Water Sensitive Urban Design through the Lens of Urban Metabolism

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Abstract: Stormwater pollution has been recognised as one of the main causes of aquatic ecosystem degradation and poses a significant threat to both the goal of ecological sustainable development as well as human health and wellbeing. In response, water sensitive urban design (WSUD) practices have been put forward as a strategy to mitigate the detrimental impacts of urban stormwater runoff quality and to safeguard ecosystem functions. However, despite studies that support its efficiency in urban stormwater management, the mainstreaming of WSUD remains a significant challenge. This paper proposes that viewing WSUD through the lens of the integrated urban metabolism framework which encourages an interdisciplinary approach and facilitates dialogue through knowledge transfer is a strategy in which the implementation of WSUD can be mainstreamed.

Keywords: Knowledge-based urban development, urban metabolism framework, Water Sensitive Urban Design, WSUD

INTRODUCTION

Stormwater pollution has been recognised as one of the main causes of aquatic ecosystem degradation and poses a significant threat to both the goal of ecological sustainable development as well as human health and wellbeing. Urbanisation results in the increase in the volume of stormwater to receiving urban water bodies, which are important community assets. The consequent anthropogenic activities due to urbanisation are closely linked to changes to a diversity of pollutants being deposited on surfaces as well as emitted to the atmosphere. In turn, they contribute to the declining quality of stormwater, leading to adverse impacts on the receiving water environments. These factors, when linked to the predicted effects of climate change in Australia such as longer dry periods with more intense rainfall, are expected to further compound the deterioration of urban stormwater quality. In response, Water Sensitive Urban Design (WSUD) practices have been put forward as a strategy to mitigate the detrimental impacts on urban stormwater runoff quality and to safeguard ecosystem functions. WSUD can be defined as the application of passive systems (such as grass swales, bioretention basins and constructed wetlands, shown in Figure 1) and use of ecological processes to mitigate the adverse impacts of urbanisation on the receiving water environment However, whilst WSUD is underpinned by rigorous scientific studies and principles of ecological sustainable development, research to ensure its adaptability within an integrated framework of climate change and compounding anthropogenic activities are still lacking. This paper proposes to address this gap by viewing WSUD strategies through the lens of the Integrated Urban Metabolism Framework as proposed by Goonetilleke et al, (submitted). By mapping the inputs, outputs and urban water and related ecological processes, the 'budget' of water use, waste and loss in urban areas can be explicitly quantified and solutions to increase efficiencies, lower demand and enable more sustainable use of this scarce commodity can be achieved more effectively.

(a) A (bio)retention basin (b) A constructed wetland (c) A grass swale

Figure 1. Typical WSUD systems

SUSTAINABILITY AND URBAN METABOLISM

The concept of sustainability is one of the most talked about principles in urban development and management today. Both the concepts of 'sustainable development' and 'sustainability' are acceptable objectives in which governments and communities alike agree that urban development and its management should head towards. In Australia, enquiries have been conducted, state of the environment reports have been produced, and national urban policies have been published in order to push the unstoppable juggernaut that is development towards a more 'sustainable' slant (House of Representatives Standing Committee on Environment and Heritage, 2005; Australian State of the Environment Committee, 2006; Department of Infrastructure and Transport, 2011). However this movement has given rise to more questions—what is 'sustainable urban development'? What does it mean to have a 'sustainable city'? How does a city achieve 'sustainable urban development'? A key step towards establishing a concrete definition of 'sustainable urban development' would be the measurement of resource flows and waste generation of urban systems and processes. Establishing a 'budget' of inputs and outputs would assist in identifying areas in which efficiencies can be improved and ascertain resources that can be reclaimed and reused. A manner in which this can be conducted is through the framework of 'urban metabolism'.

