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Sustainable Development and Management of Low Volume Road Networks in Australia

Thomas Franzen[1], David Thorpe[2]

[1]Eurobodalla Shire Council, Moruya, New South Wales Australia 2537

[2]School of Civil Engineering and Surveying, University of Southern Queensland, Toowoomba, Australia

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Abstract

While low volume roads carry only limited volumes of traffic, they perform an essential social function through connecting communities, many of which are located in rural areas. These roads form a significant component of the Australian road network and should be constructed and maintained in a sustainable manner providing an ongoing effective, efficient, safe and reliable service. However, funding for them is often ranked at a lower priority than for roads with larger traffic volumes. Therefore, innovative and best practice network management strategies are required to ensure the productivity, safety, usability, social equity, sustainable environmental management, and resilience of these roads.

In order to further investigate current strategies for managing these roads, a survey was conducted of management practices for low volume roads and their networks in 38 local government areas, primarily located in the Australian state of New South Wales (NSW). The research found that enhancements to the current practices were possible and made several recommendations for improvement. The study was also successful in defining the term "low volume road" for both sealed and unsealed roads in NSW. It identified approaches to improve the level of service provided by these roads and their networks by improved planning, design, and construction practices, along with lifecycle management and renewal strategies. It was also found that additional information specifically relating to these roads is required to be collected, recorded, and made accessible to asset managers in a formal system that supports key renewal decisions backed by sound evidence. There was significant opportunity to increase the level of road safety reviews for these roads. Leveraging funding, ensuring that new low volume roads meet future traffic demands, and continuing to investigate best practices for life cycle based sustainable asset management; development and preservation were found to be the most successful strategies to meet these challenges.

INTRODUCTION

Low Volume Roads (LVRs) account for a significant proportion of world roads but can often have limited or insufficient funding. Depending upon the exact definition of a LVR, it has been claimed that between 75% (Zimmerman & Peshkin, 2003) to 90% (Irwin, 2003) of the worlds roads are classified as LVRs. Most of these roads are unsealed. In addition, around 85% of the

sealed roads in the world have traffic volumes of less than 1000 vehicles per day (Douglas, 2016). These roads have a replacement value estimated at more than USD 7.6 trillion worldwide (Faiz, 2012). However, as world resources are finite, funding is often inadequate to cover their maintenance and rehabilitation cost (Zimmerman & Peshkin, 2003).

According to the Bureau of Infrastructure Transport and Regional Economics (BITRE), 73% of the total road length in Australia (over 873,000 kilometres) are classified as local roads (BITRE, 2017), with low traffic volumes. These roads are important to Australia's economy as many rural products start and end their transportation on local roads. Most of the estimated 640,000 kilometres of local roads in Australia are managed by local governments, with their net spending on roads accounting for 21% of total Australian road related expenditure (BITRE, 2017). It has been estimated that there is a shortfall in maintenance and renewal expenditure on local roads in Australia of AUD 17.6 billion for the period between 2010-2024 (Howard and others, 2013). Given the scale and importance of the local LVR network in Australia and funding limitations, innovative network management practices are therefore required.

LVRs provide an essential service by enabling access to communities (ARRB Group, 2005). They require careful management to serve these communities well. However, authorities have often found it difficult to justify significant expenditure on their construction and maintenance. It has been argued that this attitude often costs society in the long run, with roads in poor condition resulting in higher costs to the road users (Irwin, 2003). It can be similarly argued that low volume roads in poor condition pose a range of threats to their sustainable management, including safety concerns, excessive use of fuel for vehicles that use them, and lack of community social connectedness.

In Australia, which is governed at federal, state and local levels, state governments have the primary responsibility for managing their road networks and local governments manage the remaining roads including local roads, which include most LVRs (Austroads, 2016b; Austroads, 1998). Funding is provided by all levels of government (Department of Infrastructure and Regional Development, 2017). In the 2015/2016 financial year, an amount of AUD 26.17 billion was made on road related expenditure in Australia's Road Network (BITRE, 2017).

Because of the size of the LVR network and the challenges in Australia in the ability of this network to meet community requirements with limited funding, road authorities must manage it as efficiently and effectively as possible. This process requires a combination of best road network management practice and an innovative approach. Therefore, the objective of the research discussed in this paper has been to investigate and recommend improvements to network management strategies for Australian LVRs, in order to achieve the best options for achieving their sustainable development and management. In particular, this research has focused on the LVR network (sealed and unsealed) managed by local government authorities in regional and rural New South Wales (NSW). The main step in the research process, in terms of its inputs, processes and outputs, is summarised in the conceptual framework in Figure 1.

