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Ecologically-based Urban Design in Sustainable Stormwater Management

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ABSTRACT

Urban stormwater problems are indisputable, many countries have suffered from such problems and will be exposed to greater threats due to urban sprawl and climate change. For controlling urban stormwater, conventional stormwater approaches rely on underground pipeline systems to drain stormwater away as soon as possible. With people paying more attention to urban stormwater issues and environmental quality, multiple strategies which could be collectively called Sustainable Stormwater Management (SSM), have been proposed and implemented for solving different local stormwater problems, enhancing the natural water cycle and protecting receiving waters and aquatic habitats. This paper reviews the literature and describes how ecologically-based urban design (EBUD) interfaces and improves SSM during urban development. SSM covers planning and engineering aspects and EBUD plays an important role for keeping and mimicking nature and also sketching out the best plan for arranging SSM measures. EBUD provides stakeholders with a philosophy and guidelines from an urban design perspective for SSM development, spanning from stormwater mitigation and control to protection of the natural water ecosystem of the receiving water bodies. Subsequent research will use a case study approach to identify priority issues to address when formulating guidelines for EBUD in SSM.

Keywords: *Sustainable Stormwater Management, Urban Design, Ecological Wisdom, Resilience*

INTRODUCTION

In many cities, urban stormwater management is commonly deemed to be an environmental problem and challenge for engineers rather than for urban planners and designers (Potter et al., 2011). The main reason for this is that the scarcity of urban surface area makes underground piped drainage systems become the first choice for draining stormwater (Cettner et al., 2013). Other social and environmental interests, such as urban landscaping, transportation systems and open space access, have to be compatible with any other ground surface system but not with underground drainage pipes (Cettner et al., 2013). Current measures of SSM are mostly at the ground surface, for instance, rain gardens, stormwater wetlands and grass swales. When urban designers plan these measures into urban space, they must consider more environmental and social issues compared to planning for underground stormwater pipes. The main challenges of using EBUD to effectively implement non-structural and structural measures into urban areas, are shifting paradigms from strategic planning of stormwater control to multiple ecological objectives of stormwater design and adaptation (Wong & Brown, 2009). It means that urban stormwater planning and design should shoulder the responsibility for achievement of multiple objectives not just stormwater mitigation and adaptation, but also protection of the hydrological regime and dependent aquatic ecosystems of urban areas. The objective of this paper is to identify how EBUD plays an important role for keeping and mimicking nature and also for sketching out the best plan for arranging SSM measures. Subsequent research will use a case study approach to identify priority issues to address when formulating guidelines for EBUD in SSM. This study fits well with the focus of the conference - sustainable cities and landscape, because it aims to improve an urban design philosophy and guideline for sustainable development and delivers more ecological and sustainable outcomes, spanning from sustainable stormwater management to urban landscape conservation.

ECOLOGICAL WISDOM OF FLOOD ADAPTATION FOR STORMWATER URBAN DESIGN

There is a great example that shows how to use these urban design principles for stormwater and even flood resilience. Liao and Chan (2016) describe a flood adaptation paradigm which is called “amphibious ecology” from the Vietnamese Mekong Delta (VMD). Local people live with floods and have their own wisdom to face various troubles caused by floods, such as living in stilt houses and keeping transportation with boats and footbridges. The researchers advocate that modern cities should take lessons from the living-with-flood lifestyle from VMD. There is no scientific research for such ecological knowledge and wisdom, but all the flood resilience and adoption experience is passed down and concentrated by generations (Ehlert, 2012). Liao (2012) concludes that there are three key theories of urban stormwater resilience: response capacity of flood, timely adoption after each flood event and adequate preparation in subsystems. This experienced wisdom gives urban designers insight into how to improve local people's consciousness of flood risk for flood events is essential rather than blindly just using flood control infrastructure. Furthermore, flood control devices lead the public to produce a false illusion of security, and also maintaining and upgrading them always take years and money.

