CLIMATE CHANGE IMPACTS ON ROAD INFRASTRUCTURE SYSTEMS AND SERVICES IN SOUTH EAST QUEENSLAND: IMPLICATIONS FOR INFRASTRUCTURE PLANNING AND MANAGEMENT

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INTRODUCTION

Infrastructure systems and services (ISS), such as physical and organisational structures, are important for the functioning of communities, cities and regions. Whilst physical or hard infrastructure include roads, electrical networks, telecommunications, water supply and waste management systems, organisational or soft infrastructures enable the delivery of critical services which are essential for the governance, economy and social fabric of places. In Australia, for example, given its large territorial area and low population density, transportation systems and services in particular are crucial for the functioning of its communities and economy. As a result, Australia has an estimated road network of 812,000 kilometres which is used by over 14 million vehicles yearly (Austroads, 2008). Additionally, it supports 72% of approximately 2.3 billion tonnes of freight per year, with 50% being single driver operators (BITRE, 2008). Consequently, the cost of maintenance and rehabilitation for roads are the largest single item of expenditure for many local governments (Jeff Roorda and Associates, 2010).

In Queensland specifically, stewardship of road network lies with two organisations, namely: the Queensland Department of Main Roads and Local Governments. Road network controlled by the state and local governments is estimated to have an asset value of more than $23 billion and $10 billion respectively (Talbot & Pelevin, 2003). However, this value is expected to rise as Queensland had an average annual growth rate of 2.5% from June 2005 to 2010. This posits a challenge to fast growing regions in the state such as South East Queensland (SEQ) which accounts for 66% of the state's total population (Australian Bureau of Statistics, 2011) and is forecasted to accommodate 4.4 million people by 2031 (Department of Infrastructure and Planning, 2009). Furthermore, the region has been identified as a vulnerability hotspot due to climate change and is likely to be impacted by increased average temperature, changes in average rainfall, sea level rise and increased frequency and intensity of extreme weather events (Hennessy et al, 2007; Australian Bureau of Meteorology, 2008). Hence climate change is likely to remarkably challenge the management and planning of essential infrastructure in SEQ, including its road network. For example, because roads (urban, arterial and freeways) link and facilitate movement within cities and regions their disruption due to climate change impacts will affect businesses, trade and the lifeline of communities by impeding and/or damaging evacuation routes as well as hindering service provision, such as food and critical supplies. Further, decisions taken today with regards to the location of infrastructure will have long lasting implications associated with land use and development as well as future investments to support the region and determine how infrastructure will adapt to climate change (Committee on Climate Change and US Transportation, 2008). Thus the planning and delivery of ISS, particularly transportation infrastructure in SEQ needs to take climate change into consideration to enable its adaptation and ensure the region's economic security and public health and safety.

To enable the SEQ's transportation infrastructure to adapt to climate change it is important to understand how it is currently planned and managed in the region to identify its weaknesses and strengths in dealing with climate change, particularly through adaptation as this has received limited attention from transportation professionals and academic research (Mills et al, 2009; Committee on Climate Change and US Transportation, 2008; Tighe, 2008; Mills et al, 2007). This paper advances this understanding by investigating SEQ's institutional and organisational capacity to maintain, repair and renew its transportation infrastructure, particularly in relation to sea level rise and flooding. It also discusses key strategic issues related to infrastructure management, planning and potential implications for climate adaptation and allied sectors such as urban planning and emergency management in SEQ. The paper is organised in four parts. The first part investigates the current state of infrastructure planning and delivery in the SEQ region. The second part presents an overview of how climate change is likely to impact ISS focusing on road network. Key strategic issues associated with infrastructure planning and delivery taking climate change into consideration in SEQ are elicited in the third part. Finally, the paper provides insights to improving ISS planning and delivery to be better prepared to adapt to climate change.

