University of Southern Queensland

LOW VOLUME ROAD DEVELOPMENT AND MANAGEMENT

A review of current best practices adopted by local governments with a focus on rural areas of Australia.

A Dissertation Submitted by

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ABSTRACT

Low volume roads (LVRs) make up to two thirds of all the roads worldwide or approximately 30 million kilometres, particularly in Australia. Australia is one of the most sparsely populated countries in the world where more than 60% of its population is concentrated in the major cities located near the ocean and rely on the large network of low-volume roads as the vital link to meet the daily social and economic needs.

This project presents a review of the current best practices and management strategies used for LVRs. The focus of this report is to investigate how the rural areas of Australia implement these strategies. LVRs are generally managed by local road authorities. Various published literature has identified that amongst the challenges faced by these local road authorities, the lack of funding and availability of technical and human resources to suitably manage and conduct maintenance in low-volume road are the most significant. Thus, this research project provides an insight of the current management strategies being implemented by local authorities. Similarly, this project conducted an analysis of the most suitable maintenance prioritisation strategies currently used. The methodology for the completion of this included an in-depth literature review of the various low-volume road management strategies, a case study conducted on the City of Greater Geraldton located 420 km North of Perth in the Mid-West Reion of Western Australia. The Case Study identified the current strategies for road management and discussed opportunities for improvement. Finally, a Survey aimed at Local Government agencies in Western Australia was developed to collect information regarding their approach to low-volume road management.

The project findings hold significant implications for policymaking and resource allocation in the area of road management, particularly in remote areas. The project also highlighted the need for additional financial support, training, and the adoption of sustainable practices that local government agencies have to effectively address those challenges identified in the development and management of Low-Volume Roads.

During the completion of this project, it was identified that using a survey as a method to capture information form external government agencies posed a challenge to the researchers. The survey participation rate was significantly low. And whilst various factors played a role in this, it was identified that the survey could have been optimized to contain less questions and require less details in the answers. It is recommended that future research on this topic takes into account the lessons learned from this project.

Certification of Dissertation

I certify that the thoughts, experimental work, numerical outcomes, and conclusions reported in this dissertation are entirely my own efforts, except here otherwise acknowledge. To the best of my knowledge, I also certify that the work presented in this thesis is original, except where due references are made.

[redacted]

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Student Signature Date

ENDORSEMENT

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Signature of Supervisor

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TABLE OF CONTENTS

ABSTRACT iii
TABLE OF CONTENTS vi
List of Figures vii
List of Tables viii
List of Abbreviations viii
1.0 Introduction 1
1.1 Background 1
1.2 Project Objective 3
1.3 Project Outcomes and Benefits 3
1.4 Project Justification 4
2.0 Literature Review 5
2.1 Introduction 5
2.2 Pavement Material Selection, Design and Maintenance for Low Volume Roads 5
2.2.1 Pavement Materials 6
2.2.2 Pavement Design 8
2.3 Low Volume Roads Engineering and Development 13
2.3.1 Environmental Impact Assessment 13
2.3.2 Road Development Stages 14
2.4 Financing Low Volume Roads 16
2.5 Management of Low-Volume Roads 16
3.0 Research Methodology 19
3.1 Project Stages 19
3.2 Resources and Equipment 21
3.3 Survey and Data Collection 22
3.3.1 Introduction 22
3.3.2 Selection of Study Area 23
3.3.3 Data Collection 23
3.4 Survey Data Analysis 25
3.5 Survey Summary 30
4.0 Risk Assessment 32
5.0 Case Study 33
5.1 Introduction 33

5.2 Case Study Objectives 34
5.3 Road Selection Criteria 35
5.4 Literature Review for the Case Study 36
5.4.1 Roads Managed by Local Governments in Australia 37
5.4.2 Local Government Roads Maintenance and Renewals Expenditure 38
5.4.3 Local Government Roads and Climate Change 39
5.5 City of Greater Geraldton Road Asset Management Practices Analysis 40
5.5.1 City of Greater Geraldton Roads Condition 43
5.6 Improvement Plan 50
6.0 Summary and Conclusion 52
References 56
Appendix A: Project Specification 59
Appendix A1: Supporting Documentations / Literature Review 61
Appendix B: Project Survey 66
General Information 67
Asset Management 67
Road Preservation and upgrade information 69
Sealing an Unsealed Road 70
Road Level of Service 70
Appendix C: Risk Assessment 72

List of Figures

Figure 1 Assessing Material Grading (a) coarse material assessment (b) fine material assessment 8
Figure 2 Common Sealed Pavement Types in Australia (ARRB, 2020a) 9
Figure 3 Survey Response Summary 25
Figure 4 Wearing Course condition 2011 and 2021 (CGG, 2013) / (TALIS, 2021) 45
Figure 5 Figure 3 Sealed Pavement condition 2011 and 2021 (CGG, 2013) / (TALIS, 2021) 47
Figure 6 Project Program (Updated 09/09/2023) 60

List of Tables

Table 1 Laboratory Tests and pavement performance 7
Table 2 Assessing Material Type 7
Table 3 Assessing Material Grading 8
Table 4 Project Planning 20
Table 5 Resources 22
Table 6 Survey Questions and Answers Summary 25
Table 7 Road Hierarchy for WA (MRWA, 2023) 35
Table 8 CGG Operational Levels of Service (CGG, 2013) 42
Table 9 Road Standards adopted by CGG (TAMP 2013) 43
Table 10 Risk Assessment Parameters (CGG, 2013) 44
Table 11 Sealed Roads Condition Rating Description (IPWEA, 2015) 45
Table 12 Pavement Condition Rating Description based on Rutting 46
Table 13 Pavement Condition Rating Description based on Pavement age. 46

List of Abbreviations

AADT	Annual Average Daily Traffic
ACD	Accumulated Depreciation
AD	Annual Depreciation
ADL	Average Least Dimension
ADT	Annual Daily Traffic
AIMS	Asset Information Management Standard
ALGA	Australian Local Government Association
AMI	Asset Management Information
AMIS	Asset Management Information Standard
AMP	Asset Management Plan
ARRB	Australian Road Research Board
ATM	Aggregate Trailer Mass
BMP	Best Management Practices
CBR	California Bearing Ratio
CEA	Cumulative Effect Assessment
CGG	City of Greater Geraldton
CLoS	Customer Levels of Service
CoF	Consequence of Failure
CSDB	Customer Service Database
DBYD	Dial Before You Dig
DRC	Depreciated Replacement Cost
EIA	Environmental Impact Assessment
GVM	Gross Vehicle Mass
HIR	Hot in Place Recycling
HMA	Hot Mix Asphalt

HV	Heavy Vehicles
HVNL	Heavy Vehicles National Law
IPWEA	Institute of Public Works Engineering Australia
IRI	International Roughness Index
LoS	Levels of Service
LTFMP	Long Term Financial Management Plans
LVRs	Low Volume Roads
M&F	Milling and Filling
MRWA	Main Roads Western Australia
MS	Micro Surfacing
OMC	Optimum Moisture Content
RAP	Recycled Asphalt Pavement
RAPS	Road Asset Preservation Strategy
RAV	Restricted Access Vehicle'
RC	Replacement Cost
RD	Rutting Depth
RUL	Remining Useful Life
SEA	Strategic Environmental Assessment
TAMP	Transport Asset Management Plan
THO	Thin Hot Asphalt Overlay
TLoS	Technical Levels of Service
TUL	Total Useful Life
UCS	Unconfined Compressive Strength
VPD	Vehicles per Day
WA	Western Australia
WALGA	Western Australia Local Government Association

1.0 Introduction

1.1 Background

LVRs make up to two thirds of all the roads worldwide, or approximately 30 million kilometres of roads. (G. R. Keller, 2016). According to the Swedish National Road and Transport institute, LVRs are defined as roads with less than 1000 vehicles per day.(Pasindu, Gamage, & Bandara, 2020). The Guideline for low-volume sealed roads in Southern Africa adopts 200 vehicles per day threshold (Pinard et al., 2003). In the United States, the American Association of Stage Highway and Transportation Officials developed geometric design guidelines for “very low volume roads” with an average daily traffic (ADT) of 400 or less. (Pasindu et al., 2020). LVRs often have speeds of 80 km/hr or less. (G. Keller & Sherar, 2003)

In Australia a sealed local road generally carries less than 6000 vehicles per day in urban areas and much less in rural areas. Local roads usually carry fewer heavy trucks except in industrial areas and areas such as grain terminals. In rural areas, local roads may be subject to heavy agricultural machinery and harvest trucks. (ARRB, 2020b). Whilst there is no one accepted definition of the exact traffic volume that defines a low-volume road in Australia, Thomas Frazen and David Thorpe indicate that an Annual Average Daily Traffic (AADT) threshold of 1000 Vehicles Per Day (VPD) or less can be used as a benchmark for low-volume roads in urban areas, and 200 VPD in rural areas (Franzen & Thorpe, 2020).

Low to medium volume roads have greater social and environmental impact compared to high volume roads as they represent a vital link in the road network. They meet the daily social and economic needs of the locality. LVRs connect small towns and rural communities and provide access to farms, mine sites and natural reserves. LVRs allow access to isolated locations improving lives of remote communities, enables their development, facilitates access to public health services and education, and help to create jobs through labour-based construction and maintenance. On the other hand, the construction of LVRs in sensitive environmental areas have the potential to produce significant amounts of sediment and cause adverse impacts on the local environment, water quality, vegetation, and wildlife. (G. Keller & Sherar, 2003).

The provision and management of Australia's road assets is of critical importance, with local governments playing a pivotal role. In fact, they are responsible for more than 80% of the country's road network. Despite this massive task, local governments are often working with constrained budgets and under constant pressure to balance cost with quality. The construction and ongoing management of low-volume roads is a challenging aspect of this responsibility, one that requires innovative solutions and a focus on maximizing value.

On many occasions, planning decisions on LVRs are based on subjective judgment without a consistent objective basis due to political or other external interference. Social and environmental impacts, traffic volume, land use and aesthetics are not always the focus in the selection criteria for low-volume road maintenance treatments and pavement selection. (Ahmed, Eng, & Maher, 2006).

There is a lack of the resources needed to assess the maintenance requirements and determine suitable intervention levels. Thus, while it is common for major roads to undergo significant improvements, local low-volume roads continue to deteriorate. Determining clear intervention levels for road maintenance is a crucial step towards reducing the life cycle cost. Since maintenance and rehabilitation actions are planned based on the condition data of the road network it is important to maintain accurate records of this. Unfortunately, the condition of low-volume roads is not monitored frequently enough due to the high cost of data collection and their “Low priority”. This leads to long intervals between condition assessments that leads to inappropriate maintenance plans resulting in fast deterioration of the low-volume roads. (Kheirati & Golroo, 2020).

One of the challenges faced by road authorities managing LVRs is the lack of funding, technical and human resources to maintain the road network. The funds allocated to local authorities are insufficient to maintain LVRs in good condition. The deterioration of road pavements occurs due to the combined effect of aging of the pavement, the effects of the weather and ever-increasing traffic loads. Although various approaches to road maintenance and rehabilitations are available to keep the condition of the roads at an acceptable level, these tend to be costly. This has resulted in an increasing need for sustainable maintenance treatments, which requires the optimisation of preventative treatment programs.

Poor condition of low-volume roads represents considerable costs to both local government and road users. As reconstruction of a poorly maintained road will cost more than three times the cost of applying preventative maintenance and suitable time intervals. (Flintsch & McGhee, 2009). Additionally, a road in poor condition will represent additional cost associated with user delays due to larger maintenance works, vehicle operation cost and increased fuel consumption.

The prioritisation of maintenance of low-volume roads is essential. This is dependent on various factors including the condition of the road, the type and extent of defects, rate of deterioration and the significance of the sections of road. Most of the methods developed for the evaluation of road condition are sophisticated, costly, resource intensive and requires specialised equipment thus making it unavailable for most local road authorities to implement in low-volume roads due to their “low priority” and low funding. (Agarwal, Khan, & Choudhary, 2017).

This indicates the need for a sustainable road management strategy to select the most appropriate maintenance protocol for low-volume roads (Landers, Mason, & MacNaughton, 2015) Thus, it is important to have an objective method of assessing the road condition to achieve the best outcome from the available funds.

This research project aims to review the current best practices adopted in the development and management of low-volume roads. The aim of the project is to identify sustainable approach to low-volume roads management. It has been highlighted that local road authorities find it challenging when deciding between investing in a road that has deteriorated beyond a maintenance condition or investing in roads for which maintenance might prolong the performance and service life.

Similarly, information regarding low-volume roads that addresses innovative maintenance techniques or equipment is difficult to find, often because the literature is not scientific enough to warrant publication in professional journals. (Peraka & Biligiri, 2020)

Further to this, the approach to accident reduction usually associated with major roads does not extend to low-volume roads because these improvements tend to lead to increase of speed in low-volume roads presenting a potential for an increase in accidents.

1.2 Project Objective

The aim of the project is to present a review of the current best practices used for the development and management of low-volume roads with a specific focus on rural Australia. The project will analyse the suitability of the current management strategies and maintenance prioritization utilised in low-volume roads and evaluate if these are appropriate to the conditions presented in rural Australia. This will consider the challenges currently faced by authorities and strategies to optimise resource allocation for low-volume road management.

To ensure the aims of the project are achieved, the following main objectives proposed for the project are:

- To identify the current strategies used to prioritise maintenance of low-volume roads focusing on agencies operating in rural areas.
- To conduct a sound comparison of these strategies listing the benefits and limitations for each of them and evaluating the suitability for the Australian conditions
- To identify the current Road Asset Management strategies implemented by local governments and evaluate suitability.
- To identify gaps existing in the management of low-volume roads and present additional topics for further research.

The proposed scope for the project is to focus on the management of low-volume roads within a rural area located in Australia. Australia is one of the most sparsely populated countries in the world, with more than 60% of its people living in the major cities near the coast. A large proportion of roads across the country at times carry less than 400 vehicles per day thus making low-volume roads represent a critical asset for the Australian transport industry. The larger proportion of these low-volume roads are managed by local authorities who due to multiple reasons are challenged to fund suitable maintenance of their road network. This project aims to present a review on the current low-volume road management strategies and evaluate their suitability and sustainability.

1.3 Project Outcomes and Benefits

This project will improve the understanding of conducting a suitable maintenance prioritisation plan for low-volume roads. It will provide important information about the current management and development strategies applicable for low-volume roads in rural areas of Australia. The project will assist local governments officials in the understanding and implementation of sustainable maintenance practices for low-volume roads. This project will consider the social, economic, and environmental factors that influence the development of management strategies for low-volume roads. The expected outcomes of the project include:

- Increased understanding of the different low-volume road maintenance prioritisation strategies currently being implemented by local authorities.
- Further develop the knowledge of low-volume road development and management focus on rural areas of Australia.
- Improve the confidence in the implementation of sustainable road management strategies for low-volume roads taking into consideration the challenges related to low funding and lack of resources.
- Provide a comparison of the various road condition assessment strategies and present a sound evaluation of their suitability for low-volume roads.

1.4 Project Justification

Various studies cover pavement and road asset management, road condition and maintenance strategies along with guidelines for the financing of the increasing low-volume roads around the world. However, due to the limitations associated with the management of low-volume roads including inadequate funding, labelling as 'low priority asset' and the lack of technical resources that local road authorities have at their disposal, furthermore, limits published studies on this topic especially publications that address the characteristics of rural Australia. This represents a gap in the current body of knowledge and highlights an opportunity to review current best prices for low-volume roads and evaluate their suitability for the application under the condition of rural Australia.

This research project proposes to fill this gap. It will evaluate current best practices for low-volume road development and management and provide sound comparisons between the various methods presented. The research project will build on the current strategies for low-volume road management and will focus on management strategies adopted in rural regions of Australia. A project plan is included in this report to ensure the project goals are achievable and can be completed in accordance with the relevant work health and safety requirements. This project will focus on further analysing the current methods to prioritize the maintenance of low-volume roads and evaluate its suitability for rural areas in Australia.

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2.0 Literature Review

2.1 Introduction

LVRs represent a significant proportion of the road networks around the world. In Australia, this form of transport infrastructure is a crucial component in connecting rural areas to major cities, and consequently, it is vital for enabling daily social and economic activities. Local road authorities are responsible for managing LVRs within their jurisdiction, and it is generally agreed that the challenges faced by these authorities are vast, including insufficient funding, lack of technical expertise, and shortage of human resources to manage and maintain these roads adequately.

Therefore, this literature review will investigate the current best practices and management strategies used for LVRs and how they are being implemented in the rural regions of Australia. This project aims to provide valuable insights into the best working strategies implemented across rural areas in Australia that, when applied appropriately help to improve the management of LVRs in the region. This report aims to investigate how various rural regions in Australia manage LVRs and prioritize maintenance needs.

The literature review will cover studies, research articles, journals, and publications related to low volume road management strategies. The aim is to find the most effective and efficient strategies that could be applicable to the rural regions of Australia and their specific context.

2.2 Pavement Material Selection, Design and Maintenance for Low Volume Roads

Low-volume roads form the vital link in the road network that provides accessibility to the communities to meet their social and economic needs. Local authorities in charge of the management of low-volume roads face the challenge of insufficient funding to maintain these roads to a satisfactory condition and lack technical and human resources to conduct suitable preventative maintenance.

Thus, the selection of suitable pavement in the development, design and construction phases of low-volume roads is crucial to reduce their life cycle cost. The selection of the pavement should take into consideration the expected traffic levels, terrain, ground conditions and the social and environmental factors that are relevant to the area. This includes consideration to land use, noise, and dust generation along with connectivity to surrounding areas. The appropriate selection and testing of road materials form a crucial component of pavement design, construction, and operational maintenance. A comprehensive knowledge of road materials provides roads practitioners with the means and expertise to develop and maintain a cost-effective, long-lasting infrastructure that optimizes both sustainability and the safety of road users.

(Pasindu et al., 2020) Proposed a framework for selecting pavement types for low-volume roads that considers the traffic, social and environmental characterises of the road section. In this framework, five pavement types were assessed under a life cycle cost, maintenance requirements and road user experience to evaluate the suitability of each pavement types with the various characteristics of road segments.

There are different approaches to identify suitable pavement for low-volume roads some of which are based on traffic volume thresholds, which serve as a guide for various pavement surfaces. Asphalt is the most popular pavement type for roads with traffic volume greater than 500 vehicles/day. In addition, the threshold for a road considered for surfacing is 200 vehicles/day (Pasindu et al., 2020).

2.2.1 Pavement Materials

Road Materials Selection and Testing is an integral part of pavement design, construction, and ongoing operation. Thus, it is paramount that Road Authorities understand the road materials available in their local area to maintain a cos-effective, long-lasting road asset while maintain road safety.

A Pavement structure is made up of multiple layers of materials. Each layer spreads the imposed traffic load to the underlaying layers. The layers found in a pavement structure are the Wearing Course, Basecourse, Subbase and Subgrade. The stress imposed by traffic loads is highest at the surface and lowest at the subgrade. Thus, the quality of pavement materials must be highest at the surface where the load induce stress is higher and decreases to lesser quality materials in the lower layers.

According to (ARRB, 2020a), fit-for-purpose materials are commonly used for the construction of low-volume roads. A fit-for-purpose material exhibits properties and performance characteristics that align precisely with the intended design application. This, in turn, enables the optimization of budget resources over the entire lifespan of the pavement, without compromising the required level of service. Similarly, there can be circumstances where the characteristics of the road construction material available is identified as non-conforming with the specifications. This type of material can be considered of high risk and is likely to perform poorly in design scenarios. As a result, it is presumed that higher levels of maintenance intervention will be necessary to ensure that the road meets the minimum performance requirements throughout the design period. The use of high-risk materials may be inevitable thus risk management strategies should be implemented to mitigate potential issues. The extent of risk analysis required will be dependent on the desired level of service.

Laboratory testing is therefore required to determine the characteristics of the road construction material and its suitability for pavement design. The following table presented in section 3.7 of the Roads Materials Best Practice Guide developed by the Australian Road Research Board (ARRB, 2020a) describes the laboratory tests typical for pavement and subgrade materials.

