RESPONDING TO CLIMATE CHANGE IN CITIES: TECHNIQUES FOR MINIMISING RISK THROUGH TRANSPORT SYSTEM AND URBAN FORM PLANNING AND ASSET MANAGEMENT

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Abstract: The paper begins with a discussion of the type of issues that will likely set the context for climate change effects on urban transport. The enabling of sustainable climate change appropriate transport requires two challenges to be met. The paper outlines some practical methods for enabling this to happen. The first of these is the meaningful engagement of the community in the selection of urban form and transport system options. A sustainability framework has been developed providing the context needed for the supporting methodologies. The paper will present initial visualisations from a Sydney Case Study to illustrate the type of high level outputs that can be built from this systems approach to discern between scenarios. The second challenge is enabling the scenario selected at the urban scale phase to be developed to a physical reality. Systems engineering is cast as a practical methodology for enabling the sustainability performance expectations.

1. Introduction

Sustainability has become a fundamental expectation in our societies today. With the experience of growing cities under stress through loss in environmental quality, liveability and numerous inequities, community and governments alike have an imperative to do things better and strive for values and a future vision that has collectively become known as sustainability. The reality of climate change we now face is imposing a new timeframe for sustainability action.

Urban level responses to climate change require specific planning and infrastructure responses that are peculiar to each city, shaped by the environment, city characteristics and the socio-economic conditions of the population. Response scenarios need to be evaluated in this context to choose the appropriate one for the city. It is now widely recognised that any response scenario needs to have both mitigating and an adaptive components.

It is therefore important to foster a methodology to enable this understanding of impacts that will assist governance agencies and the community to engage with each other in the choice of responses for their city. Whilst community and government have been able to develop a shared vision for the character of a city into the future, community participation beyond visioning and goals setting has been limited. In recent years the principles of backcasting[1] have been significant in identifying trend breaking future scenarios for urban and infrastructure planning.

However, when it comes to trade off decisions on which scenario is most effective it has been difficult for government and community to know how to work together make the best choice. Without measureable assessment methods, the comparison between sustainability outcomes of scenarios is extremely subjective, to the point where little benefit may come from public discussion. But research into measurable and easy to visualise methods of assessment holds much promise. Simple strategic scans of scenario performance using these methods would give community and decision makers alike an interactive "what if" tool to facilitate choice between scenarios.

Greater transparency and integration of process from the community and government vision of a city through to the development and operation of the infrastructure that supports it, is key to enabling sustainability aspirations into sustainability responses. This paper introduces sustainability performance metrics of the type that will support strategic scans and discusses the importance of a systems approach in their derivation and application. It also introduces how the systems engineering approach can be utilised in urban planning and infrastructure delivery to minimise the risk of losing sight of the original intent of the plan/ strategy.

2. Some Context for Climate Change Effects on Urban Form & Transport Infrastructure in Cities

Under a long-term future driven by climate change urban space may have new constraints imposed, especially where areas are in low-lying areas or are close to shore lines. There is increased threat from storm intensity, which can lead to greater flash flooding risk in low lying areas, and to storm surges into shore line areas as a result of offshore storm events. Although buildings are typically designed to be in place for 50 years, it is not uncommon for them to be in place for 100 years, or even longer. Even where the structure has reached its useable life, communities have a sense of place and heritage that leads to refurbishment of the building.

A slower but just as significant effect of climate change is sea level rise. Current forecasts due to thermal expansion of the seas may well be significantly worsened as the melt down of land locked ice sheets in Greenland and Antarctica becomes clearer. The important point is that these predictions are within the time frame of urban space choices society makes in the next 10 years: these decisions will govern land use form over the next 50 to 100 years. Future scenarios for new land use areas will need to be constrained by limitations imposed by more flood prone areas and this might include the need to relocate existing land use activities accordingly.

