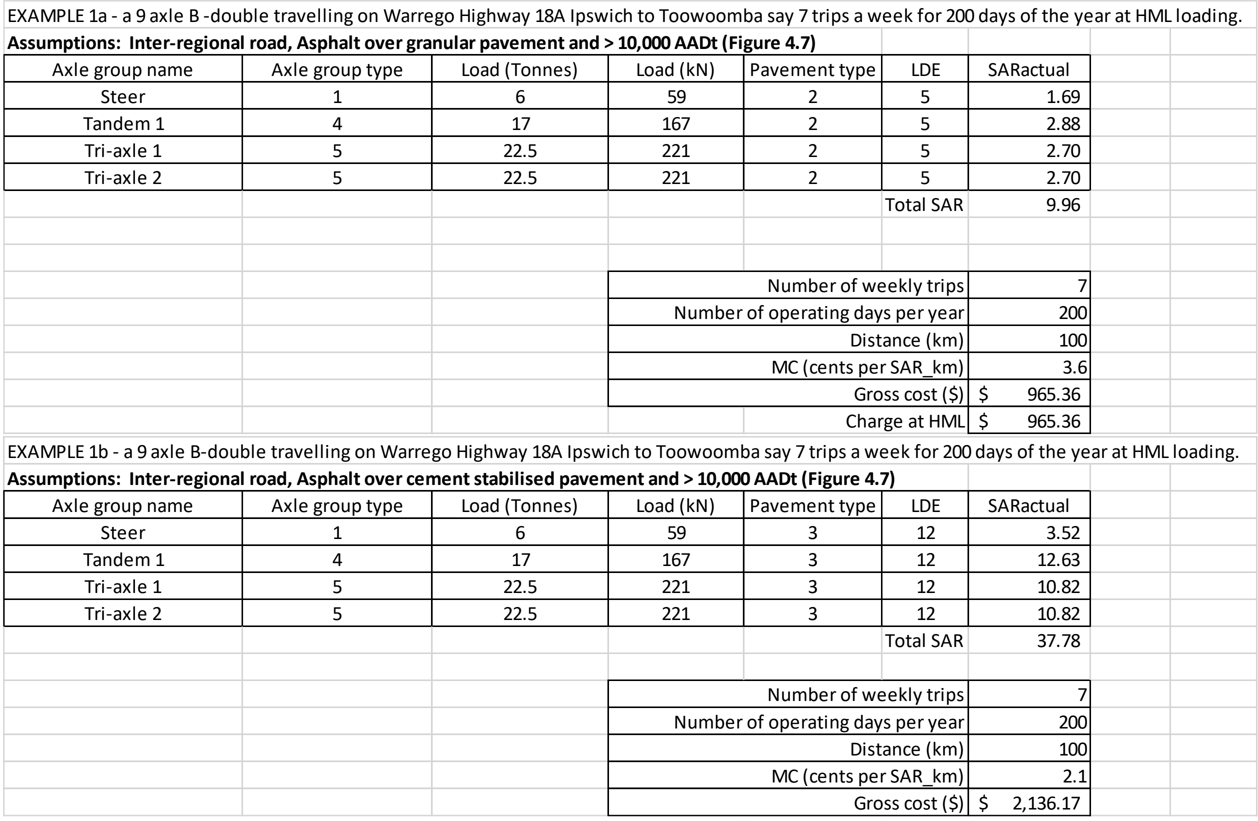
The calculation involves determining the SAR-km applied, as follows:

6. Specify the list of axle group types and codes.
7. Enter the load per axle group.
8. Enter the pavement type.
9. Assign the load damage exponent by pavement type.
10. Calculate the SAR at actual (HML) loading.
11. Enter the number of weekly trips, number of operating days per year and distance (km).
12. Enter the applicable MC (cents/km) for an asphalt pavement for a traffic level of > 10,000 AADT (from Figure 4.7 or an extract from the database).
13. Compute the total cost per trip.

The calculations are provided in a simple spreadsheet supplied with this report, which contains a calculation sheet illustrated in Figure A 1 and a set of look-up tables. The calculations are based on the axle group loads which cause the same damage as a standard axle, see Austroads Pavement Design Guide Table 7.6 (Austroads 2012a).

Two examples are shown in Figure A 1, namely for an asphalt over granular pavement (Example 1a) and an asphalt over cement stabilised pavement, with the final charge accounting for the appropriate Load Damage Exponent (LDE). The charge in whole dollars for the examples is approximately $965 and $2,136 respectively, illustrating the differences in road wear costs between the two pavement types.

Figure A 1: Example calculation of the total charge per trip



EXAMPLE 1a - a 9 axle B -double travelling on Warrego Highway 18A Ipswich to Toowoomba say 7 trips a week for 200 days of the year at HML loading.

Assumptions: Inter-regional road, Asphalt over granular pavement and > 10,000 AADt (Figure 4.7)

Axle group name	Axle group type	Load (Tonnes)	Load (kN)	Pavement type	LDE	SARactual
Steer	1	6	59	2	5	1.69
Tandem 1	4	17	167	2	5	2.88
Tri-axle 1	5	22.5	221	2	5	2.70
Tri-axle 2	5	22.5	221	2	5	2.70
					Total SAR	9.96

Number of weekly trips	7
Number of operating days per year	200
Distance (km)	100
MC (cents per SAR_km)	3.6
Gross cost ($)	$ 965.36
Charge at HML	$ 965.36

EXAMPLE 1b - a 9 axle B-double travelling on Warrego Highway 18A Ipswich to Toowoomba say 7 trips a week for 200 days of the year at HML loading.

Assumptions: Inter-regional road, Asphalt over cement stabilised pavement and > 10,000 AADt (Figure 4.7)

Axle group name	Axle group type	Load (Tonnes)	Load (kN)	Pavement type	LDE	SARactual
Steer	1	6	59	3	12	3.52
Tandem 1	4	17	167	3	12	12.63
Tri-axle 1	5	22.5	221	3	12	10.82
Tri-axle 2	5	22.5	221	3	12	10.82
					Total SAR	37.78

Number of weekly trips	7
Number of operating days per year	200
Distance (km)	100
MC (cents per SAR_km)	2.1
Gross cost ($)	$ 2,136.17