Table 1 Laboratory Tests and pavement performance

Laboratory Test	Material Relevance	Performance Influence
Grading (PSD)	• All granular materials • HMA and Spray Sealing aggregates	• Stability • Stiffness • Density/Particle packing • Particle interlock
Plasticity/Consistency	• All granular materials	• Stability • Cohesion and suction • Moisture sensitivity
Moisture content	• All granular materials	• Stability • Cohesion and suction
Density/moisture relationship	• All granular materials	• Stability • Stiffness • Bearing capacity
California bearing ration (CBR)	• All granular materials	• Bearing capacity
Repeated load triaxial	• All granular materials	• Stiffness • Permanent deformation • Bearing capacity
Unconfined compressive strength (UCS)	• Modified and cemented granular materials	• Stability • Stiffness
Marshall flow	• Hot mix asphalt	• Stiffness
Marshal stability	• Hot mix asphalt	• Stability • Bearing capacity
Aggregate durability	• HMA and spray sealing aggregates	• Strength • Harness • Toughness • Soundness
Average Least Dimension (ADL)	• Spray sealing aggregates	• Surfacing durability • Particle Shape

While laboratory testing provides the required information on the material properties, it is important for Road Construction personnel to familiarise with the physical characteristics of suitable material. The Roads Materials Best Practice Guide also presents alternatives to formal laboratory testing to assists practitioners to gain a better understanding of the properties of local materials.

This includes simple practical methods to determine the Material Type, Gradation, Plasticity and Fine Grain Material Characterisation, Dispersion Test and Material Strength.

The following tables present the steps involved in identifying the Materia Type and Gradation. For further reference on the remaining test refer to The Roads Material Best Practice Guide developed by the ARRB.

Table 2 Assessing Material Type

Material Type	
Test Check list	
Description	Material Type
Material does not react to shaking test. Material dries out slowly and leaves a crusty residue that is hard to remove and leaves stains.	Clay material
Material reacts rapidly to shaking test. Powdery residue that washes easily form the hands without staining.	Silt material
Intermediate reaction to hand test	Silt/Clay material
Enough clay to soil the hands when a sample is kneaded but not enough to form a lump	Sand or gravel with silt fines

Dusty or gritty fines	Salt or gravel with silt fines

Table 3 Assessing Material Grading

Gradation	
For a dry granular soil spread a sample on a flat surface. Use a piece of carboard as a rake to sort the larger soil particles to one side.	
Estimate the % of particles largen than 6 mm (fine gravel) and the percentage of fines (sands and clay)	Estimate whether the larger particles have a uniform size (poorly graded) or large, medium, and small size (well graded)
To fine % of fines put 3 mm of water into a clear glass jar and add enough soil to fill the class one-quarter full.	
• Add water until the soil is just covered. Mark this level with a rubber band • Fill the jar three-quarters full of water and stir the mixture. • Allow the mixture to settle for 2 minutes and mark the height of the soil that has settle out. The difference between the two marks represents the % of fines	

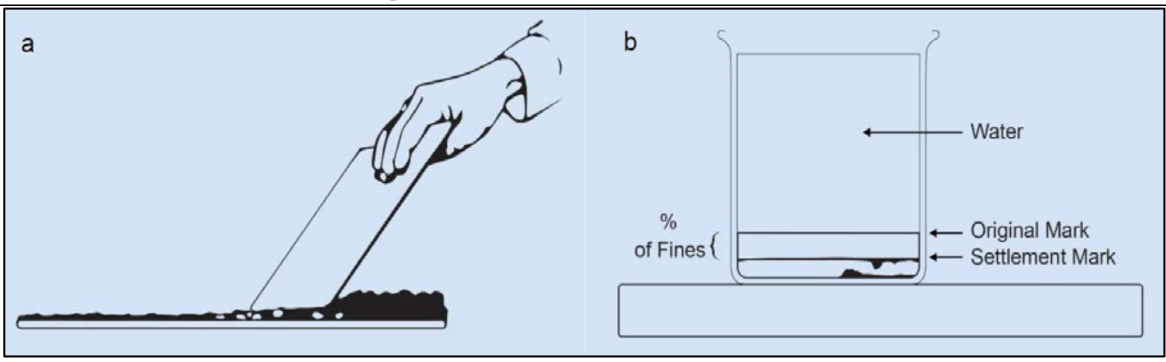


Figure 1 Assessing Material Grading (a) coarse material assessment (b) fine material assessment

The performance of material in pavement design is not only determined by the properties of the material. The environmental conditions in which the pavement is expected to operate during its design life will also influence its performance. This includes a combination of unexpected increases of traffic loads and changes in the operating moisture in the environment. Moisture infiltration into pavements has been identified historically as the most detrimental factor influencing performance. As the moisture and traffic loads increase, pavement failure risk also increases. Thus, the required properties for the pavement material becomes more stringent. Under these circumstances the use of non-standard material would represent higher economic costs during the whole-life cycle of the road asset.

Unlike traffic, the potential moisture infiltration into pavements can be controlled with suitable drainage techniques. By controlling the moisture aspect of a pavement, it is possible to consider a larger range of materials to use for road construction.

Some of the design considerations to limit moisture infiltration reduce pavement failure risk includes the sealing of shoulders to at least 1 m, ensure table drains are maintained and maintain adequate cross falls on both sealed and unsealed wearing surfaces.

2.2.2 Pavement Design

Various types of pavement structure use different material types at different layers of the pavement system. The choice of a suitable pavement type will depend on design traffic, functionality and service requirements, budget constraints, material availability, local climatic conditions, and other factors.

Sealed local roads have a pavement structure in which, in many cases, has evolve over time rather than having been designed and upgraded according to systematic procedures. In general, the main pavement structure is a flexible pavement consisting of unbound layers with a surface of spray seal or asphaltic mix. The common sealed pavement found in Australia are represented in the figure below.

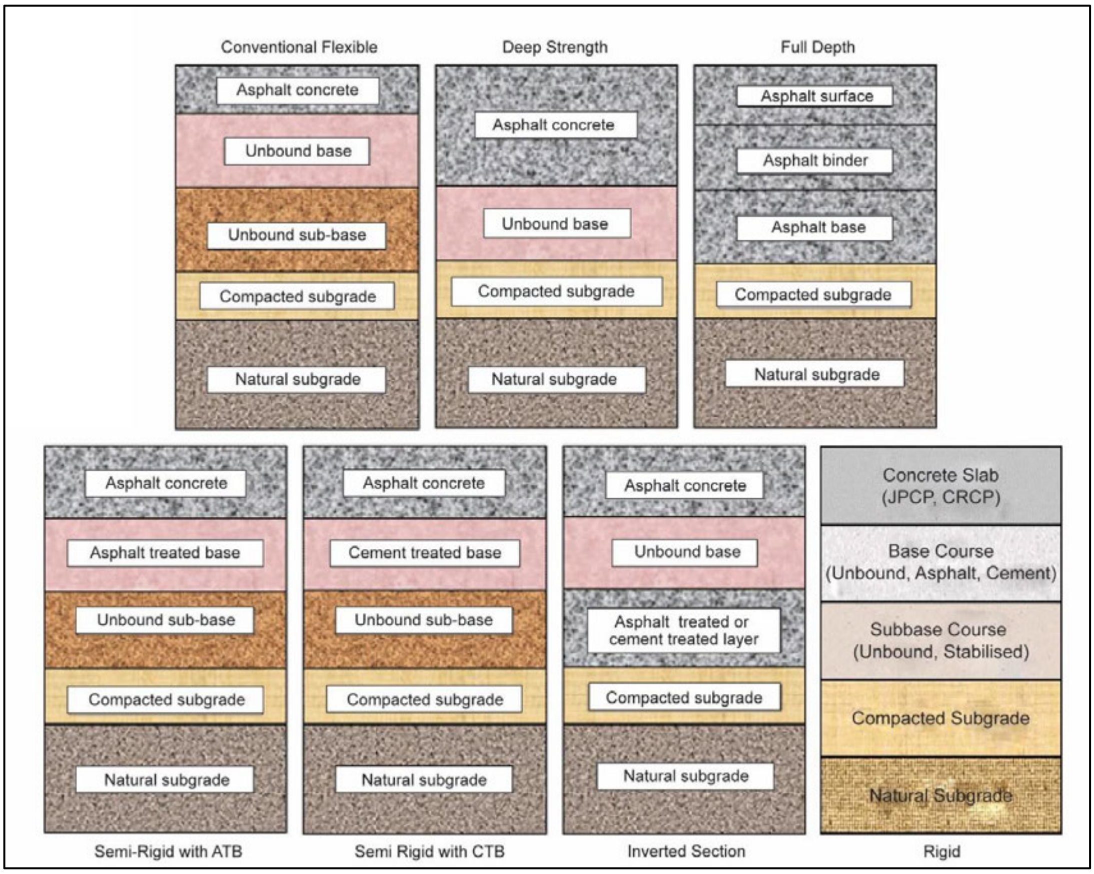


Figure 2 Common Sealed Pavement Types in Australia (ARRB, 2020a)

The main layers that constitute the pavement structure are the following:

Wearing Course

The wearing course represent the surface of the pavement structure. This is the top layer can is usually made from hot mix asphalt, spray seal, or an unsealed gravel or soil material. The wearing course provide safe and durable surface, protects the lower layers of the pavement from moisture infiltration and increases their useful life.

Basecourse and Subbase

The basecourse and subbase layers provide support to the overlying surface materials and distribute the load to the underlying subgrade. The basecourse and subbase represent the primary structure of the pavements and the three main types are described below:

- Granular pavements are made from crushed rock or other material that can be modified or bound with the addition to stabilization agents.
- Deep strength and full depth asphalt pavements, have a basecourse made from a combination of HMA intermediate course and HMA base course layers. These layers may be installed over a granular subbase layer or sit on the subgrade directly.
- Rigid Pavements, the based is made from HMA. The role of the subbase is to provide uniform support to the base layer, and this can be made from unbound granular or bound and lean mix concrete, depending on the traffic load design.

Subgrade

The subgrade layer is the lower layer of the pavement structure and represents the foundation for the top layers. The subgrade is commonly made from the materials found in-situ which is prepared to form the formation above the natural surface. The formation is shaped and compacted before the installation of the pavement layers. Alternatively, the subgrade can be constructed by removing the in-situ material and forming the box out of the formation where the pavement layers are installed.

The thickness of the pavement is influence by the strength of the subgrade and the design traffic load. Stabilization or modification of the in-situ subgrade can be done to improve the layer's strength.

Pavement Design models

An agency and user cost model for the selection of pavement like the methodology developed by (Jaarsma & Van Dijk, 2002) focused on deciding the most economical pavement type from Hot Mix Asphalt and gravel. This model considered local authorities cost, crash costs, and vehicle operating costs and the findings indicated that vehicle operating costs are higher on gravel roads than on paved roads.

It was also determined that there was a statistical relationship between crash occurrence and road surface type or Average Daily Traffic (ADT). This is due to factors such as pavement condition, environmental conditions, roadway geometry and alignment, and driving behaviours all of which contribute to crash occurrence. According to this model, gravel roads are the most economical surface type for traffic volumes between 150 and 600 vehicles per day.

A Multi-criteria analysis approach for the selection of pavement surfaces offers the opportunity to consider additional factors that are not included in traffic volume-based and cost models. (Pasindu et al., 2020) developed a model based on a numerical score using five selection factors: traffic, impact on residents, impact on local business activities, impact on long travel distance, and agency cost.

A more recent approach to pavement selection and design of low-volume roads known as Context Sensitive Design (CSD) is an interdisciplinary approach that involves various stakeholders in the design of a road that matches its physical setting and land use whilst maintaining its safety and mobility. (Ahmed et al., 2006) developed a methodology for the selection of pavement surfacing for low-volume roads combining engineering design factors such as structural capacity, safety, and durability along with aesthetics, environmental and social impacts.

Pavement Maintenance

Once suitable pavement and surfacing types are selected and constructed it must be maintained at appropriate times to ensure the life cycle cost is kept to an affordable level and the condition of the road is preserved in good condition. For this, a significant amount of money is spent on road pavement condition monitoring which is necessary to identify defects in the road network. However, pavement monitoring at times requires highly sophisticated automatic data collection systems, which limits the intervals between data collection that tend to be longer. This can result in inappropriate maintenance plans and therefore the deterioration of low-volume roads is accelerated. (Kheirati & Golroo, 2020).

(Agarwal et al., 2017) Presented a “Rational Strategy for resource allocation for rural road maintenance”. Prioritization of road maintenance activities depend on several factors such as the condition of the road, type of defects, rate of deterioration and importance of road section amongst other factors. Thus, the allocation of resources to conduct timely maintenance on low-volume roads represents a challenge for local authorities.

The strategy proposed in this study can be used for the selection of suitable maintenance activities on different rural roads sections to gain maximum benefits from the resources available.

The identification of the condition of the pavement is a crucial step towards developing suitable maintenance programs. Local Governments now have access to current road condition data for approximately two thirds of their sealed local roads. (WALGA, 2022). The two most common methods for pavement condition inspection are manual and automated. The manual approach is labour intensive, inefficient and time consuming, therefore expensive, not to mention unsafe for the road inspectors. On the other hand, automated data collection systems are fast, safe, accurate and standardised although costly. As a result, local authorities limit the frequency of automated pavement monitoring. This means that over time the data accuracy becomes limited leading to increase in maintenance operations (Flintsch & McGhee, 2009).

The Road Pavement Visual Assessment Code (Practice Note 9), Condition assessment and Asset Performance Guidelines published be the Institute of Public Works Engineering Australia (IPWEA, 2015) in section 7.0 Risk Management stresses the importance of responsible management of road infrastructure. This includes knowing the condition of the road assets, manage and minimize risks.

As one of the challenges of local road authorities is the lack of qualified resources necessary to maintain road condition data up to date, it is recommended to prioritize and determine a suitable frequency of road condition assessments. To achieve this objective, the road network is broken down into segments. Each segment is given a coarse likelihood and Consequence of failure score enabling the allocation of a criticality raring. This criticality score must also consider the condition index score allocated the corresponding road segment. A road network with clearly defined criticality rating enables road mangers to prioritize the frequency of road condition inspections allowing a suitable inspection and maintenance program that aligns with the importance of each road segment.

The condition of a pavement can be determined by identifying the roughness. Pavement roughness has an effect in the wearing of vehicles, likelihood of accidents, and impose dynamic action loads on the road that increases the pavement degradation rate. Pavement roughness also has an effect on ride quality and increases fuel consumption as much as 5%. (Kheirati & Golroo, 2020). The most common index for roughness is the International Roughness Index (IRI). Recent research and development in technology allow the measurement of pavement roughness using sensors present in Smartphones. For this, accelerometers, gyroscopes, and GPS are used to capture the ride quality. Similarly, inexpensive sensor packages that are mounted to vehicles also allow the monitoring of pavement condition. This includes The Sharp sensor that applies infrared radiation to measure distance. (Kheirati & Golroo, 2020) developed this data acquisition system and made use of the inexpensive infrared sensor along with an accelerometer to capture the pavement profile and calculate the roughness index for low-volume roads. This project was a proof of concept and was restricted to rough dry asphalt pavement and a speed of 30 km/h.

(Pan et al., 2021) conducted a cost / benefits analysis of the most used treatments used for road maintenance. The treatments chosen are the Hot in-place recycling (HIR), milling and filling (M&F), thin hot mix asphalt overlay (THO) and micro-surfacing (MS). This study focused the treatment effectiveness in repairing pavement rutting. The Rutting Depth (RD) was selected as a performance indicator. The outcome of the research identified that HIR represents the highest effectiveness and cost-effectiveness. This is due to the utilisation of Recycled Asphalt Pavement (RAP). It was also determined that the effectiveness of the treatment is increased when the maintenance occurs at the appropriate time.

Additionally, there has been an increased interest in using recycled materials for the construction and maintenance of roads with the aim of adopting a sustainable approach to road construction. In (Gomes, Magalhães, Rocha, & Fonseca, 2021) a sustainability-oriented framework is presented for the selection of optimum soil-by-product proportion for unbound base layers of unpaved roads. The proposed framework provides guidelines to road authorities on how to incorporate environmentally friendly materials in a cost-effective way, while maintaining the technical quality of base layers.

(Celauro, Corriere, Guerrieri, Casto, & Rizzo, 2017) presented an environmental analysis of different construction techniques and maintenance activities for local roads. The results demonstrated how Reclaimed Asphalt Pavement (RAP) can lead to a significant reduction in pollutant emissions and energy consumption compared to that of pavement constructed with only virgin materials. A similar conclusion was made for fine soils stabilized (in situ) with lime. The study demonstrated that this technique improves the mechanical properties of soil that otherwise would be considered as waste. Thus, the use of sustainable construction techniques will result in the reduction of life cycle cost, allowing funds to be allocated to a suitable preventative maintenance plan.

2.3 Low Volume Roads Engineering and Development

LVRs are an essential infrastructure asset that meets the social and economic needs of the communities. They are a vital link in the road network that enables the connectivity of small towns, rural areas, and the development of local industries. LVRs enables the access to public health services, education, and helps to create jobs through the various stages associated with the management of road infrastructure.

On the other hand, the construction of a new roads, particularly in rural areas have the potential to create excessive soil erosion compared to other activities. Thus, the planning and design of roads must consider the potential adverse effects these activities will have on the environment, wildlife, and quality of the water in these areas. Sediments from roads can become a direct source of water pollution. Roads constructed without careful planning and design often have high maintenance and repair requirements and tend to generate excessive material erosion. These adverse effects may become irreversible and difficult to manage. These roads often fail to meet the minimum expected performance requirements. The construction of new roads often produces a change in the land use and facilitate unplanned population growth. (G. Keller & Sherar, 2003). Therefore, the social, environmental, and financial cost of constructing new roads must be carefully considered.

Some of the common challenges faced when constructing a new road include the natural topography of the terrain and soil characteristics on which roads are to be built. This includes avoiding constructing roads in steep slopes or in close proximity to a stream channel to prevent material erosion and seeking well-draining soils to ensure the structural integrity of the road is preserved through is design life. The availability of suitable pavement materials often requires careful consideration, and this will have a direct economic impact in the cost of constructing new roads. Similarly, the identification of a suitable location for the road to be built and the environmental constraints that must be adhered to ensure the protection of natural habitats for wildlife and native flora are also to be considered when constructing new roads.

On the other hand, a road that is properly planned, designed, constructed, and maintained represents a cos effective investment for the community. Carefully planned roads will incur in low maintenance and repair costs and its environmental impact will be better managed and controlled. The long-term social, environmental, and financial aspects of a new road need to be carefully considered.

2.3.1 Environmental Impact Assessment

An Environmental Impact Assessment (EIA) is a mandatory process that looks at making sure all potential environmental and social impacts are carefully considered when new development projects are assessed for approval. (*What is an environmental Impact Assessment*, 2022). This includes the construction of a new road.

There is an increased concern about the procedures followed when completing project-specific EIA for the construction of new roads. Jaeger identified that poor efforts are made in considering all potential negative environmental impacts. This concern has been identified across various countries (Jaeger, 2015). In the paper titled 'Improving Environmental Impact Assessment and road Planning at the Landscape Scale' Jochen argues that negatives impact on the environment are only lightly considered and tend to ignore the large-scale effects. Jochen states that EIAs for road projects are generally insufficient and poorly conducted. He identified a lack of knowledge of the cumulative effects of landscape fragmentation and habitat loss of wildlife. Jochen states that many potential ecological effects associated with road construction should be treated with greater precaution and states that there is a need for allocation of additional resources to improve the quality of project specific EIAs. Similarly, he identifies the importance of completing Cumulative Effect Assessments (CEA) at a large scale, strategic environmental assessment (SEA), proper road planning and land-use planning.

EIA are an essential tool that when completed properly will bring numerous benefits to the project development and implementation of new infrastructure projects. These benefits include a reduction in the project costs since project managers are better prepared to avoid costly modifications during the project construction. EIA may also improve the project's performance and public acceptance by properly identifying and balancing the public's needs and environmental impacts. Finally, EIA prevent the violation of laws and regulations.

2.3.2 Road Development Stages

According to (G. Keller & Sherar, 2003) a successful road project requires the careful consideration and completion of a series of stages, these include:

- Road Planning
- Road Desing and selection of suitable location
- Road Construction
- Road Maintenance

Planning

The Planning stage for a new road considers the needs of the future users, it ensures the road is designed to meet their particular requirements and prevents the overdesign / overbuilt of it. It ensures the funding is appropriate and minimises its impact on the natural environment and communities that reside along the road. During the planning stage of a new road, the authority / organisation in charge of its management will define and document the road's purpose, the standards it must follow and the way in which the road is intended to be used, maintained and how it will be founded.