Climate change effects also include changes to transport system performance. Increases in temperature extremes and storm events can alter the operating characteristics of transport systems. High temperatures can restrict operating speeds on railway services during these events, storm events reduce the reliability of both rail and road-based services (Planning Research Centre, 2006). Corridors exposed to low-lying areas and storm surge effects may

[1] "setting a vision of a desirable future and then working backwoods to identify the policy and projects needed to achieve it"

require the transport network itself to be relocated - depending on the frequency of events. The time scale for putting major transport system changes into effect can be 10 to 15 years from the master planning stage to commissioning and operations. The expected life expectancy is at least in the order of 100 years. As transport infrastructure is difficult to change it is important to carefully choose the appropriate transport system at inception and to add as much flexibility to adapt to potential changes as can be managed.

How the community responds to changes in climate may see relocation of residents to cooler coastal parts of cities. At the same time, communities within storm surge areas may retreat away from the coast. Community aspirations for climate change mitigation may see a shift in demand towards smaller carbon footprints in their journeys taken. This is likely to cause a consequential shift in demand for minimising trip lengths, more carbon efficient vehicles, and public transport – these demands have a feedback effect to further shape the type of urban form and transport system.

Agencies and businesses with the role of managing and operating transport services and infrastructure are themselves at risk from climate change. Where a rail business incorporates climate change effects in its advance business planning, a better managed cost of change and opportunity to adjust to demand changes would be expected to lower the risks significantly. With large, long-term investments in the transport system, failure to align the effects of climate change places the revenue streams for these businesses at risk. The community confidence in the rail business is also at risk when demand exceeds capacity or service quality falls below customer expectations. This can lead to wider effects for community, with increased congestion and social exclusion. When community concerns are significant enough governments themselves, as the over arching responsible party, are also at political risk at the next election cycle.

For transport businesses that offer a lower carbon footprint than others, the opportunity may well provide a stronger market position than higher carbon footprint businesses. The cost of carbon being added to the business financial ledger gives advantage to the low carbon transport business. At the same time, demand for these services is likely to increase as community and government alike favour the transport systems that these businesses provide. The 2008 world financial crisis has shifted thinking in investment agencies to a more cautious approach to investments compared with previous decades. Transport systems that meet sustainability criteria are being considered more favourably for investments due to their greater certainty and therefore prospects of stability (Rubinstein, 2008).

3. Using the System Approach to inform planners, governments and the community stakeholders on scenario characteristics.

Climate change response scenarios need to reflect the infrastructure and landuse planning and other policies aimed at mitigation of greenhouse gases, but also the realities of adapting to impacts of climate change on cities at the same time. To properly define a scenario it is important to have a vision but also an understanding of the system characteristics which gives the basis for the sustainability effectiveness. This includes an understanding of the system vulnerability to committed climate change impacts. Each system's adaptive capability to climate change impacts may be different and may reduce the effectiveness of the system to the point that the scenario is not suitable.

City infrastructure scenario characteristics are determined with a systems engineering approach using industry accepted asset management methods. These identify capability of infrastructure to meet requirements and vulnerabilities through failure modes and effects analysis, reliability and availability analysis. This approach is able to be applied to all major infrastructures that are the foundations of the city fabric, i.e electricity/energy, transport, buildings, waste facilities, water supply & sewers, drainage and foreshore infrastructures.

The systems engineering approach is conventionally applied at an agency level downwards into projects. However, the approach can also be used to advantage to inform the urban/master planning of the system characteristics when generating urban scale sustainability performance metrics.

Information derived is used to inform scenario assessment. This principle can be illustrated by focusing on the urban transport system. The urban system scenario characteristics and system vulnerability can be considered in the context of the sustainability framework shown in Figure 1.

The systems engineering approach informs the landuse and transport interaction and transport modelling (the building block methodologies of the sustainability metrics). Using the building block methods, the system wide effects from transport are identified in this framework. Climate change impacts are drawn in from the physical infrastructure characteristics and network relationships, but also from behavioural changes due to climate change impacts. The population of each city is likely to have different resilience due to differing financial and social situations.

