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Road Asset Management: the role of location in mitigating extreme flood maintenance

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Abstract

Australia recently experienced a doubling of the annual rain fall during one seven-month period resulting in widespread and extensive infrastructure flooding. The increasing number of these disrupting weather events makes it difficult for Australian state road authorities to follow their predictive road maintenance plans. This report on desktop research using road authority annual reports focuses on the differences between the expected outcomes of open or closed systems perspectives. The study suggests that location-based thinking provides the underlying concept for effective efforts in linking predictive and reactive road maintenance activities. A location-based framework provides a synergistic resilience for Australian road networks.

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Keywords: Australian infrastructure; location-based thinking; predictive road asset management; reactive flooding road maintenance.

1. Introduction

Historically, road travel has played a dominant role in the lives of Australians. In a country that has a large landmass and a small population, roads are always critical for national productivity, local economic growth and individual social wellbeing (BCA, 2014). Thus, responsibility for construction and maintenance of public roads is a major function of all levels of government. Australian has three levels of government; federal government, the

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governments of six states and two territories and local governments (Allen, 2009). The major cooperative policy development mechanism is a COAG (Council of Australian Governments). The Transport Infrastructure COAG consists of state and territory government ministers working with the Australian federal minister (or ministers) responsible for transportation and infrastructure. The Transport Infrastructure COAG creates policy and operational ways and means for all Australian public road networks to ensure positive economic and social outcomes.

One way in which to obtain positive outcomes is to manage road assets responsibly. Highway infrastructure asset management is now considered the benchmark for effective public sector road authorities (Burningham and Stankevich, 2005). The assumption underlying short, medium and long-term planning has its foundation in a 'steady state' premise with utilitarian measuring of road 'wear and tear' in this sector of the built environment. The main purpose of managing assets is to have a well ordered, standardized plan of predictive maintenance within a closed cyclical system (design, build, and operate).

However, predictive maintenance is often replaced with reactive maintenance. For example, during the seven month period between September 2010 and March 2011 Australia experienced a doubling of the annual rainfall. The heavy rains resulted in widespread and extensive flooding inundating the roads of major cities, towns and regional areas (ABS, 2012). Roads are open to the elements and the effects of severe weather can mean short, sharp change rather than predicted long-term change (Schraven et al., 2011). Thus, road maintenance can also be viewed from an adaptive open systems perspective (Bosher, 2014) considering recovery issues for people and the landscape.

Managing road assets must also take into account unplanned impacts of the natural environment such as extreme weather events. For road authorities responsible for a significant proportion of the national road network, the issue of managing road maintenance and repair during and after heavy flooding is of growing concern (MRWA, 2012; QLDMR, 2012; RMS, 2012). This concern might be mitigated by location-based thinking which offers a method of linking the preferred outcomes of both management and resilience perspectives for public road assets.

The balance of this paper provides the description of this desktop study, in five sections. Section two describes the differences and similarities between open and closed systems views related to public road assets. Section three provides a description of the two phase research design. Internet mediated documents related to public road asset maintenance produced by Australian government departments were analyzed for information concerning maintenance and natural disasters and the role of the Natural Disaster Relief and Recovery Arrangements. Data from three states with the largest road networks; Queensland, New South Wales and Western Australia are discussed. Section four presents a more extensive case study based on data available from one state road authority, New South Wales Roads and Maritime Services. Section five offers concluding remarks and suggestions for future research.

2. Public road assets: open and closed systems

The concept of a closed system is based on linking elements that make up a whole, rather than focusing on specific features or parts. Scholars have critiqued this view as being 'static' rather than 'dynamic'. Their argument is that a dynamic system that is more like 'reality'. Dynamic systems are considered to be both open and adaptive, which makes it more difficult to identify and claim causality between system elements. The common expression 'the sum of the parts is greater than the whole' means that patterns of activity and the structures related to those activities' causality is not easily measured (Teigão dos Santos and Partidário, 2011).

