Application of Future Scenario Planning to Flood Risk Management

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Abstract

Future scenario planning has proved to be a powerful tool for identifying and managing the drivers of change of a flooding system. Gold Coast City Sustainable Flood Management Strategy has endorsed scenario planning as one of the tools for managing the adverse impact of climate change on flooding.

This study

- Examines various methods of scenario planning and their applicability for flood risk management on the Gold Coast,
- Explains the difficulties in achieving internal consistencies when applying these methods to flood risk management under the impact of climate change, and
- Suggests an approach for resolving the issue of internal consistency of future scenarios.

Introduction

Flood risk management starts with assessing flood risk. Assessing flood risk involves understanding three issues:

1) **Source** of hazard (in this case, flood).
2) **Receptor** (the elements that are subjected to the harm from the hazard, in this case Gold Coast City).
3) **Pathway** through which the impact of hazard is exerted on the receptor. Examples of pathway are river and floodplain.

Change in any of the abovementioned elements will change the level of flood risk. The status of source can change due to a change in key climate indicators and the status of receptor can change due to a change in socio-economic conditions. A recent study by Bouwer (2010) demonstrates the importance of correct assessment of future socio-economic conditions. Investigating flood risk in the Netherlands, he showed that even without climate change future flood damage would increase due to socio-economic growth within the flood prone areas. He also demonstrated that the contribution of socio-economic growth within the flood prone areas to future flood damage is more than the contribution of climate change.

On this basis, flood risk management through a planning process involves:

- Assessing the status of these three elements, e.g. source, pathway and receptor.
- Understanding how they change over time, i.e. identifying the drivers of these changes; and
- Finding how changes in source, pathway and receptor can be managed through managing their drivers of change.

Source (Flood)

In a stationary condition, the likelihood of occurrence of a flood can be assessed using standard statistical methods, mainly based on extrapolation of past data. Uncertainty associated with such predictions is due to:

- Uncertainty in data
- Uncertainty in modelling

These uncertainties can be mathematically calculated and be accounted for in risk management analysis, i.e we have some level of control on these types of uncertainties.
Climate change has shifted the past relatively stationary climatological condition of the Gold Coast to a non-stationary condition, adding a new dimension to the uncertainty associated with flood hazard predictions. This new uncertainty is due to multiple possible futures with equal probability of occurrences. On this basis, flood managers have to deal with multiple equally probable hazards in future. For instance, a 1 in 100 year flood at a catchment could be 1000 m3/s, 1200 m3/s, 1500 m3/s, etc. The number of equally probable Q100 events is equal to the number of plausible futures.
We cannot mathematically calculate the uncertainty associated with the non-stationary nature of climate change. Nor can we control all aspects of such uncertainty through limited authority and resources that are available to a local authority. These uncertainties are to a great degree controlled by global scale drivers. Therefore, all that we can do is to assess them as accurately as possible and adapt to the changes.

Receptor

Variation of receptor drivers, similar to those of hazard, is expected to have a non-stationary nature. Growth and diversification of the most coastal cities in Australia over the past few decades have been significant, resulting in potentially exposing more assets to environmental hazards such as flood. Drivers of change of receptor are numerous, spanning across a wide range of social, demographical, economical, ecological, political and legal issues. The status of the receptor at any point in time seems to be a compromise among the abovementioned drivers. Figures 1 and 2 schematically depict how a receptor can change in a city where growth has happened on its floodplain. Past experience shows that floodplains that are generally part of flood risk pathways become the place where high value urban assets are located, e.g. have become receptors of hazard. In a sense, growth has converted part of the pathways of flood risk to receptor of flood risk.

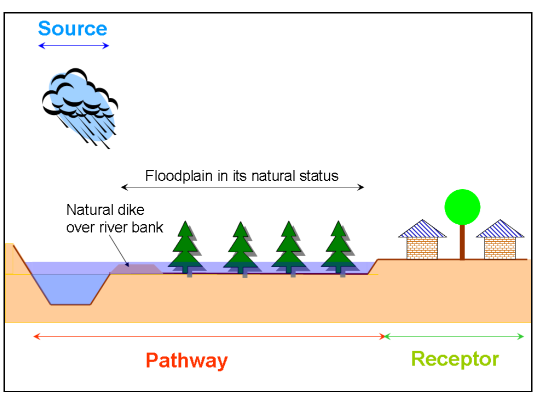

Figure 1 – Source, pathway and receptor in their predevelopment condition.