In the document titled Low-Volume Roads Engineering, Best management Practices Field Guide for (G. Keller & Sherar, 2003) present a series of Best Management Practices (BMP) to be considered during the Planning stage of a LVR. These include the following:

- Minimizing road width and area of disturbance.
- Avoiding alteration of natural drainage patterns and providing adequate surface drainage.
- Avoiding steep ground with slopes over 60 percent.
- Avoiding problems such as wet and unstable areas.
- Maintaining an adequate distance or separation from creeks and minimizing the number of drainages crossings.
- Designing creek and river crossings with adequate capacity and bank erosion protection and allowing for fish passage at all stages of life.

- Reducing erosion by providing vegetative or physical ground cover on cuts, fills, drainage outlets, and any exposed or disturbed areas.
- Using stable cut and fill slope angles.
- Using slope stabilization measures, structures, and drainage as needed.
- Providing thorough, periodic road maintenance.

Road Design and Location

The Desing of new LVRs is a critical stage that should not be overlooked. Whilst it is reasonably expected that LVRs will not carry high volumes of traffic, these should meet minimum road design standards to ensure the safety of the road users and safeguard the surrounding natural environment form the environmental hazards associated with road construction and maintenance. In the BMP field guide (G. Keller & Sherar, 2003) some recommended practices for road design are stated. The guide suggests that new roads should be constructed with grades not greater than 12%, and only use short sections of up to 15% where necessary, since the provision of suitable drainage and erosion control measures is challenging in roads with steep grades. The guide also indicates the importance of careful disposal of unsuitable or excess exaction materials as it may represent a hazard to the natural environment if done incorrectly. Finally, the guide states that a cross-fall slope between 3-5% is the standard along with suitable swale for adequate drainage. Culverts should also be considered in the road design to cater for cross drainage.

The correct selection of the location of a new road is key to the success of a road project. (G. Keller & Sherar, 2003) presents recommended practices to consider when selecting the location of a new road. These include the use of topographic control pints and physical features to select the location of the road. This includes avoiding steep slopes, minimizing stream crossings, selecting locations preferably high to provide more distance between roads and streams, select locations with well drained soils and slopes that facilitates the flow of run off away from the road and finally avoid construction of roads through areas with native wildlife and flora.

Road Construction

The road construction stage determines the financial cost of the project. These costs are determined by several factors including the road dimensions such as with and length, materials selected for pavement construction, the surface type adopted, the topography of the terrain along and weather conditions of the selected road location. Roads constructed along areas that requires extensive excavation, vegetation clearing, on steep slopes, multiple stream crossings and rocky terrain add a financial cost. Thus, estimating of the road construction cost is a key stage in the planning and design stages as these will determine the founds required to complete new roads projects. As it has already been mentioned, roads that are well planned, designed and constructed may incur in high initial costs but their maintenance needs will be minimized along with any other cost associated with negative environmental impacts.

Road Maintenance

The maintenance a road must be uphold during its useful life. Road maintenance activities are to be completed periodically after major storm events to ensure roads provide a safe service to all its users. Major storm events have the potential to cause extensive damage in road infrastructure. Excessive moisture can weaken the structural integrity of the road pavement, this can lead to the development of potholes and ruts. Excessive soil erosion can block drainage structures such as culverts and cause the water to flow over the road thus increasing the damage in the road pavement and its deterioration rate.

Road maintenance activities are needed to ensure roads structural integrity is kept to a suitable level of service. This also includes the provision of suitable road drainage system. A well-maintained road will reduce the users cost over its useful life.

2.4 Financing Low Volume Roads

In 2017-18 $22 billion was spent on road and bridge transport infrastructure engineering construction work (Transport & Regional Economics Bureau of Infrastructure, 2018). In the 2019-20 federal budget it was highlighted that the Australian Government will invest $100 billion in significant transport infrastructure project over the next 10 years. Sealed roads play a key role in the nations road network, so any efficiency gains in the construction, maintenance and rehabilitation of sealed local roads will result in significant benefits.

A widespread challenge for the management of the extensive road networks is raising the required funds for conducting suitable and timely maintenance activities. There are several documented cases of underfunding for the maintenance of the road network, for low-volume roads. In Latvia, only 40% of the funding needed to adequately maintain their road network is available. This is even worse for local rural roads where only 20% of the total amount needed is funded. The maintenance costs for low-volume roads, particularly those that serve a small number of properties or farms and have limited local traffic is often poorly funded. (Jaarsma & Van Dijk, 2002) presented a model for the cost distribution of maintenance activities of two local rural roads. The model indicates that the owners of the properties should pay for the basic facilities along a road that enable access to their private properties. It also indicates that ‘extra facilities’ such as additional paving width that benefit inter local road users should be paid by local authorities.

The existing annual funding on construction, maintenance and operations on all public roads in Australia is over $30 billion, with around one-third of this spent on road maintenance (ARRB, 2020b). With increasing road user demand and increasing funding requirements on a large and highly dispersed road network, sound evidence-based processes and decisions need to be practised across the technical, economic, financial, and environmental areas that local road authorities deal with.

2.5 Management of Low-Volume Roads

Australia’s population is over 25 million and it has 907, 520 km of road network length (Transport & Regional Economics Bureau of Infrastructure, 2013). The bulk of the road network length, 574,660 km (63%) is unsealed. The remaining length of 332,860 km (37%) is sealed with nearly 87% of these roads being a sprayed bitumen seal over an unbound crushed rock base. The remaining 13% of the sealed roads are surfaced with asphalt. Nearly half of the sealed roads (146,000) are in urban areas.

Although national highways and state and arterial roads carry the major portion of the road traffic by volume, sealed local government roads are estimated to make up 210,000 km or over 60% of the total sealed road network by length in Australia.

Good asset management practices are essential to ensure an efficient use of resources. The implementation of pavement asset management systems provides the required information to optimize resource allocation for road maintenance. Recent development in pavement data collection and processing allows road authorities to estimate remaining service life and suitable selection of maintenance strategies. (Peraka & Biligiri, 2020). Despite the advancement in technology that facilitates the automated data collection and processing of road condition including artificial intelligence and machine learning, the application of these technologies for low-volume roads is yet to be fully realized due to the challenges of high cost and lack of technical resources.

Distresses in pavement occurs, if they are structurally adequate but functionally deficient, or in some cases when pavements are both structurally and functionally deficient. If pavements are structurally adequate and functionally deficient, minor maintenance is sufficient to maintain the pavement in an operating condition. Thus highlights the importance in developing and implementing good road management strategies. According to the American Association of State Highway and Transportation Officials (AASHTO) a properly planned and implemented data collection program will significantly increase credibility, cost effectiveness and overall utility of the pavement management systems. The management of Low-volume rural roads should be conducted in a way that it is context sensitive, ensuring a balance between economic, social, and environmental factors and align with the community values and needs (Faiz, Faiz, Wang, & Bennett, 2012).

The Sealed Roads Best Practice Guide presented by ARRB introduces the need for the development of Road Asset Preservation Strategies (RAPS). These strategies facilitate the management of the condition and performance of road networks taking into consideration the technical levels of Service and the Customers expectations (also known as Customers Levels of Services) accepted by local road authorities. RAPS identifies and prioritizes the asset maintenance and renewal activities are needed to maintain the necessary asset condition and performance standards. It identifies both measured and forecast patterns of deterioration of asset condition, the effect of various treatment strategies on life-cycle costs of the asset and the effect of asset condition on road user costs, rider quality and safety.

The key elements in formulating a RAPS as presented in (ARRB, 2020b) are listed below:

- Develop an inventory of the Road Assets
- Develop data collection program to identify the condition of the Road Network
- Review of the minimum Customer Levels of Service acceptable for road conditions. Include a description for ride quality (roughness), safety (rut depth, pothole frequency, wearing-surface stability) and the accessibility of travel identified through community consultation.
- Complete an analysis of the road condition trend over time, (patterns of deterioration and improvement).
- Forecast a five and ten-year expected condition and performance of the road network.

- Complete an analysis of the effect of different surface treatments on routine and periodic maintenance.
- Complete an analysis of different intervention levels for maintenance treatments on road asset.
- Identify the optimum condition intervention level to achieve and sustain acceptable target Customer Levels of Service at minimum life-cycle cost.
- Complete an assessment of the current and projected maintenance treatments needs and costs, recognising the current life-cycle stage of each road, predictions of deterioration and treatment effectiveness under assume traffic demand growth scenarios.
- Establish a method for the prioritisation of projected maintenance needs as per the impact on road user safety.
- Complete a Review of forward funding scenarios.

3.0 Research Methodology

3.1 Project Stages

The first stage of this project is to complete all necessary tasks associated with the project planning and preparation. This includes the project approval by the University of Southern Queensland, the identification of all resources required for the completion of the project. The methodology for the completion of this project includes the development of a Case Study focus on the management of Low-Volume Roads that are under the responsibility of the City of Greater Geraldton. Approvals for the completion of this project will be completed during the first Stage.

The second Stage involves the completion of an in-depth literature review to identify the current best practices in developing a low-volume prioritisation maintenance program. The review will include scientific journals, Road / pavement construction and maintenance guidelines and road asset management and planning guidelines. The literature review will also analyse recent developments in road condition and automated data collection systems and evaluate their suitability for low-volume roads. A review on how the social, economic, and environmental factors are considered in the management and development of low-volume roads will also be explored. Lastly, a literature review of the best practices of low-volume road management in rural Australia will be conducted as the literature review conducted during the development of this proposal highlighted the lack of published works on this subject.

The third stage of the project will consist of the analysis of the various strategies identified during stage two. This analysis will include a comparison of these strategies and an evaluation of their suitability for implementation on low-volume roads. The focus of the project is to validate the suitability of these strategies for rural roads in Australia. A summary of this literature review will report relevant outcomes and findings, which will provide an insight of the current best practices applicable for low-volume roads.

Stage four will consist of the development of a survey using findings from stages two and three. The survey will be distributed to several local governments in Australia. This will aim to identify any correlations between the strategies for road management being implemented by these agencies and the findings from stage two and three. The survey will be aimed at understanding the following aspects of road management:

- Road maintenance prioritisation strategies
- Road condition assessment strategies
- Resource allocation for road management and maintenance
- Road funding strategies
- Road asset management systems in use
- Challenges faced by local authorities.
- Technologies in use for road management

Stage five will consist of the analysis of the survey answers. A summary section will present the findings and describe the various management strategies currently being implemented for Low-Volume roads.

Stage Six of this project will consist of the development of a Case Study based on the City of Greater Geraldton. The Case study aims to identify the management strategies used for Low-Volume Roads by this Local Government. The Case study will identify any similarities and differences from the findings in Stages three and five. The case Study will also highlight any gaps in current management strategies and will present a list of actions with the aim to fill these gaps.

The final stage will consist of the development of the final report and the presentation of the outcomes found during project. This report will synthetise the best practices for low-volume road management and development in Australia.

The proposed project is expected to be completed during the academic year of 2023. The tasks will align with the enrolment of ENG4111 (Research Project part 1) and ENG4112 (Research project part 2). To ensure the project objectives can be achieved during the time allocated and suitable monitoring of the project tasks and milestones, a project schedule is presented here. The main tasks presented in the project schedule have been described in this document however the following schedule presents a breakdown of these tasks.

Table 4 Project Planning

Stage 1	Project Planning and Preparation
1.1	Project approval: Obtain official approval to commence project form USQ
1.2	Resources: Ensure availability of all resources required to complete the tasks listed under this project. This will include approval form employer (City of Greater Geraldton).
1.3	Selection of low-volume roads to conduct the case study. Identify the low-volume roads that will be included for the development of a case study. The City of Greater Geraldton is the council selected for the case study development.
Stage 2	In-depth Literature Review
2.1	Identify Literature Review: Conduct an in-depth literature review on low-volume roads development and management. This will include published literature on the management of rural roads in Australia.
Stage 3	Literature Review Analysis
3.1	Conduct the literature review analysis: In-depth analysis of the literature chosen. This will follow the guidelines to assess the quality of literature review.
3.2	Extract data obtained from literature review
Stage 4	Survey Development and Distribution
4.1	Development of a survey aimed at officers from local governments in Australia based on the findings from the analysis of the literature review. The survey will adhere to the guidelines for survey development.

4.2	Selection of Local government to be include in the survey. This stage will require the engagement with various local governments to obtain their approval to participate in the survey for this project.
4.3	Distribution of the survey: The survey will be distributed to the selected local governments via email.
Stage 5	Survey Result Analysis
5.1	Survey Completion: The selected local government agencies will be expected to complete the survey in a period of no longer than 4 weeks. This time frame is allocated to facilitate the participation of the agencies chosen.
5.2	Survey Results Analysis: The survey will be analysed to determine the most common used strategies for the management low-volume roads. The intention of this analysis is to compare the results from the surveys with the finding form the literature review. This will assist in identify opportunities for the improvement low-volume road management strategies.
Stage 6	Case Study development
6.1	Case Study Development: This project will include a case study focus on the management of low-volume roads within the City of Greater Geraldton. The case study will present the current management strategies, and limitations faced by this local government.
Stage 7	Write-up and Presentation results phase
7.1	Prepare draft dissertation: The draft dissertations will be completed and submitted to the project supervisor from USQ for review
7.2	Present results at ENG4903 Profession Practice 2. A in person presentation of the results from this project will be completed during the residential school for the Professional Practice 2
7.3	Final Dissertation submission: Feedback from project supervisor will be used to complete any required amendments to the dissertation. And final submission for marking will be completed.

The full project schedule can be found in **Appendix A**.

3.2 Resources and Equipment

Various resources will be utilized during the completion of this project to ensure the objectives are achieved. The primary requirement to be considered is the time required for the completion of the various tasks. Additionally, a personal computer or laptop along with specific software and technical equipment will be required. These resources will already be available to the student completing this research at his workplace.

The project is estimated to be completed during the first and second semester of the academic year in 2023. The approximate starting and finishing times will be the last week of February and first week of November. This corresponds to approximately 38 weeks. The estimated workload allocated per week is 10 to 12 hours. This time will be allocated for the completion of the various stages of the project research. Most of the tasks for this project will be completed outside normal working hours although it is anticipated that certain tasks might be completed during work hours. This could include regular communication with USQ project supervisors, potential meetings either in person or via videocall with other professionals working in the field of road management and site visits to roads in various conditions.

The following table presents the list of equipment that will be utilized during the completion of this project.

Table 5 Resources

Item	Source	Cost	Comment
PC	Workplace / Personal	Nil	Require compiling the various activities for this project
Microsoft office: (Word, Excel, Power point, Project, Teams, Zoom of Skype)	Workplace / Personal	Nil	Word processing is needed to maintain records of this project. Microsoft Project will be used to develop the project plan and Power point will be used to complete the presentation of dissertation. Excel will be one of the tools needed to complete data analysis and calculations. Microsoft Teams, Zoom or Skype will be used to communicate with Project supervisor and conduct meeting with other professionals in the field.
Headset	Workplace / Personal	Nil	Will be required for the videocalls with project supervisor and other professionals in the field.
Asset Management Program: (ASSETIC)	Workplace	Nil	Require using as a local case study of Road asset management practices in a local government in rural Australia
Traffic Counters	Workplace	Nil	Required to capture traffic count data to be use as a case study.
Other office items	As required	$50 - $100 Estimated	As supporting materials to complete the project report and conduct the project dissertation.

3.3 Survey and Data Collection

3.3.1 Introduction

This project will use a survey to capture key information from local government agencies on their strategies for managing low-volume roads.

Low-volume roads, although serving as vital transportation links in rural and remote areas, often face unique challenges in terms of maintenance and management. Understanding the strategies adopted by local government agencies in managing these roads is essential for effective decision-making and resource allocation. The survey, consisting of 34 questions, aims to provide a comprehensive overview of various aspects of low-volume road management, including asset management, road preservation and upgrades, sealing of unsealed roads, and levels of service provided.

The need for conducting this survey arises from the recognition that low-volume roads play a significant role in connecting communities and facilitating economic development in remote areas. By gaining insights into the strategies employed by local government agencies, policymakers and road managers can make informed decisions to improve the overall performance and sustainability of low-volume road networks.

To analyse the data collected from the survey, a rigorous and systematic approach will be followed. The findings from this survey will serve as a valuable resource for both researchers and practitioners involved in low-volume road management. The data collected will provide a better understanding of the current practices and challenges faced by local government agencies, allowing for the identification of best practices and areas for improvement.

Ultimately, this survey aims to contribute to the development of more effective and sustainable strategies for managing low-volume roads, thereby enhancing connectivity, and promoting economic growth in rural and remote areas.

The template use for the project survey can be found in **Appendix B: Project Survey.**

3.3.2 Selection of Study Area

The Survey will be distributed to at least all Local Government listed under the Western Australia Local Government Association (WALGA). A total of 137 Local Government Agencies will receive the Survey questionnaire along with the information sheet detailing a description of the survey, a description of the benefits expected from this project research, information regarding the confidentiality of the information captured, and information about the consent to participate in the survey.

Similarly, the Australian Local Government Association (ALGA) has been contacted to request the full email list for all local government agencies in Australia. A total of 547 local government agencies are listed in this email list. Whilst efforts will be made to capture as much information as possible, the time frame for this project has been drastically affected by the process followed in obtaining the ethics approval required for the development and distribution of the Survey. Thus, it is reasonably expected that the number of responses that may be obtained will be limited by the time frame of the project. A total of 3 weeks will be allocated for the completion of the responses although, participants will be encouraged to complete the survey by the preferred date 29th of September. This will allow two weeks for the completion of data analysis and the write-up of the conclusion section of this project report.

3.3.3 Data Collection

The survey questionnaire was developed to gain an insight into the approach to develop and manage Low-Volume Roads in Local Government Agencies in Australia. The questions in the survey are classified in five separate categories as listed below. The survey consists of a total of 34 questions. The breakdown of the questions in the survey and their corresponding category is as follows:

- Genera Information
    - Consists of three questions
    - Aimed at obtaining general information about the LGAs.
- Asset Management
    - Consist of fourteen questions
    - Aimed at identifying the AM practices adopted by LGAs.
- Road Preservation and upgrades information
    - Consists of Nine questions
    - Aimed at identifying the Road Preservation strategies adopted by LGAs.
    - Also aimed at identifying the criteria and processes adopted by LGAs in determining the need for road upgrades.
- Information on Sealing an Unsealed Road
    - Consist of 3 questions
    - Aimed at identifying criteria and processes adopted when selecting Unsealed Roads to be candidates for sealing.
- Roads Levels of Service
    - Consist of five questions
    - Aimed at capturing information on processes adopted to develop and implement Road Levels of Service particularly for Low-Volume Roads.

The questions included in the survey were selected to capture information regarding the various approaches adopted by Local Government Agencies in the management of Low-Volume Roads. The survey was reviewed multiple times and the number of questions included were reduced to ensure that the time taken for its completion was limited to 45 minutes.

Participants are encouraged to make best judgement in questions where the information may not be readily available. It is understood that the level of data capture for Road management will vary from organisation to organisation. Similarly, it is expected that some questions may not be answered or applicable for some organisations. Additionally, participants are reminded that their participation in the survey is voluntary and that they are in no obligation to participate.

The target audience for this survey is Local Government Officers directly involved in the management and maintenance of the road network in their locality. The language used in the survey was chosen to cater for this target audience limiting the use of technical jargon and providing sample answers to enhance the reliability of the questions. Efforts were made to provide questions with simple Yes or No answers, and participants are encouraged to provide brief descriptions as an opportunity to add further details where applicable. The questions in the survey are not mandatory. This means that participants can chose to skip questions for which information is not readily available.

The survey will be distributed via email, using the University of Southern Queensland’s Survey Tool. This tool allows potential participants to be added to a participants list. The survey can then be distributed via email through a unique link. The survey tool captures information on the number of participants that got a survey participation email, number of responses received along with other statistical information.

3.4 Survey Data Analysis

Due to a delay in obtaining the ethics approval, the survey distribution was delayed until the 18th of September 2023. This corresponds to week 31 of this research project. The initial program was developed with this task scheduled to be completed on week 15. This represented a 16-week delay. This has been identified as a contributing factor in the low participation rate observed for this survey.