Table 1. Comparison of closed and open systems

Type	Closed system	Open system
Principle characteristic	location	location
Application	Built environment	Natural environment
Framework	Management	Resilience
Focus	Economic	Social-ecological
Outcome	Predictability	Adaptability

Table 1 outlines some features of two types of system that share a common principal characteristic: location. Some scholars have argued that the concepts of open and closed systems are not opposites, but that the different types of systems are used to emphasize larger or smaller parts of a whole. This is the view that underpins the research being reported (Kenley in press). This paper suggests that the common feature of location is more important for managing road networks than are differences in outcomes expected from an open or a closed system.

2.1 Roads as assets: rational choice theory for a closed system

The 2013 UK *Highway Infrastructure Asset Management Guidance* provides an explanation for the purpose, the processes and the monitoring of a road authority asset management system for the built environment. The most effective means of managing assets is a well ordered, standardized plan of maintenance within a closed system.

In their 2014 journal article, Taggart et al. provide an easy-to-read, step-by-step overview of this guide from the perspective of rational choice theory. Their paper describes public road asset management complexity: levels of policy decision-making responsibility, operationalization processes and whole-life monitoring/audit expectations.

The authors' statements, in which a well-managed and well-funded predictive maintenance regime is the outcome of an asset management plan, are based on standardized ratings for prioritizing works. Prioritized planning, which aims at the identification of short, medium and long-term activities, has its foundation in a 'steady state' premise with utilitarian measuring of road 'wear and tear'. Human use, such as vehicular traffic, can be measured, and changing safety or construction standards can also be factored into maintenance requirements.

However, we have to accept that statistical analysis of data on road use (Taggart et al., 2014) is only one part of the story. What is missing are the increasingly important natural phenomena, and the 'wear and tear' impact of extreme weather events.

2.2 Maintenance of flooded roads: resilience theory for an open system

Walker and Salt (2006) suggest that open adaptive systems are best for both people and the natural environment. They provide a positive description of resilience, 'the capacity of a system to absorb disturbance and still retain its basic function and structure' in action.

They write that the ecological system that is manipulated by people (social and economic systems) for the sake of efficiency cannot resolve issues of diminished resources. Resilience is located within the complexity of the current economic system that, for the most part, manages resources as though they were limited, which of course they are. Therefore, efficiency efforts seem the obvious response to change within a system (Bosher, 2014).

At the same time, changing one part of a system to obtain positive effects appears to create negative effects in another part of the system according to Walker and Salt (2006). This appears to be true for both the built and natural environments. Resilience obviously grows from adaptation to change, slow change or fast change.

Increasingly, a significant proportion of road maintenance requirements are the consequence of unexpected natural disasters. Thus, managing road assets must also take into account unplanned impacts of the natural environment. Planned maintenance can be managed within a closed predictive system, but roads are open to the elements and the effects of weather can mean short, sharp change requiring reactive maintenance (Schraven, et al., 2011). Thus, road maintenance can be viewed from the two perspectives outlined in Table 1. An adaptive open systems perspective allows for a synergy with the rational choice model of asset management. The outcome of this synergy is a resilience model of disaster recovery to deal with extreme weather events.

2.3 Location: the importance for closed and open systems

As noted in table 1, location is the principle feature of both closed and open system perspectives. Location is also the organising principle of economic activity as well as social-ecological interaction. Whether or not roads have just been built, just been flooded or are undergoing some maintenance work, their geographic location provides an epicenter for government administration and user 'reality'.

Obviously, rational choice decision-making for budget allocation is necessary for both a closed-system asset management long-term plan and an open-adaptive system for dealing road damage caused by the negative effects of major weather events, especially flooding (Hassler and Kohler, 2014). Location-based thinking is implicit in all decisions for public road asset management. Location-based thinking can also assist road asset portfolio managers when considering effective project budgeting (Kenley, 2014), especially when dealing with natural disasters. Extreme weather events place excessive unexpected demands on 'normal' social, political and economic decision-making (Bosher, 2014; Biggs, 2012). Using either a management or a resilience framework, location-based thinking is a key to both predictive and reactive maintenance for public road assets.