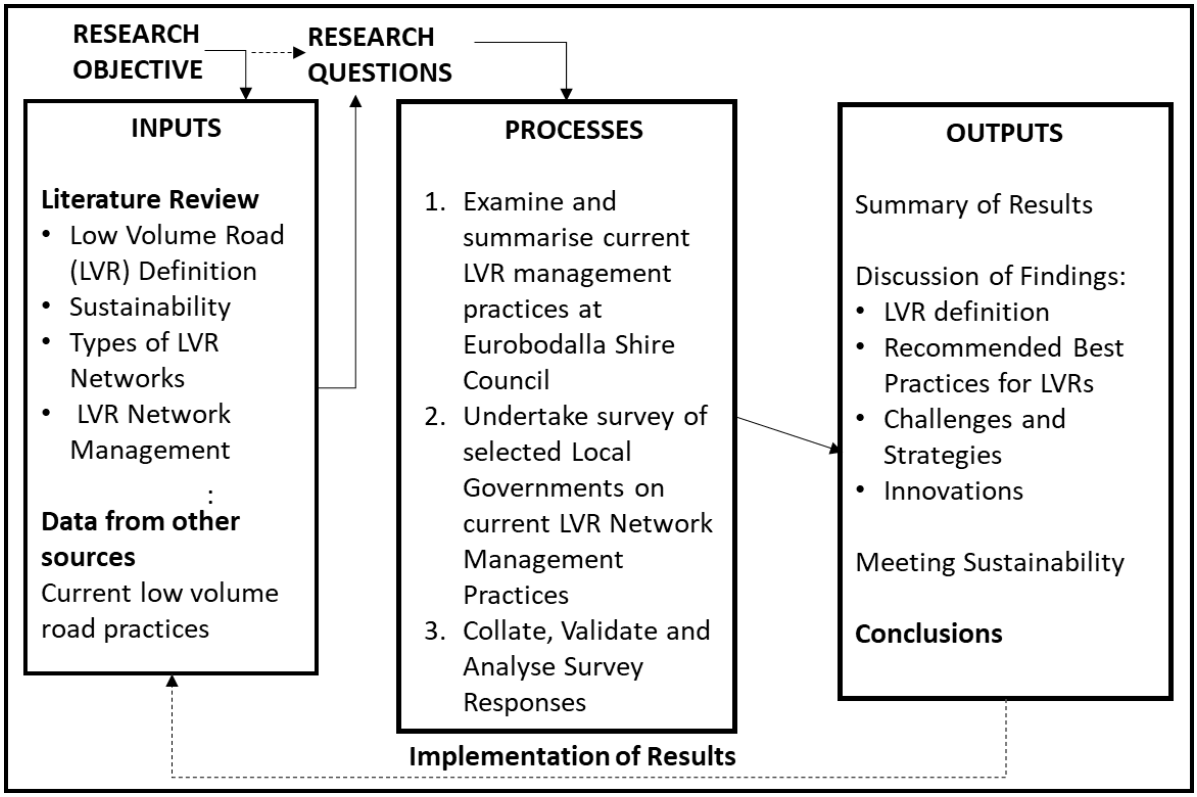

Figure 1, Conceptual Framework of Research

LITERATURE REVIEW

Key Terms

There is no one accepted definition of the exact traffic volume that defines a low volume road. For example, Faiz (2012) suggested that an Annual Average Daily Traffic (AADT) threshold of 1,000 Vehicles Per Day (VPD) or less as defining a LVR. Alternatively, the American Association of State Highway and Transportation Officials (AASHTO) have used an AADT of 400 VPD or less (AASHTO, 2001). Other threshold values of AADT range from that of the Transportation Association of Canada value of 200 VPD (Douglas, 2016). Thus, there does not appear to be a universally accepted definition of the threshold traffic volume that defines a LVR. Similarly, in Australia a survey of state and local road authorities on sealed roads found that the commonly accepted equivalent AADT definition of LVR varied between 200 VPD and 400 VPD, with the most common definition being 200 VPD (Austroads, 2015b). Another Australian survey indicated that LVR's had traffic volumes up to 1000 VPD (Austroads, 2000). Given these ranges in threshold values for the traffic volumes of LVRs, it is clear that there is no common definition of a LVR and that its identification is a function of items like location, land use, topography, traffic composition, population and other factors (Douglas, 2016).

