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Towards a practical assessment methodology and toolbox for transport systems

Sustainability vulnerability under climate change

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Abstract:

Brings into play the vulnerability of city transport networks and technologies when faced with climate change related hazards. Transport systems are designed to have an operational performance and are expected to contribute to a city's overall sustainability. However, under climate change related hazards, the transport system is at risk of being in a failed state, either below its expected operational performance level, or unavailable all together. The paper introduces the types of failed states for different modes and considers how the vulnerabilities can be better understood by first understanding the effect on reliability and availability of service.

Sustainability itself is therefore a key contributor to mitigation of climate change hazards, but conversely climate change hazards put at risk the sustainability improvement we strive for in our cities. The paper explores measuring the vulnerability to climate change hazards, in terms of the change caused to sustainability performance when the transport system suffers loss in reliability or availability. A methodology which generates visual sustainability metrics based on the concept of a sustainability goal in "environmental sustainability – accessibility space" is outlined as a much needed basis for assessing the change in sustainability under the stresses and shocks of climate change.

The paper concludes with a discussion of next steps and need to further case study the work in collaboration with other researchers.

Keywords: Assessment, Risk, Sustainability, Tools, Vulnerability

1 Introduction

Climate Change risk and sustainability are two paradigms that need to be considered together. Indeed, the nexus between the two is especially important in the urban context. Sustainability as a concept has been with us now for more than 30 years and becoming an increasing desire as liveability, stewardship of our environment and material resources for this and the next generations is becoming of greater value to many people. Climate change can now be considered irrefutable, coming about largely out of existing unsustainable practices and increasingly an urgent issue. The emphasis in contemporary times towards urban sustainability has become a key contributor to mitigation of climate change hazards. However, climate change hazards have created shocks and stresses putting at risk the sustainability improvement we strive for in our cities. This paper focuses on the transportation system, the shocks and stresses that impact this system and outlines a methodology for assessing the sustainability risk under climate change.

2 Transport System Shocks & Stresses

Shocks that can result from climate change events, include flooding due to high intensity or sustained periods of rain; inundation due to storm surge; visibility in high intensity rain; high temperatures; high winds and lighting strikes.

Behavioural effects impact driver behaviour in extreme events, such as cautious speeds and braking and can result in collision incidents in worst case situations. Passenger behaviour at interchanges, pedestrian behaviour and non motorised vehicle behaviour can also become altered in extreme events, leading to transport system delays.

Localised effects to the transport system vehicles and infrastructure include disruption to electrical supplies and equipment, signalling, and communications due to lightning strikes, water inundation or equipment damage due to falling trees and high winds. Civil infrastructure such as roadways and rail lines in extreme rainfall and stormsurge can be disrupted by localised flooding. High temperatures can trigger reductions in speeds due to rail buckling risk and overhead catenary sag. Both road and rail can be disrupted due to bush fire damage of infrastructure in high temperature and high wind events. Each of these can result in delays or suspension of transport services due to these localised effects.

The transport systems under these type of extreme weather shocks can be considered as operating in a failed operational state for the duration and period of recovery after the event subsides. Systems engineering processes in todays asset management disciplines, are enabling these effects to be translated into overall loss of system performance. It is becoming possible to estimate changes in route availability, travel time and reliability for these failed states in comparison to normal operational conditions.

Longer term, or repeated exposure to climate change stress can affect both the behaviour of people and the durability of infrastructure. In some cases may also necessitate the infrastructure to be adapted to the new norms. For example, people under repeated exposure on coastal or low lying areas, or in hotter parts of a city, may decide to move, impacting the demands in the transport system, challenging available capacity in some areas while resulting in underutilised infrastructure in other areas. Infrastructure durability may be impacted by repeated exposure to salt water inundation on civil structures, while extended high temperatures may require railway rails to be rewelded to adjust for different temperature extremes.