Urban metabolism

The concept of 'urban metabolism' was coined by Wolman in his seminal paper in 1965. Wolman (1965), who was discussing the then looming problem of water shortages in American cities, wrote that "the metabolic requirements of a city can be defined as all the material and commodities needed to sustain the city's inhabitants at home, at work and at play". Newman (1999) brings this concept further, stating that to solve environmental problems in urban areas, cities need to be seen not as an inorganic being, but as an ecosystem with the characteristics of a living organism that survives on inputs of energy and materials and returning them to the environment as waste and emissions. Thus, through analysing the city as an entire being, as opposed to the piecemeal manner in which management has been traditionally conducted, it will be possible to recognise areas in which management systems and technologies can be utilised to improve the sustainability of cities (Newman, 1999).

WSUD and urban metabolism

The achievement of sustainable urban development has been proven to be fraught with difficulty and is not as simple as 'making good decisions' to ensure a reduction in resource use (Schremmer & Stead, 2009). A case in point is that of urban stormwater management. While stormwater has proved to be a major impediment in attaining a state where urban development can be considered sustainable, strategies in its management in many cities is yet to move beyond the age-old objective of rapid flood conveyance. WSUD is one of the key responses to address the need to better manage urban stormwater runoff through the provision of an alternative, innovative and effective strategy to traditional stormwater management. Specifically, by utilising naturally occurring tools such as native vegetation, WSUD ensures that the environmental quality of the water body to which stormwater discharges, remains as unpolluted as possible. Furthermore, as WSUD is a feature of urban design, it can contribute towards enhancing the aesthetics of urban areas, improving quality of life while providing important environmental outcomes. This is especially important as the world struggles to enhance the quality of urban areas and to adapt to the impacts of climate change. In fact, it is looking increasingly inevitable that urban development is turning from mitigation to adaptation (Evans, 2011). With this in mind, there is a need to explore the opportunities and challenges for mainstreaming and implementing WSUD as a norm rather than an exception. The proposed Integrated Urban Metabolism discussed in the following section is a framework which can be utilised to overcome this challenge in mainstreaming the strategy of WSUD.

The Integrated Urban Metabolism Framework

Goonetilleke et al. (2011) proposes a framework shown in Figure 2 below, which addresses the integration of mono-disciplinary studies into a multidisciplinary framework for application to enhance the sustainability of urban areas. This requires the integration of knowledge inputs from a range of expertise that are not solely limited to planning, design, ecology or engineering, is assimilated to establish a framework for sustainable development. This framework provides a stage whereby different disciplines are able to create, learn, and absorb knowledge from each other to produce a holistic approach to urban development which is under global pressures of climate change, population growth, resource scarcity, as well as financial constraints.

This framework closes the current linear process of input-process-output, and views what is traditionally called 'waste' as a resource to be used 'fit for purpose', augmenting traditional resource inputs rather than to be returned to the environment, usually in a state of decay. While these concepts are not new, the consistent failure of current urban management systems to utilise this integrated management have contributed to the existing rapid degradation of the urban environment that is so prevalent today. This framework aims to shift the manner in the way urban development and its management is conducted to a more holistic, sustainable urban development. On that note, this paper draws inspiration from the principles and concept from the Integrated Urban Metabolism Framework to tackle the much problematic issue of urban stormwater management.

INTEGRATED URBAN METABOLISM FRAMEWORK FOR WSUD

Practitioner perception to challenges of WSUD

A paradigm shift from traditional urban stormwater management strategies, whereby stormwater is viewed as a waste and a community hazard that needs to be disposed of into the nearest waterway is yet to occur on a large scale (Brown, 2007). Despite recent gains in the scientific and practical knowledge of WSUD as an ecologically friendly and efficient manner in which to manage urban stormwater, this holistic strategy has yet to move on from the 'conceptual, investigational and demonstrational stages linked with government and academic partners (Gardiner & Hardy, 2005). Professionals, practitioners and academics involved in research and implementation of WSUD note that while the concept has been underpinned by vigorous scientific studies to be an effective method to maintain stormwater runoff quality and to safeguard ecosystem functions; its adaptability into an integrated framework, which includes input from a range of disciplines, is still lacking.