Another aspect of defining a LVR is to link it with the functional classification (or hierarchy category) of roads (AASHTO, 2001). This approach determines appropriate road management and maintenance practices, and aligns engineering standards with the road's function (Giummarra, 2003), which is based on mobility and access. A road with a higher classification

might focus on mobility and one with a lower classification more on providing access to properties. A road's function, which is typically used by road authorities to divide roads into different functional classifications (such as local roads) is reflected in its characteristics, such as like likely traffic volume (Austroads, 2015a). This classification aids in the allocation of resources (Giummarra, 2003). In this classification, LVRs tend to be associated with lower hierarchy roads such as local roads where the main function is to provide access to properties, farms and businesses, as opposed to meeting through traffic requirements (AASHTO, 2001). From this point of view, LVRs in NSW tend to have an AADT of less than 1000 VPD for urban roads and less than 200 VPD for rural roads (IPWEA NSW, 2015).

The other term that requires definition is "sustainable development", which is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). This concept is further defined in terms of the three pillars of economic development, social equity and environmental protection (Drexhage & Murphy, 2010). From these three pillars, this research has proposed six sustainability goals with respect to LVR development and management. These goals are productivity, safety, usability, social equity, sustainable environmental management and resilience.

Types of Low Volume Road Networks

The length of the unsealed LVR network in Australia is about 500,000 kilometres (Austroads, 2006). The Unsealed Roads Manual of the Australian Road Research Board (ARRB) (Giummarra, 2009) is normally followed in designing them. Unsealed LVRs often do not require the same carriageway width as higher volume roads, and often have open table drains to drain water from the pavement (Giummarra, 2009). In addition, the pavement design and configuration of unsealed LVRs differs from that of sealed roads, as traffic volumes and relative benefits from them are usually lower. Additionally, LVRs have often been developed in stages, from a basic cleared unformed surface, to a formed road with no gravel, to a gravel paved road with sheeting material on its surface (ARRB, 1993). As a result, a number of them may not necessarily meet current design standards.

It is also estimated that there are 210,000 kilometres of sealed local (or lower volume) roads in Australia. Many of their pavement structures have evolved over time and have therefore not been upgraded systematically (ARRB Group, 2005). Normally, they consist of a flexible pavement and a bitumen or asphaltic surface. The main function of the surfacing material is to protect the underlying courses from moisture and withstand loading and environmental effects. Certain surfacing materials, like asphaltic concrete, can aid the road's structural strength. It has been claimed that many of the current challenges facing their planning, design, construction and maintenance are focused on improving sustainability, equity of access and transport choice (Austroads, 2009b).

Management of Low Volume Road Networks

It is important to operate and manage road networks using a strategic, planned approach that makes the best use of resources. This approach aims to optimise road infrastructure at a

network level in order to meet the needs of users (Austroads, 2016a). It requires an interdisciplinary approach, and is embodied in the development of network level innovative solutions focused on adding value to the road network and increasing the efficiency of network operations (World Road Association, 2003). This process requires the integration of asset management, safe systems and road infrastructure strategies. The implementation of an organisation's asset management strategy will therefore directly influence the performance of the road network and how it meets community expectations (Austroads, 2016a). The important function of maintenance aims to ensure that adequate levels of service are provided, and that the road reaches its intended asset service life. Such maintenance can be divided into preventive maintenance, which aims to predict when defects will occur in advance and rectify them (ARRB, 1993) and corrective (or reactive) maintenance, which addresses defects as they arise, and is thus considered a less efficient use of limited maintenance resources. Reactive maintenance can also lead to higher costs for road users and more severe deterioration impacts if defects are left uncorrected.

Challenges in maintaining unsealed LVRs include rapid deterioration from rain and traffic (Giummarra, 2009), relatively high operating costs, limited access during and after high intensity rainfall events (thus impacting on their resilience), higher consumption of natural materials, environmental and heritage impacts, a higher demand for water due to frequent maintenance requirements, and often more risk of accidents (Austroads, 2009a). Some of these issues can be addressed through regular maintenance activities, which include routine grading and periodic reshaping and re-gravelling (ARRB, 1993; Giummarra, 2009).