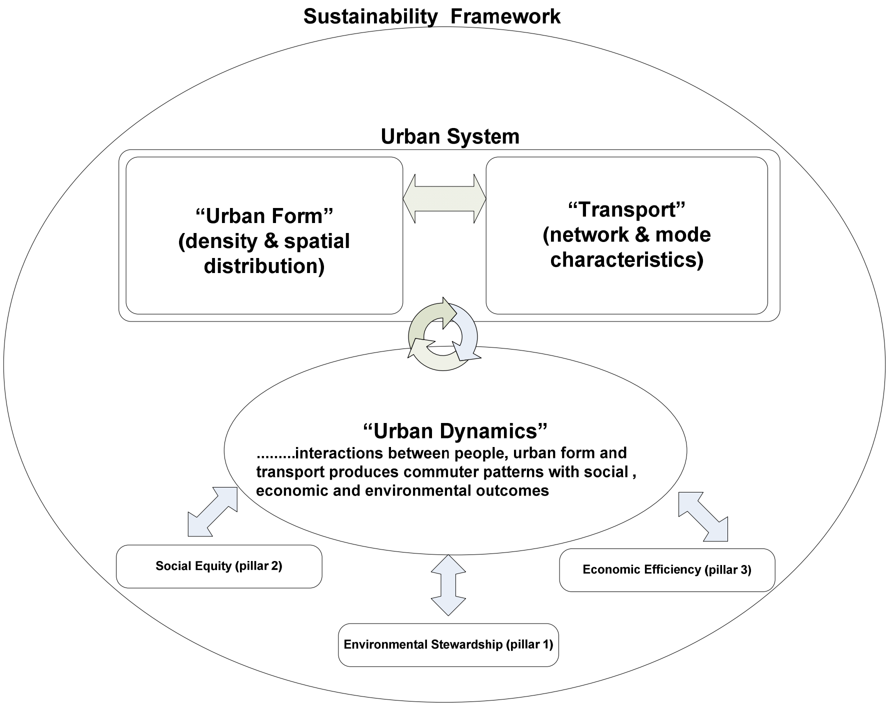

Figure 1 The urban "sustainability framework"

A new novel application is to generate alternative sets of these sustainability performance metrics under failed system states due to infrastructure system vulnerabilities to climate change impact. For example a rail system with increased frequency of lighting strike or increased effect of forest fires. This difference in sustainability performance between normal operational system state and the failed system state can be a consideration in the various scenarios under review, as a measure of vulnerability or resilience. The sustainability metrics developed are city specific and infrastructure scenario specific. They incorporate the capability to mitigate and resilience for adapting to climate change impact.

In a Sydney Case Study of the visualisations, the environmental sustainability measure (Pillar1), was formulated from known fuel consumption of vehicles (see Cosgrove, 2003, p342) with speed and used to calculate CO_2-e footprints for motor vehicles between each trip origin/destination pair. Detailed operational methods using transport planning building block techniques were developed (Doust, 2008, Chap 4) and applied to generate a quantifiable measure of greenhouse gas mitigation effectiveness.

Accessibility has been identified as a useful measure in social and economic aspects of sustainability (see Expert Group on the Urban Environment, 1996; Warren Centre for Advanced Engineering, 2003; Kachi, et al., 2005; Kachi, et al., 2007). Accessibility measures were derived (Doust, 2008, Chap 4) for each travel zone pair. Separate operational methods were developed to generate worker and employer focussed accessibility measures. These are measures that are relatable to social equity (Pillar 2) and economic efficiency (Pillar 3) respectively.

An approach to visual sustainability metrics was developed based on the concept of a sustainability goal in "environmental sustainability – accessibility space". Figure 2 illustrates this spatial concept and the idealised performance goal.