3. Research design

This two phase study is based on document content analysis of internet-mediated sources (Bryman and Bell, 2007). No statistical analysis is attempted because comparative data are not publicly available.

3.1 Phase one: Natural Disaster Relief and Recovery Arrangements (NDRRA)

The Transport COAG (with oversight of Australian transportation infrastructure) was instrumental in the development of the National Disaster Relief and Recovery Arrangements (NDRRA) (Biggs, 2012). The aim of NDRRA is to reduce the financial burden for states, communities and individuals by providing financial assistance for specified items during emergencies or recovery.

Table 2. Comparison of the number of Declared Natural Disasters and the percentage with flooding (2006-2014)

State	Previous	Current	Flooding as % of total number
New South Wales	20	42	40.3
Queensland	20	19	80.0
Western Australia	22	13	74.3
Total	**62**	**74**	**61.2**

A Declared Natural Disaster (DND) is specified by the Federal Minister responsible at the time of event. Two types of natural disaster affect Australia. Bush fires are usually related to hot, dry weather. Storms (excessive rainfall, cyclones and tornadoes) are related to wet weather. Destruction of the natural and built environments as a consequence of both types of extreme weather events is accompanied by highly dangerous winds.

The NDRRA archive lists DND (Australian Government 2014) as shown in table 2, events between January 2006 and January 2014 for the three states with the largest road networks.

Table 3. Comparison of the number of extreme flooding events and number of local government areas (LGA) involved (2010-2012)

State	2010	LGA2010	2011	LGA2011	2012	LGA2012
New South Wales	4	87	5	70	2	18
Queensland	1	5	4	85	3	32
Western Australia	1	12	8	38	3	16

The DND descriptors provide evidence of the number of extreme wet weather events characterised by storms and flooding. The expected high percentages for both Queensland (80.0%) and Western Australia (74.3%) during this period are not replicated in NSW in table 2. This is because NSW was afflicted by an usually large number of dry weather DNDs. NSW flooding events were outnumbered by the 34 Bush fire DNDs (many burning concurrently) that occurred between August 2013 (Australian winter) and January 2014 (Australian summer).

Table 3 shows the number of DNDs associated with extreme flooding during 2010-2012. Although the number of events is small, the extent of the flooding indicates the extent of the area covered. In this case, a definition of an extreme weather event can be measured by the size of the geographical area flooded. This size can be inferred from the high number of local government areas (LGA) receiving NDRRA assistance listed on the website.

3.2 Phase two: Australian Road Authorities: Maintenance Operations

Australian state transport authority Annual Reports are required to be compiled and made available to the public (MRWA 2012; QLDMR, 2012; RMS, 2012). Annual Reports for the years 2009 to 2013, for three states, Western Australia, Queensland, and New South Wales, were accessed through their websites. (In Australia the financial year runs from 1 July to 30 June, which means that the 12 month period actually covers parts of two different calendar years.)

These Annual Reports were electronically searched for evidence of Planned Road Asset Management. Details of maintenance planning, funding, performance and future work were found. In addition, evidence of specific reporting of road repairs which were necessary due to extreme weather was sought firstly by key word searching (disaster and road) in the complete reports. A second level of search involved a content analysis of the paper copies of all sections relating to the keyword electronic search. Due to limited space, a report of the findings from the state of New South Wales is presented for 2009-2013. The types of data contained in the Annual Reports constitute data sets that make possible the comparison of maintenance activities related to extreme weather events, specifically road flooding.

4. Case study: RMS road asset management -- maintenance

The New South Wales Department of Transport was restructured and re-named in November 2011 (RMS, 2012). The Road Transport Authority (RTA) became the Roads and Maritime Services (RMS). However, the change of internal structure does not appear to have changed the road management systems for the years under consideration (2009-2013) and in this report RMS will be used. Table 4 provides some details of the extent of the NSW road networks and the jurisdictional demarcation (changes in actual number during the period being studied is minor).

Local Government roads within cities and towns far outnumber those in rural regionals areas (Allen, 2009). It is interesting to note that types of road surface are as important as the location of the asset. Of course, significant maintenance relates to resurfacing.

