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Research Paper

What drives the location choice for water sensitive infrastructure in Melbourne, Australia?

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ABSTRACT

Distributed and green urban drainage infrastructure known as Water Sensitive Urban Design (WSUD) is increasingly being implemented in cities globally to combat climate change and urbanisation effects. Rigorous consideration of the urban context in terms of biophysical, socio-economic and urban form related factors is crucial for optimal design outcomes. The extent to which the urban context is considered in current planning and decision-making processes remains unclear. This study investigates this relationship between current WSUD infrastructure in Melbourne (Australia) and each of the aforementioned factors for the first time. We obtained and pre-processed one of the most extensive and complete geo-located WSUD asset databases in the world (containing over 2000 WSUD assets), and undertook an evidence-based analysis of WSUD planning outcomes. Relationships were investigated using spatial analysis techniques (e.g. overlaying), as well as a number of statistical methods (e.g. exploratory regression). It was found that biophysical and urban form factors strongly explained variability in WSUD location choice, while socio-economic factors appeared to be overlooked. Our findings imply that the current WSUD planning practices are primarily governed by standard engineering design. Opportunistic WSUD planning leads to unintentional outcomes that fail to capitalise on the full potential of WSUD benefits. Increased investment in asset inventory development and analysis is critical to inform WSUD planning moving forward. Knowledge gained from this and additional studies can further planning through application in planning-support systems, to deal with the complexity and diversity of the broad set of decision criteria.

1. Introduction

Water Sensitive Urban Design (WSUD) refers to the introduction of distributed 'green' technologies in the urban landscape for stormwater treatment, detention and reuse with the primary aim to protect and restore natural waterways, decrease the risk and severity of floods and diversify sources of water supply (Dietz, 2007; Wong & Brown, 2009; Woods Ballard et al., 2007). This innovative approach to water management and similar concepts (e.g. Low Impact Development (LID), Sustainable Urban Drainage Systems (SUDS) and Best Management Practice (BMP)) are increasingly being implemented around the world as a strategy to adapt to the pressures of increasing urbanisation and climate change on urban water management (Fletcher et al., 2014; Wong & Brown, 2009). Aside from the abovementioned benefits, WSUD serves a broader set of functions, such as increasing the aesthetic value of neighbourhoods (Backhaus & Fryd, 2013; Dobbie & Green, 2013), providing recreational space (Dobbie & Green, 2013; Wong & Brown, 2009), mitigating urban heat island effects (Coutts, Tapper, Beringer, Loughnan, & Demuzere, 2012; Mitchell & Cleugh, 2006; Steeneveld, Koopmans, Heusinkveld, & Theeuwes, 2014), and educating communities about urban sustainability (Lundy & Wade, 2011; Rijke, De Graaf, Van de Ven, Brown, & Biron, 2008). WSUD is a relatively young addition to urban planning practice and although technical design guidelines have been developed, rigorous and experience-based information on the relationship between urban planning and water management is lacking (Sharma, Cook, Tjandraatmadja, & Gregory, 2012). Anecdotal evidence from municipal planning practitioners suggests that WSUD practice has predominantly been driven by

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'opportunistic' approaches in both infill developments (retrofitting rain gardens in road renewal sites), or greenfield developments (leaving WSUD integration as the last planning consideration), which may result in less than optimal planning outcomes (Allan, S., personal communication, 1 September 2015; Innes, S., personal communication, 23 October 2015; Chaffin et al., 2016; Fronteira, Kauhanen, & Kunze, 2014). WSUD implementation and management guidelines necessary to prevent such opportunistic approaches are scarce (Roy et al., 2008) and largely issued on local (municipal) scale. Only for new (greenfield) developments is centralised regulation present (DELWP, 2017).

A growing body of literature reports on the factors that determine the 'suitability' of a location for WSUD implementation (e.g. Ashley, Booker, & Smith, 2004; Ellis, Deutsch, Mouchel, Scholes, & Revitt, 2004; Martin, Ruperd, & Legret, 2007; Scholz, 2006). Traditionally, various abiotic (non-biological) biophysical factors (hereafter simply referred to as 'biophysical') are considered for design and placement of WSUD and stipulated in guidelines (e.g. Melbourne Water, 2005; Woods Ballard et al., 2007), such as hydrology (e.g. rainfall), soil, slope and imperviousness. However, recent literature suggests that a wider variety of spatially variable factors can impact the functioning of these technologies, including socio-economic and urban form (e.g. Barbosa, Fernandes, & David, 2012). For example, high public literacy and awareness of the function and benefits of WSUD may improve community acceptance and interaction with WSUD. Such literacy and awareness, in turn, is expected to be more easily attained by communities with high environmental awareness and higher education levels, as is the case for public acceptance of similar green innovations such as water recycling schemes (Dolnicar, Hurlimann, & Grün, 2011; Domènech & Saurí, 2010).

