Scenario Planning and Emerging Global Trends for the Future of Roads and Automobile Transport

A Sustainable Built Environment National Research Centre (SBEnrc) Discussion Paper by Curtin University and the Queensland University of Technology

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1. Introduction

Roads and road infrastructure will be faced with multiple challenges over the coming decades – challenges that in many ways bear little resemblance to those previously faced - and as such will require new approaches. The opportunity exists to transform the way road infrastructure is conceived and constructed, as a key part of the process of assisting society to respond to climate change and reduce other environmental pressures. Innovations in road construction, use and management in order to manage these changes can now be seen. Scenario planning is one tool that can take into account emerging challenges, develop or adopt new approaches, and thus help this transformation to occur. The paper explores scenario planning methodologies, global innovations and trends in road construction and maintenance and the findings from stakeholder workshops in Brisbane and Perth. It highlights key opportunities for road agencies to use scenarios to enable planning that, in the face of future uncertainties, facilitates appropriate responses.

The findings of the Future of Roads research project highlight the opportunities for road agencies to utilise scenarios to enable planning for possible future uncertainties and to help facilitate responses. It is important to consider the future environmental, economic and social impacts of roads because of their role in our society and the scale of the infrastructure. Also challenging to consider is how this use and impact might change in the future. For example, roads support an automobile industry that employs millions of people and sells a copy of its product every 1.5 seconds.[1] Road infrastructure also supports vehicles that combust 310,000 barrels of oil every day in Australia and emit 17% of Australia's greenhouse gases in turn threatening global climatic stability, local ecology and agriculture industries.[2] Much research also supports that mode choices are changing as people adopt more sustainable lifestyles and choose locations which support reduced car dependence.[3,4] [5] Scenarios provide a shared language through which decision makers and stakeholders can overcome preconceived ideas, and discuss and develop informed strategies and plans that combat risk and incorporate necessary and positive changes.

While the economic benefits of road construction and use is well known, the environmental impact and associated future social and economic impacts is underestimated. The past decade has seen a focus on the footprint and alignment of roads to minimise ecological disturbance. The coming decade will see a focus on the resources required to build and maintain roads along with, increasingly, the use of roads, the distribution of road space and also the community expectations of roads. These focuses were firmly established during the Brisbane stakeholder workshop (2011).

In the future, the whole complex transport system, from road construction to road use by all mode users, will have to be planned comprehensively, in line with changing societal expectations regarding mobility and mobility choices, rather than the current practice of different modes competing with one another. Together with pressures from climate change, transport agencies are facing predicted resource shortages, increases in energy and natural resources prices, increased costs related to greenhouse gas emissions, and changing usage and expectations of roads. Hence, transport agencies around the world are reconsidering their approach to the coming decades as the requirements will be much different to that of the last two decades. Understanding this, and seeking to inform efforts, Figure 1 shows a stylistic representation of the changes that are likely to be experienced in transport agencies in the coming two decades. The figure shows two circles for each division within a typical transport agency. The unbroken line indicates the baseline and the broken like indicates the level of additional focus that will be needed in this area in the coming decades. Each of the three focuses of this project will provide valuable guidance in this process, namely: highlighting opportunities to reduce carbon intensity of roads, informing efforts to monitor and report on sustainability performance, and providing a structured approach to interrogating trends to identify risks and develop strategies.

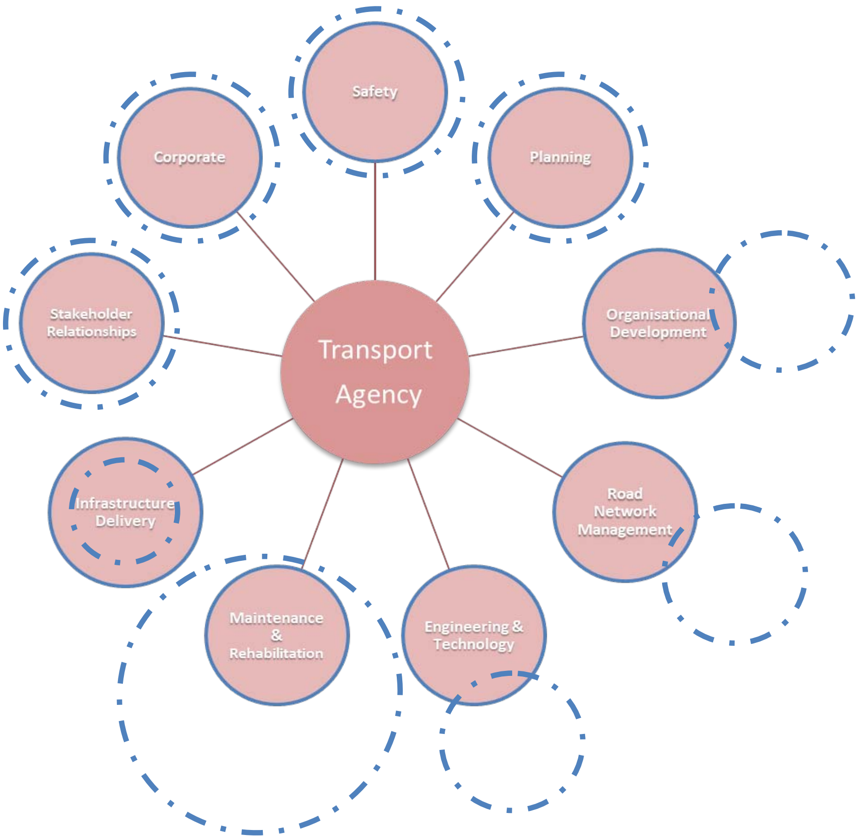

Figure 1: A stylistic representation of the potential changes in both focus and scope to the form of transport agencies in the coming decades (based on the structure of the Western Australian and Queensland government)

This paper provides the background necessary for the third component of the ‘Future of Roads’ project, strategic area three. The project developed and tested a scenario planning methodology through which a range of scenarios can be created. These can consider the availability, reliability, appropriateness and cost of existing and emerging options, and the likelihood of adoption, in the context of various socio-economic and environmental conditions. The findings highlight the opportunities for road agencies to use scenarios in planning, given future uncertainties. This report is divided into 3 parts:

1. An overview of scenario planning methodology as applicable to a workshop style format and to road agencies;
2. An outline of emerging global trends for the future of roads and automobile transport; and
3. A report of the workshops conducted with stakeholders in Perth and Brisbane in April 2012.

The trend sheets constructed for the stakeholder engagement scenario planning workshops are also provided in Appendix C.

PART 1: SCENARIO PLANNING METHODOLOGY

1. Introduction: Utilising scenario planning strategies

It is vital to consider the future environmental, economic and social impacts of roads given their role in our society and the scale of the infrastructure involved, but it can also be very difficult to do this. In this respect, scenario planning helps. Scenarios are stories of the future. They are not predictions; rather, they are narratives aimed at developing constructive thinking about the future. They support informed decision making, enabling analysis of decisions, the understanding of relationships between issues, and the challenging of cultural norms and assumptions. They are part art and part science. In the act of developing scenarios, strategies and plans are created that address risk and incorporate necessary and positive changes. The availability, reliability and cost of existing and emerging options are considered, as well as the likelihood of adoption and the appropriateness of each option in the context of various socio-economic and environmental conditions.

In order to enable scenario development specific to road agencies to occur, various scenario planning methodologies were explored, and a scenario planning method for the future of roads was developed. This was then tested in stakeholder and expert workshops conducted by the research team in April 2012 in Perth and Brisbane (see Part 3), building on the findings of prior stakeholder workshops in 2011. The workshops enabled the research team to learn from the experiences of participants, identified a range of challenges for the team to consider, and generated a strong understanding of how the research can directly support and enhance industry and government practices and policies. Hence, the workshops were a valuable opportunity for the research teams to engage with the project partners and experts in the field so as to ensure that the projects are well informed and guided towards tangible outcomes.

This discussion paper provides the initial scenario planning discussion for the third component of the project. It does not focus on scenario modelling research, rather focuses on scenario methodology that could be accomplished within the time frame and the limitations of the project and also scenario methodologies that are applicable in a workshop style framework. Furthermore, this review focuses not on the content of the scenarios but rather on how they are developed. The primary disciplines investigated include futures research, resource management and business, and sustainability based methods.