From the aforementioned ecological wisdom from VMD, the three urban design principles for flood resilience which mentioned above could be further explained as: predicting, keeping watch and adopting urban stormwater approaches; urban designing with ecological procedures of urban stormwater; and raising public perception of stormwater dynamics (Liao, 2012). In urban areas, modern buildings are hard to simulate stilt houses, but Singaporean architects use “void deck” to achieve ventilation and flood adaptation. The ground floor of modern high-rise buildings may be designed as open space and only the main load-bearing structure stays there. This open space could be used for recreation and ventilation in dry-weather times and accommodate stormwater during flooding times. These types of buildings have great adaptation and resilience to urban stormwater events. However, compared to the simplicity of creating open space to detain stormwater, such construction is much more complex (Liao, 2012; Gill et al., 2007). Ground level open space creation may be impractical and expensive in some high density cities such as Singapore. From the earlier Emerald Necklace (Boston, USA, 1895) to the recent Qunli Stormwater Wetland Park (Harbin, China, 2009), these fantastic urban design works show how to use open space to mitigate, retard and purify stormwater based on urban ecological design principles; another extreme type is sinking square and an outstanding example is Water Square Benthemplein (Rotterdam, Netherland, 2014), the hard-paved sinking plaza could become a big cistern for retarding and temporarily storing stormwater when urban floods happen (Silva & Costa, 2018).

ENGINEERING RESILIENCE AND ECOLOGICAL RESILIENCE

In the engineering aspect, resilience focuses on the ability to rapidly spring back from a damaged condition to the original condition when the pressure eases and the ability to swiftly recover becomes the central issue for engineering resilience (Wang & Blackmore, 2009). In ecological resilience, just the same as in engineering resilience, there is also a desire to have the ecology bounce back from the damaged condition. However, dynamic and multiple equilibria are the key characteristics of an urban ecosystem and it is hard to return to the previous condition (Scheffer et al., 2001). So, for ecological resilience, the ability to absorb disturbances, tolerant interfere and self-renewal, and holding a dynamic balance are the key issues, rather than recovery after damage like in engineering resilience (Holling, 1996; Scheffer et al., 2001). Holling (1996) accurately summarises the two types of resilience: these two resilience concepts are different and even contradictory; it is abnormal in engineering resilience if any change happens from optimal conditions while fluctuation within a reasonable range is an extremely conventional phenomenon for ecological resilience; low ecological resilience exists in elevated engineering resilience systems and vice versa.

Engineering resilience for stormwater management means to help a city to be more resistant using stormwater control infrastructure (SCI) (including physical devices, construction and relative engineering technology) while considerable investment is made in engineering devices, and construction does not achieve favourable results and urban riverine ecosystems are degraded by artificial infrastructure (Liao, 2012). Engineering resilience relies on SCI and the following limitations of SCI should be notable for policy-makers, urban designers and engineers: SCI always has a fixed capacity to take charge in a large area and centrally process stormwater, but the rigid construction is not enough to handle rapid urban sprawl and changing boundaries (Jones et al., 2012); SCI's efficiency is not stable and reliable because of some unsteady factors such as erosion and damage to facility performance by uncertain natural factors and untimely manual maintenance (Smits et al., 2006); social injustice is caused by SCI because it is always concentrated in urban areas and costs a mass of funds, while rural areas also suffer from floods and these areas are always ignored (Smith & Ward, 1998); SCI has a significant impact on natural ecological systems and hinders and influences the natural water cycle (Tockner et al., 2008).

In addressing urban stormwater problems, urban designers should help modern cities to transform conditions from engineering resistant cities to ecologically resilient cities. Also assisting urban areas to shift the stormwater paradigm from stormwater control to stormwater resilience and adaptation will create a gigantic social challenge for urban designers – the existing stormwater control and management structure is tough to shake up (Liao et al., 2016). "The associated technologies, management practices, legal frameworks, and social perceptions have coevolved to stabilize one another" (Pahl-Wostl 2006), all these structures need to be improved gradually.