IMPLICATIONS FOR INFRASTRUCTURE PLANNING AND MANAGEMENT STRATEGIES: A CASE STUDY OF SOUTH EAST QUEENSLAND

Since 2005, the SEQ region has established an infrastructure management program to plan and deliver ISS to support the region's ongoing population and economic growth through its *South East Queensland Infrastructure Plan and Program 2010-2031* (SEQIPP) (Department of Infrastructure and Planning, 2010c). The SEQIPP outlines infrastructure priorities for the region and sets a 20-year planning timeframe and budget commitments to ensure ISS are delivered to support regional growth. SEQIPP is also a catalyser for ISS provided by government owned-corporations, local government and private sector (Department of Infrastructure and Planning, 2009). In alignment with the *South East Queensland Regional Plan 2009-2031* (SEQRP) (Department of Infrastructure and Planning, 2009), the SEQIPP was set to be reviewed annually and ensured that other state agencies' programs reflected the priorities established by the Regional Plan. More recently, however, the Queensland Government has started a consultation process to assess a new initiative to be implemented to deliver infrastructure across the state, namely the *Queensland Infrastructure Plan* (QIP) (Department of Local Government and Planning, 2011a). The QIP will replace the SEQIPP, albeit being built upon it, and support the state's Regionalisation Strategy (Department of Local Government and Planning, 2011b). The initiative will be guided by five principles, one of which focuses on climate change and sustainability. Nevertheless, it is unclear under this principle how climate change and sustainability will be taken into account and ultimately influence infrastructure planning and delivery in SEQ. Furthermore, infrastructure planning in Queensland is also informed by a range other government documents that have direct implications to transport infrastructure in SEQ. These include, for example, the *Queensland Transport and Roads Investment Program 2011-12 to 2014-15* (QTRIP) (Department of Transport and Main Roads, 2011a) and *Connecting SEQ 2031* (Department of Transport and Main Roads, 2010).

Amongst all ISS, authorities in SEQ have a strong commitment to deliver transportation infrastructure to support regional growth which is demonstrated by allocated expenditure. Transportation infrastructure, including roads, account for more than 70% of the total allocated investment of AU$134 billion for infrastructure projects across the region to be delivered until 2031 (Department of Infrastructure and Planning, 2010c). This infrastructure is managed and delivered by the Department of Transport and Main Roads (TMR) through its QTRIP (Department of Transport and Main Roads, 2011a). For the purpose of planning and management of transportation infrastructure in SEQ, including roads, the region is divided in three areas, namely: the South Coast Region (Gold Coast City Council, Scenic Rim Regional Council), the Metropolitan Region (Brisbane City Council, Redland City Council, Ipswich City Council and Lockyer Valley Regional Council) and the North Coast Region (Moreton Bay Regional Council, Sunshine Coast Regional Council and Somerset Regional Council) (see Figure 1). Together, these areas within SEQ, excluding Toowoomba, have an estimated road network extension of 3,990 Km (Department of Transport and Main Roads, 2011a) (see Table 1).

Table 1: **Road network extension across SEQ**

SEQ areas	Road Network Extension (km)	
	State-controlled roads	National network
South Coast Region	1,050	131
Metropolitan Region	1,152	186
North Coast Region	1,352	119
Total	**3,554**	**436**

Source: *Queensland Transport and Roads Investment Program 2011-12 to 2014-15* (Department of Transport and Main Roads, 2011a)

TMR manages and controls state-controlled roads which support 80% of Queensland's road traffic. It also owns, manages and operates the National Network within the State. Local roads of regional significance are managed by Regional Road Groups (RRG) which are a result of a collaboration between local authorities and TMR. The SEQ region comprises four RRG (groupings of local