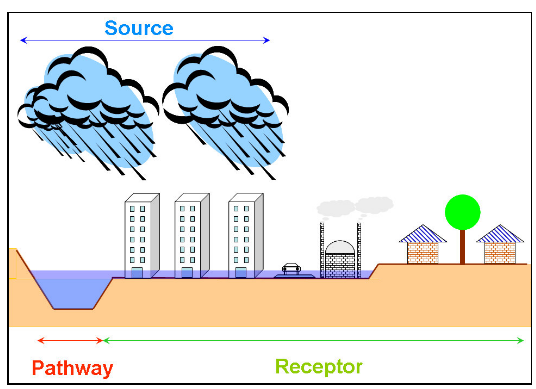

Figure 2 – Change in source, pathway and receptor due to social, economic and environmental changes.

Climate change is expected to have a substantial impact on the nature of receptor, in terms of vulnerability, resilience to future changes and sustainability. Local control on receptor drivers of change is expected to be more than the control on source drivers of change (in the context of flooding). There are a number of policy and legislative instruments that can be used to exercise this control. Land use planning, population policy and setting strategic direction for economic development are only a few of them. Having said that, all the abovementioned drivers are expected to be influenced and impacted by forces well beyond the control of local authorities. Peak oil, climate change and macro level socio-economic and political changes at global scale are only a few of these external forces. Uncertainty associated with these macro level changes are a main source of uncertainty in local level planning, depriving local authorities from having full control on the receptor drivers of change.

Pathway

Pathway shows the physical processes that allow the harm resulting from hazard occurrence to be transferred to the receptor in the form of impact. Figure 1 shows the pathway of flood hazard as an example. Physical processes include rainfall over the catchment, overland flow over the catchment, flow through creeks that join together to form rivers, rise of water in the river and spilling over natural dikes along the river bank as well as the flow of water across the floodplain towards receptors at the fringe of flood prone areas. In this example, catchment overland flow, small flow paths, creeks, river, natural dike on the riverbank and floodplain are part of the pathway. It goes without saying that all the abovementioned elements of pathway can change for a wide range of reasons. Drivers of a change of pathway are closely related to those of receptors. Some of these drivers can be managed through local policy and legislative instruments. Similar to source and receptor situations, a substantial portion of uncertainty in pathway drivers of change is due to forces beyond local authorities' control.

Scenario Planning

To understand changes to the source of flooding, we need to understand how the key climate indicators change over time; and to understand changes to the pathway and receptor of a flooding system, we need to understand how socio-economic conditions of the subject area evolves over time. Recent advances in computing technology and climate science has provided us with an ability to make estimations of the key climate indicators, such as global average temperature or precipitation in distant futures. However, these projections are still regarded as highly uncertain due to fundamental uncertainties in modelling and data. Such projections are even more uncertain when applied to the fields of economy and social science. Our economic forecasts are highly limited in terms of time horizon. Our forecasts of social changes are equally limited by our lack of understanding of highly complicated interaction between drivers of social changes (Berkhout and Hetin 2000). Further complicating such forecasts, socio-economic evolution of human communities are path dependent. Our future depends on how we behave now and how we behave at the present time depends on how we perceive the state of future. It appears that there is no straightforward method of forecasting the distant future socio-economic conditions.

Scenario planning has long been used as an alternative to forecasting for planning purposes. Scenario planning emerged as a powerful tool for strategic planning in the early 1970s when the Royal Dutch Shell oil company successfully used it during the 1973 oil market crisis. Royal Dutch Shell was the only company that considered dramatic increases in oil price as a plausible future scenario and had prepared itself for shocks resulting from such a price hike. Since then, scenario planning has been used by various private and public bodies for strategic planning. An example for the use of scenario planning in strategic planning for local governments can be found in Docherty and McKiernan (2008).