3 Sustainability Risk Assessment

3.1 Evidence based methodology

The underlying methodology for this paper, was first published in 2008 and incorporated in the 2011 Climate Change and Cities First Assessment Report by the Urban Climate Change Research Network (Black and Doust, 2011). This methodology provides the analytical based metrics for assessing changes in sustainability performance under climate change.

The approach, which recognises that accessibility has been identified as a useful measure in social and economic aspects of sustainability, generates visual sustainability metrics based on the concept of a sustainability goal in “environmental sustainability – accessibility space”. A city’s sustainability performance in relation to the goal is generated using plots of environmental sustainability & accessibility for each travel zone pair in the city. A collective plot of sustainability measures for individual zonal pairs creates a simple, but analytically rich visualisation, giving 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. A feature of the methodology is its systems based drivers or levers. All visualisations have traceability back through the algorithms, Figures 1 & 2, to the source inputs, allowing changes in system scenarios to be made.

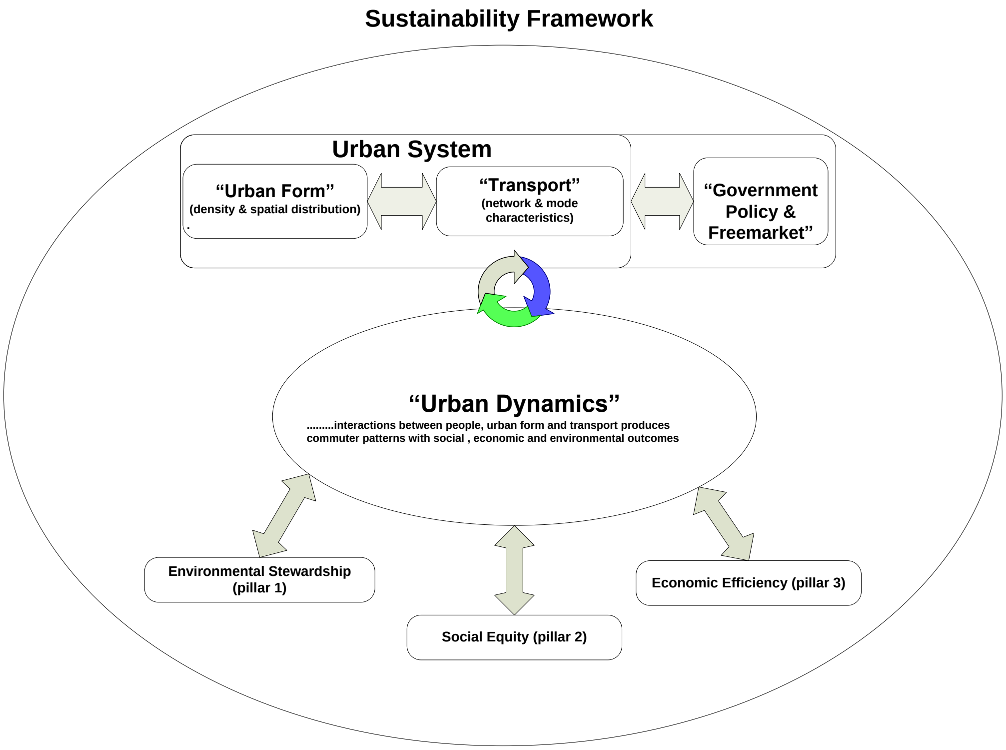

Figure 1: An Evidence Based Assessment Methodology.