Table 4. Indicative Road Infrastructure RMS Managed Assets

State Roads	Local Government Roads (regional)	Local Government Roads (local)
42,000 lane-km arterial pavement	13,600 km sealed roads	20,000 km urban sealed roads
750 lane-km unsealed road	4,800 km unsealed roads	40,000 km non-urban sealed roads
200 million m of surface		82,000 km non-urban unsealed roads

The Assets to be managed are listed in tables 4 and 5, and include both a ferry (because the waterway to be crossed is considered a highway) and the iconic Sydney Harbour Bridge.

Table 5. Indicative Non-road Infrastructure RMS Managed Assets

State Structures	Local Government Structures (regional)	Local Government, Structures (local)
4,800 bridges	1,500 non-timber bridges	5,000 bridges non-timber
37 tunnels	323 timber bridges	2,600 timber bridges
3,300 signals		

According to the ARs, Asset Management for the New South Wales road network is developed within the context of projections for population growth, economic prosperity and environmental sustainability. The aims, goals and outcomes are related to the State Plan and reports of the Auditor-General (RMS, 2010-2013).

The performance of the department is monitored for a wide variety of outcomes. The major categories are road usability, transport capacity and public safety. Major and/or minor maintenance works focus on road surface condition, slope, stability and culvert functionality. The planning for these activities is linked to continually improving regulation, rising technical standards and effective management of ICT systems (RMS, 2010-2013).

The consistent expectation is for the state road authority to provide a cost effective or 'value for money' infrastructure, based on available funding (Rouse and Chiu, 2009). A variety of sources of funding is identified: individual road users as part of their vehicle license fee, company road user fees and federal infrastructure support.

These basic Asset Management activities and funding sources are impacted by severe weather events that cause flooding of any part of the road network within the state.

4.1. RMS 2009-2013 Declared Natural Disasters: road repairs for storms and flooding

Annual Reports do not provide a breakdown of maintenance for Declared Natural Disasters into units smaller than 'road' as shown in table 6. The RMS annual reports provide a picture of natural disaster flooding increasing between 2009 and 2012, which is inferred from the ever increasing repair bill provided in Table 6. A significant amount of funding is provided by the Commonwealth government to be administered by state governments for local government road repair and recovery to pre-disaster condition (RMS, 2010-2013).

Table 6 provides an indication of the continuing number of extreme weather events that are disruptive to both the natural and built environments. According the ARs, during 2009-10 some NSW communities experienced up to five separate extreme weather events. The growth in funding for reactive rather than predictive maintenance could be perceived as an example of road infrastructure resilience, as the 'disruption is absorbed' by the open adaptive system.

Table 6. NSW Designated National Disaster road expenditure: AU$ m during financial year

Government level	2010-2011	2011-2012	2012-2013
Local Government Roads	120.0	158.4	167.0
State Roads	71.2	32.4	39.4
Regional Roads	22.6	27.2	36.2
Crown Roads	0.8	1.5	0.7
Total	**214.6**	**219.5**	**243.3**

4.2. Location-based thinking and DND road recovery

Table 7 illustrates the importance of location for road asset management responsibility throughout the entire road network. Weather events such as tornadoes or cyclones may destroy both the natural and built environments, but not cause major long term flooding maintenance issues. However, the flooding was extensive during the protracted rainfall during the seven-month period September 2010 to March 2011. The number of local government areas effected was 95 of 154 (about 62%) in the state.

Table 7. Comparison of DND for NSW severe weather, local government areas involved and road repair expenditure

	2009-2010	2010-2011	2011-2012	2012-2013
Number of severe weather events Declared Natural Disasters (NDRRA)	6	8	7	5
Number of Local Government Areas effected (NDRRA)	87	95	94	104
Repair of ROAD storm & flood damage (RTA/RMS)	$80.5m	$214.6m	$219.5m	$243.3m

The extent of the damage to a multiplicity of roads, within the variety of administrative jurisdictions, and funding from an assortment of sources means that repair and 'restoration' will continue outside of the financial year in which the flood occurred. Again, because of the severity of the damage suffered, and the number of local government areas affected by flooding, both a long-term and short-term priority of works is the only option. Walker and Salt (2006) argue that the ecological system that is manipulated by people (social and economic systems) for the sake of efficiency cannot resolve issues of diminished resources.