Scenario planning can be defined as exploratory or extrapolatory in approach. Extrapolatory scenario planning approach generally involves in trend analysis and deals with forecasting and predictions of future situations. Exploratory scenarios, in contrast, are not predictions, but stylised constructions of possible future developments (Floodsite, 2008).

Intergovernmental Panel for Climate Change (IPCC) have used exploratory techniques for creating contrasting future scenarios related to climate change. IPCC's definition of a scenario is "...a coherent, internally consistent and plausible description of a possible future state of world…" (IPCC2007). Based on this definition, scenario is not a forecast or extrapolation of current trends into the future. IPCC's scenarios (Nakicenovic et al 2000) were constructed to explore how social, economic, political, and technical alternatives at global level can change the status of greenhouse gas emissions.

IPCC developed four equally plausible families (the A1, B1, A2 and B2 worlds) of self-consistent social and emission scenarios based on two key drivers (Nicholls 2004). These drivers are i) the balance between environmental concern and economic growth and ii) the balance between national interests and global (regional) cooperation. Figure 1 shows that how the four storylines can be framed using the two abovementioned key drivers and their relationship with increase in average global temperature`.

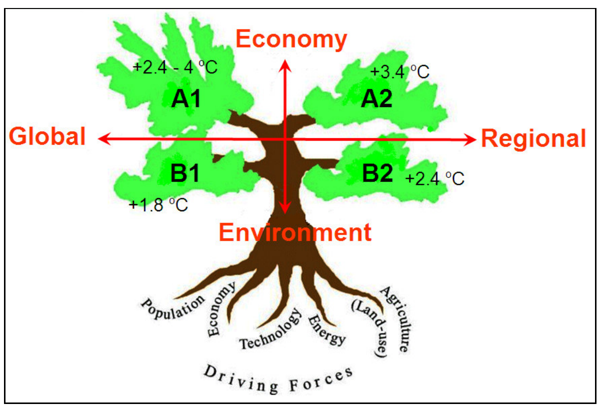

Figure 3 Scenario axes used for SRES scenarios, adopted from Groves and Lempert (2007).

The IPPC's methodology, also known as the two-axis method, has been used by various national and international bodies to frame future scenarios.

WLO (Dutch acronym for Welfare, Prosperity and Quality of the Living Environment) study used scenario-axis method and developed four scenarios, namely 'Global Economy', 'Strong Europe', 'Trans-Atlantic Enterprise', and Regional Communities'. The study considered the balance between international cooperation and National sovereignty as one key driver and the balance between private responsibility and Public responsibility as the second key driver of change.

Foresight program similarly used scenario axis method and developed four scenarios, namely 'World Market', 'Global Sustainability', 'National enterprise' and 'Local Stewardship'. The key drivers in this study are i) the balance between autonomy and interdependence and the balance between consumerism and community.

Figure 4 shows future scenarios and key drivers as envisioned by SERS, WLO and Foresight study. The scenarios are pictured in the four quadrant created by the key drivers associated with each study. Key drivers are shown beside the end arrows of the axis. The figure shows a high degree of overlap and similarity among the scenarios developed by these three methods.