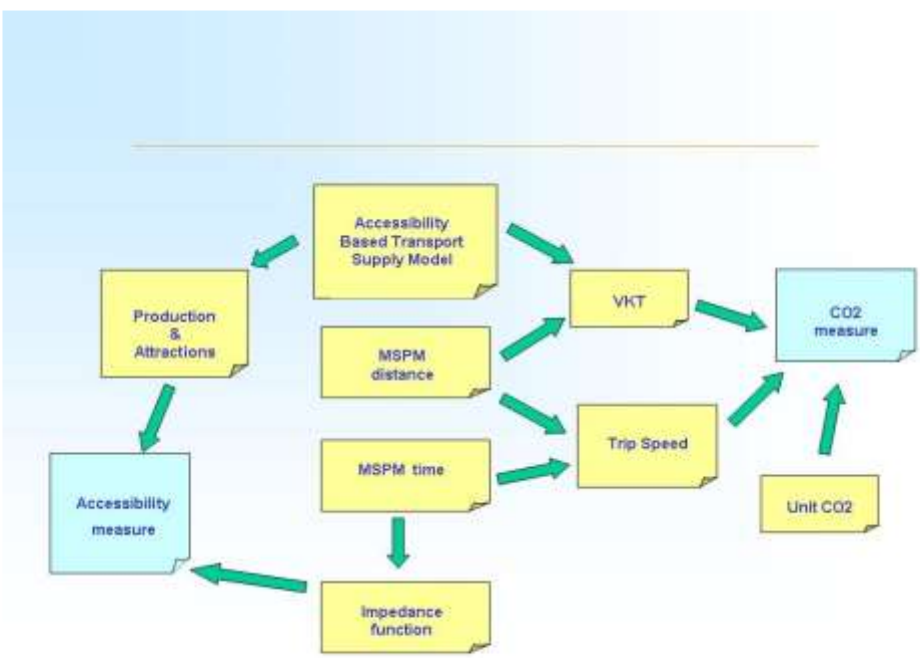

Figure 2: Derived from traditional transport models.

A particular strength is that the metrics are derived from data sets more likely to be found amongst transport and city planning departments. Figures 3 & 4 are visualisations from a Sydney case study to illustrate the type of high level outputs that can be built from this systems approach. Sydney is a city of nearly 5 million on Australia's pacific coast. Figure 3 represents the use of the concept of sustainability accessibility space, whilst Figure 4 gives an example plot of taking the data and replotting in a geographic information system (GIS) visualisation.

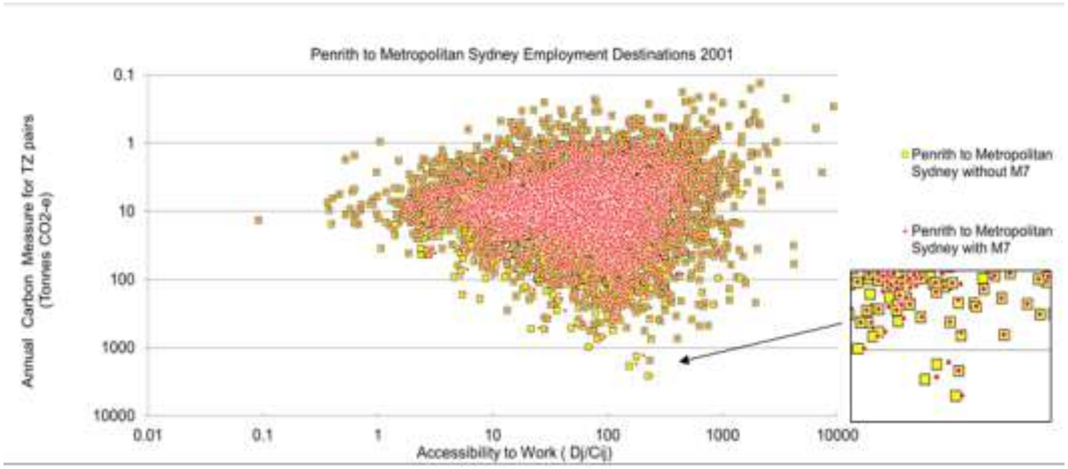

Figure 3: Visualization in sustainability accessibility space.