2. Scenario Planning

The process of developing scenarios is as important as the final scenarios themselves, in that it facilitates active and interdisciplinary learning, and involves the deconstructing of preconceived ideas about the future, as well as biases and cultural or institutional norms. The process, therefore, enables positive, practical and proactive strategies to be developed. Scenarios are stories of the future. They are not predictions. Rather, they are narratives aimed at developing constructive thinking about the future;[6] 'a means of exploring a variety of long-range alternatives'.[7] '[W]hile we cannot know what will be, we can tell plausible and interesting stories about what could be'.[8]

The scenario planning methods commonly used today started primarily in the 1970s, with the Royal Dutch Shell (Shell) organization. Shell was concerned with increasing oil prices and other uncertainties resulting from the formation of the Organization of Petroleum Exporting Countries (OPEC) would impact on their business. In order to help reduce some of the possible risks they developed a scenario plan addressing how they might respond. Thus, when the oil price did rise in October 1973 Shell was prepared. Shell's scenario planning method uses a relatively qualitative technique designed to be conducted in a workshop, to include various decision makers and to enable them to see beyond their preconceived ideas of the future. The technique develops a small number of scenarios (usually 2 or 4) from a set of critical uncertainties or key trends. Many of the current scenario planning methods have been developed (or built upon) from the Shell's scenario planning methods.[9]

Scenarios need to represent a range of alternatives, not just the best and worst outcomes, and their reliability is less important than the conversations, learnings and decisions introduced to the discussions. The common generic types of scenarios are:

> **Inductive scenarios:** These are stories about the future based on the critical uncertainties developed from discussion and exploration of drivers and trends.
>
> **Deductive scenarios**: These are scenarios created using two or more critical uncertainties to structure scenarios.
>
> **Incremental scenarios**: These are scenarios developed from one 'official' future and two plausible alternatives.
>
> **Normative scenarios**: These are visioning futures: they are the futures we want to happen.[10,11,12]

The process of developing scenarios, usually conducted in a workshop setting lasting one to three days, is as important as the final scenarios themselves. The process, through active and interdisciplinary learning, allows for the deconstructing of preconceived ideas about the future, and of biases and cultural or institutional norms. The process, therefore, enables positive, practical and proactive strategies to be developed, rather than 'reactive decision making'.[13]

Scenarios provide support for informed decision making, enabling analysis of decisions, the understanding of relationships between issues, and the challenging of cultural norms and assumptions. They enable strategies and plans to develop that combat risk and incorporate necessary and positive changes. They are part art and part science.[14,15]

2.1 Uncertainties

Scenarios revolve around driving forces and critical uncertainties. These are the 'on-going forces that help to shape the future' and the acronym STEEP identifies key aspects of scenarios: social, technological, economic, environmental and political.[16] The driving forces that are most important trends to the focal issue and the most important and uncertain of these are critical uncertainties. Driving forces can be predetermined, and certain or uncertain. The critical uncertainties are the key driving forces, used to develop and shape scenarios that can challenge current thinking and provide insight into how the future might develop. Critical uncertainties can be weighted or grouped as appropriate to the development of the scenario.[17,18]

Critical uncertainties do not have to be catastrophic events, although this is often the case, with scenarios revolving around risk management or large-scale environmental or economic disasters. There is a growing trend for scenarios concerned with global futures, particularly around issues of climate change, population growth and the depletion of natural resources. These scenarios usually depict alternative futures, offering either pessimistic or hopeful worlds.[19] Common critical uncertainties, or drivers of change are discussed in section 6 below, including the drivers of change that emerged from the stakeholder workshops.

3. An Overview of a Scenario Planning Methodology as applicable for the future of roads

This project has determined that when developing scenarios on the future of roads, an organisational situation and as identified through the stakeholder workshops, the scenarios need to:

1. Provide a snap-shot of the future to guide future planning; and
2. Have a clear audit trail in order to facilitate future planning.

In addition, a scenario planning framework that is useable in a workshop situation is needed. Therefore, a basic scenario planning framework could be considered to consist of the following steps:[20]

1. Background preparation:
    a. Conduct interviews with a wide range of stakeholders.

   b. Develop an overview of current issues, trends, emerging technologies, innovations and investments in the field.
   c. Identify key issues.
2. Define a scenario question/problem/statement/focal issue.
3. Define a timeframe. (This could be a staged time frame, i.e. ten years, twenty years and so forth).
4. Determine and discuss current trends. Make sure all participants understand the trends. From these, determine what is certain (will apply regardless of what the scenario is), what the driving forces and the critical uncertainties are, and any relationships between these.
5. Work through the critical uncertainties and develop a basic scenario structure (sometimes called mini-scenarios) for each scenario. This step can use various structuring elements or frameworks such as:
   a. Various inductive matrix tools, such as the 2x2 matrix;[21] or the Millennium project matrix.[22] These can be simple as creating a table and placing the chosen driving forces down the left-hand side and the columns for scenarios placed along the top.[23] The driving force parameters are then assigned to the scenarios looking at an appropriate range. This table produces the overall parameters for the skeletal scenarios;
   b. Inductive or story telling approaches;
   c. Normative approaches where you work backwards from a future you want to happen;[24]
   d. Shell's branches of uncertainties;[25]
   e. CLA inflection; or
   f. Grouping methods (i.e. enabling, unclear, absent and restrictive).
6. Test the scenario structure outcomes against the current trends, making sure the scenarios are valid, internally consistent, relevant, and different enough from each other to provoke useful dialogue. Determine whether any of the interactions in the scenarios can be formalised via a quantitative model, and whether this would be helpful
7. Develop the scenario details into a coherent story. This step should be done in groups using the framework as a guide to create a narrative.
8. Construct a powerful title/metaphor for each scenario.

   Identify strategies and action plans for each scenario. Determine the possible strategic opportunities and barriers embedded in each scenario, and develop action plans. This step looks at how the scenarios can be implemented and developed, including the implications of each action.

A typical workshop style scenario planning methodology is illustrated in Figure 2. This was developed further to be applicable to road agencies, and then tested in the stakeholder workshops (see Part 3). The process explores future trends related to roads and sustainability in order to consider a range of possible strategic responses.

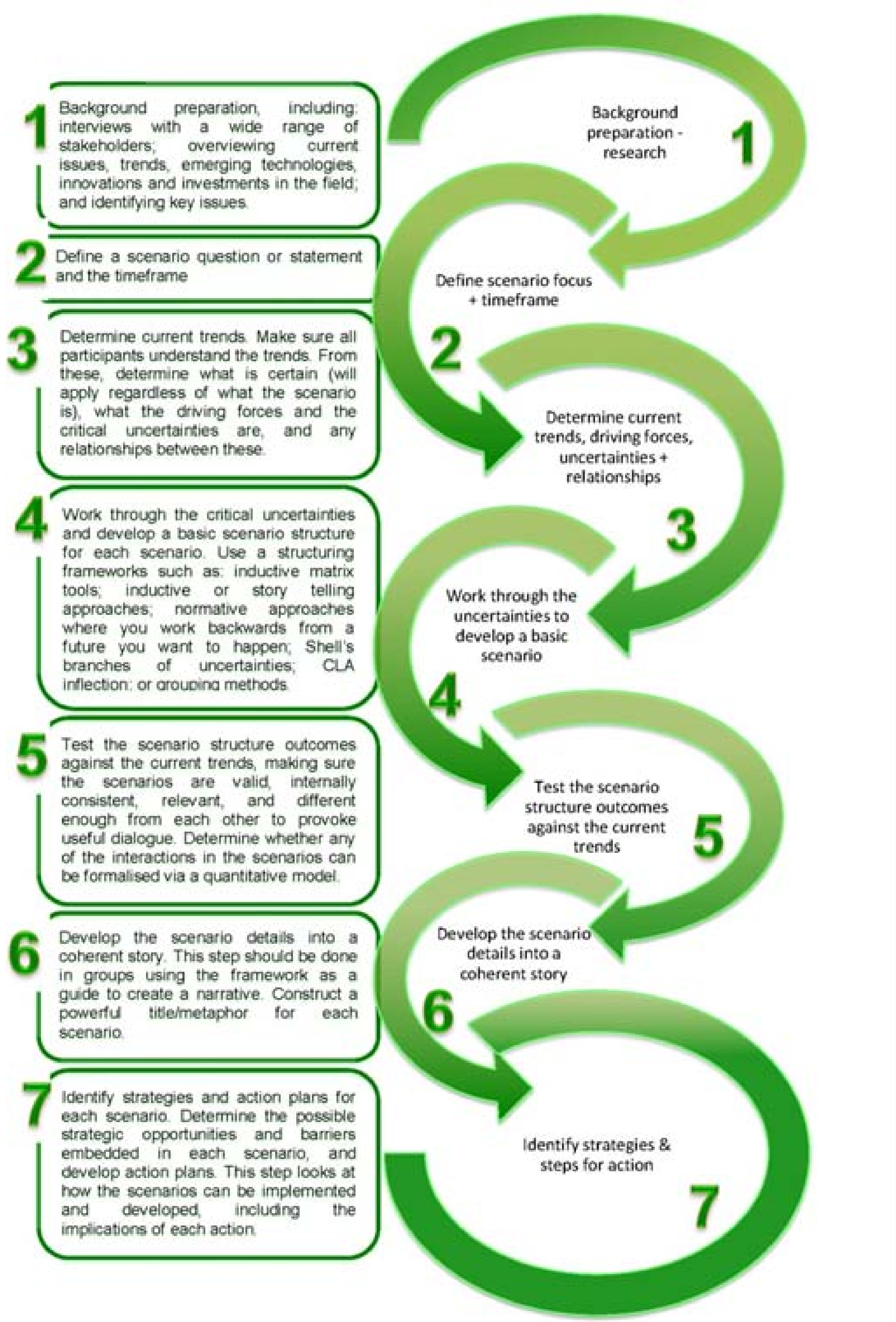

Figure 2: A typical workshop style scenario planning methodology.[26]