Interviews conducted with practitioners has shown a high understanding of the strategy—indeed this concept is not lacking or new, and is studied and implemented in locations around the world (for example van Roon et al, 2006; Roach & Sargent; 2007; Roy et al., 2008). Most respondents also had a good perception of WSUD, stating that it was 'common sense' and that it was worth doing due to the perceived positive outcomes it would bring. Some developers see implementation of such ecologically-friendly features as a corporate responsibility, where the minimisations of adverse stormwater quality impacts were important to the reputation of the company as a responsible developer. It was stated that in addition to the environmental benefits, developments with WSUD were also more marketable in a society with growing awareness of the concept of sustainable urban development (Gardiner & Hardy, 2005). When interviewed, a stakeholder from the development sector stated that implementation of WSUD helps 'sell' a project, stating that it is helps buyers 'feel better' about their purchases, and that consumers would feel that they were being more environmentally conscious by choosing a residence that had a smaller impact on the environment. Further to this, practitioners stated that the utilisation of natural features such as swales and rain gardens, as well as native vegetation often contributed to the quality of place by providing a more 'green' environment and created a 'resort style living' which was seen as a prestige as well as 'family friendly'. However, one of the key impediments stated in both the literature and practitioner interviews is the lack of conviction of the degree of effectiveness of WSUD systems in practice, and the perceived inadequate levels of technical skills and knowledge to design, assess and maintain these systems (Wong, 2001). While these principles and skills are in actuality available, they are often available only to certain agents, or are scattered amongst professions that do not necessarily communicate with each other (Lloyd, 2001). Wong (2001) also notes that linkages between concept, construction and maintenance are not well established, resulting in poorly translated works on the ground. Researchers working in this field who were interviewed supported this, stating that there was often a knowledge gap between the designers, the constructors and the maintenance staff, which affected the eventual efficiencies of stormwater treatment. A good concept and design on paper could often be ruined by inadequate implementation and construction, or through poor or insufficient maintenance. This is compounded by the fact that regulatory authorities often do not have consistent criteria and guidelines to ensure that common standards are maintained in management plans and implementation (Gardiner & Hardy, 2005; Roy et al., 2008). Without a consistent baseline, some interview respondents stated, it was difficult to determine which, or even how many of the features are needed in order to meet stormwater quality targets. Without a common guideline, implementation and maintenance was also often determined by consultants and engineers employed by developers, whose skill sets may not be consistent across the board. With these challenges in mind, this paper proposes that an effective, efficient and flexible WSUD application framework is needed in order to adapt and mitigate urbanisation impacts on urban stormwater management.