However, resilience can also be expressed as adaptation. Although the uncertainty of severe weather event road damage cannot always be included in a state Roads Asset Management Plan, adapting the Plan by using rational choice theory optimizing techniques, based on location, could assist. This is especially important because the percentage of the total road maintenance budget allocation to deal with continuing disruptive effects of flooding events has been increasing since 2010 as shown in table 8. These worrying figures indicate that by 2013 over half the available budget was allocated to natural disaster recovery driving the need for methods to minimize expenditure.

Table 8. NSW DND road recovery expenditure and planned recovery, plus percentage of total road maintenance budget (2009-2013)

	2009-2010	2010-2011	2011-2012	2012-2013
Total ROAD maintenance budget (RTA/RMS)	$412.5m	$849.7m	$856.6m	$933.2m
Repair of ROAD storm & flood damage (RTA/RMS)	$80.5m	$214.6m	$219.5m	$243.3m
Estimate of outstanding ROAD recovery damages (RTA/RMS)	--	$200.0m	$240.0m	$280.0m
Percentage of total ROAD maintenance for disasters	19.5%	25.3%	25.6%	26.1%
Percentage of total ROAD maintenance budget for current year (disaster recovery plus outstanding disaster recovery)	**--**	**48.0%**	**53.4%**	**56.1%**

Location-based thinking (Kenley, 2014) provides a means of enhancing the management of recovery efforts by factoring location into the decision making on prioritization. Location-based thinking can assist road asset management portfolio managers to use proximity more effectively in project budgeting (Kenley, 2014). The aim is to exploit proximity opportunities to drive cost efficiencies by eliminating waste from the supply chain. While this seems contrary to the Walker and Salt (2006) view that optimizing of resources is harmful for the natural environment, in the instance of extensive flooding road damage, optimizing repairs by proximity (as if for a closed system) can actually positively affect the open adaptive system.

Infrastructure resilience, such as 'the capacity of a system to absorb disturbance and still retain its basic function and structure', is obviously an outcome that is desirable. The integration of both predictive and reactive maintenance decision-making, based on minimizing limited budgets for natural disaster recovery efforts, moves beyond limitations of conceptual models to practical application of the common principle characteristic, location.

5. Conclusion and suggestions for future research

Resilience grows from adaption to change; slow change or fast change. If this is the case, then providing an efficient asset management system for road infrastructure is the basis from which adaptive change is created during and after extreme weather events. For example, Australia experienced a doubling of the annual rainfall during the seven-month period between September 2010 and March 2011. Those heavy rains resulted in widespread and extensive flooding inundating the roads of major cities, towns and regional areas.

The National Disaster Relief and Recovery Arrangements (NDRRA) were designed to provide funds to assist state governments to repair roads that have been damaged by flooding during a Declared Natural Disaster. Examination of the Annual Reports of three Australian state road authorities provides ample evidence of an increase in the number of extreme weather events with associated widespread flooding. While NDRRA does assist with recovery efforts the time between events does not appear sufficient to actually recover.

The reality of continuing and growing extreme weather events points to a need for a dynamic uncertainty model of works. Clearly, a solution lies in the synergy between rational choice and resilience theories because location is the principal characteristic of both theories, and because all roads and floods are defined by their geographic location.

The New South Wales RMS case study detailing budgets, maintenance issues and the extent of the flooding indicates the clash between well-planned and reactive road maintenance activities. Much of the data collected from the 2009-2013 Annual Reports indicates a growing expenditure. It is possible that a prioritization of works based on location for both the long and short term is the only option.

The findings of this pilot study indicate future research with individual road authorities to test the value of applying location-based thinking in planning both extreme weather recovery and planned maintenance for managing their road assets.

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