3.1 Structuring elements or frameworks

The development of scenarios is not nearly as linear or mechanical as the above process implies. Rather this basic framework could be varied depending on the purpose of the scenarios. It is important to use judgment and intuition in the development of scenarios. In addition, as highlighted by Shell International, the use of probabilities is problematic when constructing scenarios as the point is to incorporate variations into scenarios, rather than 'collapse differences into a single quantifiable and comparable value'.[27]

Scenario structures can be combined as appropriate with the principle variation in how the critical uncertainties are developed into a scenario framework (step 5 above). Some of these variations can be expanded. The 2x2 matrix or double uncertainty method is used to develop four scenarios that generate challenging questions.[28] The method follows a clear problem solving structure using two uncertainties and generating four possible outcomes or scenarios within a workshop setting using a matrix (illustrated in ***Figure 1***). The 2x2 matrix uses two unrelated critical uncertainties as the drivers (axes) of the matrix. The interface between the two uncertainties (how they play off each other) is what creates the scenarios, with the uncertainties representing conceptual poles encompassing what is possible within the timeframe, or in other words 'continuum of possibilities ranging between two extremes.'[29]

For the purposes of this project, while the use of a 2x2 matrix provides a clear and logical structure from which to develop scenarios, it is very dependent on what is chosen as an axes and is very much based within current ideologies without allowing much room for critical thinking or the incorporation of varying standpoints, which can somewhat result in scenarios that offer little in the way of surprise.[30,31] For this project, it would be useful to combine this method with others such as the Manoa method of creating a futures wheel or the inflection phase used in causal layered analysis (CLA). The Manoa approach is a creative approach used for long-term scenarios (25 plus years) and uses emerging drivers (also called weak signals—the drivers of change that are only just becoming noticeable).[32] This approach uses a mindmap or cascade of impacts (primary, secondary and resulting) of each uncertainty referred to as a 'futures wheel'. From the futures wheel it is the cross interactions of the resulting impacts that help to create the scenarios. CLA is a post-structural participation approach developed by Sohail Inayatullah in 2004, used mainly Australia and Asia.[33] CLA divides knowledge into four layers: litany (how trends are presented in the public domain, for example: 'Globalisation will erode the local colour in our organisation'); systems ('causal understanding-ideology'); worldview; and metaphor (**Figure 2**).[34] The inflection or metaphor stage introduces a challenging metaphor or perspective into the story developed aimed at introducing a change in direction (an 'inflection') that enables scenarios and insights to emerge that would not otherwise. This inflection needs to be treated with some caution however so as not to produce scenarios that result in policy and strategic insights that are hard to determine.

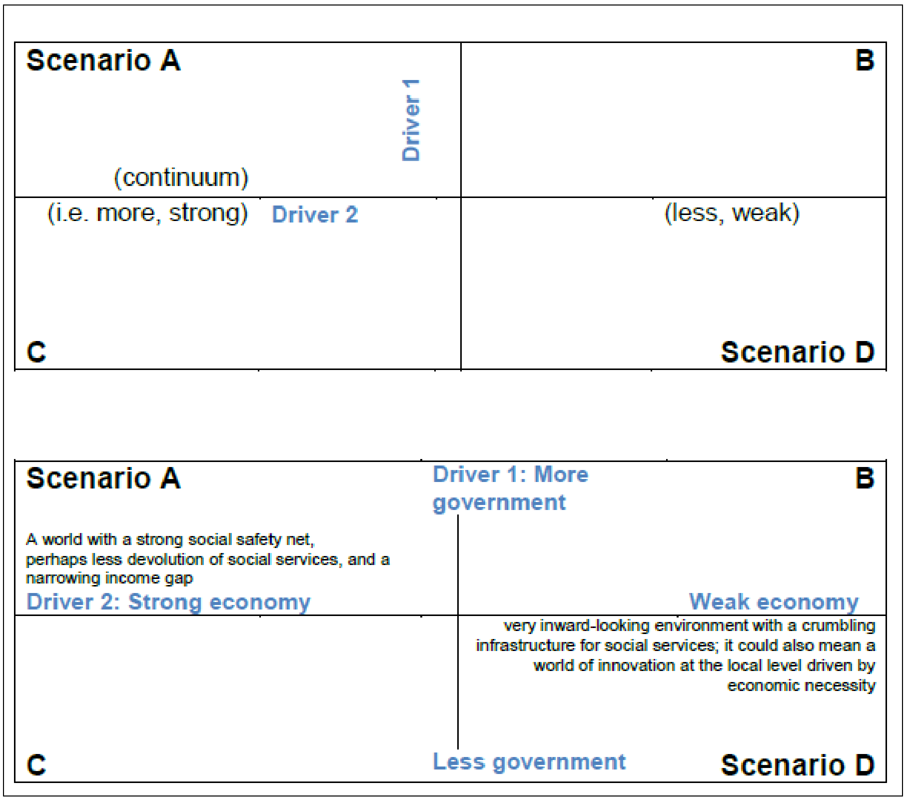

Figure 1: Example of the 2x2 matrix framework. Source: Example compiled and constructed from Global Business Network (2004)

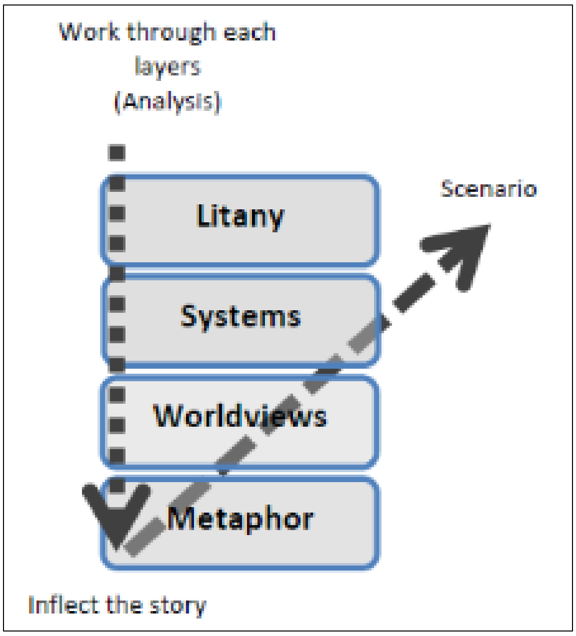

Figure 2: CLA approach to scenario planning. Source: Redrawn and altered from Curry & Schultz (2009)

3.2 Consistency and plausibility questions

It is important to check the scenarios for consistency and plausibility. This can be done through asking:

a. Is the scenario relevant?

b. Does the scenario connect directly to the mental maps and concerns of users?

c. Is the scenario internally consistent, and is it perceived as consistent?

d. Are the scenarios archetypal (do they describe different futures, rather than just variations on the one theme)?

e. Is the period of time for the scenario realistic? (Each scenario should describe an equilibrium or a state in which the system might exist for some time, rather than a highly transient state for which companies and organizations cannot prepare.)[35]

4. Common Drivers of Change used in Scenario Planning

There are common drivers (key trends) of change that emerge in many scenario planning frameworks that worth consideration in the development of the critical uncertainties for scenario development within the future of roads.

Some important ones are listed in Figure 5.

Common Drivers of Change	
Economics.	How will the economy change?
Leadership.	Is there appropriate leadership that can drive the changes needed?
Governance.	What are the current governance structures? Are they likely to change? What changes are needed here?
Employment.	What are the employment rates & models?
Demographics & Population.	What are the current population trends?
Social & cultural Issues.	What are the current cultural trends, barriers, norms & requirements? Are there gender, poverty and/or equality issues?
Environment.	What are the current environmental barriers? What are the trends in environmental policy? What areas of land need to be protected?
Air Quality.	What are the trends in air pollution regulation? What are the CO_2 levels and the CO_2 reduction policies, mitigation requirements & targets?
Water.	What is the cost of water? What are the water saving measures, policies stressors? What are the water reuse technologies and trends?
Energy.	What are the energy use trends? What are the energy policies? What are the energy requirements? What are the trends in energy provision?
Infrastructure costs.	What are the infrastructure costs? What are the projected changes in infrastructure costs? What are the timings of infrastructure costs?
Infrastructure maintenance.	What are the timings of infrastructure maintenance?
Housing.	What is the growth rate for housing?
Transportation.	What are the trends in transportation? What are the transportation investment trends?
Land use.	What is the density? What are the percentages of different land uses? What are the land use trends?
Technology.	What are the current relevant technology trends?

Figure 5: CLA approach to scenario planning. Source: Redrawn and altered from Curry & Schultz (2009)

A key aim of the workshops is to allow the workshop findings to guide the scope and structure of the SBEnrc project, ensuring that the project would deliver strategic benefits to stakeholders and partners. This is discussed in the next section.