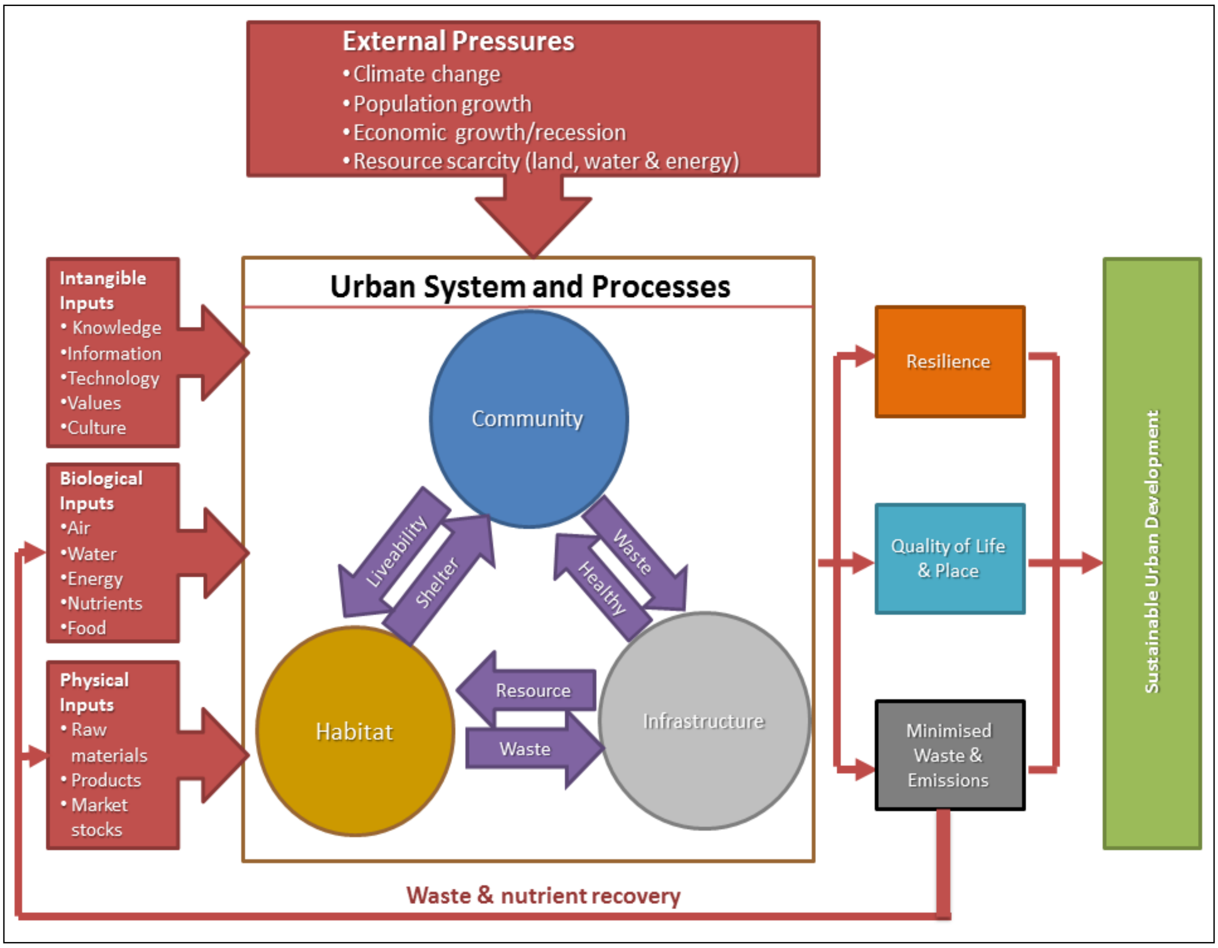

Figure 2. The Integrated Urban Metabolism Framework (Source: Goonetilleke et al, submitted)

The WSUD Integrated Urban Metabolism Model

Following from the discussion above, the strategy of WSUD is viewed through the lens of the Integrated Urban Metabolism Framework discussed previously, as shown in Figure 3. This conceptualises the flows, processes and goals of a successful WSUD process utilising the framework of the Integrated Urban Metabolism Framework.

The world today is under many critical pressures, ranging from globally impacting phenomena such as climate change to localised problems such as urban sprawl, all of which exert significant stressors on water resources. In urban areas, resources ranging from the intangible (e.g. knowledge and skills) to more tangible biological (e.g. water and nutrients) and physical inputs (e.g. raw materials and funding) feed into urban areas to provide a constant and sustainable water supply for its residents. This water is then utilised to not only sustain life but also to maintain the lifestyle of residents. Under the proposed framework, water is treated as a precious resource and not as something that is constantly available and taken for granted; it involves sustainable provision and uptake which leaves healthy waterways, provides communities with liveability and sanitation, supports habitats which are safe and climate adaptive as well as considers unaccounted water through leaks and evaporation. The aspirational outcomes include a community that is resilient, able to mitigate and adapt to the impacts of climate change; a community that provides a high quality of life and place to live and thrive and lives in harmony with its environment; a community that recycles, reclaims and recovers its water to augment available resources in order to reduce its reliance on conventional supplies, all of which lead to the still elusive utopia of sustainable urban development.

One of the most important components of this framework is the transition of cities from the current linear processes to a closed loop system that mimics the eco-system model. Newman's (1999) eco-system model states that the main environmental (and economic) problems stem from the spiralling inputs of resources and the management of the waste products. Specifically, Newman (1999) proposes that waste is minimised, and where possible reused or harvested to supplement 'virgin' resources that cities are currently so reliant. Put differently, sustainable development is not only about increasing the quality of life and place but also having resilience and adaptability towards impacts of stressors such as climate change, population growth and resource depletion. Furthermore, it is also about inter- and intra-generational equity, efficient use of resources that sustain communities as well as not 'polluting its own nest', so to speak (Goonetilleke et al, 2011).