As mentioned above a total of 137 councils in WA were invited to participate. In the weeks leading up to the end of this research, efforts were made to encourage the invited participants to complete the survey. Two additional participation reminders emails were distributed to all participants the latest being on the 13th of October 2023. Out of the 137 councils invited to participate, only 12 responses were received. Only 3 out of these were full responses. The remind 9 were incomplete responses. The figure below is a snapshot of the survey summary page. Similarly, table 6 presents a summary of the survey questions and answers provided by the participating councils.

Response summary

Full responses	3
Incomplete responses	9
Total responses	12

Survey participant summary

Total invitations sent	138
Total surveys completed	3
Total with no unique token	0
Total records	138

Figure 3 Survey Response Summary

Table 6 Survey Questions and Answers Summary

	Question Description	Answer Summary
Question 1	What Local Government (LG) do you represent?	Out of the 138 invitations sent. 7 Participants Responded.
Question 2	How would you describe the region of your LG (e.g., metro, regional, or remote)?	7 Participants Responded. They were Categorised as follows - 2 Regional Councils: Shire of Harvey & Shire of Wongan-Ballidu - 3 Metro Councils: East Fremantle, City of Armadale, City of Fremantle - 2 Remote Councils: Murchison Shire, Shire of Mount Magnet.

Question 3	What is the Road length for Unsealed and Sealed roads according to their classification. The classification adopted for this survey is Main Roads WA. Please indicate if your LG uses a different classification?	**Seal Road Network (km)** **Unseal Road Network Length (km)**
	Local Access	1084.95 -- 1967.56
	Local Distributor	861.16 -- 1459.07
	Regional Distributor	862.54 -- 613.54
	Other	98.6 -- 0
	Totals Road Length (km)	**2907.25 -- 4040.17**
Question 4	What best represents the approach in your LG to managing unsealed roads?	- The most common response was: '*A combination of proactive maintenance used for higher order roads and a reactive maintenance approach to other roads*' - Metro councils appear to have a more '*proactive maintenance regime to all road categories*'
Question 5	Does your organisation have a Road Assets Condition inventory for your road network? If so, can you contribute the information?	- Metro councils reported having good Road Asset Condition inventory. The answer provided reported that 100% of their **Unsealed Rds.** in Fair condition are in the register, 100% of their **sealed roads** in Very Good condition are in their register, 90% of their **Sealed Roads** in Fair condition are in the register and 1% of the **Sealed Roads** in Poor condition are in the register. - The Remote shires reported that 96% of the **Unsealed roads** inventory is in their register, and 4% of the **Sealed Roads** are in the register.
Question 6	Does your organisation have traffic volume data for your sealed and unsealed road network?	- Only one remote council reported having traffic volume data for their road network in their register. The ADT reported for their Low-volume Roads was 75 VPD on average.
Question 7	Please indicate what Road Levels of Service (LoS) / Intervention levels does your Local Government target by answering Yes or No for each road category.	- Metro councils reported placing a high LoS based on Safety, Reliability and Condition. - Remote councils do not reported a specific criterion for LoS
Question 8	Please provide a briefly description on how maintenance practices may vary for roads with known traffic volumes and traffic compositions?	- One answer from a remote council indicating that maintenance practices are based on Local knowledge and experience. They also reported the effect of rainfall and flood events in their areas and indicated that traffic volume is only relevant to a few areas.
Question 9	What is the frequency of inspection adopted for Low-Volume Roads in your jurisdiction for **maintenance purposes**?	- Metro council indicated that they complete at least 1 inspection of their Road Network per year. - Remote councils indicated that their frequency of Road inspections varies. Some Local Access roads can be inspected Bi-Monthly.
Question 10	Are road maintenance inspections conducted by in-house personnel or outsourced to external contractors?	- Metro council indicated that their road maintenance inspections are completed by external personnel. ' Remote councils indicated that road maintenance inspections are completed by in-house personnel
Question 11	Does your organisation provide access to training programs for personnel involved in the management of Road Assets?	- Metro council responded that their personnel get access to training provided by various training organisations such as ARRB, and AustRoads. - Remote councils responded that minimal training is commonly available but at occasions they arrange tanning with external engineering consultants.

Question 12	What methods or technologies are utilized to collect data on the condition of low-volume roads?	- Responses indicated that the most common method to collect road condition data is through Visual Inspection. - Responses indicated that no Automated Road Inspection is conducted in their jurisdiction in-house.
Question 13	How often is Road Condition data collected and updated for road management purposes?	- Metro council indicated that they collect Road condition data at intervals every 3 - 5 Years. - Remote councils indicated that they collect Road condition on regular basis. At least once a year.
Question 14	Are Road Condition inspections conducted by in-house personnel or outsourced to external contractors?	- A Remote council and a Metro council outsources the completion of Road Condition inspections to external contractors. - One Remote council completes both in-house and external road condition inspections. In-house conditions are completed regularly, and external ones are completed every 4 - 5 years in preparation for revaluation of road assets.
Question 15	Does your organisation have considered the incorporation of advanced technologies for road data collection?	- One Remote council has considered the use of Pavement Deflector for the inspection of the Sealed Roads (Regional Distributors). - One Metro council has considered the use of ground penetrating radar for the inspection of their road network. - The other participants reported that No Advance Technologies have been considered for road data collection so far.
Question 16	Does your organisation use a 1 to 5 grading system for the allocation of condition score to the Road Network?	- One Metro council responded that they use the 1- 5 grading system to allocate a score condition to their road network. - Two remote councils also responded that they use the 1- 5 grading system. - The other participants answer either N/A and No.
Question 17	Which Asset Management System does you organisation uses for the management of Road Assets?	- A Remote council and a Metro council both indicated that they use RAMM as their Road Asset Management System. They supplement this along with excel files.
Question 18	What is the cost and frequency of typical routine/ periodic maintenance on roads in your Local Government area?	- A Remote council responded that they complete 2 grades / year on Regional Distributor Roads, 1 grade / year on Local Distributor and Local access or whenever they are in the area and the road is in poor condition. They indicated that their re-sheets are completed on 'As needs' basis. - A Remote council responded that the cost of maintaining their road network is as follows: * Regional Distributor: $50,400 / km (Maintenance) * Local Distributor: $39,200 - $50,400 / km (Maintenance) * Local Access: $36,600 - $39,400 / km (Maintenance) * Re-sheets: As needed or up to 25 km / Year * 17 km / year (Reseal) * Average Reseal cost: $47,520 / Km - A Metro council indicated that the cost of Maintaining their road network was on average $200,000 / Km of Sealed Local Distributor Roads.
Question 19	Briefly outline what criteria is used in your organization to determine when a Low-volume Road requires resurfacing?	- All responses indicated that they use Visual Inspections to identify defects such as rutting, cracks and surface deterioration to determine the needs for resurfacing.
Question 20	Are recycled materials considered for the use in road maintenance activities?	- All responses indicated that they have not considered recycled materials for the use in road maintenance.

Question 21	Briefly discuss any challenges or limitations that your organization faces when utilizing recycled materials on Low-volume roads?	- Responses indicated that 'Remoteness' is one of the main challenges in adopting the use of Recycle materials in the road maintenance practices. - Similarly, Responses indicate that the use of Recycle materials are not considered an applicable method currently.
Question 22	Which factors are considered when prioritizing maintenance activities for low-volume roads?	- A metro council responded that Traffic Volume and Road Condition are the main factors considered. - Two remote councils indicated that Road condition is the main factor to consider. - Participants indicated the Roads LoS are not considered currently
Question 23	How does your organisation ensure that maintenance activities on roads are completed within a reasonable timeframe?	- Two Remote councils responded that they use Work Orders and a programming of a maintenance Schedule to ensure Maintenance work is completed in a reasonable time frame. - A Metro council responded that they use the response time allocated based on the record of complaints made by members of the public.
Question 24	What are the biggest challenges you face in maintaining low-volume roads?	- A Metro council responded that their biggest challenge relates to insufficient resources. - A remote council responded that their biggest challenge relates to both insufficient funds, resources and Personnel recruitment. - Responses do not consider Asset Management Systems to be challenge.
Question 25	Briefly outline what challenges your organisation encounters when securing sufficient funding for the management of low-volume roads?	- A remote council responded that external flood damage founding and management scheme is poor, cumbersome and not fit for purpose. And it does not provide value for money. - A Metro council responded that there are no challenges in securing funding.
Question 26	Is the Annual budged allocated for the Road Renewal Program sufficient to maintain agreed levels of service?	- A Metro council responded that they use the Road to Recovery funding to maintain the agreed LoS for their road network and that this founding is suitable. - A Remote council responding that generally the founding is adequate. Except when there is extensive damage due to flooding events.
Question 27	Which of the following factors does your organisation considers critical when deciding the correct time to seal an unsealed road? Road Condition, Traffic Composition, Environmental Impacts, Whole of Life Cost, Road Safety.	- Two Remote councils responded that all conditions are considered as factors when deciding when to seal an unsealed road. - A Metro council responded that only Traffic composition, Whole life Cost and Safety are the factors considered.
Question 28	Considering the answer provided in the previous question, how / why the criteria selected impacts your organisation's decision-making process?	- One Remote Council responded: Their approach to manage the maintenance to their Low-Volume Roads has been developed and refined over year of practical experience. Their declining population has an effect in their management approach. The CSIRO / SKA project has specific needs with minor impact on road condition. - A Metro council responded: The approach to manage the maintenance of their Low-Volume Roads aligns with their Asset Management Policy and long-Term Community objectives.

Question 29	Does your LG organisation have any guidelines that addresses the question of when to upgrade / seal an unsealed road?	- A Remote Council responded: Due to the low volume of traffic, and the climate region, there is no need to consider the sealing of any of the roads. - Another Remote council responded: There is an road management strategy in place for Regional Roads. The extend of any reseal works is subject to the funding received, potential impacts of mining activity. - A metro council responded: There is no need for a guideline of resealing unseal roads since they only have 13 km of unseal roads.
Question 30	Does your organisation have a documented Roads Levels of Service?	- A Remote council responded: No, there is no documented LoS for Roads. Although there is a re-sheet schedule with an specific frequency. This is based on local knowledge and according to the road condition. This schedule assist in prioritising works and facilitates the budgeting of the annual projects. - A Metro council responded: Yes, there is a LoS documented. It covers the tolerable limit of the percentage of the network in poor condition and also includes triggers for Road renewals.
Question 31	Does your organization have a mechanism to measure the performance and effectiveness of low-volume roads in meeting the desired levels of service?	- A remote council responded: There is no mechanism in place. Although the local and regional feedback has historically been good. - A Metro council responded: Yes, there are mechanisms in Place. It includes acceptable levels of defect scores.
Question 32	Does your organisation have a mechanism to adopt public input in determining the acceptable levels of service for low-volume roads?	- A Remote council responded: The mechanism in place relies on the local feedback received on continuous basis. - A metro council responded: No, there are no mechanisms in place yet.
Question 33	Briefly outline how your organisation handles public complaints or concerns related to low-volume road management?	- A Remote council responded: Public complains are handled on an as required basis. There is an inherent understanding of the realities of the region. - Another Remote council responded: All concerns are investigated and prioritized. - A Metro Council responded: Complains are assigned to the responsible officer and the response times, due dates are assigned through the system.
Question 34	Does your organisation have a mechanism to address the needs of pedestrians, cyclists, and other non-motorized users on low-volume roads?	- A Remote council responded: Not applicable. Due to the large distances and the fact that there is not stablished townsites, just settlements. - A Metro council responded: Yes, these are addressed through public complains and a footpath master plan.

3.5 Survey Summary

Whilst efforts were made to encourage multiple local government councils in WA to complete this survey, it has been highlighted that the time available for its completion was greatly reduce due to circumstances that were outside the control of the researchers. The following statements aim to present a summary from the responses obtain form this survey.

These statements represent the responses of the few participants and should not only be considered as a summary of the survey. Further research will need to be completed to verify the accuracy of the statements presented here. The statement where categorise in various sections as follows.

Maintenance approaches: The survey shows that most councils use a mix of proactive and reactive maintenance for different road hierarchies. Proactive maintenance is applied to higher hierarchy roads, while reactive maintenance is used for lower hierarchy roads.

Road asset register and condition data: The survey indicates that the councils have increased confidence in the accuracy and completeness of their road asset register and condition data. They use visual inspections as the main method to collect condition data, and some outsource this task to external contractors. They also use RAMM and excel spreadsheets to store their data.

Road traffic data: The survey does not provide a clear picture of the level of road traffic data for councils in WA. This is because of the low participation rate and incomplete answers regarding this topic.

Road levels of service: The survey reveals that metro councils have well-defined road levels of service, while rural and remote councils do not. This may affect their decision-making process and maintenance practices.

Maintenance practices for LVR network: The survey shows that remote councils rely on local knowledge and experience to maintain their LVR network, while metro councils have more formalized practices. The survey also shows that flood events have a high impact on the maintenance needs of remote councils.

Frequency and outsourcing of inspections: The survey shows that the frequency of inspections for maintenance purposes varies across the road hierarchy and the type of council. Remote councils conduct regular inspections by driving the roads, while metro councils have more structured inspection programs. The survey also shows that metro councils are more likely to outsource their inspections to external contractors, while remote councils tend to do them in-house.

Training of personnel: The survey shows that training opportunities for personnel involved in road management differ across the type of council. Remote councils limit their training to an as-needed basis, while metro councils offer more training options.

Criteria for sealing roads: The survey suggests that remote councils consider traffic volume and composition data, and average climate conditions when deciding whether to seal an unsealed road. Due to WA’s inherent climate and low vehicle volume, remote councils rarely justify the need to seal an unsealed road. In contrast, metropolitan councils are likely to adopt a road management strategy.

Use of recycled materials: The survey indicates that recycled materials are not widely used in road maintenance activities. 'Remoteness' was highlighted as a major challenge in adopting recycled materials.

Monitoring of maintenance activities: The survey shows that maintenance activities are monitored in various ways, including the use of work orders and response times based on public complaints records.

Challenges in managing LVRs network: The survey reveals that some of the challenges faced in managing their LVRs network include insufficient funds, lack of qualified resources, and recruitment of road maintenance personnel. However, Asset Management Systems do not represent a challenge.

Funding for maintenance: The survey suggests that the funding allocated for road network maintenance is only sufficient to cover basic planned maintenance activities. There is insufficient funding to address severe or extreme weather events such as flooding.

Approach to road network management: The survey shows that the approach to managing the road network varies across councils in WA. Remote councils manage roads based on practices developed and refined over time and practical knowledge and experience from local personnel. In contrast, metro councils are likely to adopt an asset management policy aligned with Long-Term Community Objectives.

Record of Levels of Services (LoS): The survey indicates that the formal record of LoS varies across councils in WA. A remote council relies on a re-sheet schedule with specific frequencies to maintain their network's LoS. A metropolitan council documents LoS and uses it as a guide on the tolerable limit of the percentage of the network in poor conditions.

Measurement of performance and effectiveness: The survey shows that for a remote council, there is no formal mechanism to measure performance and effectiveness in meeting the agreed LoS, yet they have received historically positive feedback. A metro council uses acceptable levels of defect scores as a measure of their road network's performance.

4.0 Risk Assessment

A risk assessment is the process of identifying and evaluating the potential hazards and harms that may arise from conducting any task. Risk assessments facilitates the adoption of appropriate measures to protect all those involve in the task from any physical, psychological, social, legal, or economic harm. A risk assessment is also a requirement for obtaining ethical approval for research.

Some of the typical risks considered when conducting a risk assessment are:

- **Social risks**: disclosures that could affect participants' standing in the community, in their family, and their job.
- **Legal risks**: activities that could result in the participant, researchers and / or University committing an offence; activities that might lead to a participant disclosing criminal activity to a researcher which would necessitate reporting to enforcement authorities; activities that could result in a civil claim for compensation.
- **Psychological risks**: distress, anxiety, embarrassment, or discomfort caused by the research procedures or questions.
- **Physical risks**: injury, illness, or adverse effects caused by the research interventions or equipment.
- **Economic risks**: financial loss or damage caused by the research participation or outcomes.

The objectives of the risk assessment completed for this project research include the following:

- The identification of the potential sources of harm and who/what could be affected by them.
- Assessment of the likelihood and severity of the harm that may occur.
- Decide on the appropriate control measures to prevent or reduce the harm.
- Monitor and review the effectiveness of the control measures.
- Demonstrate your ethical and legal responsibilities as a student and researcher.

The Risk Assessment for the research project presented in this report has been edited and adapted from the template provided in the USQ Study Desk. Risks associated with personnel, environment, financial, reputation and legislations are considered in this document. The purpose of the risk assessment is to identify the potential hazards, analyse the risk these represent and identify control measures to eliminate them or minimize them.

A Risk Assessment has been completed for this project within the online platform Safe Track. The Risk Assessment's reference number is 2399.

Please refer to **Appendix C Risk Management** for further details

5.0 Case Study

5.1 Introduction

The Case study on the CGG aims to identify the management strategies used for Low-Volume Roads by this Local Government. This case study includes a review of several reports related to the approach on asset management adopted. These include Long-Term Financial Management Plans, Asset Management Plans, Maintenance Programs and Transport Strategies. The list of City of Greater Geraldton Documents reviewed is listed below:

- Transport Asset Management Plan (2013)
- Integrated Transport Strategy (2015)
- Roads Levels of Service (Maintenance - Draft) (2017)
- ROADS Asset Management Plan (Concise – First Draft) (2019)
- Strategic Asset Management Plan (2019)
- Asset Management Maturity Diagnostic and Improvement Plan (2020)
- Asset Information Management Standard – Strawman (First Draft) (2022)
- Community Strategic Plan (2021 – 2031)
- Corporate Business Plan (2021 – 2025)
- Asset Management Policy (2021)
- Annual Budget (2022 / 2023)
- Long Term Financial Plan (2024 – 2033)

The Case study identifies similarities and differences in adopted road AM strategies by the CGG and those identified from the findings in the literature review analysis and the survey analysis. The case Study also highlights identified gaps in current management strategies and presents a list of actions with the aim to fill these gaps.

The City of Greater Geraldton is in Western Australia's Mid-West region and is situated 424 km north of Perth. The city is located along the coast on the west and comprises a vast inland area that extends eastward to the town of Mullewa. According to the 2021 Census, the population of Geraldton in Western Australia is 39,4891 (ABS, 2021). Geraldton is the third most populous place in Western Australia after Perth and Bunbury, and the 41st largest urban centre by population in Australia (Population-Australia, 2023). Geraldton is an important service and logistics centre for regional mining, fishing, wheat, sheep, and tourism industries and covers an area of 12,625 square kilometres. This is the area of the local government area that incorporates Geraldton, Mullewa, Walkaway, and other rural areas.

The climate in Geraldton is classed as Mediterranean; with mild to warm weather in autumn and spring and hot dry summers with winds from the east in the morning and from the south/southwest most afternoons. Winters are mild and most rainfall is during June to September with an average 350mm (Climate-Data.ORG, 2023). The City of Greater Geraldton is the hub of the Mid-West region considered a thriving and sustainable regional city and is fast becoming a significant centre known internationally for its liveability; science, mining and trade industries; food production; and renewable energy (Jenkins, 2015).

Transport networks are widespread and include Primary Distributor roads that extend significantly beyond Greater Geraldton and even beyond the Mid-West region. some transport links in Geraldton have been developed in an irregular manner, resulting in a challenging asset to manage and maintain. Furthermore, the vast land area and low population density of much of the region limit the rate base for asset renewal. Due to the vast distance within the region, private vehicles are the predominant mode of transport, which reduces the usage of public transport networks. However, in recent years, there has been an increasing demand for active travel infrastructure, such as pathways and public transport.

There are also issues related to freight movements such as seasonal freight movements combined with relatively high base load freight movements which can be step-increased with resource sector operations. Balancing these modes and maintaining safety and amenity for the community is a challenge with limited funds.

The traditional custodians of the land now call the Mid-West region consist of several language groups including the Amangu people, Naaguja people, Wajarri people, Nanda people, Badimia people and Western Desert people. Collectively known as Yamatji, this group's history in the Mid-West dates back at least 40,000 years. Yamatji culture continues to have a strong presence in the region.

