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Context specific adaptation grammars for climate adaptation in urban areas

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A B S T R A C T

In the context of climate adaptation planning there are relationships between adaptation drivers and adaptation measures, which makes the selection and implementation of the adaptation measures a challenging task. This challenge may be addressed by: structuring the adaptation problem using a multiple perspective adaptation framework; and applying a context specific precedence grammar logic for selecting and evaluating adaptation measures. Precedence grammar logic is a set of rule based algorithms (grammar) that are based on the relationships in a local adaptation context. This paper demonstrates the application of a context specific precedence grammar logic in an adaptation context in Can Tho, Vietnam. Adaptation pathways comprising flood adaptation measures (i.e. dike heightening) for this case were generated using rule based algorithms based on the relationships between the drivers and the adaptation measures. The results show that complex adaptation issues that are structured, can be resolved using a context specific adaptation grammar approach.

1. Introduction

Urban areas, which are home to more than half the world's population and composed of complex interdependent systems are a major challenge for climate change adaptation planning (Revi et al., 2014). The complexity is due to the interactions between social, economic and environmental stressors; where all or any can exacerbate risk to individual and to the households wellbeing (Radhakrishnan et al., 2017). - The economic capacity and ability to make comprehensive decisions in deploying adaptation measures are seen as the key factors in determining the sustainability of Deltas, where the urbanisation and economic activities are concentrated (Tessler et al., 2015). The current frameworks on risk assessment and adaptation call for accounting of all significant natural and anthropogenic drivers in adaptation related decision making (IPCC, 2014; UN, 2015). This can improve the long term resilience of cities against climate change. Decision making at a programme or project level is beset with uncertainties associated with the multiple drivers (Buurman and Babovic, 2016). Also there are uncertainties related to system performance in the range of scenarios anticipated in the future, and uncertainty regarding the ability of any strategy to adapt to future scenarios (Maier et al., 2016). Hence it can be concluded that adaptation related decision making in urban areas should take into account: (i) the complexity of adapting urban systems to climate change; (ii) the need for the consideration of multiple drivers, especially socio-economic (e.g. population, urbanisation, gross domestic product – GDP etc.); (iii) uncertainties associated with the drivers and; (iv) approaches set out in extant enabling frameworks for carrying out risk assessment and development of adaptation plans (Dittrich et al., 2016; Maier et al., 2016; Matteo et al., 2016; Young and Hall, 2015).

Expertise on climate change, socio economic drivers that increase vulnerability and impacts, integrated assessment modelling for assessing impacts and vulnerability, is becoming increasingly sophisticated (Hallegatte et al., 2011; IPCC, 2013; O'Neill et al., 2015). However, at the municipality level – the level which

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matters most for urban adaptation – there is a lack of enabling conditions and frameworks to support the timely evaluation of emerging urban adaptation measures that operate across a range of scales, timelines and how these are rooted in local contexts (Revi et al., 2014). There are recent decision supporting frameworks such as dynamic adaptation policy pathways (Haasnoot et al., 2013), real options (De Neufville and Scholtes, 2011; Woodward et al., 2014) and robust decision making under uncertainty, which was used in the planning of Thames estuary 2100 project (Sayers et al., 2012). There are also frameworks that approach adaptation from an investment perspective (Young and Hall, 2015), which consider the performance of measures across multiple scenarios, scales and timelines. In addition to dealing with uncertainty, the strength of real options approaches applied in infrastructure domains is the consideration of path dependency (Gersonius et al., 2013). Path dependency is the dependability of the decisions made in the present on the decisions made in the past and/or the decisions that would be made in the future, that are always likely to affect the current decision. However, inclusion of path dependency in a multiple driver or multiple adaptation context and the inclusion of inter-relationships is lacking in adaptation pathways and real options approaches. Also, these frameworks do not address the complexity arising out of the relationships between multiple drivers and the interaction between adaptation measures at a finer scale such as at household level. Hence in order to help decision makers to choose and implement adaptation measures at the municipal scale, it is essential to develop an evaluation framework that is: (i) broad enough to accommodate the complexities arising out of multiple drivers; (ii) sufficiently detailed to model the interactions at finer scale; (iii) easy to understand and modifiable with a simple logical structure and; (iv) context specific, i.e., represents the inter-relationships between the drivers and adaptation measures for the local adaptation context.