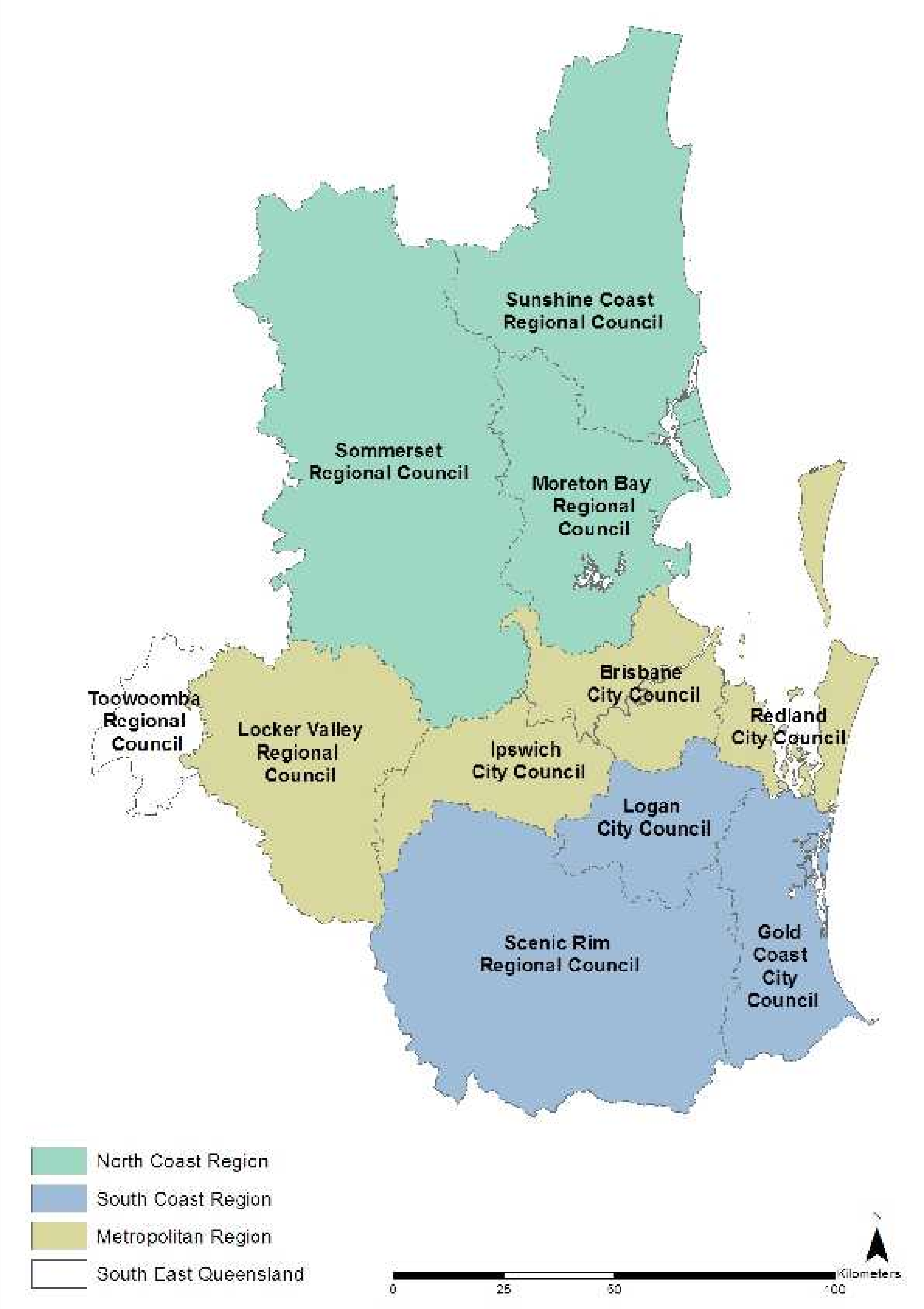

Figure 1: Map depicting regions within SEQ for the purpose of planning and management of transportation infrastructure

authorities), namely: Brisbane Metro Alliance, Northern SEQ, Scenic Valleys and Southern RRGs (Department of Transport and Main Roads, 2011b). The necessary funds to deliver, maintain and operate transport and roads projects are provided by both the state and Commonwealth governments. State funds come from revenues related to vehicle registrations and fines, whilst other projects may draw funds from specific programs such as the Natural Disaster Relief and Recovery Arrangements which has been established to assist in the relief and recovery after disasters (Department of Transport and Main Roads, 2011a).

Furthermore, SEQ local authorities are also responsible for a significant road network given that local governments are responsible for about 80% of public road network in Australia (Australian Local Government Association, 2010). Local roads are planned, managed and maintained predominately through funds derived from council rates. However, of all infrastructure local governments are responsible for local roads represent the most capital intense (Council of Mayors SEQ, 2009). Additionally, a report commissioned by the Australian Local Government Association in 2006 revealed that there has been a funding gap for the recovery of roads across most councils in Australia which may challenge the financial sustainability of some local authorities (PricewaterhouseCoopers, 2006). Currently, local roads are valued at AU$75billion (Australian Local Government Association, 2010) and it is estimated that an increase of around AU$1.2billion per year is needed Australia wide to fund ongoing maintenance and recovery of local roads for the next 15 years (Jeff Roorda and Associates, 2010).