5.2 Case Study Objectives

The principal objectives of the case study are the following:

- To identify the management strategies used for Low-Volume Roads
- To identify any similarities and differences from the findings in the literature review on Low-Volume Roads Development and Management.
- Highlight any gaps in current management strategies implemented by the city of Greater Geraldton
- Present a list of actions with the aim to address the gaps in the current management strategies on the low-volume roads.

The first objective of this case study is to identify the management strategies used for Low-Volume Roads (LVRs) by the city of Greater Geraldton. LVRs are roads that carry less than 400 vehicles per day and form a significant component of the Australian road network. (Franzen & Thorpe, 2020). Management strategies refer to the planning, design, construction, maintenance, and rehabilitation of LVRs to ensure their sustainability, efficiency, safety, and reliability. (G. Keller & Sherar, 2003)

The second objective of this case study is to compare the management strategies used for LVRs by the city of Greater Geraldton with the findings in the literature review on Low-Volume Roads Development and Management. The literature review provides a comprehensive overview of the current practices, challenges, and opportunities for LVRs in Australia and other countries. (Sunitha, Veeraragavan, Srinivasan, & Mathew, 2012). The comparison and contrast will highlight the strengths and weaknesses of the management strategies used by the city of Greater Geraldton.

The third objective of this case study is to identify any gaps in the current management strategies implemented by the city of Greater Geraldton for LVRs. Gaps refer to the areas where the management strategies are insufficient, ineffective, or inconsistent with the best practices for LVRs. (G. Keller & Sherar, 2003). Identifying the gaps will help to assess the performance and impact of the management strategies on LVRs and their users.

The fourth objective of this case study is to present a list of actions with the aim to address the gaps in the current management strategies for LVRs by the city of Greater Geraldton. Actions refer to the specific measures or recommendations that can be taken to improve or enhance the management strategies for LVRs. The actions will be based on the evidence from the literature review and the case study analysis.

5.3 Road Selection Criteria

This case study will review the Road Asset Management practices adopted for a sample of roads taken as representative of each Road Asset Hierarchy.

The current Functional Road Hierarchy adopted by the CGG is based upon Main Roads WA (MRWA, 2023) classifications. While the AM system of the CGG uses a terminology slightly different to that presented by MRWA, the Road Hierarchy classification is equivalent. The table below presents the Road hierarchy classification as described by MRWA, a description for each of these classes and the equivalent adopted by the CGG as it appears in the AM system.

Table 7 Road Hierarchy for WA (MRWA, 2023)

Sealed Road (MRWA)	Road Description	CGG Equivalent
Primary Distributors	Provide for major regional and inter-regional traffic movement and carry large volumes of generally fast-moving traffic. Some are strategic freight routes, and all are State Roads. They are managed by Main Roads Western Australia.	Managed by MRWA
District Distributor A	Carry traffic between industrial, commercial, and residential areas and generally connect to Primary Distributors. These are likely to be truck routes and provide only limited access to adjoining property. They are managed by local government.	Distributor Road
District Distributor B	Perform a similar function to type A District Distributors but with reduced capacity due to flow restrictions from access to and roadside parking alongside adjoining property. These are often older roads with a traffic demand more than that originally intended. District Distributor A and B roads run between land-use cells and generally not through them, forming a grid which would ideally space them around 1.5 kilometres apart. They are managed by local government.	Distributor Road
Regional Distributor	Only Non-Built-up area. Connectors to Primary Distributor or other distributor roads. Roads links significant destination and are designed for efficient movement of people and goods between and within regions.	Regional Distributor
Local Distributors/Industrial Roads	Carry traffic within a cell and link District Distributors to access roads. The route of the Local Distributor and Industrial Roads discourages through traffic so that the cell formed by the grid of Local Distributors/Industrial Roads only carries traffic belonging to or serving the area. These roads should accommodate buses but discourage trucks, except where they are servicing industrial development areas. They are managed by local government.	Urban Collector / Unsealed Collector
Access Roads	Provide access to abutting properties with amenity, safety and aesthetic aspects having priority over the vehicle movement function. These roads are bicycle and pedestrian friendly. They are managed by local government.	Urban Local / Unsealed Local

Lanes	Lanes - For movement of cars from higher hierarchies for access to rear of residences within the municipality	Unsealed access

The criteria considered for the selection of the roads to be included in the cases study is described below:

- Select 5 roads for each hierarchy Classification.
    - Distributor Road
    - Regional Distributors
    - Unsealed Access
    - Unsealed Collector
    - Unsealed Local
    - Urban Collector
    - Urban Local
- Spread the selection across most of the localities.
- Consider roads with Traffic Counts that are classified as Low-Volume Roads. Only roads with traffic counts of 1000 VPD or less where considered.

5.4 Literature Review for the Case Study

A case study is a detailed study of a specific subject, such as a person, group, place, event, organization, or phenomenon. Case studies are commonly used in social, educational, clinical, and business research. Case study research usually involves qualitative methods, but quantitative methods are sometimes also used. (Hassan, 2022)

The implementation of a Case study has been proven to be a suitable methodology to supplement a research investigation (Tellis, 1997). Case studies require access to multiple sources of information and present the findings considering the perspective of the participants.

Case studies usually focus on one or two fundamental issues related to the subject it intends to study. In other words, it is preferred for case studies to be selective. As mentioned on the report titled Application of a case study methodology by Wilson T. (Tellis, 1997) case studies are considered multi-perspectival analysis, in which the researcher takes into consideration not just the perspective of the participants, but also that of the relevant groups or actors and the interaction between them.

A case study is suitable research method when concrete, contextual, in-depth knowledge about a specific real-world subject is required. It allows the exploration of the key characteristics, meanings, and implications of the case. Case Study can be use in the research of Asset Management, particularly to investigate the impacts and performance of Asset Management Strategies adopted by Local Government agencies for the administration of Road Assets. (J.W, 2002).

The Case Study presented in this research project examines the Asset Management Policy and Strategy of the City of Greater Geraldton. The Asset Management Strategy establishes the processes that link Asset Management Plans to Long Term Financial Plans and Workforce Plans and defining levels of service agreed by both the members of the public and the CGG.

5.4.1 Roads Managed by Local Governments in Australia

Local Government agencies are responsible to maintain road infrastructure in a condition that optimises its useful life while meeting the community needs and expectations over the long term. They are expected to manage local roads in and effective and sustainable manner adopting best AM practices.

The Local Government Act 1989 mandates that councils provide fair and appropriate services and facilities for the community and ensure that those services and facilities are managed efficiently and effectively. Therefore, it is crucial to manage and maintain all infrastructure assets continuously to optimize their useful life, capability, and utilization. In the case of road assets, councils must be aware of the condition of their road infrastructure and undertake necessary repairs and works to ensure the long-term sustainability of the asset.

The primary objective of councils is to attend to roads with defects to ensure the maximum life of the road is realized and that the high cost of replacement is minimized. Additionally, councils must be aware of their exposure to potential litigation resulting from dangerous road or footpath conditions that may cause injuries to users of those assets. (J.W, 2002).

Local Government organisations oversee the management of public infrastructures, including local roads. They are responsible for maintaining ongoing monitoring of road infrastructure and making decisions that support the long-term sustainability of these assets. These actions are translated into strategic documents such as Asset Management Plans and capital works programs. These documents are aimed at providing the list and the costing for projects that are identified as critical and need to be addressed over a period of usually 3 to 5 years. This usually includes routine maintenance programs, major maintenance works/replacement of assets and new capital projects. Whilst it was common for local governments to complete these capital programs with in-house staff, nowadays it is more common to contract out these activities. Many councils are adopting a mix-approach to the completion of capital programs by using in-house staff to complete a portion of the work and contract out the remaining. This is the case for the City of Greater Geraldton in WA.

Western Australia comprises 10.7% of the national population but 19.2% of the local road length. The disproportionate length of roads in the State is a function of the size of the State. The cost of maintaining a kilometre of Local Government Road in NSW is shared between 55 people, while in Western Australia this cost is shared between 22 people. This is partly due to lower population density and partly because Local Governments in WA are responsible for a larger proportion of the road network. (WALGA, 2022)

Due to the large size of WA and length of the roads in this state, Local Government roads are regularly used by a considerable number of Heavy Vehicles. For this reason, more than half of Local Government Roads are accessible to double road trains, and a quarter of the roads are open to triple road trains. A heavy vehicle is defined in the Heavy Vehicle National Law (HVNL) as a vehicle that has a gross vehicle mass (GVM) or aggregate trailer mass (ATM) of more than 4.5 tonnes. The GVM of a vehicle is the maximum it can weigh when fully loaded, as specified by the manufacturer (NHVR, 2023).

Similarly, a restricted access vehicle (RAV) refers to vehicle usually a truck and trailer combination with a gross mass exceeding 42.5 tonnes or more than 19 meters (Business.gov.au, 2023). RAVs are only permitted to operate on a network of roads approved by Main Roads WA. The RAV network consists of 10 levels, which accommodate vehicles with varying lengths and mass. The RAV networks in Local Government roads have increased in the past 12 months.

5.4.2 Local Government Roads Maintenance and Renewals Expenditure

In Western Australia, local Government maintains 127,067 kilometres of road of which 32.1% are sealed. Local Government roads make up 87.2% of the WA public road network. Local Government roads have a replacement value of $35.08 billion as at June of 2022. (WALGA, 2022)

In 2021/2022, local governments invested $1022 million on the local road and path network, which was an increase of $79.8 million from the previous year. This was the first time that the annual investment exceeded 1 billion. (WALGA, 2022) However, the cost of key materials, such as bitumen, and skilled labour shortages caused the benchmark road construction and maintenance price index to rise over the same period. This resulted in a decline in the amount of construction and maintenance delivered.

Most of the State and Federal funding approximately 75% was allocated to local roads in regional areas due to the extensive and critical road network outside of the metropolitan area and the limited capacity to fund its maintenance from other sources. Approximately $77 million was spent in 2021/22 reinstating roads damaged or destroyed by floods. This is a 52% increase over the previous year. (WALGA, 2022).

According to the records presented in the Report on Local Government Roads Assets and Expenditure 2021-2022 (WALGA, 2022) it is clear that the Local Government sector in WA does not have the financial resources required to fully maintain its road network and to keep up with its road improvement needs. The Report presented by the Western Australia Local Government Association (WALGA) reported an estimate of the cost of maintaining WA’s road network in its current condition in 2021-22. The estimates were derived through consultation with local government engineers, and it reported that the cost is estimated at $945.54 million. However Local Governments spent during this period (2020-202) was $663.24 million on road preservation. This represents a short fall of $282.3 Million. (WALGA, 2022).

Similarly, the same report presented the estimated useful life for Road Assets and estimated the Asset Renewal frequency for road pavement reconstruction, resealing of sealed roads and re-sheeting gravel roads. The data used for this estimate was provided by local government engineers and validated in consultation with Main Roads WA. The analysis revealed that the current rate of road reconstruction in the metropolitan region is insufficient, as it would take 503 years to reconstruct the complete network, while the estimated life is only 75 years. Similarly, the current rate of road resealing is inadequate, as it would take 56 years to reseal the network, while the estimated life is 15 to 30 years. (WALGA, 2022).

The Australian Local Government Association (ALGA) has developed a National Performance Measure for the sustainability of Sealed Road assets. The performance measure is calculated by dividing the annual preservation (maintenance and renewal) expenditure by the annual life cycle cost. The higher the percentage, the better is the performance. The WA state-wide performance is 59%, this is a decrease on the previous year (63%). The data presented in the road expenditure report indicated that the worst performing regions are Wheatbelt South (44.9%) and Mid-West (30.4%.). Expenditure on roads from a local Government's own resources is an important indicator of the priority the Local Government places on its road needs (WALGA, 2022).

5.4.3 Local Government Roads and Climate Change

The IPCC Fifth Assessment Report (AR5) released in 2013 stated that "Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, observed warming and understanding of the climate system." (Gebre & Ludwig, 2015). As a result, the global mean temperature is expected to rise by at least 2C by mid-century.

This rise in global temperatures will lead to an increase in maximum and minimum temperatures, frequency and severity of heatwaves and bushfire weather, humidity, and evaporation. It will also lead to an increase in rainfall in the tropics and a decrease in rainfall across the mid-latitudes. Additionally, it will increase the intensity and frequency of extreme rainfall events, the intensity and range of tropical cyclones, sea levels, and the acidity of the oceans as they absorb Co2 (IPWEA, 2018).

It is therefore expected that climate change will have a profound effect on the useful life of infrastructure assets, including Road infrastructure. This poses additional challenges to evaluate the useful life of road assets. The evaluation of the effects of climate change on an asset's useful life should be completed at both the component and larger scales. The reason for this is that each component of an asset may have different physical or functional responses to the anticipated climate changes. Similarly, the asset as a whole may be impacted as a result of its location, local environment, design, existing adaptation measures, and policy environment (IPWEA, 2018).

Projections of future changes in the climate are made using global climate models that have been tested for accuracy against historical data (IPWEA, 2018). The latest climate models account for both natural internal climate variability as well as changes to the climate system that are driven by changes in greenhouse gases, solar radiation, and volcanic activity. Natural sources of greenhouse gases include among other things methane released from Artic areas because of melting permafrost and peat bogs. Much of the climate change over the coming decades will be the result of the greenhouse gases already in the atmosphere (Gebre & Ludwig, 2015). Globally averaged atmospheric water vapour, evaporation and precipitation are all projected to increase under climate change.

Among the expected effects of climate change, the following represent the greater challenges to infrastructure assets in Australia. These include; the increase of the frequency and intensity of extreme daily rainfall for most regions, the increase in the frequency of extreme sea-level events and sea-level rise, ocean acidification will continue, the increase in the intensity of tropical cyclones, temperature to raise with more hot days and fewer cool days, increase in extreme fire-weather days in southern Australia and a longer fire season as a result, and a decrease in annual-average rainfall in southern Australia with an increase in Droughts (IPWEA, 2018).

Since the largest category of infrastructure assets for most Local Governments is roads, it is expected that climate change will have a direct impact in the useful life of road assets. The two main ways in which climate change will impact road assets are physical damaged and chemical deterioration. An example of physical damaged includes the collapse of a timber bridge because of large quantities of debris being push by a flood, or the melting of an asphalted road because of a heatwave. An example of chemical damaged includes the accelerated corrosion of a steel reinforced beam due to the ingress of salty water cause by raise in water levels.

The effects of climate change can cause devastating damage to road assets due to extreme weather conditions. Unsealed roads are usually vulnerable to excessive damaged when exposed to extreme rain events and flooding. The excess moisture contend softens the road pavement making it susceptible to damage under normal traffic conditions and causes a risk to the road users. Similarly, extreme temperature fluctuations can accelerate the rate of deterioration of sealed surfaces. This is more evident in extreme heat conditions such as fires or heat waves. Since bitumen is made from hydrocarbons, a flammable material, it is prone to break down under high temperatures. Heatwaves can also cause flushing or bleeding of the bitumen causing great damage to road assets. Road assets are also susceptible to salt intrusion. Saline water reduces the bond strength of the binder and weekends pavements. Therefore, bitumen roads exposed to sea level rise or extreme weather fluctuations and heatwave will have a reduced useful life.

In 21-22 a total of $72.21 million was spent on repairing flood damage. The Mid-West region has been the worst affected region during the last 5 years. (WALGA, 2022).

5.5 City of Greater Geraldton Road Asset Management Practices Analysis

As mentioned in the introduction of the case study, various reports and other documents were reviewed during the completion of the case study. These include:

- Transport Asset Management Plan (2013)
- Integrated Transport Strategy (2015)
- Roads Levels of Service (Maintenance - Draft) (2017)
- ROADS Asset Management Plan (Concise – First Draft) (2019)
- Strategic Asset Management Plan (2019)
- Asset Management Maturity Diagnostic and Improvement Plan (2020)
- Asset Information Management Standard – Strawman (First Draft) (2022)
- Community Strategic Plan (2021 – 2031)
- Corporate Business Plan (2021 – 2025)
- Asset Management Policy (2021)
- Annual Budget (2022 / 2023)
- Long Term Financial Plan (2024 – 2033)

The CGG road network is comprised of 830 km of Sealed roads and 1,280 km of unsealed roads. Of the 2110 kms of roads maintained by CGG, 61% is gravel roads, 39% sealed roads and the most predominant sealed surface type is chip seal at 25%. (CGG, 2023)

The CGG currently has transport assets valued in excess of half a billion dollars and very limited access to discretional capital funds in the future. (Jenkins, 2015). CGG does not own and is not responsible for the management of Declared State Roads such as the Northwest Coastal Highway, Brand Highway and John Wilcock Link. These roads are managed by Main Roads Western Australia (MRWA).

In 2013, the CGG developed a Transport Asset Management Plan (TAMP). This TAMP was focused on adopting a proactive and strategic approach to the AM of Roads and transport assets owned by the CGG. It presented strategies that considered the lifecycle of roads assets and enable the development of cost-effective management strategies for the long term.

This TAMP also presented a defined level of service and monitoring performance. This includes the measuring and monitoring of the condition, performance, utilisation, and costs of roads assets. Similarly, the TAMP considered strategies to meet the demands of growth through demand management, infrastructure investment, risk management, sustainable use of physical resources and continuously improvement of AM practices. (CGG, 2013)

It is the responsibility of Local Government Agencies to sustainably allocate resources to the guarantee the correct operation and maintenance of road assets under their management and ensure the services provided are in line with the desires of the community. This is commonly referred as Levels of Service (LoS). Levels of services are key business drivers and influence asset management decisions. Levels of service statements describe the outputs the CGG intends to deliver to customers and stakeholders. They relate to service attributes such as quality, reliability, responsiveness, sustainability, timeliness, accessibility, and cost. Levels of service provide the link between higher level corporate and asset management objectives and more detailed technical and operational objectives. (Lancaster, 2019)

The levels of service adopted by the CGG as described in the TAMP focuses on identifying the costs and benefits of the services offered, informing all customers of the proposed type and level of service to be offered and enabling customers to assess the suitability, affordability and equity of the services offered.

Levels of service are the building blocks for infrastructure asset management. Community engagement is the process of informed communication between a local government and its community in an issue prior to the local government deciding or determining a direction on that issue. Community engagements with the is a crucial part of delivering infrastructure services in a financially sustainable way. Councils are therefore expected to establish the service delivery needs and define service levels in consultation with the community, establish quality and cost standards for services to be delivered from assets and regularly review their services in consultation with the community to determine the financial impact of a reduction, maintenance or increase in service. Asset Management focus is to provide the LoS the current and future community want and are prepared to pay for, in the most cost-effective way (IPWEA, 2016).

In the TAMP, the CGG has identified two tiers of levels of service. These are the Strategic Levels of Service and Operational levels of Services. (CGG, 2013). The Strategic Levels of Service describe the key customer outcomes the CGG expects to provide. These are listed below:

- Road's accessibility to users 24 hours a day, 7 days a week.
- Affordability – acknowledging that the organisation can only deliver what they can afford.
- Access to CGG road network by HVs is to be limited to those necessarily using the local roads and then for them to use only District Distributor A and B roads other than when immediately accessing properties.
- Limited through access directed along residential streets.
- Minimal conflict between various road user groups/vehicle types (e.g., cars, trucks, motor cyclists, bicyclists, pedestrians, children, and people with disabilities).
- Road surfaces that create minimal adverse noise conditions in residential areas, are smooth riding, accessible and safe in all the prevailing local weather conditions (i.e., non-slippery when wet) and free draining.
- Street lighting that provides good visibility at night.
- All road structures (e.g., pavement base, surface, bridges, and traffic devices) to be maintained in a safe, workable condition.
- Street and roadside trees to be selected to maximise aesthetic benefit but with minimal ongoing problems with hazards caused by root movement and droppings (e.g., berries).
- Verges (nature strip) to be suitable for easy maintenance by adjoining property owners.
- Adequate provision of street signing to facilitate access for non-locals.

Similarly, Operational Levels of service describes the commitment of the CGG to maintain the reliability, functionality, and adequacy of the Road assets. The TAMP presents the maintenance standards adopted for road assets. This includes intervention levels for repairs, renewals, and upgrades to meet the customer expectations listed in the strategic levels of Service.