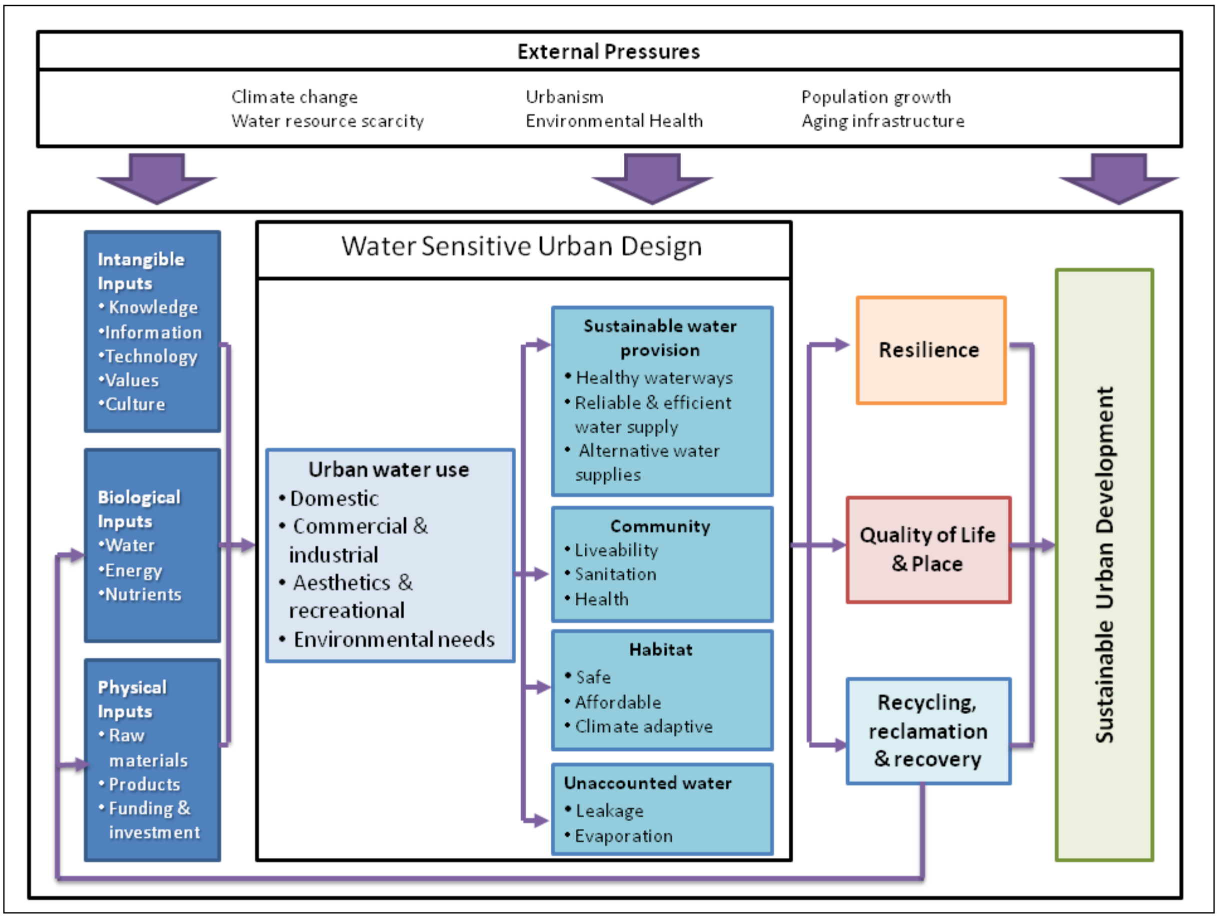

Figure 3. Looking at WSUD through the lens of urban metabolism

DISCUSSION

Interdisciplinary approach

The proposed paradigm shift, where cities transform from being resource-sinks to a sustainable urban area requires considerable change and increase in cooperation between disciplines in order to change the ways in which communities, neighbourhoods, cities and regions are planned and managed (Newman, 2010a). This form of cooperation calls for dialogue between multi-disciplinary teams that would include professionals, regulatory agencies and other stakeholders to map the water flows of the city. The audit of all waste, and losses of the cities would enable stakeholders to consider its re-use or revitalisation (Newman, 2010a). Newman (2010b) points to the example of Singapore, where water resources are so scarce it imports its potable water from neighbouring Malaysia. Due to this reliance, and the resulting lack of water security, the Singaporean government has developed one of the best eco-efficiency strategies in the world. The city-state is a leader in the recycling of wastewater to potable water, and a very high fraction of all rainfall and stormwater is collected to augment its water supplies. This closed loop approach to water resources is made possible through an integral working relationship between policy makers, engineers and planners. This interdisciplinary network not only enables each stakeholder to utilise skills previously unavailable to aid in their own work, but also enables stakeholders to learn from each other.

McIntyre et al. (2000, p. 5) argues that it is important that 'an interdisciplinary, quantitative and considered description of an urban ecosystem such that projects and findings are easier to compare, repeat, and build upon' is created. Due to the inherent complex nature of urban systems, Battencourt and West (2010) point out that this loop is critical to allow elements of the urban systems to be considered