While the Federal government has contributed to diminish local governments' infrastructure renewal backlogs through a number of funding programs (Department of Infrastructure and Transport, 2011), ongoing backlogs are likely to continue as current fiscal constraints on the state and federal governments hinder a potential rise in funding availability (Engineers Australia, n.d.). Hence local authorities have to source additional funds to maintain and renew their existing road network through a combination of initiatives, including increases in infrastructure charges and rates, improving efficiency in expenditure as well as grants from other government agencies (PricewaterhouseCoopers, 2006). This posits significant challenges as maintenance and renewal expenditure should augment to deal with increased ageing of road network (Engineers Australia, n.d.) as well as future climate change impacts.

Nevertheless, funding is not the only constraint fronting local authorities when it comes to ISS as they also face challenges related to both asset and financial management skills (PricewaterhouseCoopers, 2006). The Commonwealth government, through the *Local Government Act 2009* has required that all local governments should have asset management plans to deal with issues associated with underestimation of future funding demands for infrastructure by the end of 2010 (Engineers Australia, n.d.). Consequently, SEQ local authorities are in the process of preparing their asset management plans. This is a significant step towards improving local governments' asset management practice to ensure provisions for maintenance, operation and renewal costs are incorporated into long-term financial models, particularly related to local roads as currently only 17% of all local governments across the state have management plans for this asset class (Department of Infrastructure and Planning, 2010b). However, local governments have fragmented information about their infrastructure assets which creates great difficulty to accurately account for their operating and maintenance costs as well as lifecycle costs (Gold Coast City Council, 2010). This issue is further compounded by ageing infrastructure assets thereby demanding substantial investments for their ongoing maintenance and future renewal.

Adding to the challenges of infrastructure funding and management, more recently, the Queensland Government has started to privatise major infrastructure assets to offset government debt and fund other government infrastructure and services (Queensland Government, 2011). Similar to the 1990's infrastructure privatisation wave (House of Representatives Standing Committee on Transport and Regional Services, 2003; Silva et al, 2006), the privatisation of these assets comprise full and partial operational transfers to the private sector as well as public-private-partnerships and involve long-term operational leases (Queensland Government, 2010). This strategy raises questions about how to ensure that private operators provide the necessary funds for the ongoing and future maintenance and rehabilitation of infrastructure assets that could significantly increase due to climate change. Further, while overall privatised firms tend to perform better than public firms (D'Souza et al, 2005), private operators may increase prices and user fees to acquire necessary funds and/or secure their investment return, therefore leading to greater social costs (Mansour and Nadji, 2006). This comprises a critical issue as costs to road users have already been estimated to be around 200% in Queensland by the study undertaken by Austroads in 2004.

CLIMATE CHANGE IMPACTS ON TRANSPORTATION INFRASTRUCTURE IN AUSTRALIA

The impact of climate change upon the road network and road pavement will indirectly affect the location of human settlements and associated activities. For example, the road network is not only essential for the interconnection and movement of goods amongst major urban and regional centres but also critical to stimulating and sustaining their industrial development and economy. At an urban scale, it sustains the 'lifeline' of communities by enabling the supply of food, water and other critical services. The road network also plays an important role during extreme events or disasters by providing evacuation routes and communication channels between communities. Therefore, it is important that the planning and delivery of the road network should consider the potential impact of climate change.

Climate change impacts on the road network demand a re-think about how roads are designed, constructed and maintained (Tighe, 2008), particularly due to potential effects on road pavement. For example, changes in average rainfall, temperature and evaporation patterns can alter the moisture balances in the pavement foundation. Further, the rise in the water table due to rising sea level can lead to the reduction of the structural strength of the pavement (Doré et al, 1997). Additionally, a rise in air temperature can accelerate the ageing of road surfacing bitumen layers (Ahmad et al, 1998; Masad et al, 1996). Consequently, climate change is likely to have impacts on the pavement performance and influence the rate of pavement deterioration. Nevertheless, given that the lifetime of some transportation infrastructure such as road pavement is relatively short (e.g. 10-20 years), there is considerable scope for the sector to adapt to climate change impacts as they emerge (Committee on Climate Change and US Transportation, 2008).