The CGG's Operational Levels of Service that were adopted as described in the TAMP are presented in the table below as:

Table 8 CGG Operational Levels of Service (CGG, 2013)

Key Performance Measure	Strategic Level of Service	Performance Measure Process	Performance Target
Condition – Wearing Course	Condition assessment of road network every 3 years.	Condition Assessment	An average Asphalt or Binder/Stone Condition Index of 2.5 (out of 5) or better, with 1 being the best and a maximum of 2% of the network in Condition 5
Condition – Sealed Pavement	Condition assessment of road network every 3 years.	Condition Assessment	An average Rutting Condition Index of 2.5 (out of 5) or better, with 1 being the best and a maximum of 2% of the network in Condition 5
Condition – Unsealed Pavement	Condition assessment of road network every 3 years.	Condition Assessment	An average Cross-section Condition Index of 2.5 (out of 5) or better, with 1 being the best and a maximum of 3% of the network in Condition 5
Condition – Footpaths	Condition assessment of footpath network every 3 years.	Condition Assessment	On average, footpath network to be in condition 3 (out of 5) or better, with 1 being the best and a maximum of 2% of network in condition 5

Condition - Kerbs	Condition assessment of kerbs every 5 years	Condition Assessment	Maximum of 10% of network in condition 5.
Condition - Bridges	Level 2 Bridge Inspection – Annually Level 3 Bridge Inspection – as required or once in 4 years	Condition Assessment	On average, bridge network to be in condition 3 (out of 5) or better, with 1 being the best.

The CGG Road assets have been maintained at a level that meets design standards, where these are available. The table below presents the standards used for the design and construction of the CGG Rods. These standards are in accordance with the Local Government Guidelines for Subdivisional Development. (IPWEA, 2017)

Table 9 Road Standards adopted by CGG (TAMP 2013)

Road Hierarchy	Seal	Base	Sub-base
Urban Roads			
Access & Local Distributors	25mm AC	100mm Laterite	150mm Limestone
District Distributors	30mm AC	100mm Laterite	150mm Limestone
Rural Roads			
Access & Local Distributors	10mm stone chip	Full depth laterite	NA
District Distributors	10mm stone chip	Full depth laterite	NA

5.5.1 City of Greater Geraldton Roads Condition

The maintenance of accurate records on road conditions is essential for proper management of road maintenance activities and strategic planning. By keeping accurate records on road conditions, the development of suitable maintenance and renewal programs is facilitated. Accurate records assist councils in identifying areas that require immediate attention. This targeted maintenance programs help councils ensure that their resources are being used effectively and efficiently.

The benefits of maintaining roads in adequate condition are numerous. Properly maintained roads reduce the risk of accidents and injuries. They also reduce the cost of vehicle repairs and maintenance. In addition, well-maintained roads improve fuel efficiency by reducing the amount of fuel consumed by vehicles. This is because vehicles consume more fuel when driving on poorly maintained roads due to increased rolling resistance.

The condition inspections of the road network at the CGG are undertaken on a periodic basis. The current frequency of conducting visual condition inspection of the entire road network is over a three-year cycle (i.e., one third of the network each year). The CGG currently does not undertake any periodic mechanical testing of the pavement. This is done on an as needs basis.

The condition inspections identify the measured risk in accordance with a set of predetermined parameters. The following parameters are used for assessing risk:

Table 10 Risk Assessment Parameters (CGG, 2013)

Risk Consequence Descriptors (Severity)	Risk Likelihood Descriptors (Frequency)
Catastrophic	Almost Certain
Major	Likely
Moderate	Possible
Minor	Unlikely
Negligible	Rare

The assessed "severity" and "frequency" identified for the defect is then to be fed into the Risk Analysis Matrix to determine the overall assessed risk associated with the defect. For roads, the risk assessment is determined by the size of various modes of failure and hierarchy classification of the road. Condition reporting identifies the potential risks to be recorded against each asset. Once the data is recorded, the priority works are reviewed, and the program of remedial works is developed and passed on to works crews.

The CGG receives regular requests to seal rural gravel roads. According to the road management standards established by the CGG, unsealed roads are only sealed when the following conditions are met:

- Minimum 100 vehicles/day
- Road is identified as a high order rural road.
- The road is a school bus route.
- The road is used as a grain haulage route.
- The existing road geometry has been audited and declared suitable for high-speed limit (up to 110 km/hr)

Sealed roads add greater annual depreciation expense to the CGG and introduce risk. Drivers using unsealed roads are required to "drive to conditions", which places the duty of care essentially on the driver. Sealing roads introduces a much higher level of service with the higher speed limits as the road needs to be maintained to facilitate the operating speeds to which it is signed. The purpose of sealing a road is to keep moisture out of the pavement and minimise operational maintenance. Sealed roads without sufficient volumes to keep the sealed surface in good condition will experience accelerated deterioration. Where sealed rural roads don't qualify under the above criteria, they may be returned to an unsealed road standard.

Local governments should consider the Whole of life costs when making decision about sealing rural roads. The whole of life cost for a sealed rural road is typically $11,662 a kilometre a year compared to $4,234 for a kilometre of gravel road. (WA Local Government Grants Commission Asset Preservation model 2022-23).

The process followed by the CGG to conduct visual inspection on the Road Surfaces and Pavement is based on the IPWEA Practice note 9: Condition Assessment & Asset Performance Guidelines (IPWEA, 2015) and the WALGA Road Visual Condition Assessment Manual (WALGA, 2016).

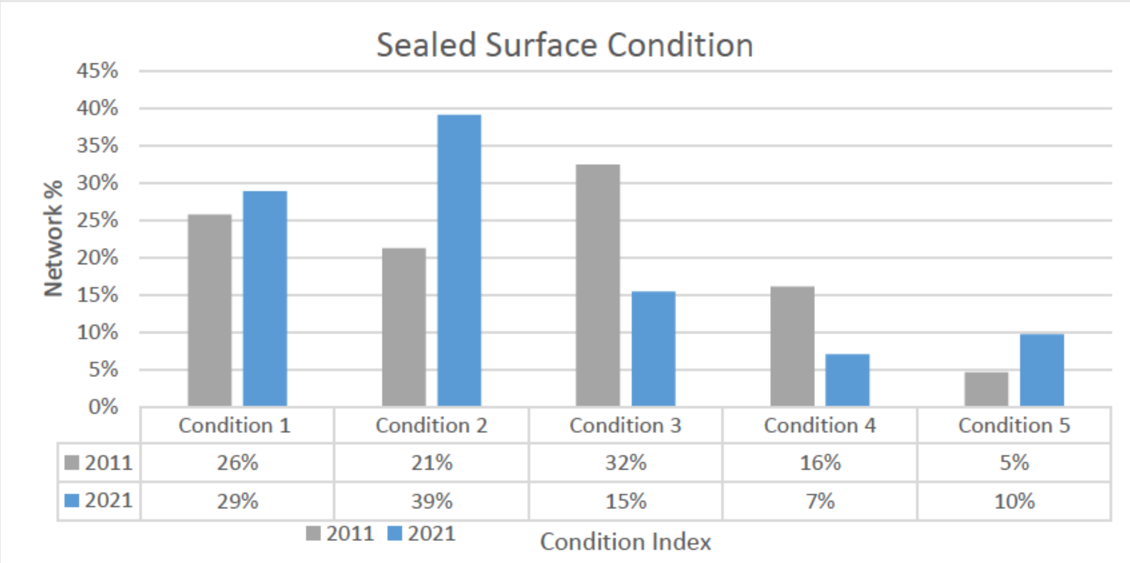
The TAMP presented the condition of the Road Network at the time of this data being available. The data used was taken from a road survey completed in 2011. The CGG utilises a 1 to 5 rating system as described below to provide a strategic assessment of these assets. Scores are assigned based on how the representative section best corresponds with the conditions summarised below. The condition of the roads is allocated on the 1 – 5 classification criteria.

Table 11 Sealed Roads Condition Rating Description (IPWEA, 2015)

Condition	Tag	Spray Seals Description	Asphalt Description
1	As New	<1% of area affected by inadequate surface texture	Even surface rough to the touch. The tops of stones are angular and visible. No excess bitumen oil contamination in cracks.
2	Very Good	1% to <5% of area affected by inadequate surface texture	Even surface with no loss of stone. No excess bitumen visible. Some polishing of stone tops.
3	Average	5% to <10% of area affected by inadequate surface texture	General even surface with some minor irregularities. Some stones missing or broken. (0% to 1%)
4	Poor	10% to <20% of area affected by inadequate surface texture	Slight surface irregularities. Some stones worn broken or missing (2 to 5%.) Excess bitumen over 0 to 3% of area. Shoving < 6% of the area.
5	Very Poor	>20% of area affected by inadequate surface texture	Surface irregularities. Stones worn, broken, or missing >5% of area. Excess bitumen > 3% of area. Binder crumbles when crushed in hand. Signs of delamination. Shoving or slipping >5% of area.

The condition parameters used for the scoring the wearing course in TAMP were focused on the asphalt condition and the binder/binder Stone Condition. These two parameters provided a good overall condition rating for the wearing course. It is important to note that sealed surfaces rating differs according to seal type.

Comparing the data presented in the TAMP from 2013 (CGG, 2013) with the most recent data collected during a road survey completed in 2021. (TALIS, 2021) It can be concluded that the overall condition of sealed Road Assets managed by the CGG have improved in the last 10 years. The figure below shows a comparison of the condition of the sealed wearing surface for roads managed by the CGG for the years 2011 and 2021.



	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5
2011	26%	21%	32%	16%	5%
2021	29%	39%	15%	7%	10%

Figure 4 Wearing Course condition 2011 and 2021 (CGG, 2013) / (TALIS, 2021)

Similarly, the condition of the sealed pavement for the roads were presented in the TAMP. Historically the CGG has recorded sealed pavement condition as a measure of road roughness and unsealed pavement as a measure of profile shape.

There are several tests that can be used as a gauge of pavement condition. At the time of the development of the TAMP in 2013 the CGG adopted a visual measure to gauge the condition of the pavements. This is the most cost-effective method and provides basic yet useful indication of the pavement condition. The process to visually assess the condition of the pavement varies according to whether it is sealed or unsealed. (IPWEA, 2015)

Sealed pavement condition is visually measured using the parameter of 'Rutting'. Rutting takes the form of depressions along the wheel paths on pavements. Rutting is common in pavements that are not thick enough to take the loads imposed by the traffic using them. However, this measure only identifies pavements nearing the end of their useful life and localised failures (IPWEA, 2015) . For the purposes of valuations and to develop a condition distribution the CGG utilises construction date and useful life of the sealed pavement.

The assessment of the condition of unsealed roads differs significantly from that of sealed roads. Unsealed roads are highly dynamic systems with the appearance and condition varying almost from day to day. Assessment of unsealed pavements typically considers unsealed shape, dust nuisance and depth of base. The effective operation of adequate cross fall and table drains is the predominant aspect to be considered when rating unsealed shape. (IPWEA, 2015). The table below broadly describes each condition rating for the allocated for the pavement.

Table 12 Pavement Condition Rating Description based on Rutting.

Condition	Tag	Sealed Pavement Description	Unsealed Pavement Description
1	As New	Negligible or no rutting – average depth <10mm.	Crossfall adequate – material good with well-defined crown.
2	Very Good	Slight rutting – average depth <10mm.	Crossfall adequate – materials good with reasonably well-defined crown.
3	Average	Moderate rutting – average depth 10 < 20mm.	Crossfall variable – material fair with poorly defined crown.
4	Poor	Extreme rutting – average depth >20mm.	Crossfall inadequate – material poor with poorly defined crown.
5	Very Poor	Extreme rutting – average depth >20mm over >20% of area affected.	No crossfall – materials very poor with little or no crown.

The Sealed Pavement Condition distribution used for the development of the TAMP was based on the construction date and useful life of the pavement (CGG, 2013). The table below indicates the condition rating and the age relationship. Pavements showing poor condition scores are then analysed on a project basis by further in-depth testing.

Table 13 Pavement Condition Rating Description based on Pavement age.

Condition	Description	Sealed Pavement Age	Remaining Useful Life
1	As New	0 - 18 yrs..	73 – 90 yrs.
2	Very Good	19 – 36 yrs.	55 – 72 yrs.
3	Average	37 – 54 yrs.	37 – 54 yrs.
4	Poor	55 – 72 yrs.	18 – 35 yrs.
5	Very Poor	73 – 90 yrs.	0 - 18 yrs.

The figure below shows a comparison of the condition of the sealed pavements between the condition reported in 2011 and used for the TAMP (CGG, 2013) and the condition reported as part of the road survey completed in 2021 (TALIS, 2021).

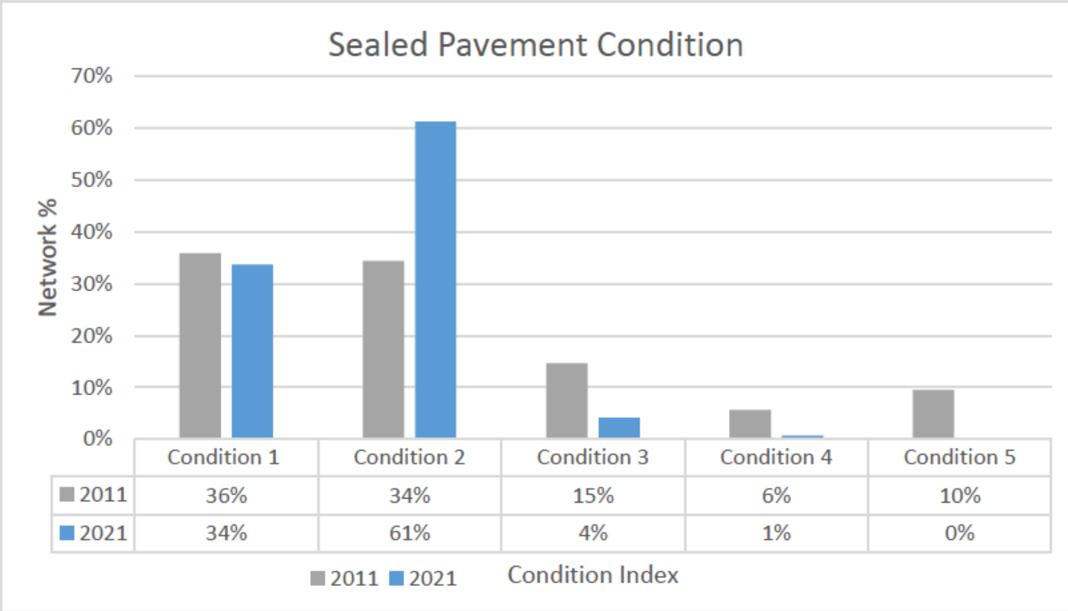


Figure 5 Figure 3 Sealed Pavement condition 2011 and 2021 (CGG, 2013) / (TALIS, 2021)

The data indicates that there has been an improvement in the overall condition of the sealed roads pavements. By understanding the current condition profile of the sealed road network, road asset managers can make informed decisions on the cost requirements for the maintenance and upgrade of the road network.

In November 2020, the City of Greater Geraldton engaged Brightly (formerly known as ASSETICS) to conduct an Asset Management Maturity Diagnostic and Improvement Plan. Brightly is a software and service provider for Asset management that provides support in the development of Maintenance and Operations plans and enterprise management to support strategic decision making. (Brightly, 2023). The objective of conducting the AM maturity analysis was to review the existing asset management strategies being implemented. This analysis consisted of a review of the quality of existing asset data and the identification of areas in need of improvement. The findings of this assessment identified areas of Asset Management still underdeveloped along with areas where the current AM approach is working.

The AM maturity analysis highlighted that at the time of its completion, the City of Greater Geraldton did not have documented processes for consistently updating and maintaining asset information. Similarly, it identified different varying levels of data completeness between the various asset's classes managed by the organisation. As an example, it pointed out that not all assets are componentised. On the other hand, the analysis identified that the data on Road Assets presented a high level (< 10% uncertainty) on the records.

The AM maturity assessment also highlighted the need to develop business process manuals (BPM), particularly for road assets. The objective of a BPM is to formally document the framework implemented to Asset Management systems and processes. A BPM describes the technical levels of service adopted, its relationship to asset condition and the processes implemented for planning and decision making. A BPM also highlights the need for a well-developed asset data structure in an Asset Management Information System (AMIS). (Daaboul, 2020)

It was identified that in general; asset condition information is irregularly captured. This indicated the need for the development of detailed Condition Assessment Manuals. These manuals should detail the inventory and condition collection, assessment and recording procedures.

The AM Maturity assessment also pointed out that the City of Greater Geraldton's processes, regarding strategic planning is underdeveloped. Asset candidates for capital works at present are typically selected using non-optimised methods, which effectively ranks assets that are already failing into a prioritised list that competes against other projects for an allocation of the capital budget. This process is considered poor utilisation of capital budgets, as it is short sighted and does not lessen the number of assets that are failing and typically results in a lower return on investment of council funds. (Daaboul, 2020).

Similarly, the AM maturity assessment identified the need to strengthen the linkages between capital works and lifecycle asset management. The life cycle cost of new asset expenditure should become part of new asset decision making, with the "Best-Value" framework, theory and understanding in place.

The AM maturity assessment also evaluated the approach to complete asset maintenance, particularly for road assets. It was identified that most of the maintenance is ad hoc and completed on an "as needs" basis rather than planning and scheduling of works. Maintenance is completed based on the available budget as opposed to on an "as required" basis. Therefore, it was noted that the City of Greater Geraldton would benefit from improving how it records its maintenance defect activities and costs and introduce activity-based costing concepts that can be used to inform the predictive modelling process. It was highlighted the need to record maintenance history at the asset level. Similarly, the AM maturity assessment indicated the benefits of developing a process to utilize and analyse failure data to develop organization-specific asset lifecycle degradation profiles.

In August of 2022 the City of Greater Geraldton engaged ARUP to assist in the development of an Asset Information Management Standard (AIMS). Arup is a global professional services firm that provides engineering, design, planning, project management and consulting services (ARUP, 2023) The objective of the AIMS considered was to identify a set of strategic and technical specifications for the management of asset information with the aim to standardize the gathering, processing, and recording of asset information required to effectively manage CGG assets. (Lahne, 2022).

Asset data Information describes the physical and non-physical attributes of an asset. This includes design drawings, asset registers, and spatial locations. Additionally, it includes information that describes the functional characteristics of an asset such as operating manuals, maintenance manuals, and failure modes. Asset data also includes records of approvals, tests, and certifications along with financial records such as capital acquisition, maintenance, and depreciation costs. Finally, performance history such as maintenance, defects, usage records and condition are also included. (Lahne, 2022).

The CGG has identified the need for the development of an AIMS in the previous AM assessments (Daaboul, 2020). The AIMS would improve the quality of asset information held by CGG and enable a consistent recording and reporting of asset data. It would facilitate the digitisation of asset information, improve the efficiency in data processing and retrieval. An AIMS will also enhance asset accounting and reporting, improve service delivery due to a more efficient communication of asset information to stakeholders, and facilitate asset information driven decision making.

During the completion of the AIMS, it was identified the various individual systems currently being used by the CGG for the storage and management of different types of asset information. The systems and their functions are listed below:

- **Brightly (Formerly known as ASSETICS):** This is the asset management master database that contains various forms of asset information and is used primarily for high level summaries of asset status and for planning asset renewals**.**
- **Predictor (Part of the ASSETIC System)**: This is an asset lifecycle modelling tool. It can assist with predicting and planning for asset renewal requirements and strategy planning.
- **Customer Service Database (CSDB):** Tracks historic data and reoccurring problems raised by CGG customers as complaints.
- **GIS CadCorp:** Spatial mapping system for representing geospatial locations of assets. Used to provide spatial representation of assets as required for into Dial Before You Dig (DBYD) asset protection service. Links in with Intramaps.
- **Intramaps**: Spatial mapping system for representing geospatial locations of assets. links with GIS Cadcorp system to overlay asset location information with georeferenced satellite imagery and mapping.
- **Magic:** Long term financial planning system. Primarily used for financial reporting and long-term financial forecasting.
- **Nintex**: Safety management system. Primarily used for safety audits of site inspection activities. Also includes ProMapp used this to document processes across the organisation, such as the Project Delivery Framework that indicates actions required from Planning, Design, Delivery and Close-out.
- **Synergy:** Financial information management system. Predominately used by finance function from tracking of capital cost, operational costs, and depreciation calculations.
- **Trim**: Document records management system. Contains documents which can be linked to the asset information in ASSETIC.