in conjunction as infrastructure, social and economic components of cities are all interrelated. Practitioner interviews and research literature supports this stance, with one respondent from the development sector stating that the utilisation of an inter-disciplinary team to establish regulatory guidelines and to share knowledge is paramount if mainstreaming of WSUD is to materialise. Utilising a wide range of expertise from various fields to design, assess and maintain WSUD features based on site specific considerations is important to ensure that linkages between concept and construction are maintained. This, however, would require the integration of various stakeholders involved in urban stormwater management, which currently is undertaken in a piecemeal manner, for example in Australia (Lloyd, 2001; Brown, 2005; Wong, 2006). For this integration and inter-disciplinary cooperation to succeed, the following section discusses the process of knowledge transfer and how this would facilitate dialogue between different fields.

Knowledge transfer

Research into the barriers of effective policy implementation has long been looked into (see Dinar, 1998; Fletcher et al., 2004; Brown et al., 2008). However, Jeffrey & Seaton (2004) argue that despite this significant history, most research has focused on ways in which paradigm shifts can occur, or on optimisation of policies. Motivation for stakeholders to accept and respond to paradigm shifts are still significantly understudied (Jeffrey & Seaton, 2004). The focus of this study is on mainstreaming of WSUD strategies. As discussed above, knowledge transfer and sharing is key to the implementation of the Integrated Urban Metabolism Framework for WSUD due to its dependence on an interdisciplinary approach. Figure 4 below details the conceptual framework on how the process of knowledge transfer can be utilised to support the urban metabolism framework and to overcome the challenges faced in mainstreaming the WSUD implementation process.