ECOLOGICALLY BASED URBAN DESIGN

Applying EBUD for stormwater management, the core philosophy is "ecological wisdom". An ancient Chinese philosopher Laozi (571 BC-471 BC) gave his point of view for ecological wisdom: "human follows the earth; earth follows the universe; the universe follows the nature; the nature follows only itself" (Wu, 1961, p.35). Naess (1973) defines ecosophy (the origin of ecological wisdom) as "a philosophy of ecological harmony or equilibrium" and ecosophy is more correlated with individual philosophy; Xiang (2016) conceives ecophronesis as "the master skill par excellence of moral improvisation to make, and act well upon, right choices in any given circumstance of ecological practice". After years of development, ecological wisdom has become an amalgamation of ecosophy and ecophronesis and covered individual and public values (Xiang, 2016). With regard to EBUD concept for stormwater issues, one of the fundamental research direction is developing sustainable and green drainage-related urban design concepts, such as LID, WSUD and LIUDD, to mitigate stormwater by using structural and non-structural measures (Mascarenhas & Miguez, 2002). Through constructing multifunctional urban landscapes and normalizing sustainable development standards (Barbedo et al., 2014), EBUD-SSM provides urban planners and designers with new concepts and guides to improve urban resilience and rehabilitate natural water cycle. EBUD principles to mitigate and adapt stormwater issues need to lead the whole stormwater management sector. Urban planners, urban designers and landscape architecture should take more responsibility for urban stormwater management, using urban design principles to give urban stormwater management a clear plan and blueprint and applying ecological wisdom in planning and design to mitigate and adapt stormwater rather than blindly utilizing engineering measures and concepts, constructing engineering devices and systems to control stormwater rigidly.

There was an interesting and meaningful experiment within Copenhagen, where researchers recruited six teams of professional landscape architects and let them plan and design a school and neighbourhood area of approximately 30 ha, for stormwater management by using the Sustainable Urban Drainage Systems (SUDS) (Backhaus and Fryd, 2012). The researchers wanted to identify the challenges and difficulties that designers confront when planning and designing stormwater management by using one of the green stormwater approaches (Sustainable Urban Drainage Systems) from the perspective of landscape architects.

Two-week workshops demonstrated that designers could provide urban stormwater management within a good framework to integrate various aspects of stormwater planning and design. Moreover, landscape architects identified the challenges they faced when making a plan and designing for the site, and these gave future research clear and targeted missions. The challenges were mainly from three categories: research deficits, collaboration, and practice. Knowledge and research deficits mainly lie in the aspect of dimensioning, water quality, biodiversity, and economy. For example, with respect to biodiversity aspects of green stormwater planning and design, the suitable vegetation selection and form need more in-depth research; to economic parts, the detailed data and information of established stormwater planning and design projects should be collected and this could provide precious experience and knowledge for future plan. In hydrological aspects, the stormwater data of short return periods and dimensioning outlines the need for revision and enhancement that makes it easier for designers to recognize. The challenges from the collaboration are mainly because there is estrangement between different research fields, especially between engineering and urban planning & design. During their research, they found that urban planners, urban designers and landscape architects should be the leaders in the urban stormwater management process instead of the engineers who are currently leading it. The chief reason why planners and designers should be at the leading position is that planners and designers could have a more general overview than other professionals and integrate different research departments and knowledge, such as engineering, botany, and hydrology. The results of six teams showed approval for the special role of planners and designers in urban stormwater management because urban planning and design approaches reflect powerful and unique abilities to solve many problems in urban stormwater management processes, and also in establishing and refining urban design guidance for stormwater management as a top priority.

Some regional and central government agencies have woken up to the important role of urban planning and design in urban stormwater management. But shifting the paradigm from traditional stormwater drainage and current engineering dominated green stormwater management to ecologically-based stormwater planning and design as the leader of the whole urban stormwater planning, design and management, is still hindered by some factors. Too many factors are correlated to urban planning and design and usually stormwater planning and design is not considered as the most important specialisation for urban planners and designers (van Herk et al., 2011); other barriers include growing uncertainty of stormwater issues by climate change and human activity (Milly et al., 2008), the lack of awareness and understanding of the efficiency of urban design and planning in urban stormwater management, and unsound mechanisms and standards of urban stormwater planning and design (Adger et al., 2005).

