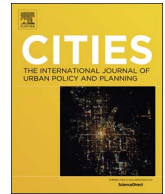


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Flexible adaptation planning for water sensitive cities

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ABSTRACT

Cities have started adapting to uncertain climate drivers such as temperature and sea level rise, and some cities are also transitioning towards concepts such as Water Sensitivity. In adaptation planning, flexibility is considered as an important characteristic to respond to changing circumstances. This paper develops a novel approach to identify where flexibility can best be embedded in urban flood risk management systems. The identification of a flexible water sensitive adaptation response is based on change propagation; i.e. the response's ability to minimise negative or maximise positive *impacts* in urban systems. The Flexible adaptation planning process (WSCapp), comprising change propagation – especially how positive and negative impacts propagate in an urban environment, can be used by those concerned with urban planning and urban adaptation to identify “where” the flexible adaptation responses can be implemented. WSCapp can be used to decide the type of adaptation response such as changes to streetscape, place making or architectural forms that can best contribute towards the objectives of a water sensitive city.

1. Introduction

Adaptive approaches in planning, design and implementation can help to minimise the hazardous effects of climate change and explicitly allow for the uncertainties associated with these in urban areas (Revi et al., 2014). Policy makers, planners and others managing urban areas have recognised the likely effects of climate change and have initiated strategic adaptation actions that are aligned usually according to a particular vision used by a particular sectoral or service provision (Chu, Anguelovski, & Roberts, 2017; Jabareen, 2013). There are also signs of a breakaway from a sectoral vision, in which urban adaptation planning is compartmentalised, with moves towards multi-sector and multi-disciplinary planning approaches to better bring about sustainable development (Malekpour, Brown, & de Haan, 2015). However, decision making related to adaptation faces uncertainties, which necessitate a flexible approach that can adapt to the changes. Flexibility is important for this and is here defined as the attribute of a system which enables the system to respond in an efficient way in terms of performance, cost and time, when the system is confronted with uncertainties, negative consequences and opportunities (Anvarifara, Zevenbergen, Thissen, & Islam, 2016).

Flexibility is increasingly seen as a desirable feature that enhances system capabilities and functionality in the face of uncertainty (Schulz, Fricke, and Igenbergs (2000). Gersonius et al. (2016) recommend

flexibility in combining different types of strategies “retain, resist, relieve, retreat, accommodate and prepare” (4RAP) to increase resilience towards flooding in designing and planning systems for water sensitivity (Fig. 1). For example, the City of Melbourne's resilience strategy considers flexibility as an important characteristic to respond to changing circumstances when using a mix of strategies such as adapt, survive, thrive and embed (City of Melbourne, 2016). Flexibility is also a property which counters the effects of maladaptation throughout the entire life cycle by allowing system change (Gersonius, Ashley, Pathirana, & Zevenbergen, 2013).

A “water sensitive city” (WSC) vision (Brown, Keath, & Wong, 2009) considers urban water management from a perspective of intergenerational equity and resilience to climate change and hence is more than just Water Sensitive Urban Design (Ashley et al., 2013). The WSC approach recommends an urban design that reinforces ‘water sensitive’ behaviours. This is evident in the adaptation plans and actions taken by cities such as Rotterdam, Copenhagen, Dresden and Melbourne (City of Melbourne, 2016; EEA, 2016) and is an aspiration for London (HM Government, 2016). The adaptation measures in these cities are termed as ‘transformational adaptation measures’ (EEA, 2016). They use behaviour and technology to change the performance of urban systems fundamentally. In addition, transition or strategic planning for sustainable development requires a proactive planning culture in order to create conditions for change to deal with future issues (Malekpour

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Fig. 1. 4-RAP model of available strategies – where the 4R's signify the retain, relieve, resist and retreat strategies; 'A' signifies accommodate strategy; and 'P' signifies prepare strategy - to enhance flood resilience.

(Adapted from Gersonius et al. (2016))

et al., 2015). For example, in Melbourne, water, wastewater and stormwater management was formerly aimed at the protection of waterway health, tackling water shortages during drought, ensuring water supply through alternative sources and protection against flooding (Ferguson, Brown, Frantzeskaki, de Haan, & Deletic, 2013). Now Melbourne has moved beyond this and is including the objectives of being resilient to climate change and becoming a water sensitive city (City of Melbourne, 2016). An important characteristic of a resilient city is flexibility, e.g., having a number of alternative ways to provide services and respond to changing circumstances as these arise (City of Melbourne, 2016). It allows the city to respond to future needs from climate change as well as changes in objectives.

An effective WSC requires a process that incorporates flexibility into planning, implementation and operation. The context-first approach adaptation planning process (e.g. Thames Estuary project TE2100) makes adaptation flexible using a high level route map of adaptation measures (Reeder & Ranger, 2011). Techniques such as real in options (RIO) (e.g. Woodward, Kapelan, and Gouldby (2014)) value the flexibility built into a (flood risk management) system in monetary terms. However, these approaches do not identify the optimal places where flexibility can be embedded. Hence, in addition to the value it is necessary to know where, how and when to incorporate flexibility to achieve the objectives of a WSC.

This paper develops a novel approach to identify where flexibility can best be embedded in urban flood risk management systems. This has been developed by drawing on knowledge and procedures from the automobile and aerospace industries, where flexible adaptation planning is everyday practice (Suh, de Weck, & Chang, 2007). The flexible physical components are selected based on the components' ability to propagate change in the urban system (Eckert, Clarkson, & Zanker,

2004). An adaptation response is an ideal flexibility 'candidate' when it minimises negative impacts or maximises positive impacts throughout the area under consideration (i.e. change propagates throughout the system) and not just in the vicinity of the adaptation response. For example, a dewatering pump reduces flooding in a neighbourhood (reduces negative impact), whereas green roofs in addition to reducing the peak flow during rain, also have ecosystem service benefits in the neighbourhood (increases positive impact). Both these urban water management adaptation responses are capable of propagating change throughout the neighbourhood either by reducing negative impacts or by increasing the positive impact and contribute towards increasing resilience in the urban system. Further, prior identification of flexible adaptation responses makes the response to change rapid, i.e. making the change process agile (Pathirana, Radhakrishnan, Ashley, Quan, & Zevenbergen, 2017). In this context, agility is defined as the ability of the adaptation system to respond quickly to uncertainties, threats and opportunities.

The sections in the paper explain: (a) the relevance of flexibility in flood risk management; (b) methods that are used in embedding flexibility in the manufacturing sector; (c) the need for a planning process that ensures that adaptation is flexible in a WSC context; (d) development of a flexible adaptation planning process (WSCapp) for identifying WSC elements or components where flexibility can be embedded; and (e) theoretical and practical considerations for applying this flexible adaptation planning process.

2. Flexibility in contemporary flood risk management practices

Flexibility is often considered as a valuable capacity to cope with uncertainty and change, although there is no consensus about what

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