4.1 Potential drivers for scenario planning on the future of roads from the workshops

The 'Contribution of Road Areas to the Mitigation of Climate Change' strategic area discussed in the stakeholder workshops identifies the opportunity for utilising road areas to contribute to the mitigation of climate change and strengthening infrastructure resilience. Potential drivers were determined to be: climate change and resource shortages (including labour and skill shortages along with resources such as oil and water). The workshops also identified key considerations for the development of future scenarios for roads and considered aspects that would be critical for analysing the scenarios. Of particular interest to the stakeholders was that the scenarios enable them to be able to deal with surprise (environmentally and financially), to determine the appropriate response, enable them to develop relationships (collaboration) across stakeholders and disciplines, inspiration, enabling political frameworks to be respond to events beyond political timeframes, inform risk identification/management and also illustrate a wider use and function of roads than is currently considered within road agencies. Key critical topics for the development of scenarios identified during the Brisbane workshop are illustrated in **Table 1**.

Table 1: Potential key drivers for scenario planning on the future of roads. Source: SBEnrc, Project 1.3. Future or Roads Stakeholder workshop report (unpublished, 9 September, 2011)

Potential key drivers for scenario planning on the future of roads	
Resource availability	Governance and law
Greenhouse gases/ fossil fuel vulnerability	Increasing freight impacts
Community	Technology advances
Skill shortages	Road funding vulnerability
Increased mobility choices	Population
Mobility fees and charges	Land use planning
Climate impacts	

In addition to the critical topics above, the workshops identified that a key 'game changer' is that in the future the complexity of the whole transport system from road construction to road use by all modes users will have to be planned comprehensively rather than in competing objectives between the modes as it currently is. Furthermore, this is important because of the changing societal expectations regarding mobility and mobility choices.

5. Future Research Needs and Directions

This discussion paper highlights the need for further research on integrating the use of models within scenario planning. This research has focused on workshop style scenario planning framework rather than those that use models, however, increasingly the use of models is being incorporated into the development of scenarios. Modelling is particularly helpful when looking at scenarios dealing with changes in population and the corresponding changes in consumption (ecological footprints) and water use. In addition models are often used in conservation to track the changes of vegetation and when investigating the possible impacts of climate change, particularly sea level rise. Of particular interest to this project is the Australian Stocks and Flows Framework (ASFF) modelling platform, which is an interactive model looking at physical economies developed by CSIRO and 'Whatif? Technologies'. This is a growing area of research and requires integration with most scenario planning literature focusing solely on creating qualitative narratives rather than on quantitative modelling. This is a growing area of scenario planning.[36]

In addition the use of Collective Intelligence (CI) is an emerging field. CI creates intelligence from synergies between data, information and software/hardware. It continually learns from feedback and produces just-in-time knowledge. An example of CI would be Wikipedia. CI is being explored by the Millennium Project, and possibly could create synergies in developing scenarios.

6. Conclusion

Scenarios provide a shared language in which decision makers and stakeholders can develop and discuss strategies for the future. They are not predictions. The scenario planning method described here aims to provide a basis for a framework for the development of an 'Innovative Scenarios for Sustainable Road Infrastructure' (ISSRI) scenario planning methodology. Furthermore, the discussion outlines possible key drivers of change and critical uncertainties from which scenarios on the future of roads can be developed in order to facilitate adaptation and mitigation of climate change.

PART 2: EMERGING GLOBAL TRENDS FOR THE FUTURE OF ROADS AND AUTOMOBILE TRANSPORT

1. Introduction: What are the emerging global trends?

There are a number of global trends emerging that will have an impact on road use, construction, maintenance and distribution of space. Australian cities are facing increasing pressure from climate change, population growth, infrastructure constraints, significant changes to weather patterns, increases in energy and resource prices, resource shortages and changing use and expectations of roads. Of particular importance are changing community expectations regarding road space allocations and mode use. Car ownership is declining and there is a growing shift towards more sustainable lifestyles and higher density living in Australian and U.S. cities. Public transport use is rising. However, although car ownership is declining, transport infrastructure as a whole (for both transit and roads) in Australia is reaching capacity. Resources, particularly oil, but also water and aggregates, are decreasing. These issues raise some interesting questions when looking at the future of roads. . Global trends impacting on road infrastructure, use, maintenance and operation are explored, looking first at general global trends and then at some specific trends impacting on roads.

The Intergovernmental Panel on Climate Change (IPCC) Assessment Report concludes that the 'warming of the climate system is unequivocal'.[37] The financial implications of the impacts of this warming are significant. The average land temperature in Australia has risen by 0.9°C since 1950. Average global temperatures will increase between 1.1 and 6.4°C by 2100[38] with Australia's temperatures projected to increase by between 0.4°C and 2.0°C above 1990 levels by 2030 and 1 to 6°C by 2070.[39] These increases are causing the established weather patterns to change and extreme weather events, such as flooding, storm surges, droughts and heat waves, to become more common. Australian cities may be affected more by tropical cyclones, heat waves and extreme precipitation that would degrade infrastructure and have public health implications. Inland areas are expected to warm faster than the global average, while coastal areas would warm at around the global average. This warming will result in more extreme heat events, with the average number of days in which the temperature exceeds 35°C expected to increase by 10 to 100% by 2030.[40] Changes in average precipitation are also expected to result in more extremes, with areas in which rainfall increases are expected seeing more extremely wet years, and those in which the rainfall is likely to decrease seeing more droughts. A further decline in average precipitation in southwest and southeast Australia is predicted, with increases in precipitation in the northwest. Sea level rise of between 8 and 88 centimetres along Australia's coastlines, where all the major cities are, is also predicted.[41] These changes indicate that extremes will become more frequent and more severe resulting in more extreme weather events and have significant implications for the future of road construction, maintenance and use.

Many natural resources are becoming constrained or negatively impacted by human activities. Roads require a large amount of resources, particularly aggregates and water. A typical two-lane bitumen road with an aggregate base can require up to 25,000 tonnes of material per kilometre (km), but these resources are becoming scarcer with a major shortage of quarry products. Water resources are also becoming difficult to utilise as Australia has been experiencing droughts and increasing salinity in ground water and stricter regulations on water use.

Road construction also uses a lot of energy, much of which is derived from oil oil, which is becoming increasingly scarce and expensive. There has been much debate about when the geological peak of oil will happen, however in economic terms the peak occurred in 2005 when the production of conventional oil (cheap oil which can be produced under about $65/bbl) peaked. The oil production of the five major oil companies peaked in their oil production in 2005 and has gone down since. The production of unconventional oil (deep water, remote and shale) is increasing, but this is very inefficient and expensive. Furthermore many of the oil resources are located in conflict zones.

Much research indicates that mode choices are changing as people adopt more sustainable lifestyles and choose locations that reduce car dependence.[42,43,44] Thus levels of walking, bicycling and public transport use are increasing, while kilometres travelled by private vehicles are decreasing This is due to a number of factors including the negative impacts of urban sprawl and traffic, particularly the environmental and social impacts, along with negative impacts on human health, the rising cost of petrol, the adoption of sustainability or 'green' values, and a marked cultural shift of people moving to more urban locations. The car fleet in the U.S. has peaked, with plunging car sales exacerbated by economic contraction. Australia is following this trend, with public transport usage and cycling usage increases and the use of private vehicles decreasing. From "2001 to 2009, the average annual number of vehicle-miles travelled by young people (16 to 34 year olds) decreased from 10,300 miles to 7900 miles per capita – a drop of 23 per cent."[45] In the U.S. this trend is even more pronounced with, "young people (16- to 34-year-olds) who lived in households with annual incomes of over $70,000 increas[ing] their use of public transit by 100 per cent, biking by 122 per cent, and walking by 37%" from 2001 to 2009.[46] The global cities data show that in ten major U.S. cities from 1995 to 2005 transit boardings grew 12% from 60 to 67 per capita, five Canadian cities grew 8% from 140 to 151, four Australian capital cities rose 6% from 90 to 96 boardings per capita, while four major European cities grew from 380 to 447 boardings per capita or 18%.[47] In Perth the rail patronage grew from seven million passengers per year to 60 million passengers per year. Furthermore, for the first time in history, the Australian Federal Government funded more urban rail than roads. It is predicted that this trend will continue.

In addition to changing transportation use and requirements are planning programs based on the idea of compactness. Compactness is a widely accepted planning policy in Europe and is increasingly being implemented in an Australian and U.S. planning context.[48] A tighter (or fine) urban grain enables cities to maintain continuity within a small area and be easily accessible on foot and by bicycle. A sustainable city needs to be compact[49] and compactness has been shown to influence travel choices and to result in greenhouse gas emission reductions more than sprawling cities.[50,51] All major metropolitan urban plans in Australia have set targets of between 40 and 70% of residential development to be built in developed areas (infill development) and around existing infrastructure. In the Perth Metropolitan region 47% of development needs to be in existing urban areas. These plans require compact urban development in appropriate locations, for example, close to public transport, along urban corridors and near existing retail and employment centres. As a result of these plans, as well as changing residential needs and lifestyle choices, densities are increasing in Australia. *As this occurs and road use declines, roads will be used for different purposes, posing a challenge for road management.*

Furthermore, transport planning is becoming increasingly integrated and holistic and taking into account social, economic and environmental drivers and outcomes. This can been seen recent planning processes in relation to Hoddle Street in Melbourne and the South Road Planning Strategy in Adelaide. Such processes are becoming mandatory as part of large infrastructure projects, and are recommended by Infrastructure Australia and COAG. They require that the wider impacts – particularly community impacts – of projects be considered, including land development opportunities and needs, and the balancing of social, economic and environmental needs.