Another typical and successful example was conducted in the Netherlands. Van Herk et al. (2011) point out and reveal the key position of urban planning and design frameworks in urban stormwater management procedures. The researchers carried out the study from the perspective of a social learning framework of urban planning and design, the framework is called: Learning and Action Alliance (LAA). The framework is implemented and tested in The Netherlands and the LAA positively supports an integrated approach for stormwater planning and design in two case studies. Most of the interviewees reported that the LAA of stormwater planning and design made great improvements for three joint activities: stormwater analysis, cooperative stormwater design, and governance. The new framework confirms that an effective urban planning and design guide is very helpful for urban stormwater management. It could not only address the fundamental problems, optimize stormwater solutions and stimulate policy, but also create convergence of the scattered urban stormwater segments to form a system of overall planning and design.

DISCUSSION

Sustainable and green stormwater management in urban areas requires unified and coordinated approaches of engineering and ecologically-based urban planning and design. The intensive and deep-delving collaboration between urban designers and institutions is critical for sustainable and green stormwater planning, design and management. Currently, too much engineering focus leads urban stormwater management to the extremes and unbalanced development exists between structural measures and non-structural measures. Physical devices have been technologically advanced (e.g., rain gardens, retention ponds, living roofs, vegetated trenches) and corresponding practical guidelines for these techniques also have been well established. Unfortunately, compared to rapid engineering improvement, urban design aspects of stormwater management have often been ignored in many engineering-led projects and research (Costa et al., 2015). Technological aspects are almost no problem, while the main obstacles for SSM in urban areas are organized planning and design, public awareness, and social performance (Hoyer et al., 2011). In urban planning and design circles, it is very common for urban designers and planners to neglect to use watersheds/catchments as the spatial basement for sustainable stormwater design (Krebs et al., 2013). Poor urban planning and design is also directly related to potential damage by urban stormwater, for example, uncontrollable urban sprawl with no or little sustainable stormwater planning, design and management for stormwater-sensitive areas, is often accompanied with high flood and erosion possibility (Costa et al., 2015). The above examples of sustainable stormwater planning and design have shown that urban planning and design is critical for holistic SSM.

Sustainable stormwater planning and design should be considered at the earliest stages in the process of urban planning and design and regarding water sensitiveness as one of the key parts of urban design will bring multiple benefits to the whole natural environment and human society. Several sustainable stormwater projects, such as WSUD as part of Green Infrastructure of local urban plans in Dublin, Ireland, SSM in the River Besos, Spain, and water quality mitigating wetland design in Vihti, Finland (Costa et al., 2015), have successfully demonstrated that SSM based on EBUD guidance could achieve multiple benefits for urban areas. The benefits include effectively mitigating urban stormwater quantity and improving stormwater quality, refining urban landscape value, enhancing landscape amenity and optimising water cycle control and biodiversity in urban areas.

CONCLUSION

This paper has demonstrated how EBUD works as a core part of SSM and delivers more ecological and sustainable outcomes. Shifting the paradigm and awareness of current stormwater "engineering" control to stormwater adaptation and resilience by using EBUD approaches is a challenge in old urbanized areas, where there is the strongest and densest artificial construction and human activity. SSM based on EBUD needs to extend objectives, not only to improve stormwater resilience and adaptation, but also to protect the hydrological cycle and aquatic ecosystems in urbanised areas. EBUD aims to provide urban planners, urban designers, engineers and government officials with philosophy and guidelines from an urban design perspective in SSM development, spanning from stormwater mitigation and control to protection of the natural water ecosystem of the receiving water bodies. Subsequent research will use a case study approach to identify priority issues to address when formulating guidelines for EBUD in SSM.

This research may contribute to achieving Sustainable Development Goals (SDGs) 9, 11 and 13. Goals 9 aimed to enhance urban areas ability to achieve stormwater resilience and sustainable development. This could be achieved through EBUD-SSM's philosophy and green approaches. As EBUD-SSM seeks to attain improved environmental outcomes for urban ecosystems and communities, it may also contribute to sustainable cities and communities Goal 11. In relation to Goal 13, climate change is worsening the urbanisation caused water-related problems that EBUD-SSM proposes to solve.

Under Covid-19 pandemic, EBUD and SSM should also pay more attention to the design and management of multifunctional urban open spaces which are indispensable social environments for the public confined to local neighbourhoods. Feasible design and management of these open spaces are vital both for social distancing for pandemic control and public physical and mental health. Future combined landscape and urban design and stormwater management should include such mechanisms of epidemic prevention, control, and social support.

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