Normally the maintenance of sealed LVRs is classed as routine or periodic (ARRB Group, 2005). While routine maintenance activities are normally minor, periodic maintenance, which aims to reinstate the condition or surface of the pavement, requires planning and tends to be more expensive and cyclic. Thus, the overall maintenance strategy for sealed LVRs is to undertake regular inspections and review, to identify defects and minimise deterioration.

Other issues in managing LVRs include having a duty of care to the safety of road users, maintaining community productivity, managing social equity (for example, providing access in remote areas), practising sustainable environmental management, providing resilience (ensuring that the network can withstand and bounce back from shocks), and using innovative practices to make the most effective use of funds.

Research Questions

In summary, the literature review has focused on definitions of the key terms of low volume roads and sustainability and has considered issues in the management of LVRs. It has also indicated several questions with respect to the information available and the main principles by which LVRs are managed in Australia, including NSW, where the research described was undertaken. These questions, which underpin the overall research objective, include:

1. What is the commonly accepted definition of a LVR?
2. What level of service should be provided for LVRs and how is this achieved?

3. What should the design life be for a typical LVR pavement or surface treatment?
4. What standards are commonly adopted for planning, design, and construction of LVRs?
5. Are there any common activities that are being successfully used to extend the life or reduce the costs spent on the renewal of LVRs?
6. What are the most critical issues in the management of LVRs?
7. What strategies are being used to overcome these challenges?

RESEARCH METHODOLOGY

Background

The research discussed herein has reviewed and recommended key best practices for managing LVR networks within regional and rural areas of NSW. A first step was to investigate the current network management practices being used at the Eurobodalla Shire Council (ESC) in NSW, in which one of the authors works. This investigation formed the baseline for a survey questionnaire from practicing engineers and professionals representing a cross section of other local government authorities across different regions in NSW to investigate current LVR network management practices. Where possible, it was verified and validated against publicly available information and previous local government surveys.

The second component of the research involved a survey questionnaire that was distributed to selected local government organisations, primarily in NSW. This constituted a major source of data. Such data was critical in analysing current road network management practices that were used for both sealed and unsealed LVRs, particularly within rural and regional areas of NSW. The survey collected data on current network management practices related to levels of service and maintenance, future demand management, planning, design and construction, lifecycle and asset management, asset renewal, and monitoring and performance. Ethics approval was obtained prior to carrying out the survey and ethical practices were implemented during its administration. A significant amount of data was obtained from primary information sources, where there may be some limitations and potential individual respondent bias. To minimise resulting errors in the survey, additional measures were taken, such as verifying data against that published independently in a range of government and professional organisation sources, and validation against previous survey findings by reputable organisations such as the Institute of Public Works Engineers of Australia (IPWEA) and Austroads, the association of Australasian road transport and traffic agencies.

The Survey Questionnaire

The survey followed a similar methodology as adopted by Austroads (2015b) in the LVR survey relating to seal design improvements, but covered broader aspects relating to the management of both sealed and unsealed LVRs at a network level. It was undertaken online using a proprietary platform, thus giving it a range of advantages including speed, timeliness, flexibility, convenience and ease of data entry and analysis. To overcome any concerns by participants, the survey was made completely voluntary with confidentially assured.

It was comprised of a set of structured questions with a mix of both multiple-choice questions (single answer and multiple answer responses), along with some open-ended questions that were designed to be as straightforward as possible. Questions were grouped as follows:

1. General questions on the size and definition of the local LVR network for which the council is responsible
2. Questions related to levels of service and maintenance, in in terms of community expectations and technical measures of performance for sealed and unsealed roads
3. Questions related to the planning, design, and construction of LVRs
4. Questions related to lifecycle management and renewal of LVRs
5. Questions related to current challenges and strategies for the LVR network

Responses were obtained from 33 local government organisations throughout NSW, or 26% of all local governments in that state. A further five responses were received from other local governments in Australia and New Zealand. It is therefore considered that data was obtained from a good cross section of LVR Network Managers in NSW. Participation in the survey was encouraged with the offer of providing participating councils a summarised report of the findings at the completion of the study upon request, thus allowing them to review their current practices and highlight if there are any other innovative practices that could be implemented that would lead to improved outcomes.

RESULTS

There were 30 questions in the survey. A summary of responses to them, listed by the number of the research question that they are addressing, is in Table 1.