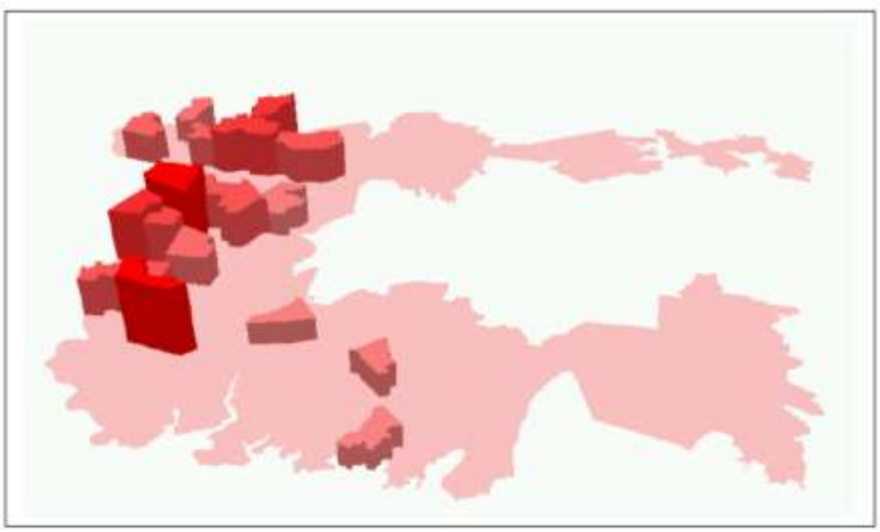

Figure 4: Visualization concept for sustainability risk in geographic information system space.

3.2 Benchmarking

The benchmarking reference scenario is developed using a strategic scan of the transport network based on either existing or planned performance without climate change impacts. This gives a city the choice to perform a scan using the existing transport system or alternatively, where a city has prepared a future strategy, a sustainability scan of planned city transport structure as the reference for benchmarking loss in performance under climate change shocks and stresses.

3.3 Assessing climate change impact on sustainability

The sustainability scan applied to the benchmark network scenario is rerun for both the short term failed state of the transport system, due to climate change shocks, and also for the system state under longer term stresses. For example with modified network characteristics due to the climate change shocks e.g. disabled or slowed network links that represent the conditions during the event and during recovery after the event. The scan of the stress scenario would include the effects on change in demand behaviour.

3.4 Building a profile of city sustainability risk

Comparison of the sustainability scans under climate change against the benchmark scan enables the stakeholders to quantify the changes in the sustainability performance at different locations and for different trips throughout the city. By plotting the change in metric values in sustainability accessibility space and using GIS thematic mapping, it will be possible to effectively build a visual profile of the city sustainability risk, that can be used in optioneering of resilient sustainability solutions under climate change shocks and stresses.

4 Next Steps

For the strategic scan approach to provide a more substantial contribution to supporting the sustainability planning decision in cities that are resilient, a database of metrics applied to multiple cities is needed.

In particular collaboration from other researchers is needed on:

- strategic sustainability scan data preparation & modelling.
- sustainability benchmark scans of transport systems operating normally
- sustainability impact scans of failures in the transport systems due to climate change.

This will enable a typology of sustainability performance and resilience to emerge over time to guide decision makers on resilient urban form and transport network choices tailored to the context of each city. To participate in the resilient sustainability database and typology project contact kendoust@unsw.edu.au or windana@maxi.net.au and view our website www.sustainabilitystep2.org.

References:

Black, J. and Doust, K. (2011) A sustainability framework tailored for transportation and applied to Sydney, Australia In: Rosenzweig, C., Solecki, D., Hammer, S., Mehrotra, S. (ed) *Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network.* 2011 Ed. Cambridge, UK: Cambridge University Press.

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Bio

In a climate change future, sustainability has become a community imperative. In an effort to contribute, Ken recently completed his Phd in Engineering focused on sustainability performance measurement in cities. This has come from Ken's enthusiasm for creative approaches to appropriate sustainability planning for the future.