Nevertheless, transportation professionals have not taken climate change into consideration when planning and designing transportation infrastructure (Mills et al 2009; Committee on Climate Change and US Transportation, 2008; Tighe, 2008; Mills et al, 2007). An exception to this trend is the work of the Australian and New Zealand road transport and traffic authorities (Austroads). In 2004, Austroads produced a report to assist local authorities to improve their understanding about the impact of climate change on road infrastructure. The report specifies that expected pavement deterioration can be predicted through pavement numerical modelling techniques which are based on the Thornthwaite moisture index (an index which is a function of precipitation, temperature and potential evapotranspiration). The report refers to two modelling techniques, namely: the ARRB TR pavement life-cycle costing (PLCC) and the Highway Development and Management 4 (HDM4). The first technique enables the determination of pavement deterioration as well as annual average maintenance expenditure. The second provides more detailed information about pavement deterioration (i.e. roughness, rutting, cracking, potholing, revelling and strength). However, both techniques are unable to account for the effects of weather extremes, such as severe storms or flooding. Nonetheless, the report provides an analysis of a road segment for each state and territory, located in or near a metropolitan area, using HDM4 which indicates that the road agency costs may change considerably in 2100 when compared to those of the baseline year 2000. The analysis also shows that Queensland has the third largest percentage increase in road agency costs at 27% which includes a projected change of around 200% in cost to road users (see Table 2). It is important to note that changes in passenger car traffic have no effect on deterioration rates. While the predicted expenditure provided by the analysis should be regarded as broad indications only and qualitative conclusions should be treated with caution, the impacts of climate change upon road network could result in even further costs to both road users and road agencies.

The ongoing population and economic growth observed in SEQ has already inevitably led to increasing need for the expansion, rehabilitation and maintenance of the road network in the region. This is likely to be further compounded by climate change. Nevertheless, the planning and management processes of the road network in SEQ have generally not considered potential climate change impacts with existing infrastructure being predominately designed, constructed and maintained based on historical climate data (Department of Infrastructure and Transport, 2011). More recently, however, local authorities within SEQ have begun to acknowledge that climate change impacts, particularly sea level rise and increased potential for flooding and/or drought, need to be included in decision making related to infrastructure planning and management. For example, the Gold Coast City Council's Asset Management Strategy highlights that climate change impacts are to be considered in the acquisition,

Table 2: Change in Maintenance and Rehabilitation Costs from 2000 to 2100 (Austroads, 2004)

State/Territory	Change from 2000 to 2100 (%)	
	Road Agency Costs	Road User Costs
Australian Capital Territory	0	2.53
New South Wales	57	85.28
Northern Territory	0	344.22
Queensland	27	200.48
South Australia	-2*	-45.01
Tasmania	14	13.23
Victory	38	73.03
Western Australia	19	37.57

*'-' indicates decrease in costs.

creation and renewal of long life assets (Gold Coast City Council, 2010). The Logan City and Scenic Rim Regional Councils identify the need for mitigation and adaptation to climate change to be considered in infrastructure development (Logan City Council and Scenic Rim Regional Council, 2009). Finally, the Sunshine Coast Regional Council undertook a risk assessment to evaluate the implications of climate change on its own assets and infrastructure through a Climate Change Infrastructure Adaptation Project. The project provided important supporting information for the development of its *Climate Change and Peak Oil Strategy 2010-2020* (Sunshine Coast Regional Council, 2010).

Furthermore, Queensland's *ClimateSmart Adaptation 2007-12* action plan recognised that most infrastructure may not be at risk now, however they may need to withstand more frequent extreme weather events in the future (Department of Natural Resources and Water, 2007). The action plan also mentioned that climate change should be a factor in decisions of replacement or rehabilitation of major infrastructure and design standards and construction methods to increase its resilience. Queensland's *Climate Ready Infrastructure* initiative builds on *ClimateSmart Adaptation 2007-12* by stating that State Government grants for new infrastructure consider greenhouse gas reduction and climate change adaptation (Department of Infrastructure and Planning, 2010a).

These recent initiatives may contribute to increasing the strength of transportation infrastructure in the region under future climate change impacts but transportation professionals have to be better prepared to deal with climate extremes that may challenge the capacity of current infrastructure to withstand their effects. Additionally, other transportation infrastructure, such as major bridges, have longer lifetimes between 50-100 years, thereby also demanding the consideration of climate change in their planning and design (Committee on Climate Change and US Transportation, 2008). These examples highlight the complexity in the planning and delivery of infrastructure to enable it to adapt to climate change. The next section investigates how this planning process is currently being undertaken in SEQ and derives key implications for the sector.