Table 1, Summary of Survey Responses

RQ	Summary of Question	Main Response (percentages rounded)
	GENERAL QUESTIONS	
NA	Name of Council	Provided by respondent
NA	Urban or rural	26% urban; 74% rural
NA	Estimated population	>20000 – 52%; <20000 – 48% (NSW only)
NA	Length of roads (km)	Average 1,936 km. Most <2,000 km
1	Traffic threshold unsealed LVR	<100 vpd – 49%; <150 vpd – 69%
1	Percentage unsealed LVRs of total	81% to 100% - 38%; 61% to 80% - 12%
1	Traffic threshold sealed LVR	<100 vpd – 29%; <250 vpd – 76%
1	Percentage sealed LVRs of total road network	0 to 20% - 16%; 21% to 40% - 34%; 41% to 60% - 22%; 61% to 80% - 19%: 80% to 100% - 9%
	LEVELS OF SERVICE	
2	Community satisfaction - unsealed road service	Neither satisfied or dissatisfied – 50%; Satisfied – 27%
2	Annual expenditure – unsealed	Other data (Verity, 2018) – AUD 1,791/km*
2	Inspection frequency – unsealed	One per year – 31%; twice per year – 17%

RQ	Summary of Question	Main Response (percentages rounded)
2	Grading frequency – unsealed	Once per year – 24%; Once per 2 years – 17%
2	Community satisfaction - sealed road service	Satisfied – 45%; neither satisfied nor dissatisfied – 41%
2	Annual expenditure – sealed	Other data (Verity, 2018) – AUD 3,832/km*
2	Inspection frequency – sealed	Once per year 45%, twice per year 24%
2	System to record/ manage defects	Software based – 78%, None - 11%
2	Conduct road safety reviews or audits	Yes – 29%; No 71%.
2	Extraordinary practices improving level of service	17 responses received: 11 nil; 2 using "Otta Seal"; 2 using polymer additives
	PLANNING, DESIGN, AND CONSTRUCTION	
3	Typical design life – unsealed pavements	0 to 5 years – 24%; 5 to 10 years – 17%; 10 to 15 years – 21%; 15 to 20 years - 17%
3	Typical design life – sealed pavements	10 to 20 years – 31%; 20 to 30 years – 31%; 40 to 50 years – 17%
3	Design life – sealed surface treatment	Bitumen: 10 to 15 years – 39%; 15 to 20 years – 36%; 20 to 25 years – 14%; Asphalt: 20 to 25 years – 35%; 25 to 30 years 29%
4	Technical guidelines followed	Multiple responses – most used Austroads Guide to Road Design; Several did not indicate they were using LVR standards
	LIFECYCLE MANAGEMENT AND RENEWAL	
3	Average pavement age – unsealed	5 to 10 years – 11%; 10 to 15 years - 11%; not recorded 64%
5	Renewal activities – unsealed	14 participants – resheeting with new gravel; 14 participants – resheeting with gravel nearby; 7 participants – stabilisation
3	Average pavement age – sealed	10 to 20 years – 11%; 20 to 30 years – 15%; 30 to 40 years – 15%; not recorded 52%
3	Average age – bitumen sealed surface	5 to 10 years – 7%; 10 to 15 years – 18%; 15 to 20 years – 25%; not recorded – 32%
5	Renewal activities – sealed (number of response)	Bitumen resealing – 26; replacement of drains/culverts – 17; stabilisation – 15.
5	Innovative or out of the ordinary activities – extending service life of LVR networks	6 participants – includes stabilisation; rubber S35E for reseals; widening road for larger trucks
	CHALLENGES AND STRATEGIES	
6	<u>Main challenges in managing LVR network – rank 1 to 5</u>	

RQ	Summary of Question	Main Response (percentages rounded)
	Inadequate funding – 53 responses; ageing network – 42 responses; increasing traffic volume – 31 responses; increasing construction cost – 25 responses	
7	Strategies for managing challenges New assets to meet traffic demands – 17 responses; leveraging funds – 17 responses; investigate emerging techniques for asset preservation and management – 15 responses. Set and deliver on preventative maintenance targets – 14 responses.	

"RQ" = "Research Question Number (1 to 7); * Individual data varied. Thus used other sources.

DISCUSSION AND CONCLUSION

Main Findings with Respect to Research Criteria

Overall, the above results, which have addressed all research questions, indicate that low volume road practices vary significantly between local governments. The main findings of this research are summarised below.