In 2010, the Organisation for Economic Co-operation and Development's Economic Survey reported that Australia is suffering from an 'infrastructure deficit'.[52] Growing population and lack of spending of transportation infrastructure have led to increased congestion on roads and on rail lines. Public transport use has grown rapidly in recent years, as discussed above, and is reaching capacity limits in most major cities, especially during peak hours. Furthermore rail freight has also reached capacity. A recent Royal Automobile Club (RAC) survey reported that in the last year 43,000 more cars came onto Western Australian roads with 400,000 more cars are expected to be added to the Perth roads over next 10 years.[53]

Currently, during peak hours, drivers in WA are often delayed 45 seconds for every kilometre they have to travel, Sydney residents add a minute to every kilometre (Association of Australian and New Zealand road traffic and transport authorities). Yet our cities have limited space in which to build bigger roads able to cope with increased growth and Australian cities lack complete transit networks particularly in the outer areas. This trend has huge impacts on the economy. The RAC report found that 70% of businesses surveyed found that road congestion was adding to their business costs and was impacting on staff punctuality. Furthermore one in five business owners said they can't take on more work because of traffic gridlocks. The Bureau of Infrastructure, Transport and Regional Economics, in 2007 reported various costs of urban road congestion with some projections of up to $20 billion per annum by 2020.[54] Furthermore there are costs associated growing obesity related to increased time spent commuting.

The Australian road network spans a wide variety of geographic areas and according to the Bureau of Infrastructure, Transport and Regional Economics (BITRE) it extends a distance of 814,000 kms. Road maintenance costs are estimated to be $5 billion per year. However these costs are expected to increase by over 30% by 2100. The climate change impacts of hotter temperatures and changes in rainfall (both making some places in Australia wetter and some places drier) will increase the cost of road maintenance, both by making road maintenance harder to accomplish due to extreme weather and likely material and skill shortages, and making it more necessary. A wetter climate will lead to a higher rate of pavement deterioration, while higher average temperatures will increase the loss of volatiles from bitumen, causing roads to lose elasticity, become brittle and have a shorter service life. Increased temperatures will also accelerate the deterioration of seal binders and require earlier surface dressings. Higher water tables will accelerate the rate of pavement deterioration as capillary action will increase the moisture content of pavements. This means roads will have to be thicker and have additional measures to cope with increased moisture. However, material costs are rising, and if road surfaces are not suited to the future climate, they will need more and more maintenance and cost more money.

Freight is expected to increase rapidly, with some reports of a trebling of freight by 2050. The freight task in Australia’s eight capital cities is expected to grow by 50-70% between the years 2003 and 2020, with 60% of freight being moved by trucks rather than trains. Furthermore, freight vehicles are becoming bigger and bigger. This has implications both for space and also for road construction, maintenance and longevity. Freight transport already accounts for 4% of Australia’s national emissions, and this is expected to increase to 13.5% by 2020.

At a community level there is a growing trend more towards consuming less and sharing more, primarily through the internet. Botsman and Rogers describe it as ‘collaborative consumption’—the sharing of assets, both goods and knowledge, through the use of real-time network technologies, such as Facebook, Twitter, or the trading or selling of goods over the internet. In their word, “(w)here the 20th century was about hyper consumption, the 21st century is about collaborative consumption…We have moved from the age of ownership to the age of access…We are going back to old behaviour, reinvented for the Facebook age. We are sharing, trading, swapping – all through social media.”[55] They cite a survey indicating that 75% of young people would rather own a smart phone than a car.

However, there is a key opportunity for road designers to contribute to climate change mitigation efforts through the use of innovative design and technologies and also reduce the resource requirements.

2. What are the emerging global trends that will impact on roads and on automobile transport?

This report looks at some of the emerging global trends that will impact the future of roads and on automobile transport in cities. The report is structured around trends in various themes:

- Road construction innovations:
    - Repurposing Waste: Roads as Repositories for industrial, municipal and agricultural waste; Roads constructed from plastic.
    - Roads as repositories for carbon.
    - Reducing carbon emissions.
- Generation of Renewable Energy:
    - Solar roadways.
    - The charging of electric vehicles through magnetic energy.
    - Motion power.
    - Electrokinetic generators.
    - Piezoelectric material.
- Changes in vehicles and fuel use:
    - Renewable transport (electric vehicles and smart electricity grids).
- Improving the efficiency of existing road infrastructure:

- Behaviour change.
- Technology innovations to improve efficiency of existing road infrastructure.
- Managed lanes and carpooling.
- Road pricing.
- Car restrictions through vehicle licensing.
- Bus Rapid transit.

- Sustainable streets and reclaiming public space:
    - Shared streets
    - Dismantling freeways
- Freight alternatives

3. Road construction innovations

Roads require a large amount of resources, particularly aggregates and water. A typical two-lane bitumen road with an aggregate base can require up to 25,000 tonnes of material per km. Road construction also uses a lot of energy, much of which is derived from oil. However, there is a key opportunity for road designers to contribute to climate change mitigation efforts through the use of innovative design and technologies and also to reduce resource requirements.[56]

3.1 Repurposing waste: Roads as repositories for industrial, municipal and agricultural waste

Road construction uses large amounts of quarried aggregates, however there is potential to repurposed industrial, municipal and agricultural wastes, such as glass, steel, tyres and plastics for the use as a secondary material in road construction. This process would reduce the amount of virgin materials needed for road construction and decrease the amount of waste needed to be disposed of. Recycled materials have generally been used in the lower course material, but many countries are faced more with repair and maintenance work than with the construction of new roads, and therefore the use of recycled materials in the surface layers is an area that needs further exploration. Examples of this include the reuse of plastic for road construction in India. The reuses of industrial waste for road construction was investigated by Aravind and Das[57] and presented in Table 2. A United Kingdom (U.K.) study determined that asphalt pavements containing 10-15% crushed glass in the surface course mixture performed satisfactorily.[58] Tyre rubber has also been used in asphalt mixtures to reduce cracking, improve durability and mitigate noise.[59] The use of tyres to create a 50 mm rubber/asphalt overlay has been found to reduce wet-weather accidents by 50%. A road constructed purely from recycled tyres and sand was completed to a high standard in Pennsylvania, costing $US 3 million per mile, compared to the typical local road construction cost of $US 310 million per mile.[60]

There are initiatives regarding the recycling of vehicles at the end of their life. In 2007, the U.K. enacted an end of vehicle life directive, based on the one by the European Union (E.U.), stipulating that every vehicle must be taken back free and that certain components must be recycled.[61]

Table 2: The reuses of industrial waste for road construction

Source: Redrawn and adapted from Aravind and Das (n.d.) Industrial waste in highway construction, http://home.iitk.ac.in/~adas/article07.pdf

MATERIALS	ADVANTAGES	DISADVANTAGES
Fly Ash	Lightweight, can be used as a binder in stabilization base/ sub-base because of pozzolanic properties	Lack of homogeneity, presence of sulphates, slow strength development
Metallic Slag – Steel	Higher skid resistance	Unsuitable for concrete works and fill work beneath concrete slabs
Metallic Slag – Nonferrous	Lightweight (phosphorus)	May show inconsistent properties
Construction and demolition waste	Being strong can be used as aggregates granular base	May show inconsistent properties
Blast furnace slag	Used in production of cement, granular fill	Ground water pollution due to leachate in used as unbound aggregates
Colliery spoil	-	Combustion of unburnt coal, sulphate attack in case of concrete roads
Spent oil shale	-	Burning of combustible materials
Foundry sands	Substitute for fine aggregate in asphalt mixes	Presence of heavy metals in non ferrous foundry origin, less affinity to bitumen
Mill tailings	Some are pozzolanic in nature	Presence of poisonous materials
Cement kiln dust	Can be used in soil stabilization because of its hardening property when exposed to moisture	Corrosion of metals (used in concrete roads) in contact because of significant alkali%age.
Used engine oil	Being very good air entrainer be used in concrete works	Requires well organised oil collection system
Waste tyres	Enhances fatigue life	Requires special techniques for fine grinding and mixing in bitumen, sometimes segregation occurs.

3.2 Repurposing waste: Plastic roads in India

In India, K.K. Plastic Waste Management has been building roads made out of recycled plastic waste.[62] In November 2009 they had built approximately 1,200 kms of roads, primarily in the Bangalore region. The company create a compound called polymerized bitumen by mixing the plastic with asphalt, and have found that although the material costs about 3% more than traditional asphalt, the roads increase in longevity. The Chennai Corporation plans to lay 371 kms of roads within Chennai with thin plastics mixed with bitumen in order to increase the lifespan of the roads and to also help the city dispose of plastic waste, however the project is now experiencing a plastic shortage.[63] The project is estimated cost 110 crore.