KEY STRATEGIC ISSUES

While authorities have had significant experience in strategic infrastructure planning in SEQ for the last decade (Department of Infrastructure and Planning, 2010c), a number of key strategic issues should be considered in the planning and management of the region's road network to address potential climate change impacts. These include issues related to: (i) road design, maintenance and rehabilitation processes; (ii) existing financial constraints and funding backlogs; and (iii) economic, social and environmental challenges involved in the planning process of road infrastructure.

First, climate change impacts projected to affect SEQ such as increased temperatures, extreme rainfall events and sea level rise (CSIRO, 2007) are likely to accelerate the degradation of road networks and challenge their design, maintenance and rehabilitation processes (Engineers Australia, n.d; Department of Climate Change and Energy Efficiency, 2011). For example, a sea level rise of 1,1m could place an estimate of 1,000km of road network at risk in SEQ (Department of Climate Change and Energy Efficiency, 2011). Hence the sourcing of more resilient infrastructure operational materials and the building of road infrastructure that allow and support ongoing adaptation are essential to minimise climate change impacts (Zimmerman and Faris, 2010; Mills et al 2007). Further, as increased periods of extreme wet weather can accelerate degradation of roads, additional funds will be required for their repair and rehabilitation (Engineers Australia, n.d.).

Second, the current funding backlog (Jeff Roorda and Associates, 2010) in combination with limited asset and financial management skills presented by some local authorities (PricewaterhouseCoopers, 2006) may lead to a potential failure in securing long-term recurrent funding to account for increased damage and losses of infrastructure assets due to climate change. Additionally, the complex ownership of infrastructure assets and associated operational arrangements under privatisation processes will strongly influence the development and implementation of climate adaptation policies in the infrastructure sector (Zimmerman and Faris, 2010). This includes policies that could secure adequate expenditure in road maintenance and rehabilitation from the private sector. Thus, based on the USA experience, the provision of public infrastructure services, such as roads, by private operators may need to be publicly regulated to ensure successful delivery of infrastructure services to communities and businesses under the threat of climate change (Mansour and Nadji, 2006).

Third, SEQ has inherited a legacy of existing infrastructure assets located in low-lying areas and floodplains as well as nearby erosion-prone coastal areas (Department of Climate Change and Energy Efficiency, 2011). For example, roads were the most damaged asset by the recent January 2011 floods that affected SEQ (Department of Transport and Main Roads, 2011a). The floods caused the closure of major highways disrupting essential services and connectivity within the region. While some roads were reopened quickly after flood waters receded, others required complex recovery works which are still under way as part of the restoration phase of the state’s approach to flood response (Department of Transport and Main Roads, 2011a). Thus a better understanding of road infrastructure interdependency in the region is critical to inform adaptation policies (Rinaldi et al, 2001) as well as maintenance and rehabilitation works in order to minimise social, economic and environmental consequences by keeping the system operational (Little, 2004; Zimmerman and Faris, 2011).

Additionally, the SEQ Regional Plan also proposes the identification and protection of infrastructure corridors and sites as a key strategy to support regional growth through its policy 10.4 (Department of Infrastructure and Planning, 2009). Once identified, these corridors could potentially accommodate joint ISS, including transport, pipelines, transmission lines as well as biodiversity networks and recreational trails. While these corridors could result in significant economic benefits for the region, caution should be taken when choosing their location to avoid future risks related to climate change impacts. This caution lies on the premise that infrastructure generally functions as an attraction to future development (Neuman, 2009) and, therefore, locating infrastructure on low-lying locations can not only place infrastructure itself but associated development such as housing estates at risk due to increased flooding from extreme rainfall events as well as sea level rise (Rosenzweig et al, 2011). Further, infrastructure corridors might be subject to increased risks in cascading effect of infrastructure failures due to climate change (Rinaldi et al, 2001; Little, 2004; Zimmerman & Restrepo, 2009; Zimmerman & Faris, 2010).

Furthermore, the concept of ‘tipping-point’ (cf. Larsena et al, 2011), particularly in financial terms, may also apply to determine whether infrastructure rehabilitation and repair should occur in light of climate change. As discussed earlier, road networks maintenance and repair comprise an onerous exercise, particularly for local authorities, which are already subject to a significant financial backlog (Jeff Roorda and Associates, 2010). Additionally, road users are also likely to bear the costs of needed road network upgrades and maintenance (Austroads, 2004). Consequently, the likelihood of increased extreme weather events and sea level rise due to climate change poses the question as to whether it is financially sustainable and viable to repair and rehabilitate road infrastructure that might be at high risk and as to whether the community is prepared to face these costs.