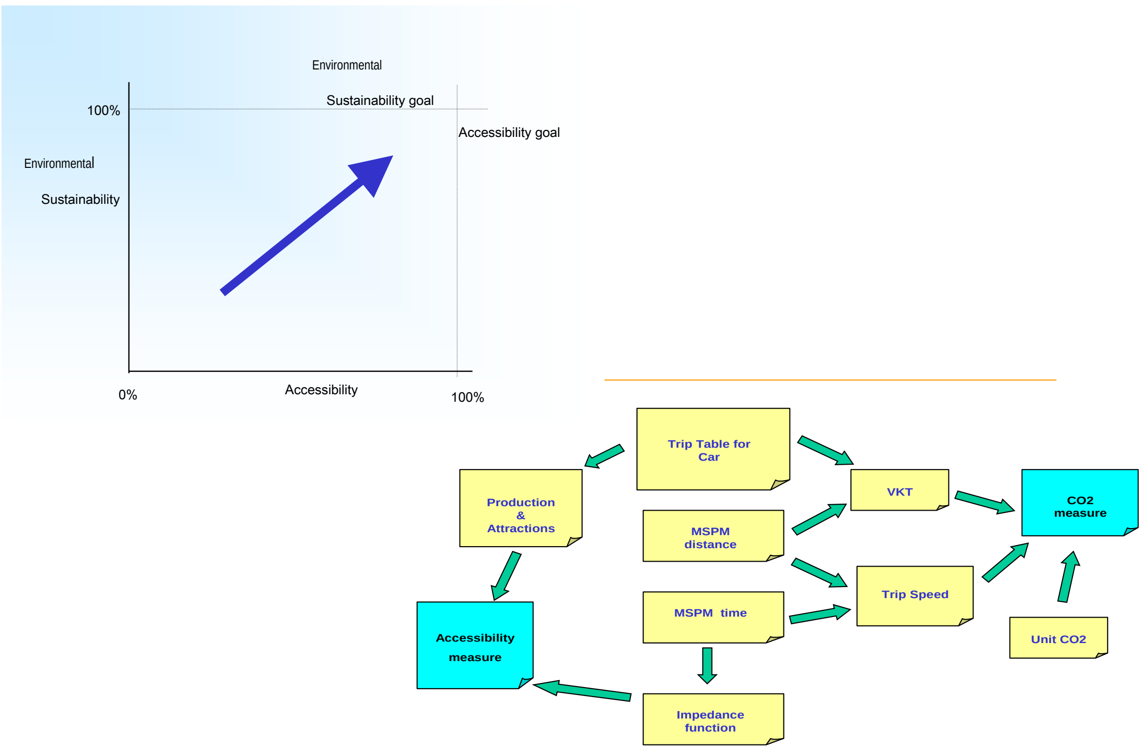

Figure 2 Environmental sustainability - accessibility space

A city's sustainability performance in relation to the goal can be analytically quantified and a simple visualisation made for assessing the three pillars of sustainability in cities.

The metrics were able to be determined for large data sets for the Sydney case study (792 travel zones) by systematic analytical techniques using trip tables, network skims and car emission rates as inputs, Figure 2.

The building block techniques have given the metrics a clear objective basis traceable to the source data. The visualisations although built from many thousands of pieces of data provided a simple representation giving a holistic view of the sustainability characteristics and trends. Figure 3 illustrates the scatter plot form of the visualisation. A trending to the top right hand corner and a limited spread in accessibility is identified as the theorised optimum.