The National Rural Roads Development Agency (NRRDA) has formulated guidelines for the use of plastic waste in rural roads construction, and in conjunction with Bangalore University and the Council of Scientific and Industrial Research's (CSIR) Central Road Research Institute (CRRI),[64] they have constructed trails of plastic roads, finding that the 'plastic roads' have increased strength, are more water resistant, decrease the amount of bitumen needed, increase the longevity of the road and reduce the amount of maintenance needed.[65]

3.3 Repositories for carbon in an aggregate

There is much discussion about roads acting as repositories for carbon in an aggregate however there is not much reputable information available. Biochar is charcoalised woody biomass is used as a soil improver, however its potential to be a storage for carbon in the soil is being investigated.

3.4 Reducing and offsetting carbon

VicRoads undertook the first carbon neutral road construction project by a state road agency, trialling the process on the Mickleham road duplication.[66] To do this they calculated the carbon footprint, looking at the GHG emissions generated during on-site electricity production, fuel used during construction and transport of materials to the site and the embodied carbon in the materials. From the footprinting exercise they determined that the road created 1,751 tonnes of CO_2-e, equating to 730 tonnes CO_2-e per km of road built. 97% of this carbon footprint came from the embodied carbon in the materials, particularly from the use of concrete, cemented treated crushed rock and aggregate, and in the on-site transportation. To off-set the road construction emissions, VicRoads sourced carbon credits from an accredited offset provider, planting around 7,463 trees in the north west of Victoria.[67]

4. Generation of renewable energy

The ability of roads to produce electricity is currently being investigated. Research has been conducted into using roads to produce solar energy, and also to implement road infrastructure able to produce electricity from the motion created by road use, looking at wireless magnetic recharging systems for electric vehicles, motion power which harnesses the excess vehicle energy created when cars decelerate, articulated plates, capturing wind created by vehicles as they move past a spot and piezoelectric crystals which could produce electricity from the weight of vehicles. Many of these technologies are still in the testing phase.

4.1 Solar roadways

Roads have the potential to produce solar energy by capturing heat, similar to solar hot water systems. One of the current solutions RES® (Road Energy Systems) is a heat exchanger that incorporates tubes in the asphalt pavement.[68] This is known as an 'asphalt collector' and has been used in The Netherlands. The technology has the potential to transfer heat from the road surface making the road cooler in summer and warmer in winter, making the application in areas with snow and ice a real possibility. Furthermore the application of RES® has been found to result in reduced CO_2 emissions and has been successfully applied in The Netherlands, Belgium and Scotland.

Many roadways worldwide are being retrofitted with solar panels being used to produce electricity to run the street lighting. The Oregon 'Solar Highway', implemented in 2009, has a 104 kilowatt (dc) ground-mounted solar array of 594 solar panels, offsetting about a third of the energy needed for lighting.[69]

4.2 Charging electric vehicles through magnetic energy

Roads also have the potential to be able to recharge electric vehicles whilst they are in motion, from a strip embedded into the road surface. A Germany company, IAV, has patented technology that would allow electric vehicles to be recharged wirelessly using recessed electrical conductors that generate a magnetic field and are embedded into the road surface and activated when an electric vehicle is detected.[70] Evatra has developed Plugless Power, a wireless charging system for electric vehicles embedded in a parking spot. The vehicle parks over the pad which communicates with the vehicle using a SAE J1772 protocol used in corded systems and automatically charges.[71] The Plugless Power wireless charging system is being tested by Duke Energy, Google, Clemson University and Hertz Rent A Car amongst others with the product to be sold later this year. Similar technology is being investigated by Stanford University and MIT in the US.

4.3 Motion power

Motion power is the harnessing of excess vehicle energy created when cars decelerate. New Energy Technologies, Inc. is developing MotionPower™ technologies which are able to harness this kinetic energy and convert it to sustainable power.[72] These technologies get installed in areas where the vehicle traffic must slow down, such as at traffic lights and intersections. This is still very much in the testing phase.

4.4 Electrokinetic generators

Electrokinetic generators are articulated plates that can be places in the road surface that generate energy when driven over through the up and down motion. These ramps are capable of generating between 1-50 kW.

4.5 Wind energy

There has been much investigation into producing wind energy along the side of freeways, utilizing the wind produced by vehicle movement. TAK Studio created a Turbine Light which produces energy used to power lighting by the wind of vehicles moving past.[73] A wind turbine able to be fit onto highway billboards was developed by Arizona State University also utilizing the wind created by passing cars.[74] Neither of these inventions have been implemented, however they show potential and also innovation regarding the use of road space.

4.6 Piezoelectric material

Piezoelectric crystals could be used to absorb heavy traffic and to convert a 1 kilometre stretch of highway into a 400 kW power plant. Piezoelectric materials, crystals and ceramics, convert mechanical energy exerted by the weight of vehicles into electrical energy, with the potential to generate 400 kW per 1 km or road. Tests of a piezoelectric generator are being undertaken at the Hefer intersection on Route 4 in Israel. The test consisted of a 10m strip of asphalt with generators installed underneath and a battery able to generate 2,000 watt-hours of electricity.[75]

5. Changes in vehicles and fuel

Vehicles are increasingly being powered by alternative fuels and electricity. Plug-in Hybrid Electric Vehicles (PHEVs), Battery Electric Vehicles and vehicles that run on alternative fuels such as hydrogen or on electricity created through solar panels embedded into the structure of the vehicle. Companies are looking into producing cars that can run on compressed air and planes, trains and cars that run on solar electricity.

Indian company Zero Pollution Motors released a vehicle powered by compressed air and able to run of speeds of 96 mph. Tata Motors, India's biggest automobile manufacturer, is gearing up to release a car that runs on compressed air, called the MiniCat. The car will be a lightweight, fiberglass bodied, six-seater mini-van which uses compressed air stored in tanks that push the engine's pistons and create movement and will be able to run for 125 miles and have a top speed of 68 mph.[76]

New developments in charging for electric vehicles are becoming more common, from more advanced batteries to fast charging stations, wireless charging stations and charging strips embedded in the road that are able to charge your electric car wirelessly while you drive. Highway 101 between San Francisco and Los Angeles in California has been retrofitted as a charging corridor with 5 electric charging stations, owned by SolarCity, enabling electric car drivers to travel between the two major cities.

Electric solar panel planes are being trialled. The E430 electric plane created by Yuneec International, weighs 2000 pounds, seats two and is powered by lithium polymer batteries. The Solar Impulse, from Switzerland, is fitted with solar panels.

Many cars have been fitted with solar-panels, from smaller installations such as those in the Toyota Prius which help to regulate the temperature inside the car, thus reducing air-conditioning needs, to larger vehicles, many of which are in the testing phase.

5.1 Renewable transport

'Renewable Transport' refers to a new collection of technologies based on 'vehicle to grid' (V2G) and plug-in hybrid electric vehicles (PHEV's).[77] V2G uses the electrical storage capacity of PHEVs linked to a smart electricity grid to enable a larger amount of renewable energy into the electricity network. V2G systems demonstration projects have been put in place in Chicago and Kyoto.[78]

6. Improving the efficiency of existing roads

Australia has approximately 814,000 kilometres of road network, covering a wide variety of geographic areas. Many urban roads are struggling to cope with increased traffic, and it is therefore imperative to investigate how existing infrastructure can be made more efficient .

Some of the ways include behaviour change, technology such as innovative congestion charging or traffic signaling devices, managed lanes and vehicle licencing measures, and the prioritising of road infrastructure for public transport such as buses.

6.1 Behaviour change

Behaviour change has big potential, alongside technological innovation, to improve the efficiency of existing roads.[79] The capacity of existing infrastructure is being reached as motor vehicles and congestion increase. Chapman estimates that for 40% of journeys a viable alternative to car travel already exists and that with modest improvements a further 40% of journeys could be switched to a different mode. Complementing this is the growing cultural shift towards more sustainable urban lifestyles and a reduction in car use in developed countries.[80,81,82] Chapman maintains that ultimately the number of cars on the road need to be reduced.[83] Policies aimed at behaviour change have increasingly been implemented, including such programs as TravelSmart, parking restriction policies(for example, Copenhagen's policy of reducing parking spaces by 2-3% per year in the city centre), as well as congestion charges as in London, Singapore, Stockholm and recently Milan.