Thus, road infrastructure planning in the region will need to take into account the risks and costs associated with retrofitting and potential relocation of these assets when planning for climate change. It is also necessary that asset management plans not only provide an inventory of existing infrastructure assets and lifecycle costs but also provide better understanding of intrinsic interdependencies to avoid cascading effects of infrastructure failures. Modelling techniques such as the one provided by the Thornthwaite moisture index could assist local authorities to develop better estimates of expected costs associated with road deterioration due to climate change. Another concept that may need to be embedded into transportation infrastructure planning in SEQ is that of redundancy (cf. Committee on Climate Change and US Transportation, 2008), particularly along the coastal zone where population growth is likely to continue and is also subject to seasonal population swell over the summer months which coincides with the wet season in the region. The disruption of road networks in these areas could severely compromise the ability of mass evacuation in the eventuation of extreme weather events.

IMPROVING ISS ADAPTATION TO CLIMATE CHANGE

Under projected extreme weather events and climatic changes, infrastructure systems and services (ISS) in SEQ are particularly vulnerable. As the single largest item of expenditure, road maintenance and repair for many local governments will necessitate significant management and planning reforms to adapt to climate change impacts. Road networks provide a lifeline for communities and are enablers of the region's economy. Tipping-points, new road designs, new decision making frameworks and asset management plans incorporating climate change considerations will aid adaptation by ensuring increased provisions for maintenance, operation and rehabilitation costs. The privatisation of major infrastructure assets raises the questions about how to ensure that private operators provide necessary funds for maintenance and rehabilitation without transferring greater costs to communities.

Overall, authorities in SEQ have extensive experience with strategic infrastructure planning. However special emphasis should be given to road design, maintenance and rehabilitation processes, securing recurrent funding to account for increased costs and understanding of road infrastructure interdependencies to fully comprehend social and environmental challenges. Furthermore, local and state government agencies need to improve their knowledge of infrastructure assets and associated life cycles to not only increase their capacity to adapt to climate change but also account for future expenditure linked to their rehabilitation.

Nevertheless, current regimes used to planning and managing ISS do not recognize the risks posed by climate change in its entirety. Hence consideration needs to be given to how climate change can be more effectively accounted for to reduce the risks for ISS. Recognition of the impact of climate change using, for example, numerical analysis tools such as PLC or HDM4 for road deterioration may help clarify and thereby help identify the effects of climate change. Perhaps assessments of climate change risks to infrastructure should be made mandatory to owners and operators. Frameworks need to be developed within existing planning processes that will assist road authorities to adequately respond to the projected impact of climate change on road ISS as well as determining appropriate investment and adaptation responses for decision makers.

Decision frameworks should accommodate uncertainty, incorporate probabilistic approaches to assessing risk and make appropriate investment decisions (Evans et al, 2008 and 2009). For example, the US Transportation and Research Board (Committee on Climate Change and U.S. Transportation, 2008) developed a number of questions that may be used when assessing how climate change could affect transportation assets and to enable efficient development of mitigation and adaptation responses within the decision-making process. These include:

- Identification of assets at risk;
- Establishment of hazards thresholds to guide and trigger response;
- Adoption of acceptable performance standards to optimize the level of investment required as well as to identify critical levels of service needed to protect health, safety and the lifeline of communities; and
- Identification of risks of adverse impacts or consequences if no action is taken.

Last, with the projected increase in extreme weather events, evacuation planning will become more critical and frequent thus necessitating transportation providers to work more closely with weather forecasters and emergency managers. This greater coordination and communication between transportation providers and emergency managers should not only occur in the post-disaster response phase but also in the pre-disaster phase to ensure that emergency management considerations are taken into account when infrastructure and roads are being developed/built and to ensure that evacuation routes will be resistant to extreme weather events. Changes to the design of road and also other transportation infrastructure are expected since many of the materials used are highly dependent on environmental factors. It is anticipated that design trends will have to be re-evaluated to address the projected impacts of climate change and will obviously necessitate extensive research and testing before, for example, alternative materials can be used. Planning methods for transport currently place a large emphasis on reducing the risk of climate change to ISS by attempting to avoid vulnerable locations such as low lying regions. Overall the adaptation strategies employed will be determined based on the possible impact that a particular ISS may have on the safety of the community, the effects on overall transport system performance, the cost of implementation, and public perceptions and priorities.

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