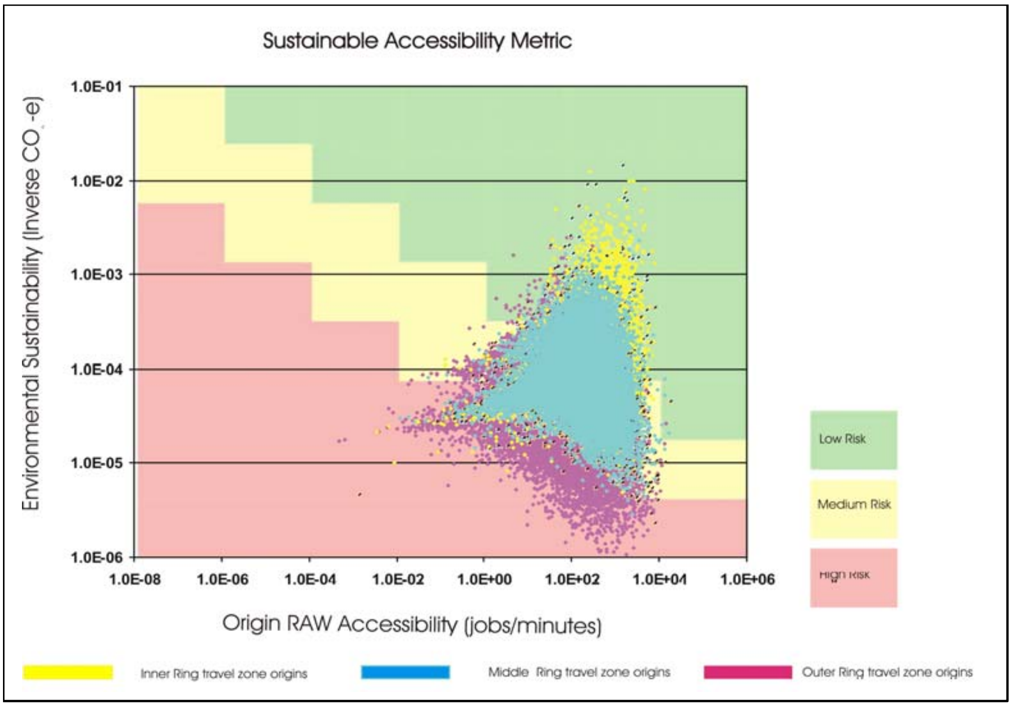

Figure 3 Sustainability risk visualisation

These metrics can also be applied in a way that expresses sustainability performance in terms of sustainability risk. High risk where sustainability performance is poor, indicated by low metric values. Low risk where sustainability performance is satisfactory, indicated by a higher metric value, above a community accepted minimum target. The grid concept can be likened to a risk matrix allowing each zone pair to be assigned a sustainability risk. The sustainability risk boundaries are specific to each city and influenced by the population's estimated resilience and trade offs between climate change impact and other sustainability criteria.

This sustainability risk rating can then be plotted onto geographic space using geographic information system (GIS) thematic mapping. Figure 4 illustrates some examples of visualizations in geographic space.

Each of these visualisations provide insight into the position, spread and internal distribution trends for a city's urban sustainability pillars of environmental stewardship, social equity and economic efficiency. For community and decision makers these visual differences give a simple snapshot of overall sustainability performance, for each scenario being considered. Change the scenario, use the building block techniques and produce a new metric plot to see the sustainability effect. Stakeholders can see measurable change for their communities in relation to sustainability goals. The process provides another dimension to visioning and sustainability strategy development by adding the means by which community can measure and judge one infrastructure and urban form scenario with another.

A particular strength of using the sustainability framework and the metrics demonstrated is that they are derived from data sets that have been commonly used by planners for many years. These are commonplace amongst transport and city planning departments. With these inputs and the assistance of readily available GIS/T software, all of the urban dynamics and sustainability metrics are able to be derived. The sustainability framework enables the holistic picture of sustainability to be maintained during the assessment process.