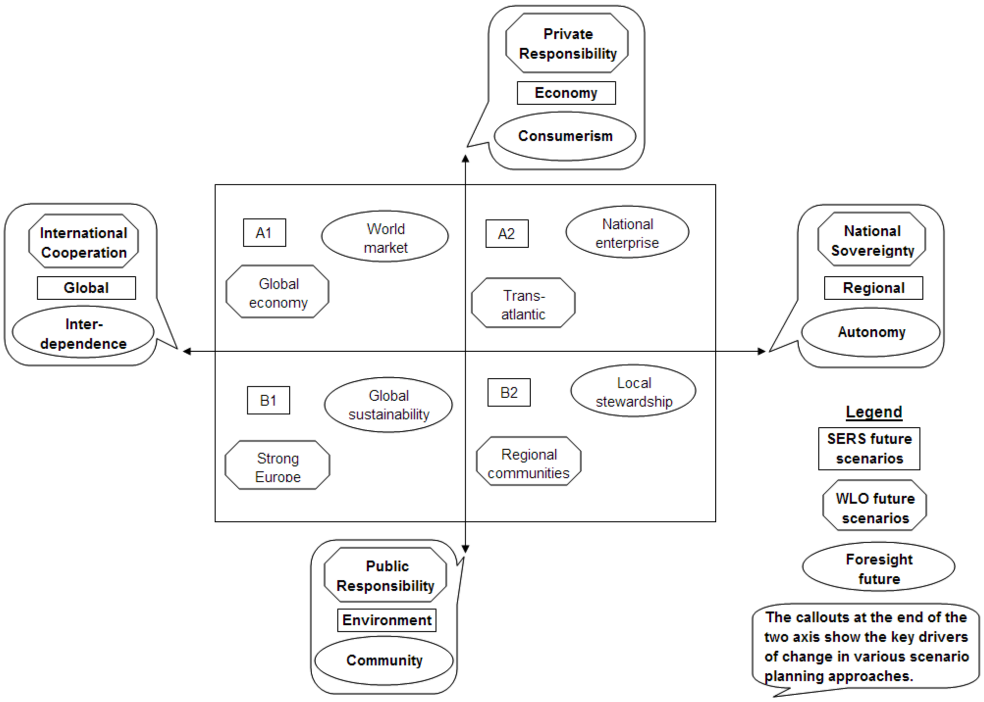

Figure 4 a comparison between SERS, WLO and Foresight future scenarios and key drivers.

GEO-3, (Global Environment Outlook) refers to a scenario analysis exercise undertaken by Bakkes et al. (UNEP/RIVM, 2004). This study considered demography, economic development, human development science and technology, governance culture and environment as main driving forces and developed four contrasting future scenarios. These scenarios are named as Market First, Policy First, Security First and Sustainability First. A full description of these storylines can be found in UNEP/RIVM (2004).

GSG (Global Scenario Group) refers to a scenario analysis exercise undertaken by Ruskin et al (2002). This study considered demographics, economics, social issues, culture, technology, environment and governance as the main driving forces and developed four contrasting views of the future world. A full description of these views can be found in Ruskin et al (2002). Table 1 shows the worldviews presented by GSG, alongside with scenarios developed by GEO-3. Column three of this table shows how the IPCC scenarios compare with those of GSG and GEO-3, showing the similarity of the future scenarios as depicted by these methods.

These approaches have used almost the same key drivers of change for scenario planning, e.g. degree of global cooperation and balance between economic growth and environmental concerns.

Table 1 – comparison between GSG, GEO and Foresight scenarios

GSG world view	GEO-3 scenarios	Foresight scenarios
Conventional Worlds		
Market	Market First	A1
Policy Reform	Policy First	B1
Barbarization		
Breakdown		A2
Fortress World	Security First	
Great Transitions		
Eco-communalism		B2
New Sustainability paradigm	Sustainability First	
Muddling Through		

Figure 4 and Table 1 show that the scenarios developed by various groups are comparable with each other and indeed do not vary significantly from IPCC's scenarios.

Gold Coast Approach

The Gold Coast Sustainable Flood Management Strategy (Mirfenderesk et al, 2011) recognises that a coastal city like the Gold Coast is substantially exposed to environmental forces such as sea level rise, storm tide and flooding. These environmental forces can change because of climate change. They have measurable impacts (comparable with those of socio-economic drivers) on the future shape of the city as a receptor and its flood risk pathways. The strategy has laid down a number of actions to estimate the future status of the Gold Coast flooding system through assessing the impact of change in its drivers of change, e.g. drivers of change of source, pathway and receptor of flooding.

To assess the change in drivers of source of flooding due to climate change, Gold Coast City Council (GCCC) commissioned CSIRO to downscale the predicted global change in precipitation for the Gold Coast (Abbs et al 2007, 2005). The results of this study was later used by Mirfenderesk et al (2008) to make a preliminary assessment of climate change impact on the Gold Coast riverine flooding. The main drawback of this study was the consideration of the current socio-economic conditions of the city in impact assessment instead of socio-economic conditions at the time of impact.