It is then clear that by having multiple individual systems the CGG encounters challenges regarding the users' ability to view related datasets and undertake related analysis. This results in asset information users undertaking extensive data compilation exercises. It is noted that some systems have overlapping functionality generating duplication of information and effort. Other legacy systems have minimal utilisation or are poorly understood. Additionally, the inconsistent implementation of system integration results in systems that function independently.

ISO 550002 (Standardization, 2014) recommends that organizations assess the criticality and value of information to facilitate decision-making in relation to the cost and complexity of collecting, processing, managing, and sustaining the information. Assets that have a high consequence of failure (CoF) resulting in significant loss or reduction of service are defined as critical assets. Criticality can also be applied to asset information, whether it is directly related to an associated critical physical asset or other critical organizational functions that depend on the accuracy and completeness of information. The assessment of information management completed during the development of the AIMS indicated that the CGG does not have a standardized model for assigning criticality to assets or asset information. (Lahne, 2022).

In the effort adopt a more strategic approach to AM. The CGG identified the importance of conducting proactive condition inspections in the road assets. This has already being highlighted in past AM plans (CGG, 2013). Proactive inspections of road assets are important for several reasons. They help to prevent minor defects from escalating into major issues, thereby significantly reducing potential costs and hazards. Regular inspections and consistent preventative maintenance are crucial strategy in maintaining the balance between performance, cost, and risk in road asset management.

At present, periodic pro-active inspections are carried out by the works team and the results are entered into the maintenance manager software in the form of maintenance tasks. This process is not currently linked to the asset management system. Similarly, the reactive inspection process is based upon reactive contact under the Customer Service Database (CSDB) also in use. This traditionally has resulted in remedial work being undertaken on a risk prioritisation basis. This approach was already highlighted in TAMP in 2013 (CGG, 2013) and continues to be the case.

Maintenance intervention triggers for road assets have been determined from historic information used by Council available from its CSDB and physical assessments. These details are translated into the road's levels of service. Some adjustments were made to the interventions to meet current service and affordability levels.

5.6 Improvement Plan

A review of various CGG documents was conducted and the following improvement actions were identified:

1. The City of Greater Geraldton has limited resources to manage its road network and therefore must develop systems and adopt processes that ensure its resources are directed to the areas where these are most need and where they provide the greatest benefit. To achieve this, it is important that the CGG consider a review of the adopted levels of service for the road assets. This should include community and stakeholders' engagement.

2. While there has been improvement in the implementation of pro-active condition inspection for the road network, it has been identified that this process is currently not linked directly with the AM system thus creating challenges to maintain up to date condition data. An integration of the AM system in the completion of asset condition inspections will greatly benefit the CGG.

3. The reactive asset defect inspection process is primarily based on the reported defects made by members of the public using the Customer Service Database (CSDB). The

CGG will benefit from adopting strategies that allow the detection of defects before they reach the intervention level. It is suggested that the CGG review the response levels of service for reactive maintenance and enable the integration of the AM system to record maintenance information.

4. Review and update the Transport Asset Management Plan (TAMP) to ensure that it is current and relevant. The CGG has attempted to update its TAMP at various occasions, but these documents remind in draft. An updated TAMP that is endorsed by the council represents a step forward in improving the AM direction of the organisation.

5. Utilise mature AM lifecycle modelling techniques to optimise and align the 5-year works program with available capital works budgets. At present moment, the CGG does not use AM lifecycle modelling which is recognised as a useful tool to improve the return on investment, efficiency, productivity, and performance of road assets.

6. Develop Business Process Manuals (BPMs) to capture all processes and procedures adopted for the management of road assets during the asset life cycle. This will provide a framework for decision-making for road assets and improve the communication between different stakeholders in matter related to the management of local roads.

7. Develop and implement a clear Quality Assurance (QA) process for updating and maintaining the asset register. This will ensure data capture on road assets is kept up to date and complies with all legislative requirements.

8. Establish a critical infrastructure risk register. The road asset register currently does not have criticality assign to its assets. This will facilitate the implementation of road maintenance strategies that ensure critical assets are maintained at adequate conditions.

9. Implement predictive modelling techniques to provide inputs into the development of long-term financial plans and Annual Works Plan.

6.0 Summary and Conclusion

This research project presented a review of the management strategies adopted in the development and management of low-volume roads. The project identified the practices adopted by some local governments in Western Australia. The project consisted of an in-depth literature review, a case study and the development of a Survey aimed at Local Government agencies in Western Australia.

In the Literature review section of this project, the importance and challenges faced when managing low-volume roads (LVRs) in Australia were highlighted. This research identified that in order to properly manage the LVR network, Local Government agencies require the implementation of good asset management practices, the development of road condition data collection programs along with suitable maintenance plans designed to optimize the performance of LVRs and life-cycle costs.

The Literature review section of this project report also stresses the importance of developing Road Asset Preservation Strategies (RAPS). These strategies facilitate the monitoring of the condition and performance of road networks based on the stablished technical and customer levels of service.

The role of the Environmental Impact Assessment is also highlighted in the Literature review of this report. EIA is a mandatory process that ensures potential environmental and social impacts are thoroughly considered during the planning stage of road development and construction projects. However, it was identified that EIAs currently conducted for road projects are inadequately completed and more resources are needed to improve the quality of project specific EIAs.

Similarly, various challenges have been identified in the management of LVRs. It has been highlighted that the maintenance works required for LVRs are often underfunded, especially in rural and remote areas. Another set of challenges encountered include lack of technical and qualified resources along with the effects of the climate change and the economic state in post-covid times.

The survey responses revealed that most councils use a mix of proactive and reactive maintenance, and the frequency and type of maintenance work will vary for the different road hierarchies. Proactive maintenance is applied to higher hierarchy roads, while reactive maintenance is used for lower hierarchy roads. The survey responses also indicated that councils in WA have increased confidence in the accuracy and completeness of their road asset register and condition data. They use visual inspections as the main method to collect condition data, and some outsource this task to external contractors. RAMM and excel spreadsheets are listed as the most common system to store the road register data.

The survey responses did not provide a clear picture of the level of road traffic data councils in WA maintain. This is due to the low participation rate and incomplete answers on this section of the survey. The survey revealed that metro councils tend to have well-defined road levels of service, while rural and remote councils do not. This may affect their decision-making process and maintenance practices.

The survey responses also confirmed that remote councils rely on local knowledge and experience to maintain their LVR network, while metro councils have more formalized and documented practices. The survey also indicated that flood events have a high impact on the maintenance needs of remote councils. The frequency and outsourcing of inspections, the training of personnel, the criteria for sealing roads, the use of recycled materials, the monitoring of maintenance activities, and the challenges in managing LVRs network are also discussed in the survey. The survey completed suggested that there are various factors that influence the management of LVRs network, such as remoteness, funding, resources, and environmental constraints.

Similarly, the survey responses confirmed that funding allocated for road network maintenance, particularly in rural and remote areas is only sufficient to cover basic planned maintenance activities. It was identified that there is insufficient funding to address severe or extreme weather events such as flooding. This highlights the financial challenges faced by councils in maintaining their road networks. The approach to managing the road network varies across councils in WA. Remote councils manage roads based on practices developed and refined over time and practical knowledge and experience from local personnel. In contrast, metro councils are likely to adopt an asset management policy aligned with Long-Term financial plans and Community Strategies.

The formal record of Levels of Services (LoS) varies across councils in WA. Remote councils relies on programs such as re-sheet and maintenance schedules with specific frequencies to maintain their network's LoS. In contrast metropolitan councils tend to document the LoS and these are used as a guide to monitor the performance of the road network and ensure LoS are maintain. The survey responses also indicates that for remote councils, is common to lack formal mechanisms to measure performance and effectiveness in meeting the agreed LoS. These councils are likely to conduct regular road visual inspection and rely on the feedback provided by the members of the public. On the other hand, metro councils are likely to have documented acceptable levels of defect scores as a measure of their road network's performance. This underscores the different strategies and challenges faced by different types of councils in managing their road networks.

The case study completed on the City of Greater Geraldton validated some of the findings obtained forms the survey. The case study listed the criteria adopted by the city for sealing of gravel roads. The case study also discussed the importance of considering the whole of life costs when making decisions about sealing rural roads. It was determined that sealed roads have higher annual depreciation expense and introduce higher risks compared to unsealed roads.

During the completion of the case study, it was identified that visual inspection is the most used method to measure the condition of the sealed roads. The Case study also presents the process followed for conducting these visual condition inspections. Similarly, the city uses a 1 to 5 grading system to provide a score on the condition of the road assets. The rating system is used to categorise the surface and pavement condition of the roads. The case study also presented a comparison between data presented in the TAMP from 2013 with the most recent data collected during a road survey completed in 2021. It was concluded that the overall condition of sealed road assets managed by the CGG has improved in the last 10 years.

The case study also presented a summary of the Asset Management Maturity Diagnostic and Improvement Plan conducted in 2020. The objective of conducting the AM maturity analysis was to review the existing asset management strategies being implemented by the CGG. The analysis consisted of a review of the quality of existing asset data and the identification of areas in need of improvement. The findings of this assessment identified areas of asset management still underdeveloped along with areas where the current AM approach is working. Some of the findings listed includes the lack of documented processes for updating and maintaining asset information, the varying levels of data completeness between different asset classes, and the high level of data quality for road assets.

Similarly, it was also identified that there is a need to develop business process manuals (BPM) for asset management processes, especially for road assets. A BPM describes the technical levels of service adopted, its relationship to asset condition, and the processes implemented for planning and decision making. There is also a need to develop detailed condition assessment manuals for asset condition information. These manuals should detail the inventory and condition collection, assessment, and recording procedures.

The case study also highlighted the need to improve how maintenance activities and costs are recorded and analysed. Maintenance should be planned and scheduled based on the required needs rather than the available budget. Maintenance history should be recorded at the asset level. Failure data should be used to develop organisation-specific asset lifecycle degradation profiles.

The findings from this research underline the pressing need for improved management strategies for low volume roads, highlighting a significant gap that still exists. It is evident that local government agencies require additional financial support; however, this alone will not be sufficient. A proactive approach to road management is crucial for local governments, this includes supporting the training of those responsible for road management in asset management theory. This research also brought to light that the use of recycled materials is not yet fully embraced by local governments in the remote areas of WA. The primary challenges associated with this are their remote location and the lack of technical and financial resources necessary to adopt these sustainable practices.

These findings hold significant implications for policymaking and resource allocation in the realm of road management, particularly in remote areas. They underscore the need for additional financial support, training, and the adoption of sustainable practices to effectively address the challenges identified.

Some of the lessons learnt from this research project included the fact that survey participation rate was significantly low. Whilst various factors played a role in this, it was identified that the survey could have been optimized to contain less questions and require less details. It is recommended that future research on this topic takes into account the lessons learned from this project.

Future research will need to be completed to validate the conclusions stated in this report. A wider sample of councils could provide further insights into the challenges and strengths that other local governments have in their implementation of Asset Management Practices.

Future research can also focus on specific maintenance activities, inspection methods used, the use of recycle materials and how to facilitate its adoption on remote areas, and sustainability and resilience practices adopted across Australia.

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Appendix A: Project Specification

ENG4111/4112 Research Project
Project Specification

For: Cristhian Camilo Rios Garcia

Title: Low Volume Roads: Development and Management

Major: Civil Engineering

Supervisor: Dr. David Thorpe

Sponsorship: City of Greater Geraldton (Employer)

Enrolment: ENG4111 – ONLY S1, 2023

ENG4112 – ONLY S2, 2023

Project Aim: To identify the key challenges and issues associated with low volume roads (LVRs) and evaluate the effectiveness of the current management strategies adopted by Local Governments in rural areas.

Programme: Version 1, 13th March 2023

1. Research the background information related to the Development and Management of LVR. This review will look at the current best practices adopted by road management authorities, and will explore the impact of social, economic, and environmental factors on the management of LVR.

2. Conduct a comparison of the strategies currently adopted by local governments in rural Australia listing the benefits and limitations and present and evaluation of their suitability.

3. Review the current best practices in developing a low-volume road prioritization maintenance program.

4. Analyse the findings from activities 1-3 and develop a survey aimed at multiple local governments in rural areas with the aim to identify correlations between the strategies identified form activities 1-3 and those implemented by these road authorities.

5. Report on the outcomes form the survey and contrast these with the strategies identified during activities 1-3.

6. Develop a case study based on the approach to the management of low-volume roads adopted in the City of Greater Geraldton (Local Government agency where I am employed).

7. Identify the gaps existing in the management of low-volume roads and present topics for further research.

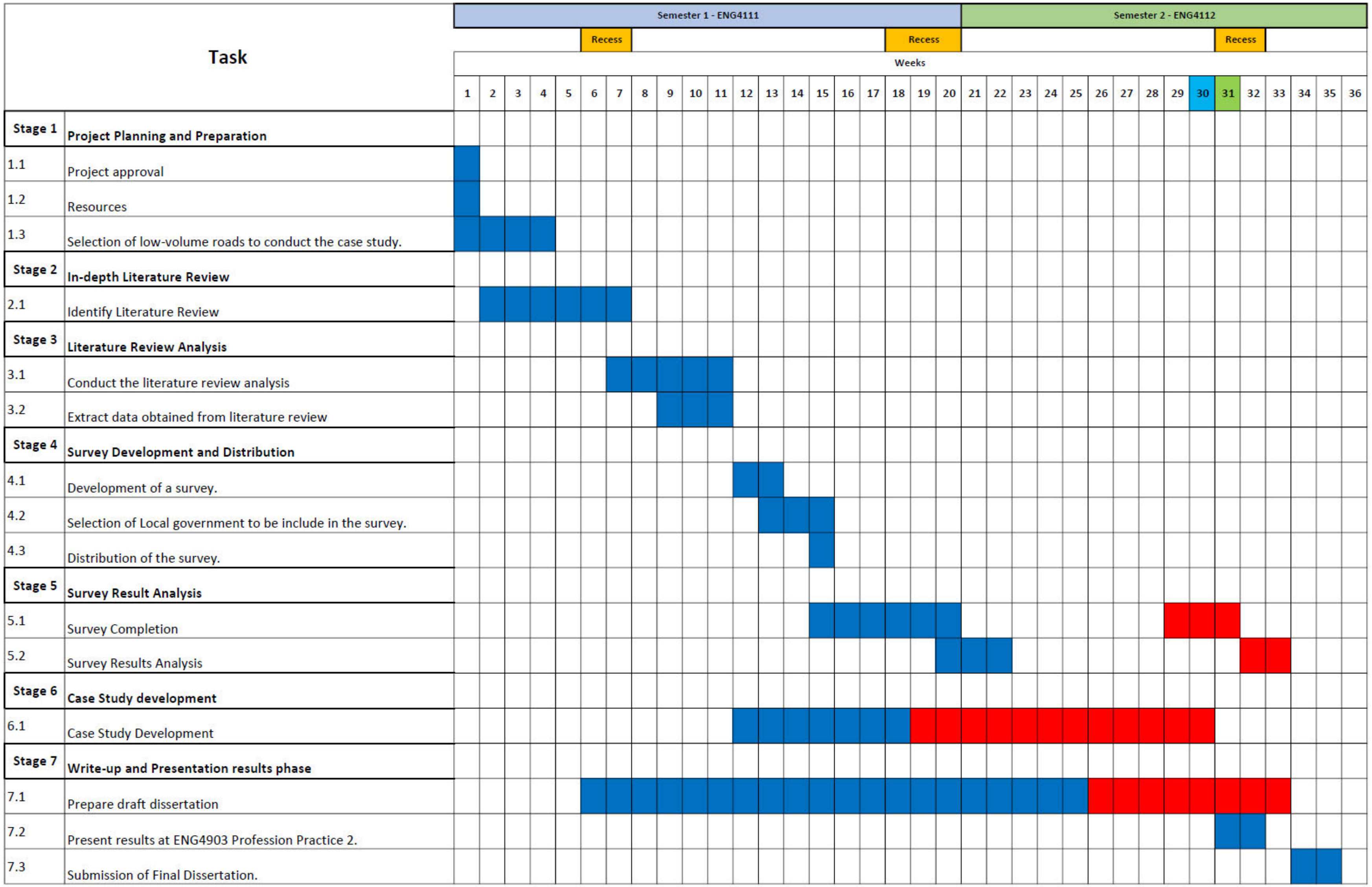

Figure 6 Project Program (Updated 09/09/2023)

Appendix A1: Supporting Documentations / Literature Review

1. Pavement Selection, design, and Maintenance for low-volume Roads

Low-volume roads form the vital link in the road network that provides accessibility to the communities to meet their social and economic needs. Local authorities in charge of the management of low-volume roads face the challenge of insufficient funding to maintain these roads to a satisfactory condition and lack technical and human resources to conduct suitable preventative maintenance.

Thus, the selection of suitable pavement in the development, design and construction phases of low-volume roads is crucial to reduce their life cycle cost. The selection of the pavement should take into consideration the expected traffic levels, terrain, ground conditions and the social and environmental factors that are relevant to the area. This includes consideration to land use, noise, and dust generation along with connectivity to surrounding areas.

(Pasindu et al., 2020) Proposed a framework for selecting pavement types for low-volume roads that considers the traffic, social and environmental characterises of the road section. In this framework, five pavement types were assessed under a life cycle cost, maintenance requirements and road user experience to evaluate the suitability of each pavement types with the various characteristics of road segments.

There are different approaches to identify suitable pavement for low-volume roads some of which are based on traffic volume thresholds, which serve as a guide for various pavement surfaces. Asphalt is the most popular pavement type for roads with traffic volume greater than 500 vehicles/day. In addition, the threshold for a road considered for surfacing is 200 vehicles/day. **(Pasindu et al., 2020)**

Similarly, an agency and user cost model for the selection of pavement like the methodology developed by **(Jaarsma & Van Dijk, 2002)** focused on deciding the most economical pavement type from Hot Mix Asphalt and gravel. This model considered local authorities cost, crash costs, and vehicle operating costs and the findings indicated that vehicle operating costs are higher on gravel roads than on paved roads.

It was also determined that there was a statistical relationship between crash occurrence and road surface type or Average Daily Traffic (ADT). This is due to factors such as pavement condition, environmental conditions, roadway geometry and alignment, and driving behaviours all of which contribute to crash occurrence. According to this model, gravel roads are the most economical surface type for traffic volumes between 150 and 600 vehicles per day.

A Multi-criteria analysis approach for the selection of pavement surfaces offers the opportunity to consider additional factors that are not included in traffic volume-based and cost models. **(Pasindu et al., 2020)** developed a model based on a numerical score using five selection factors: traffic, impact on residents, impact on local business activities, impact on long travel distance, and agency cost.

A more recent approach to pavement selection and design of low-volume roads known as Context Sensitive Design (CSD) is an interdisciplinary approach that involves various stakeholders in the design of a road that matches its physical setting and land use whilst maintaining its safety and mobility. **(Ahmed et al., 2006)** developed a methodology for the selection of pavement surfacing for low-volume roads combining engineering design factors such as structural capacity, safety, and durability along with aesthetics, environmental and social impacts.

Once suitable pavement and surfacing types is selected and constructed it must be maintained at suitable times to ensure the life cycle cost is kept to an affordable level and the condition of the road is preserved in good condition. For this, a significant amount of money is spent on road pavement condition monitoring which is necessary to identify defects in the road network. However, pavement monitoring at times requires highly sophisticated automatic data collection systems, which limits the intervals between data collection that tend to be longer. This can result in inappropriate maintenance plans and therefore the deterioration of low-volume roads is accelerated. **(Kheirati & Golroo, 2020)**

(Agarwal et al., 2017) Presented a "Rational Strategy for resource allocation for rural road maintenance". Prioritization of road maintenance activities depend on several factors such as the condition of the road, type of defects, rate of deterioration and importance of road section amongst other factors. Thus, the allocation of resources to conduct timely maintenance on low-volume roads represents a challenge for local authorities.

The strategy proposed in this study can be used for the selection of suitable maintenance activities on different rural roads sections to gain maximum benefits from the resources available.