Recently devised adaptation frameworks can be used to address the concerns regarding the difficulties of including multiple drivers and adaptation across scales (e.g. Radhakrishnan et al. (2017)). However, the detailed analysis required is always likely to be complex. The aim of this paper is to address this by showing how to overcome the challenge in modelling and evaluating a complex adaptation problem that has been structured by using a multiple perspective adaptation framework. The paper demonstrates the application of a context specific modelling and evaluation approach (Islam, 2016) in an urban climate adaptation context, where there are multiple drivers; complex interactions between the drivers; relationships between the adaptation measures; and multiple possible futures.

The paper is structured as follows: (a) a review of relevant literature on flexible adaptation approaches and making the case for a context specific modelling framework; (b) methodology describing the context specific modelling and evaluation framework; (c) application of the framework in Can Tho city, Vietnam, which is currently adapting to floods due to multiple drivers; (d) discussion and evaluation of the results; and (e) conclusions of the findings specific to Can Tho and how the approach can be applied in other contexts.

2. The need for context specific adaptation grammar

Modelling of path dependencies in a multiple driver context requires the understanding of various drivers and adaptation measures in a system that is undergoing adaptation. A majority of such systems are complex systems, where there are components such as variables, concepts, relationships and evaluation metrics (Hinkel et al., 2014; Ostrom, 2009). The essential features of complex systems are non-linear feedback, strategic interactions, heterogeneity and varying time scales (Levin et al., 2012). Hence complex systems cannot be explained, described, predicted or modelled accurately (Cilliers, 2001). For example, urban water systems can be considered as complex adaptive systems (Kanta and Zechman, 2014). Urban water systems such as urban flood risk management are comprised of variables (such quantity of rainfall, river discharge) and are based on concepts such as satisfying basic services, water sensitive cities, sustainable development goals (e.g. UN (2015)). They also include relationships between variables based on deterministic relationships such as rainfall-runoff equations or non-deterministic relationships such as how the residents of the city react to flooding (e.g. Garschagen (2015)), as well as evaluation metrics such as service level bench marks (e.g. Min. of Urban Development (2017)). In the context of cities adaptation being anthropogenic; i.e. initiated by stakeholders where a rigid system can be made adaptive through adaptation measures initiated by stakeholders. Hence adaptive systems in an urban contexts are adaptable systems. Systems whose components can be modified, by decision makers, for adapting to changing circumstances are termed as adaptable systems (Oppermann, 1994). Therefore complex adaptable systems can be defined as systems comprising variables, concepts and components that can be changed; the relationships among the variables and among the concepts can be established but cannot be fully explained, described or predicted accurately.

Understanding the relationships between the adaptation measures enables the decision makers to tailor any adaptation according to the needs and emergence of variables, especially the drivers. A common appraisal framework based on a system of systems approach, capable of comparing, combining and appraising adaptation measures across sectors is essential to achieve effective or efficient adaptation outcomes (Young and Hall, 2015). In addition to the system of system approach, other approaches and perspectives can enhance the understanding of interaction between the adaptation measures and the drivers. For example, multiple perspectives for structuring climate adaptation (Radhakrishnan et al., 2017) and integrating pathways (Zeff et al., 2016) are some of the recent approaches that can be used to ascertain the relationship between adaptation measures and drivers for enhancing the effectiveness of adaptation measures.

There are challenges in developing an overall modelling and evaluation framework for modelling path dependencies and inter-relationships in a multiple driver context. Firstly, integrating a system of systems approach into a modelling framework is a challenge, where a small system change can have a large overall systems effect (Maier et al., 2016). Secondly, developing a generic evaluation framework which considers change at a local scale is also a challenge as the number, nature and relationships between the drivers vary in every local context (Sayers et al., 2015; Tessler et al., 2015). Therefore, fitting together the uncertainties and system performance in all possible scenarios is essential for evaluating adaptation measures in a multiple perspective (Maier et al., 2016). Scenarios relate entirely to changed environmental drivers (stressors) such as sea level, rainfall intensity, temperature (e.g. IPCC (2013) scenarios); and, changed socio economic stressors such as GDP, population growth rate, rate of urbanisation (e.g. Shared socio economic pathways O'Neill et al. (2015)).

Evaluating the collective robustness of various adaptation measures together, rather than of the individual robustness of a particular adaptation measure has been proposed as a way to better include uncertainty and to ensure robust system performance (Maier et al., 2016). Decision making methods to define and select robust measures are being recommended for determining the lowest level of trade-off between optimising returns (efficiency) and robustness (sustainability), although the generic toolkits for