The strategy has recognised scenario planning as a practical step in estimating the future socio-economic condition of the Gold Coast, as a surrogate to the changes to the receptor element of the flooding system. Implementing this action of the strategy, this study attempts to find an answer to the question of "how internal consistency (between all the drivers of change) in scenario planning at a local scale can be achieved"? In other words, the study tries to clarify how our assumptions about change in drivers of hazard are consistent with our assumptions about variation in drivers of change associated with pathway and receptor.

There are numerous methods that can be used for developing future scenarios for a coastal city like Gold Coast. However, these scenarios may not be necessarily consistent with the IPCC scenarios associated with change in source of flooding. A practical way to achieve this consistency is to downscale IPCC's global socio-economic scenarios instead of developing new scenarios. This approach provides consistency because IPCC's socio-economic scenarios have been used for estimating global average temperature and subsequent change to future hydrological parameters. In a sense, this would be similar to the Council's earlier downscaling of the IPCC's global climate change scenarios. Using this approach, for instance, the same scenario that generates 20% increase in rainfall intensity on the Gold Coast will be used to assess the impact of this increase in rainfall on the city.

The author of the paper has not found any reported research on the topic of the downscaling of socio-economic conditions associated with various Green House Gas Emissions (GHGEs) for Australia. Indeed, this subject has been less explored even in global scale. Van Vuuren et al (2007) have published one of the few papers in this field. This paper summarizes the methods of (socio economic) downscaling in two major groups, e.g. conditional modelling and clearly-defined algorithms.

Conditional modelling refers to smaller scale models that are informed by the coarser scale models. There is little evidence that conditional modelling can be undertaken at the scale of local authority. Van Vuuren et al (2007) supplemented conditional modelling method with three alternative empirical algorithms for down scaling of global or regional scale socio-economic conditions, e.g. linear, convergence and external-input-base downscaling.

Linear algorithm assumes similar growth rates for both global and down scaled scenarios. For instance, if global population is assumed to increase by 2% per year in a global scale, the population of the region that is subject to downscaling will grow at the same rate. Convergence method is based on the assumption that the parameter of interest, for instance population growth, within a local scale will converge to that of global scale. External-input-based downscaling technique requires availability of finer-scale scenarios. For instance, knowing the share of a state from the whole country population growth rate for a certain global scenario would assist downscaling the same parameter for other global scenarios.

Gold Coast City Council is currently examining the feasibility of downscaling both of IPCC's climatological and corresponding socio-economic scenarios to a local level. Despite achieving climatological down scaling on the Gold Coast, socio economic down scaling is facing a number of challenges. Socio-economic scenario downscaling requires national scale data and the knowledge of how national resource distribution amongst various regions and cities will change in the future.

Conclusion

In making an assessment of the impact of climate change on a city, we need to have an understanding of both its socio-economic condition and the magnitude of the change in climatic conditions at the time of impact. The former indicates the level of resilience of the city and the latter indicates the level of hazard to which the city will be exposed. Scenario planning is proved to be a powerful tool for incorporating plausible future socio-economic conditions into flood risk management strategic planning. This study suggests that developing independent socio-economic scenarios for a city could result in inconsistency between the IPCC's future climate change scenarios (the only scenarios currently available) and the future condition of the city (element at risk). The study, therefore, proposes that downscaling of globally developed scenarios by the IPCC is the best way forward for assessing future socio economic conditions at a local scale. Such downscaling ensures consistency between future climate change and future socio economic scenarios.

Unlike downscaling of key climate change indicators, downscaling of socio-economic indicators may require resources well beyond what is available to local authorities. This paper concludes that State and Federal Governments can play an important role in developing the required basis for socio-economic downscaling at a local level. The paper recommends more communication between different levels of governments with the aim of finding a work sharing arrangement for downscaling of IPPC's global socio economic scenarios to Australia's local authority scales.

The study recommends to undertake socio economic downscaling in three steps. The process can start by using conditional modelling to develop national scale socio-economic scenarios that are consistent with IPPC's global scale scenarios. These scenarios can further be downscaled to the State or regional levels, using empirical algorithms or conditional modelling. At this stage, local governments would be able to take it from here and further downscale the scenarios to the scale of their local authority. Federal, State and local authorities can each undertake one of the above-mentioned steps respectively.

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