Low Volume Roads definition

The definition of a LVR in the respondent group was typically less than 200 vehicles per day for both unsealed and sealed LVRs (this is particularly the case for rural and lower populated areas). Thus, a LVR could be defined as one with 200 vehicles per day or less.

Unsealed Low Volume Roads

Most unsealed LVRs, particularly in rural areas, provided a level of service that communities were neither satisfied nor dissatisfied with. More frequent inspections of unsealed LVRs could be related to better community satisfaction.

Councils adopted a range of grading schedules. Generally, those with lower community level of service satisfaction undertook less frequent grading than with satisfied communities. However, higher grading frequencies did not always result in good community satisfaction.

The average design life for unsealed LVR pavements adopted by the survey participants was 17 years. Most survey participants did not know or record the current average age of unsealed LVR pavements that they managed.

Improvements in the awareness of technical guidelines specifically covering the planning, design, and construction of unsealed LVRs were possible.

Sealed Low Volume Roads

Most survey participants did not know the current average age of the sealed LVR pavements that they managed. Responses from those participants which recorded this figure indicated that this average age was about 39 years.

Knowledge of the current average age of bitumen seals on LVRs was better than that for their associated road pavements, but was still not high. This figure was 23 years, which exceeded the average design age of new sealed road pavements by 6 years. This result suggests that

further expenditure on the renewal of bitumen seals in the surveyed area is required to maintain adequate levels of service.

Challenges and Strategies for Future Development

The survey found that the most common system to record and manage defects on LVR networks was through specialised computer systems. While use of these systems did not guarantee community satisfaction, the use of a formal recording system aided it.

Although the literature suggests that undertaking road safety reviews or audits on LVRs could provide significant safety and economic benefits from reduced crash rates, only a small proportion of participants undertook road safety reviews or audits on LVRs.

Maintaining and renewing drainage systems was important for maximising LVR useful life.

The major challenge in the effective management of LVRs in the surveyed area were found to be inadequate funding and an ageing network. The most effective strategies to manage these challenges were leveraging grants and investigating emerging techniques for asset preservation and management.

Innovative Practices

The study found a number of innovative solutions for managing the lifecycle of sealed LVRs. They included:

- Using rubber S35E (a polymer modified bitumen) for reseals and using cement stabilised sand as a bridging layer over poor subgrades. These practices may only be practical in certain circumstances.
- Widening selected roads to improve transportation.

There were a number of recommendations, aimed at implementing the above findings.

Meeting Sustainability Goals

Productivity: Community productivity depends on good, safe roads that foster efficient transportation and property access. Therefore, enhancing the low volume road network through developing and maintaining it in a good, safe condition is important. The survey indicated that a number of improvements could be made in these areas.

Safety: While road safety reviews and audits are important in maintaining community wellbeing, it was found that only a small proportion of respondent councils undertook them.

Usability: The road systems surveyed appeared to be usable overall. Improved maintenance, such as a higher frequency of grading on unsealed roads and maintaining drainage, is important in this process.

Social equity: The main factors in achieving social equity were having as many roads as possible sealed and having a good level of service. The decision to seal a road can however lead to significantly increased lifecycle costs, which require consideration. Similarly, the

proportion of councils that indicated that their communities were neither satisfied nor dissatisfied with their level of service was quite high. There is room for improvement in both of these areas.

Sustainable environmental management: Most unsealed road grading materials are taken from quarry sources, with the potential to damage the environment. Some councils were using stabilised materials for this purpose. Some were using polymer and other innovative seals. While questions on drainage were not asked, this is also significant environmentally.

Resilience: Resilience was not specifically reviewed. However, roads that are sealed and have good drainage could be expected to be more resilient than unsealed or poorly drained roads.

CONCLUSION

In conclusion, this study has contributed significantly to the body of knowledge that exists in network management in low volume roads in Australia, and in particular in the state of NSW. It has been found that there is a significant opportunity to increase the level of road safety reviews for these roads. Leveraging funding, ensuring that new low volume roads meet future traffic demands, and continuing to investigate best practices for life cycle based sustainable asset management; development and preservation, are considered the most successful strategies to meet these challenges.

Future work could include extending the rigour of this research through more detailed participant surveys and assessment and extending the scope of a study of this type to assess in depth practices in the development and management of low volume roads throughout Australia, and ultimately Internationally. Other studies could focus in depth in other types of low volume roads, and in-depth research into use and potential for innovative practices.

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