Besides suitability, the 'need' for WSUD varies spatially, due to the diverse benefits green technologies offer for storm water quantity, quality and amenity (Ashley et al., 2013; Marlow, Moglia, Cook, & Beale, 2013; Wong & Brown, 2009). For example, neighbourhoods with low levels of greenery significantly benefit from the introduction of WSUD, while relatively pristine waterways benefit more from pollution mitigation than degraded waterways (Walsh, Fletcher, & Ladson, 2005). Public exposure to WSUD is high in frequently visited open spaces such as train stations and shopping precincts. Hence, optimising WSUD placement requires the planning process to consider a wide variety of factors. A recently developed suitability framework attempts to capture this variety (Kuller, Bach, Ramirez-Lovering, & Deletic, 2017). Opportunistic planning approaches overlook these factors, reducing the benefits obtained from WSUD (Schifman et al., 2017).

Growing knowledge about 'suitability factors' is accompanied by a growing number of planning support tools for WSUD. Various planning frameworks incorporate some form of suitability assessment based on multiple factors/criteria (e.g. Jin, Sieker, Bandermann, & Sieker, 2006; Lee et al., 2012). Although these tools predominantly focus on biophysical factors, there is an encouraging trend towards incorporation of a wider variety of aspects, including socio-economic factors (e.g. E2STORMED, 2015; Fronteira et al., 2014; Viavattene, Scholes, Revitt, & Ellis, 2008). Application of such tools and frameworks could drastically improve planning practices without overly increasing their complexity (Geertman & Stillwell, 2004; Lee et al., 2012; Vonk, Geertman, & Schot, 2005). Nevertheless, currently available planning-support systems remain underused for a number of reasons including lack of relevance and user-friendliness (te Brömmelstroet & Bertolini, 2008; Vonk et al., 2005). This raises the question to what extent biophysical, socio-economic and urban form factors have been guiding planners' decision-making processes to date.

However, no structured investigation has been conducted to examine location choices for WSUD in metropolitan regions, assessing the impacts of the abovementioned factors. The difficulty of acquiring data on the location, type and size of WSUD assets for an entire metropolitan region may underlie this scarcity. However, this information is crucial in WSUD planning and applications. To understand how the complex urban context impacts the current practice of WSUD planning, the present study aims to characterise WSUD composition (i.e. choice of technology type) and distribution in relation to the urban context for metropolitan Melbourne (Australia). More specifically, we focus on:

(1) exploring Melbourne's current WSUD inventory in terms of types, land uptake and service area,
(2) investigating relationships between WSUD location and the urban context in terms of biophysical, socio-economic and urban form factors,
(3) assessing to what extent the current practice aligns with WSUD planning best practice as informed by local and current national guidelines.

We hypothesise that biophysical factors consistently and strongly drive location choices for WSUD, as they can prohibit their implementation. We would also expect WSUD to be often present in relatively flat areas (as prescribed by design guidelines, e.g. Melbourne Water, 2005) and close to waterways (as WSUD in Melbourne is traditionally driven by the water authority, which is in charge of the larger urban waterways: Brown & Clarke, 2007). Furthermore, we hypothesise socio-economic factors to be weakly related to the locations of WSUD. While socio-economic factors aren't prohibitive to implementation of WSUD, they can decrease its feasibility (CRCWSC, 2014). In contrast, urban form factors are expected to significantly relate to the locations of WSUD. For example, areas of high-intensity land-uses (e.g. commercial centres, high density residential) are space constrained and should therefore include smaller WSUD assets.

To the author's knowledge, this is the first systematic analysis of a geo-located WSUD dataset, using one of the most extensive and complete inventories currently available. Furthermore, for the first time the relationship between a wide variety of spatially variable factors are compared to WSUD placement. In doing so, it increases our understanding on how the complex urban context impacts the current practice of WSUD planning. Lessons from this study are vital to move WSUD planning away from opportunistic practices.

2. Methodology

2.1. Data collection and preparation

Melbourne is a rapidly growing city and currently houses 4.5 million residents, making it the second largest city in Australia. It is a sprawled city (i.e. 'low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas' – EEA, 2006: page 6), similar to others across the country (Coffee, Lange, & Baker, 2016; McLoughlin, 1991), North America and, increasingly, also Europe (Batty, Besussi, & Chin, 2003). It was selected as our case study for its comparatively large experience with the implementation of WSUD (Ferguson, Brown, Frantzeskaki, de Haan, & Deletic, 2013) and the availability of a unique, georeferenced, metropolitan-wide WSUD asset database.

2.1.1. WSUD data acquisition and pre-processing

Melbourne Water, the local water authority, undertook an extensive mapping study of all WSUD assets in 2012, which was collated into a spatial database. The database only includes assets that are primarily built as stormwater management structures, thereby excluding other structures that have an impact on stormwater management (sometimes referred to as 'passive systems', such as lawns and ponds). The assets in the database are managed by different parties, including the local water authority (for assets with a catchment of over 60 ha – Melbourne Water, 2017), local government and private parties. The scattered nature of management responsibilities is reflected in the scattered nature of data on the distribution of WSUD assets. Although the database contains significant imperfections in terms of accuracy and completeness, this