6.2 Technology innovations to improve efficiency of existing road infrastructure

Various technological innovations to improve the efficiency of existing road infrastructure are being implemented and investigated. Some of these include traffic flow streaming (contra-flows), and innovative congestion or road user charging. The Austrian Institute of Economic Research looked at various measures at reducing CO_2 emissions from road transport determining that road pricing as the most effective.[84]

One innovative technology is driverless equipment for private vehicles which will potentially be seen on roads by 2018.[85] Part of the efficiency improvements seen from driverless vehicles are that the cars can operate closer together than human driven cars adding to the capacity of roads. This technology was demonstrated in 1997 in California with eight driverless cars successfully operated just one car length apart at 65 miles per hour and again in 2007, when six driverless cars negotiated the Defense Advanced Research Projects Agency Urban Challenge.[86] As GIS technology improves, it can be utilized to keep the cars in the require position, with reports of up to two centimetres in accuracy.[87] Google was just granted the first licence for a driverless vehicle by the State of Nevada in the US, enabling the vehicle, a Toyota Prius, to be tested on public streets.[88]

The Terrafugia Transition was exhibited at the New York International Auto Show in April. It is a two-seater airplane with foldable wings able to drive on any road surface. The vehicle is currently in the testing phase, however, the company has had reservations on over 100 aircrafts with deliveries expected to begin next year. When the wings are folded the vehicle is able to be parked in a standard parking space and/or a standard garage. Under the U.S. regulatory system the Terrafugia Transition will require a Sport Pilot license in order to fly and the company is pursuing regulation for the vehicle as a 'Light Sport Aircraft' and a 'Multipurpose Passenger Vehicle'. The status outside of the US has not been confirmed.[89]

6.3 Traffic signalling to manage congestion

Increasingly freeways and highways worldwide are implementing coordinated ramp metering, sometimes called 'stop and go' systems, which spreads the flow of vehicles entering the freeway. These systems are very common in Southern California and have been implemented in Victoria, Australia.

6.4 Managed lanes

Managing lanes enables existing road infrastructure to be used in a more effective manner. This can be done through lanes used only for high occupancy vehicles, management traffic direction through movable barriers or direction reversible roads and contra-flow systems.

Managing the occupancy of lanes has been very popular in the United States with high occupancy vehicle (HOV) lanes (also known as T2/T3 lanes) that require vehicles traveling in the lane to have a certain occupancy, usually one or two passengers. There are over 2119 miles of HOV lanes currently in the United States, however, data from the US 2000 Census shows these lanes to be generally ineffective, and the lanes to be underused. Analysis of the 2001 National Household Travel Survey data illustrated that the majority of trips undertaken in the HOV lanes were by families using the lanes for discretionary activity purposes.[90] High Occupancy Toll (HOT) lanes have been proposed as a viable alternative to the HOV lanes and are lanes open to either high occupancy vehicles and to people that pay to use them. The price of entering these lanes is usually adjusted depending on the congestion levels. This aims to keep the lanes at an 'optimum flow' level.[91] HOT lanes are often seen as a precursor to implementing congestion zones, such as in London, Singapore and Milan.[92] HOT managed lanes were implemented on the Katy Freeway in Houston[93] and the possibility of implementing congestion charging through Global Positioning Systems (GPS) or Closed Circuit Television (CCTV) is being looked at in Victoria, Australia.

Changing the direction of lanes through moveable barriers, where extreme one-direction peak hour traffic flows occur, is a solution that has been used on many roads in the US. For example, on the Golden Gate Bridge in San Francisco the two center lanes are southbound during the morning rush hour and northbound during the evening rush hour, changed through the use of vertical yellow markers placed manually in openings in the roadway. The

Sydney Harbour Bridge in Sydney, New South Wales, uses a similar system reversing three of its eight lanes daily at rush hour, as does Flagstaff Road in Adelaide, South Australia, which has a reversible centre lane. This solution enables changing traffic flows to be accommodated simply by reconfiguring the existing road system.

The whole Southern Expressway in Adelaide is a one-way reversible road. This 21 kilometre expressway takes traffic into the city centre in the morning and then changes direction in the evening to enable traffic to leave the city. . A similar road operates in Brazil: a 58.5 kilometre road comprising four lanes, each of which can be reversed. Adelaide has also been operating a temporary single-lane contra-flow system on Festival Drive loop road while construction proceeds on the Adelaide Convention Centre.

6.5 Pricing congestion

There are numerous ways to implement congestion charges. Cordon charging is the most common, and involves charging drivers to enter or leave a designated zone, usually the city centre, during specific times This was implemented in Singapore in 1975, Bergen in 1986, Oslo in 1990 and Trondheim in 1991, followed by schemes in London in 2003, Stockholm in 2007 and Milan in January 2012.[94] In London's first year of congestion charging the number of private cars entering the centre dropped by 34% and the number of buses increased 22% and cyclists 28%. Drivers pre-pay a fee and failure to do so incurs a fine. Milan's scheme, which replaced the Ecopass pollution charge, consists of a flat fee of €5 regardless of vehicle type and excludes electric vehicles, service vehicles, buses and taxis.

Along with city wide congestion pricing, cities are looking into other possible pricing systems to help relieve congestion, with much interest in a distance based charge. The Netherlands has recently deferred a proposal to put a distance charge on all vehicles throughout the country. The price per kilometre would vary depending on the vehicle, but the charge agreed to by the Dutch Cabinet in 2008 averaged €0.03 per kilometre that year, with a planned increase to €0.07 in 2017.[95] A Vehicle Miles Travelled (VMT) tax is being discussed in the U.S., with proponents saying the charging system is a long term solution to help with congestion and also to raise funds to fix the aging infrastructure.[96]

San Francisco has implemented demand-responsive vehicle parking fees in pilot areas to reduce congestion from vehicles driving around to obtain parking and from double-parking. The parking fees vary by block, time of day and day of week. The parking fees vary by block, time of day and day of week. In areas of parking congestion rates increase until the congestion eases, varying from $US0.25 an hour to $US6.00.[97] In addition, San Francisco and the surround counties have made public transport free on days when extreme smog is expected.[98]

6.6 Car restrictions through vehicle licensing

Car restrictions through vehicle licensing or licence plate numbers has been implemented in numerous cities, including Sao Paulo, Brazil, 'pico y placa' in Bogota, Colombia, and in Manila, The Philippines. Most of these programs operate by restricting vehicle use on certain days depending on the last digit of the licence plate. Sao Paulo uses this licence plate system to assign a day of the week when a vehicle cannot be used during rush hour.

6.7 Bus rapid transit lanes

Bus rapid transit (BRT) systems are becoming increasingly popular particularly in countries with budget constraints, following the successful example of the system of Curitiba. , with segregated lanes, and stations with pre-boarding fare collection to enable rapid boarding and alighting. [99] BRT systems have great potential to reduce CO2 emissions. BRT systems have great potential to reduce CO_2 emissions.[100]

7. Sustainable streets and reclaiming public space

Globally there is a move towards reclaiming space that was for cars and car parking and to turn this space into spaces for people.[101,102] This process can be seen in the pedestrianisation of city centres, the implementation of bicycle ways and in the reduction of parking. Copenhagen in a global context is probably the most famous for following this transport and land use planning trajectory,[103] along with Melbourne and now Sydney in an Australian context.[104] This change is based on the realisation that city space is limited, and planning decisions must reflect how we want to use that space. For example, inn Paris, 70% of public space is devoted to traffic, of which 42% is for parking, and only 30% to pedestrians.[105]

The vibrancy and economic benefits of walkable city centres are now well recognised.[106] The changes in Copenhagen, including the turning of 22 parking lots and many central streets into public spaces, show how the gradual expansion of public spaces dramatically increases people's use of city centres, leading to increased commercial activity..[107] Furthermore, the City of Copenhagen calculated that every kilometre cycled effectively yields the City $U.S0.25 in health or road maintenance savings, whereas every kilometre driven costs the City $U.S0.16..[108]

The biggest current example of a city implementing sustainable streets and reclaiming public space is New York. The New York City Department of Transport (NYDOT) is using road capacity more efficiently and cleanly, rapidly implementing changes to the street network, the public realm and to the walking and cycling environment. The most visible changes include new plazas at Times Square, Herald Square, Union Square and Madison Square, the redevelopment of Broadway into a 'Boulevard', the introduction of a 'Summer Streets' programme.[109,110,111] The summer streets programme aims to change how people use the streets. The programme closes a number of streets during Saturdays in summer, encouraging people to enjoy the streets, and implemented programmes such as dancing in the street and 'pop-up' swimming/wading pools. In addition, the City and NYDOT have been rapidly implementing cycle paths throughout the city, with over 200 miles (321.8 kilometres) of cycle paths being added between June 2007 and November 2009, including protected cycle lanes along Broadway and 8th and 9th Avenues. Part of these changes have also included footpath extensions and many new seats throughout the city. Many of the changes involved quick and simple infrastructure changes, such as repainting road surfaces and separating car traffic and walking/staying spaces with bollards, planting boxes and fold-out chairs, enabling changes to be tested for effectiveness and changed if necessary.[112]

On May 23rd, 2009, Broadway was closed to through traffic at Times Square and Herald Square between 47th and 42nd Streets as an experiment. The trial closure was made permanent in February 2010 after follow-up surveys showed "an overall seven% improvement in traffic flow",[113] with northbound taxi trips in West Midtown (as tracked by their GPS units) 17% faster after the Broadway shutdown (comparing Fall 2009 to Fall 2008).[114,115] The closure has shown an economic benefit, with 71% of businesses in Times Square projecting revenue increases after the closure.[116] The City is still surveying the changes; however, some early results are dramatic. The above squares now accomodate 100,000 pedestrians a day and have created 11 times more space for "people activities" within the city.[117] Pedestrian injuries are also down in the project areas by 35% and 80% fewer pedestrians walk in the roadway in Times Square.[118,119] Between June 2007 and November 2009, cycling to work doubled in New York, with commuter cycling increasing by 35% between 2007 and 2008.[120]

In an Australian context, the City of Melbourne have been doing the most along these lines to implement a more stainable and people-focused city centre.[121] Since 1993, Danish Architect and Urban Designer Jan Gehl (who also worked on the New York changes above), along with the City of Melbourne, have been monitoring the results of incremental changes to the public realm and people-first planning policies. The city has experienced a dramatic growth in the number of city centre residents—from 1008 in 1992 to approximately 9,375 in 2002; an increase in pedestrian traffic of 98% on weekday evenings and 39% increase in daytime pedestran traffic; an increase in public space by 71% via creation of new squares, promenades and parks; and have revitalised their network of lanes and arcades.[122] Furthermore, the City of Melbourne has taken a number of steps to restore and strengthen the city's traditional grid pattern, including activating mid-block alleys as pedestrian spaces.