The identification of the condition of the pavement is a crucial step towards developing suitable maintenance programs. The two most common methods for pavement condition inspection are manual and automated. The manual approach is labour intensive, inefficient and time consuming, therefore expensive, not to mention unsafe for the road inspectors. On the other hand, automated data collection systems are fast, safe, accurate and standardised although costly. As a result, local authorities limit the frequency of automated pavement monitoring. This means that over time the data accuracy becomes limited leading to increase in maintenance operations **(Flintsch & McGhee, 2009).**

The condition of a pavement can be determined by identifying the roughness. Pavement roughness has an effect in the wearing of vehicles, likelihood of accidents, and impose dynamic action loads on the road that increases the pavement degradation rate. Pavement roughness also has an effect on ride quality and increases fuel consumption as much as 5%. **(Kheirati & Golroo, 2020).** The most common index for roughness is the International Roughness Index (IRI). Recent research and development in technology allow the measurement of pavement roughness using sensors present in Smartphones. For this, accelerometer, gyroscopes, and GPS are used to capture the ride quality. Similarly, inexpensive sensor packages that are mounted to vehicles also allow the monitoring of pavement condition. This includes The Sharp sensor that applies infrared radiation to measure distance. **(Kheirati & Golroo, 2020)** developed this data acquisition system and made use of the inexpensive infrared sensor along with an accelerometer to capture the pavement profile and calculate the roughness index for low-volume roads. This project was a proof of concept and was restricted to rough dry asphalt pavement and a speed of 30 km/h.

(Pan et al., 2021) conducted a cost / benefits analysis of the most used treatments used for road maintenance. The treatments chosen are the Hot in-place recycling (HIR), milling and filling (M&F), thin hot mix asphalt overlay (THO) and micro-surfacing (MS). This study focused the treatment effectiveness in repairing pavement rutting. The Rutting Depth (RD) was selected as a performance indicator. The outcome of the research identified that HIR represents the highest effectiveness and cost-effectiveness. This is due to the utilisation of Recycled Asphalt Pavement (RAP). It was also determined that the effectiveness of the treatment is increased when the maintenance occurs at the appropriate time.

Additionally, there has been an increased interest in using recycled materials for the construction and maintenance of roads with the aim of adopting a sustainable approach to road construction. In **(Gomes et al., 2021)** a sustainability-oriented framework is presented for the selection of optimum soil-by-product proportion for unbound base layers of unpaved roads. The proposed framework provides guidelines to road authorities on how to incorporate environmentally friendly materials in a cost-effective way, while maintaining the technical quality of base layers.

(Celauro et al., 2017) presented an environmental analysis of different construction techniques and maintenance activities for local roads. The results demonstrated how Reclaimed Asphalt Pavement (RAP) can lead to a significant reduction in pollutant emissions and energy consumption compared to that of pavement constructed with only virgin materials. A similar conclusion was made for fine soils stabilized (in situ) with lime. The study demonstrated that this technique improves the mechanical properties of soil that otherwise would be considered as waste. Thus, the use of sustainable construction techniques will result in the reduction of life cycle cost, allowing funds to be allocated to a suitable preventative maintenance plan.

2. Financing Low Volume Roads

A widespread challenge for the management the extensive road networks is raising the required funds for conducting suitable and timely maintenance activities. There are several documented cases of underfunding for the maintenance of the road network, for low-volume roads. In Latvia, only 40% of the funding needed to adequately maintain their road network is available. This is even worse for local rural roads where only 20% of the total amount needed is funded. The maintenance costs for low-volume roads, particularly those that serve a small number of properties or farms and have limited local traffic is often poorly funded. **(Jaarsma & Van Dijk, 2002)** presented a model for the cost distribution of maintenance activities of two local rural roads. The model indicates that the owners of the properties should pay for the basic facilities along a road that enable access to their private properties. It also indicates that ‘extra facilities’ such as additional paving width that benefit inter local road users should be paid by local authorities.

3. Management of Low-Volume Roads

Good asset management practices are essential to ensure an efficient use of resources. The implementation of pavement asset management systems provides the required information to optimize resource allocation for road maintenance. Recent development in pavement data collection and processing allows road authorities to estimate remaining service life and suitable selection of maintenance strategies. **(Peraka & Biligiri, 2020).** Despite the advancement in technology that facilitates the automated data collection and processing of road condition including artificial intelligence and machine learning, the application of these technologies for low-volume roads is yet to be fully realized due to the challenges of high cost and lack of technical resources.

Distresses in pavement occur, if they are structurally adequate but functionally deficient, or in some cases when pavements are both structurally and functionally deficient. If pavements are structurally adequate and functionally deficient, minor maintenance is sufficient to maintain the pavement in an operating condition. Thus highlights the importance in developing and implementing good road management strategies. According to the American Association of State Highway and Transportation Officials (AASHTO) a properly planned and implemented data collection program will significantly increase credibility, cost effectiveness and overall utility of the pavement management systems.

The management of Low-volume rural roads should be conducted in a way that it is context sensitive, ensuring a balance between economic, social, and environmental factors and align with the community values and needs. **(Faiz et al., 2012)** highlights the existing limitations present for low-volume roads.

4. Project feasibility Analysis and Study justification

Various studies cover pavement and road asset management, road condition and maintenance strategies along with guidelines for the financing of the increasing low-volume roads around the world. However, due to the limitations associated with the management of low-volume roads including inadequate funding, labelling as 'low priority asset' and the lack of technical resources that local road authorities have at their disposal, furthermore, limits published studies on this topic especially publications that address the characteristics of rural Australia. This represents a gap in the current body of knowledge and highlights an opportunity to review current best prices for low-volume roads and evaluate their suitability for the application under the condition of rural Australia.

This research project proposes to fill this gap. It will evaluate current best practices for low-volume road development and management and provide sound comparisons between the various methods presented. The research project will build on the current strategies for low-volume road management and will focus on studies completed in rural regions. A methodology like those projects examined will be adopted. A project plan is included in this report to ensure the project goals are achievable and can be completed in accordance with the relevant work health and safety requirements. This project will focus on further analysing the current methods to prioritize the maintenance of low-volume roads and evaluate its suitability for rural areas in Australia.

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Appendix B: Project Survey

Overview

As part of the completion of the Bachelor of Civil Engineering (Honours), project research on Low-Volume Roads: Development and Management, is being undertaken by a student at the University of Southern Queensland.

The proposed scope for the research project is to focus on the management of low-volume roads within a rural area located in Australia. Australia is one of the most sparsely populated countries in the world, with more than 60% of its people living in the major cities near the coast. A substantial proportion of roads across the country at times carry less than four hundred vehicles per day thus making low-volume roads represent a critical asset for the Australian transport industry. The larger proportion of these low-volume roads are managed by local authorities who due to multiple reasons are challenged to fund suitable maintenance of their road network. This project aims to present a review on the current low-volume road management strategies and evaluate their suitability and sustainability.

The expected outcomes of the project include:

- Increased understanding of the different low-volume road maintenance prioritisation strategies currently being implemented by local authorities.
- Further develop the knowledge of low-volume road development and management focus on rural areas of Australia.
- Improve the confidence in the implementation of sustainable road management strategies for low-volume roads taking into consideration the challenges related to low funding and lack of resources.
- Provide a comparison of the various road condition assessment strategies and present a sound evaluation of their suitability for low-volume roads.

As part of the methodology adopted for the completion of the Research Project, the following questionnaire was developed if gain an insight into the approach to manage Low-Volume Roads in your organisation. The questions in the survey are categorised as follows:

- General information
- Asset Management
- Road Preservation and upgrades information
- Information on Sealing an Unsealed Road
- Roads Levels of Service

Please save the completed questionnaire and return your responses along with any further enquiries to the email listed below.

Email: u1058515@umail.usq.edu.au

General Information

<table>
<tr><th>Question</th><th colspan="3">Response</th></tr>
<tr><td>Q1) What Local Government (LG) do you represent?</td><td colspan="3"></td></tr>
<tr><td>Q2) How would you describe the region of your LG (e.g., metro, regional, or remote)?</td><td colspan="3"></td></tr>
<tr><td rowspan="5">Q3) What is the Road length for Unsealed and Sealed roads according to their classification. The classification adopted for this survey is Main Roads WA. Please indicate if your LG uses a different classification.</td><td>Road Type</td><td>Unsealed length (km)</td><td>Sealed length (km)</td></tr>
<tr><td>Local access (LA) *</td><td></td><td></td></tr>
<tr><td>Local distributor (LD) *</td><td></td><td></td></tr>
<tr><td>Regional distributor (RD) *</td><td></td><td></td></tr>
<tr><td>Other (describe)</td><td colspan="2"></td></tr>
</table>

Asset Management

<table>
<tr><th>Question</th><th colspan="4">Response</th></tr>
<tr><td rowspan="5">Q4) What best represents the approach in your LG to managing unsealed roads?</td><td colspan="3">Current Practice Used</td><td>Yes/No - Comments</td></tr>
<tr><td colspan="3">A proactive maintenance regime to all road categories</td><td></td></tr>
<tr><td colspan="3">A combination of proactive maintenance used for higher order roads and a reactive maintenance approach to other roads</td><td></td></tr>
<tr><td colspan="3">Mostly a reactive approach in response to complaints and subject to available funding</td><td></td></tr>
<tr><td colspan="3">Other (please describe):</td><td></td></tr>
<tr><td rowspan="3">Q5) Do you have road asset condition inventory for your road network. If so, can you contribute the information?</td><td colspan="4">Proportion of roads by condition category/
Level of service (LoS)</td></tr>
<tr><td>Poor or worse
(Moderate roughness and inadequate to poor shape)</td><td colspan="2">Fair
(Moderate roughness and shape)</td><td>Good or better
(Low to moderate roughness and good shape)</td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="3">Q6) Do you have traffic data for your sealed and unsealed road network?</td><td colspan="4">Average and Maximum Daily Traffic</td></tr>
<tr><td>Regional Distributor</td><td>Local Distributor</td><td>Local Access</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="7">Q7) What Road levels of service (LoS) / intervention levels do your LG implement or target, and is there a distinction by hierarchy?

If you do not have LoS developed, please put ‘N/A’.</td><td>Road Hierarchy</td><td>Regional Distributor</td><td>Local Distributor</td><td>Local Access</td></tr>
<tr><td>Safety</td><td></td><td></td><td></td></tr>
<tr><td>Accessibility</td><td></td><td></td><td></td></tr>
<tr><td>Reliability</td><td></td><td></td><td></td></tr>
<tr><td>Condition</td><td></td><td></td><td></td></tr>
<tr><td>Sustainability</td><td></td><td></td><td></td></tr>
<tr><td>Responsiveness</td><td></td><td></td><td></td></tr>
<tr><td>Q8) Can you briefly outline how maintenance practices may vary for known traffic volumes and traffic compositions?</td><td colspan="4"></td></tr>
</table>

<table>
<tr><th>Question</th><th colspan="4">Response</th></tr>
<tr><td rowspan="5">Q9) How frequently are low-volume roads in your jurisdiction inspected for maintenance purposes?</td><td>Road Hierarchy</td><td>Regional Distributor</td><td>Local Distributor</td><td>Local Access</td></tr>
<tr><td>Twice a year (Yes/No)</td><td></td><td></td><td></td></tr>
<tr><td>Once a year (Yes/No)</td><td></td><td></td><td></td></tr>
<tr><td>Once every two years (Yes/No)</td><td></td><td></td><td></td></tr>
<tr><td>Other please specify</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Q10) Are Road Maintenance inspections conducted by in-house personnel or outsourced to external contractors?</td><td>In-house</td><td colspan="3"></td></tr>
<tr><td>External</td><td colspan="3"></td></tr>
<tr><td>Other</td><td colspan="3"></td></tr>
<tr><td>Q11) Does your LG provides access to training programs for personnel involved in low-volume road management?

(If applicable please provide some examples)</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Q12) What methods or technologies are utilized to collect data on the condition of low-volume roads?

(Answer Yes/No and provide comments if applicable)</td><td colspan="2">Visual Inspection</td><td colspan="2">Automated Inspection</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td rowspan="5">Q13) How often is Road Condition data collected and updated for road management purposes?</td><td>Road Hierarchy</td><td>Regional Distributor</td><td>Local Distributor</td><td>Local Access</td></tr>
<tr><td>Twice a year (Yes/No)</td><td></td><td></td><td></td></tr>
<tr><td>Once a year (Yes/No)</td><td></td><td></td><td></td></tr>
<tr><td>Once every two years (Yes/No)</td><td></td><td></td><td></td></tr>
<tr><td>Other please specify</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Q14) Are Road Condition inspections conducted by in-house personnel or outsourced to external contractors?</td><td>In-house</td><td colspan="3"></td></tr>
<tr><td>External</td><td colspan="3"></td></tr>
<tr><td>Other</td><td colspan="3"></td></tr>
<tr><td rowspan="4">Q15) Does you LG have considered the incorporation of advanced technologies for data collection?

(Answer Yes, no, or Unsure) If yes provide a description.

If you are using these technologies, please provide up to about three examples of advanced technologies, such as machine learning or remote sensing.</td><td colspan="2">Answer</td><td colspan="2">Comment</td></tr>
<tr><td colspan="2">Yes</td><td colspan="2"></td></tr>
<tr><td colspan="2">No</td><td colspan="2"></td></tr>
<tr><td colspan="2">Other</td><td colspan="2"></td></tr>
<tr><td rowspan="4">Q16) Does your jurisdiction use a 1 to 5 Grading system for the condition of the Road Segments?</td><td colspan="2">Answer</td><td colspan="2">Comments</td></tr>
<tr><td colspan="2">Yes</td><td colspan="2"></td></tr>
<tr><td colspan="2">No</td><td colspan="2"></td></tr>
<tr><td colspan="2">Other</td><td colspan="2"></td></tr>
</table>

Q17) What Asset Management System does your local Government uses for the management of road Assets?		

Road Preservation and upgrade information

Question	Responses			
Q18) What is the cost and frequency of typical routine/ periodic maintenance on unsealed roads?	**Road Hierarchy**	**Regional Distributor**	**Local Distributor**	**Local Access**
	Unsealed Roads – No. of gradings per year			
	Unsealed Roads – Re-Sheeting: Average (km/year)			
	Unsealed Roads – Re-sheeting: (Cost/km)			
	Sealed Roads – Average Reseal (Km/year)			
	Sealed Roads – Average Reseal (Cost/Km)			
	Sealed Roads – Average Asphalt resurface (km/Year)			
	Sealed Roads – Average Asphalt resurface (Cost/km)			
Q19) Briefly describe what criteria is used in your organization to determine when a low-volume road requires resurfacing? (e.g., Road Condition, Traffic Volume)				
Q20) Are recycled materials or Alternative methods considered for road resurfacing on low-volume roads to improve cost-effectiveness? (If so, provide an example where this has been the case.)				
Q21) Briefly discuss any challenges or limitations does your organization faces when utilizing recycled materials on low-volume roads?				
Q22) Which factors are considered when prioritizing maintenance activities for low-volume roads?		**Regional Distributor**	**Local Distributor**	**Local Access**
	Traffic Volume			
	Road Condition			
	Road LoS			
	Other			
Q23) How does your LG ensures that maintenance activities on Roads are completed within a reasonable timeframe?				

Question	Responses	
Q24) What are the biggest challenges you face in maintaining low-volume roads?	Insufficient Budget	
	Insufficient Resources Availability	
	Unskilled Resources	
	Lack of Clear AM Systems	
	Quality and availability of Road Condition records	
	Other	
Q25) Briefly outline what challenges your organisation encounters when securing sufficient funding for the management of low-volume roads?		
Q26) Is the annual budged for the road renewal program sufficient to maintain agreed levels of service?		

Sealing an Unsealed Road

Question	Responses	
Q27) Which of the following factors does your organization consider critical when deciding the correct time to seal an unsealed road?	**Factors Influencing Change**	**Yes/No**
	Current condition / deterioration	
	Changing traffic composition / volumes	
	Environmental Impacts	
	Climate factors / changing climate conditions	
	Whole of life cost of maintenance and preservation	
	Road safety	
	Other?	
Q28) Considering the answer provided in the previous question, how/why this impacts your decision-making process?		
Q29) Does your LG already have guidance which addresses the question of when to upgrade / seal an unsealed road? If please provide a description of the process implemented.		

Road Level of Service

Question	Responses
Q30) Does your organization have a documented Road Levels of Service? If so, could you please provide a brief description.	
Q31) Does your organization has a mechanism to measure the performance and effectiveness of low-volume roads in meeting the desired levels of service?	
Q32) Does your organisation have a mechanism to involve public input in determining the acceptable levels of service for low-volume roads?	
Q33) Briefly outline how organisation handles public complaints or concerns related to low-volume road management?	

Q34) Does your organisation have a mechanism to address the needs of pedestrians, cyclists, and other non-motorized users on low-volume roads?	

Appendix C: Risk Assessment

2399	RISK DESCRIPTION	TREND	CURRENT	RESIDUAL
	Low Volume Roads: Development and Management		Low	Low

RISK OWNER	RISK IDENTIFIED ON	LAST REVIEWED ON	NEXT SCHEDULED REVIEW
Cristhian Rios Garcia	10/05/2023	20/05/2023	20/05/2024

RISK FACTOR(S)	EXISTING CONTROL(S)	CURRENT	PROPOSED CONTROL(S)	TREATMENT OWNER	DUE DATE	RESIDUAL
Project Approval: Approval of project not given by USQ	Control: Request project approval by USQ project supervisor in advance ——— Control: Ensure Project Proposal meets the requirements by following recommendations from project supervisor.	Very Low	No Control:			Very Low
Resources not available: Resources needed for the completion of the project not available	Control: - Ensure resources are identified and sourced in advance. - Include Journal articles from Library Databases as resources for the project - Review resources from the Institute of Public Works Australia	Very Low	No Control:			Very Low
Survey Development and Distribution - Developed a suitable questionnaire for the Survey - Identify participants for the questionnaire - Not enough time allocated to answer Questionnaire - Not enough time allocated to complete Data analysis - Participants / Stake holders' conflicts	Control: - Obtain Human Research Ethics Committee approval for interviews. - Research the Potential participants for the project survey and contact them ——— Control: - Contact potential participants via email and provide a description of the project. - Provide all required	Low	No Control:			Low

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	information to participants to complete the Survey within the time frame expected. - Clearly communicate the project objectives and expectations of the participants - Clearly communicate project timeline to participants to ensure survey responses are received within the specified timeframe					
Assisting in the installation of Traffic counts.	Control: - Request traffic management for the completion of the task - Follow instructions given by line supervisor to complete the task - Follow organizational H&S requirements such as JHA's, SWMS. - Wear suitable PPE including sun protection - Stay hydrated and take regular breaks when working under sun exposure to reduce fatigue.	Low	No Control:			Low
Conduct road inspection. - Traffic, - Pedestrians / Public Interaction - Slips hazards and trips - Heat / Sun - Weather Conditions	Control: - Ensure all safety measures stablished by this task are implemented when conducting a road inspection. - Follow organizational H&S requirements such as JHA's, SMWMS, wearing of suitable PPE - Stay hydrated and take regular breaks to avoid heat stress Control: - Ensure Traffic Management is available when	Low	No Control:			Low

	required. Control: - Ensure Traffic Management is available when required. Control: - Use reflective long sleeve Shirt and Long Pants - Use sunscreen and a hat to protect from Sun exposure. - Wear work boots Control: - Use reflective long sleeve Shirt and Long Pants - Use sunscreen and a hat to protect from Sun exposure. - Wear work boots					
Project Progress Report Write up: Insufficient Time to complete the progress report.	Control: -Ensure project planner is followed -Maintain communication with supervisor on the progress of the research report.	Very Low	No Control:			Very Low
Case Study: - Get the approval to complete a case study - Selection of Roads for the Case Study - Access to road data required complete case study - Not sufficient allocation of time for the completion of the case study - Inadequate Data - Lack of Expertise	Control: - Request approval to complete case study - Enquire line manager regarding suitable roads to include in the Case Study and discuss the methodology to collect and analyze data. - Review road data on selected roads / Verify the accuracy of information available - Follow the Project Plan to ensure tasks are completed on time - Complete and thorough data analysis	Low	No Control:			Low

Project Report Write-Up - Bad Ergonomics - Eye strain - Headaches	Control: - Ensure regular breaks are taken while working in the Write up of the report. This includes taking time away from the screen to rest the eyes, an perform stretching movements to reduce muscle fatigue. - Stay hydrated to reduce physical and metal fatigue	Very Low	No Control:			Very Low