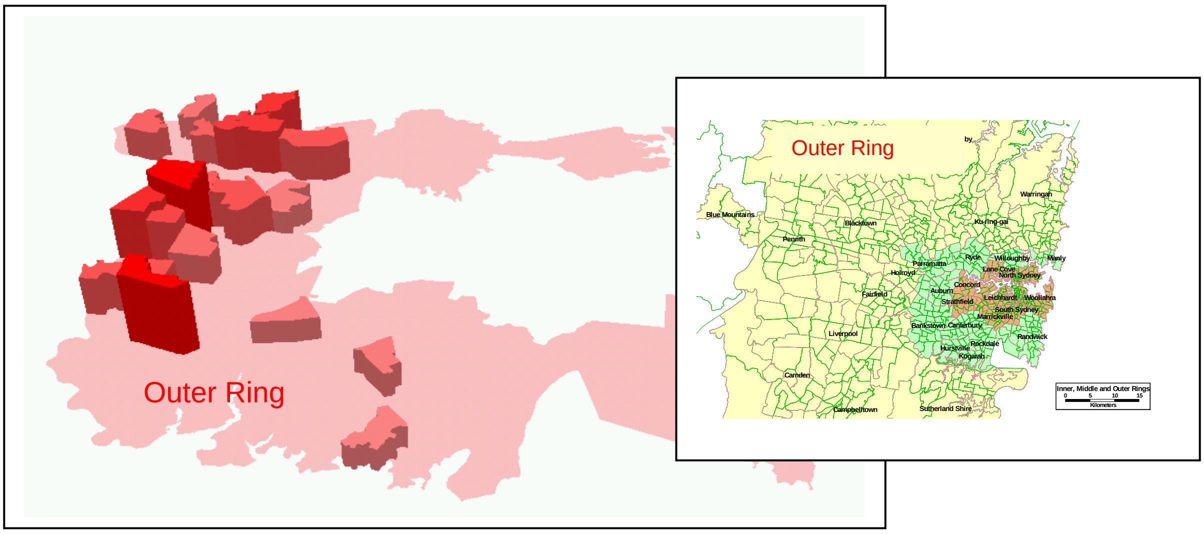

Figure 4 Map of High Sustainability Risk in Outer Ring

An important aspect of the metric methodologies is their analytical basis. All visualisations have traceability back through the algorithms to the source inputs. This is a particular strength when checking results, making scenarios changes and applying different planning instruments. The Sydney Case Study visualisations illustrate the type of high level outputs that can be built from this systems approach to discern between scenarios. Visualisations of this type can be used to inform decision makers (community & government agencies) in the process of choosing climate change policies and programs for a city.

4. Using the System Approach to Inform Planners, Governments and the Community Stakeholders on Scenario Characteristics.

City infrastructure from urban and masterplan to operations travel through a process of many years duration. Depending on the governmental policy, the course may be very hands on through the government agencies empowered to deliver, or it may be a facilitation of guiding frameworks, plans and high level contracts and alliances with the private sector. There are many elements that need to be in concert for infrastructure system to deliver good sustainability performance. With multiple agencies involved there is a difficulty in seeing the overall goal and keeping the effort integrated between the agencies. This is complicated further with public private sharing of the delivery effort. Over a long delivery time frame, integration between the teams delivering each development phase is also a significant risk. However, asset life cycle management principles based on systems engineering approaches provides practical methodology to minimise this risk. The systems engineering process has been used for managing complex engineering projects for over thirty years and has been applied to public infrastructure management in NSW since the 1990's. Most of the experience has been with the management of individual assets at a scale beginning with project level.

The principles of systems engineering are centred on specifying system functional and performance requirements and apportionment of these to subsystems. It also involves an overall approach to managing the increasing maturity of designs, the integration of the design effort and it's commissioning to enable a system that operates in accord with the system requirements. Figure 5 illustrates the key aspects showing the changing degree of focus into more detail as the design matures, the development of baselines and reviews.