The City of Melbourne has placed a 40-metre height limit on its core, ensuring that the city's public spaces receive adequate sunlight and has established policies to encourage mixed use development, especially small business uses, outdoor cafés and restaurants, and to encourage buildings to appropriately and openly connect with public spaces, and the planting of many trees along the footpaths. Beatley and Newman contend that Melbourne has emerged as "a remarkable case study in an emerging pedestrian city, having shown some dramatic, positive change in its pedestrian character and public sphere in the relatively short span of twenty years".[123]

From all the public space changes Melbourne has become a 'brand'. It is consistently named in the top great cities of the world but not many people can say why it is famous. Now it is famous for the experience of place and celebration of urban culture.[124] Gehl, in a StreetFilm in 2008, asserts that the "overriding lesson" from Melbourne is "that even if you are a city in the new world with wide streets, with a car culture, the whole thing geared for rushing from A to B, if you are willing to give people the space they need, give the bicycles the space they need, then you can have a complete change of behaviour".[125]

7.1 Shared streets (naked streets)

'Shared Streets', also known as 'Naked streets', Woonerf, Winkelerf, Naked Streets, Home Zone, Living Yard, Living Streets, Silent Streets, Shared Streets, DIY Streets or pedestrian priority streets depending on the context,[126] is a concept developed by Hans Monderman, a Dutch traffic engineer, based on the idea of forced negotiation through the removal of signage, barriers and traffic lights so drivers, cyclists and pedestrians are all forced to negotiate with each other. When this was introduced in the Netherlands Monderman discovered that it slowed down traffic.

The method prioritises the social functions of the street, building on the idea that, "it is only when the road is made more dangerous, when drivers stop looking at signs and start looking at other people, that driving becomes safer".[127] The theory contends that conventional pedestrian infrastructure is primarily established to stop the pedestrian from interrupting the flow of motor vehicles, and to prevent accidents, but does not start from the perspective of respect for the pedestrian..[128,129]

Naked Streets have been applied with great success in the United Kingdom particularly along Kensington High Street in London, Exhibition Road in London and New Road in Brighton, and in the Netherlands and Denmark. It has particularly been utilized in city centres, such as the city centre of Copenhagen, and in residential streets, such as the home zones in the U.K. Shared Space has been discovered to reduce traffic speed by about 50%.[130] Using this approach has been found to reduce the number of pedestrian motor vehicle accidents, with Kensington High Street reporting a reduction of 40 to 60% after the removal of pedestrian barriers based on research conducted two years before the redesign of the space (1998-2000) and two years after the redesign (2003-2005).[131] New Road, in Brighton, was converted into a Shared Space in 2007 with no changes in pavement between roadway and pedestrian infrastructure resulting in a 93% reduction in motor vehicle trips through the space, lower driving speeds and a major increase in pedestrian activity, with 62% more people walking through the space, 22% more cycling activity and 600% more staying activities after the project was implemented (2007).[132]

7.2 Dismantling freeways

Part of this reclamation of roads as public space is the dismantling of urban freeways. Much US freeway infrastructure was built in the 1950s and 1960s and has reached the end of its useful life, requiring either significant maintenance or dismantling. Many cities around the world are opting to dismantle inner city freeways to return to an at-grade traditional street or to create public space. This trend has been particularly noticeable in the US with the freeways removed including Harbor Drive in Portland, the Westside Highway in New York, the Embarcadero Freeway and part of the Central Freeway in San Francisco, and the Park East Freeway in Milwaukee.[133,134] Freeway removal can dramatically improve the amenity of an area, as occurred in Seoul, South Korea, and Aarhus, Denmark, where freeway removal led to the restoration of pre-existing rivers as valued public spaces.

The Chingong motorway was an elevated expressway which ran straight through the heart of Seoul in South Korea. It was constructed during the late 1960s and by the 1990s was seriously degraded. The mayor (who was originally in charge of building the expressway) ran on a platform of sustainability to remove the freeway and restore the Cheonggyecheon River which lay underneath. The demolition of the Cheonggye Elevated Highway began in 2005 and its removal and the restoration of the river, including a river park and the reintroduction of plants and animal, have been a huge success. The mayor has now become the president of South Korea.

The Boston freeway, once a surface expressway, was converted to an underground freeway in order to rejuvenate the city centre. The project was one of the most ambitious freeway removal projects in the world and took over 15 years and cost $US15 Billion.[135] The project converted a six-lane elevated freeway to an underground freeway of 8 and 10 lanes and included two new bridges. The project opened up more than 300 acres of land and reconnected the city centre to the waterfront.

The removal of the Embarcadero freeway in San Francisco in the 1990's is one of the most famous examples of a freeway removal and restoration of a historic waterfront. The Loma

Prieta earthquake in 1989 caused serious damage to three major freeways in the city requiring them to be closed. Following this it was decided that the Embarcadero Freeway that ran along the waterfront in downtown San Francisco and the Central Freeway would be removed (the third freeway, the intersection of Interstate 280 and U.S. Highway 101 in the south part of the city was repaired as it was a major junction of two freeway systems). The Central Freeway was redesigned in 2005 into an at-grade boulevard. The Embarcadero Freeway was originally designed to connect the Golden Gate Bridge and the Bay Bridge along the waterfront with a two level elevated freeway, however as part of the 'Freeway revolt' in the 1960s only a one mile stretch of it was built. This one mile carried 60,000 cars per day. Following the earthquake, the freeway was demolished in 1991 with a six-lane boulevard, a historic tram line and cycle paths. The demolition also allowed for the restoration of the historic ferry terminal, which was once separated from the centre by the freeway.[136]

8. Freight alternatives

As discussed earlier, the freight task in Australia's capital cities is expected to grow by 50-70% between the years 2003 and 2020, with 60% of freight being moved by trucks rather than trains, while freight vehicles are becoming bigger and bigger. These trends have implications both for space and for road construction, maintenance and longevity. Freight transport already accounts for 4% of Australia's emissions, and this is expected to increase to 13.5% by 2020. Trucking has continued to grow faster than rail and water freight in most of the International Energy Agency (IEA) countries despite the fact that the shift the other way would reduce CO2 emissions from freight substantially.[137] Practical freight alternatives is an area that needs a lot more attention..

9. Conclusion

There are many innovations happening worldwide to enable roads and road infrastructure to be able to address some of the emerging challenges such as significant changes to weather patterns, increases in extreme weather events, predicted increases in energy and resource prices, predicted resource shortages and changing use and expectations of roads. These innovations illustrate that positive opportunities exists to transform the way road infrastructure is constructed, maintained and used.

In particular trends show a change in the way that road space is being used. Many cities around the world are changing the allocation of road space from private vehicles to people walking and cycling, public transport infrastructure and to the creation of public space. Rapid innovations seem to be happening in the way that road space is managed, particularly in city centre, and include traffic signally, congestion charging systems, parking fee systems, vehicle restriction schemes and ways to distribute road space to allow for the direction of predominant vehicle movement, such as reversible roads or lanes that can change direction.

There are many changes in vehicle technology, including some ‘far-fetched’ trends towards flying cars and driverless cars. Predominantly the technology innovations are focused on improving the fuel efficiency of vehicles and on changing the fuel used to power vehicles primarily towards electric powered vehicles. Furthermore, there have been advances in using road space and/or materials to produce electricity, with motion power, electrokinetic generators and solar roadways.

There are many investigations on the use of alternative and recycled materials in road construction, including the use of recycled plastic as a road building material which is gaining traction in India. This allows for the reuse of a waste material, thus freeing up landfill space and has been found to increase the longevity of roads. Pavements developed from recycled tyre rubber have also been found to improve the durability of roads and mitigate noise.

Road construction, maintenance and use innovations will be impacted by other global trends further than those that focus directly on roads and road management themselves. In particular the growing cultural shifts towards more sustainable lifestyles, the declining car use and shift towards higher density cities, along with changing community expectations regarding streets will have a big impact on how roads are managed. Further to this are the rising costs of materials including oil and aggregates, population growth, climate changes and infrastructure constraints. All of these issues, challenges and innovations raise some interesting questions when looking at the future of roads and also importantly, offer some potential opportunities.

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