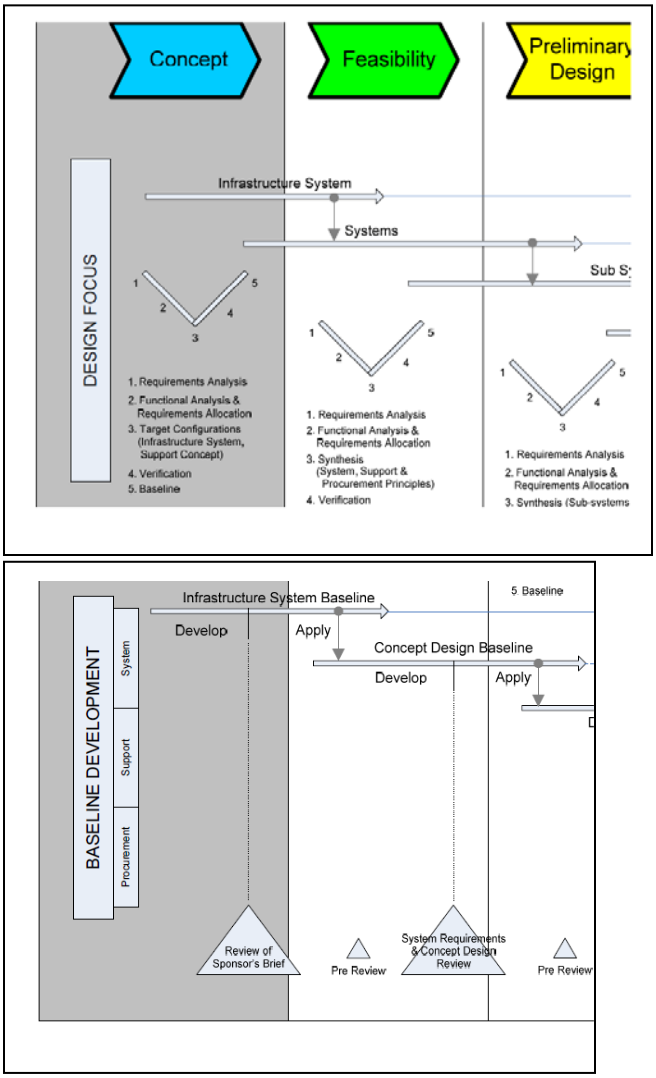

Figure 5 Systems Engineering Process

Design is carried out with a number of parallel themes to achieve outcomes for specific requirements such as reliability, safety, maintainability and capability requirements. By adding a new set of requirements that can be managed using this already mature process, it offers a novel and efficient method of enabling sustainability and climate change response in infrastructure.

5. Conclusion

The methods described provide a suitable methodology to support informed decisions by communities, businesses and government and help chart the most appropriate options from the challenges of global environmental change. Climate change effects impose constraints and changes to the urban system that directly affect its characteristics but also change the urban dynamics that effect demand for transport. These changes, and the feedbacks, need to be included in any optioneering of scenarios to support the vision of a sustainable city.

Agencies and businesses that deliver and operate the transport systems need to be actively involved in early stage planning to incorporate the effects of global environmental change, especially climate change, in their business, to minimise the risks to their customers and themselves. This also provides a take up of opportunity that responding to climate change provides for businesses which have low carbon services and systems. Thus, for those discerning transport system businesses with lower carbon footprints, climate change is an imperative with risks that they share with their competitors, but with opportunity to be in a competitive advantage over higher carbon businesses. The opportunity to plan and enable more sustainable transport systems carries with it the prospect of lower relative cost and greater revenue than the higher carbon transport businesses and more available investment funding.

The approaches described in this paper will help to deliver the types of visions for a sustainable city and to do so in the complex setting of the real world of trade offs between environmental sustainability, social equity and economic efficiency. The urban sustainability framework with its three pillars of sustainability and associated modelling and visualisation techniques provides a methodology to assist governments, businesses and their communities meet these trade-off challenges as cities enter into a future period driven by climate change imperatives. Further more, businesses and agencies are in a position to enable sustainability and climate change responses effectively and quickly by using the systems engineering asset management techniques which are already widely used in delivery of infrastructure in cities.

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