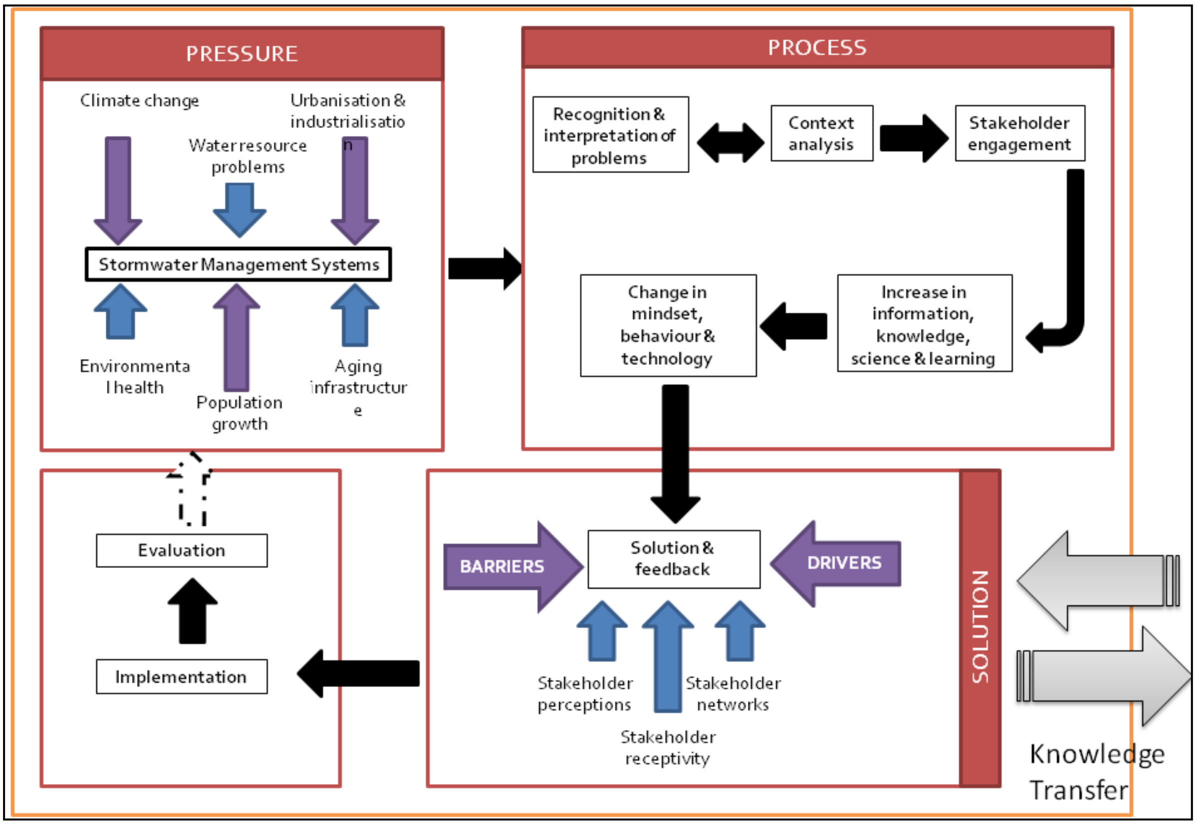

Figure 4. Conceptual framework of WSUD and sustainable stormwater management through knowledge transfer (adapted from: Pearson et al., 2010)

Flow of knowledge between stakeholders, rather than that of physical equipment, is the key to technology transfer (Seaton & Cordey-Hayes, 1993). Smith and Smith (2006) stress that sustainable outcomes are most likely achieved through a comprehensive learning process, whereby stakeholders from various disciplines are engaged and all knowledge is shared. Further to this, it is important to learn and share knowledge, and to act upon this knowledge with urgency and meaning in response to current unsustainable practices (McManus, 2005). McManus (2005) quotes the 2003 New South Wales State of the Environment Report that states that the current speed in which the paradigm shift is occurring is inadequate to correct 'the underlying path of degradation' (EPA NSW, 2003, p. 3). On this note, Wong (2001) suggests that current methods of knowledge transfer in relation to WSUD such as through the medium of publication and conference discussion need to be augmented by comprehensive community engagement. This is particularly important, as the mode of publication and conference discussion often do not reach the audiences such as those in the field of construction or development. Education, awareness and education on the benefits of WSUD strategies, as well as how to properly implement them is particularly important in the practitioner side of development, as many remain unconvinced and perceive WSUD features as being overly expensive and unnecessary. Effective communication on what is needed and expected is vital in order to ensure that all stakeholders are able to participate and are able to increase their knowledge and interest through this learning process (Pearson et al., 2010), which is an integral part of the learning process required by the Integrated Urban Metabolism Framework. With an effective communication and knowledge sharing channel, many of the challenges stated by practitioners, as discussed in sections above, could be minimised or even eliminated completely, therefore assist in the mainstreaming of WSUD.

CONCLUSION

Although the urban metabolism framework has roots that stretch back to the 1960s, it has only recently become popular again. Increasing awareness of the anthropogenic impacts on the environment due to increasing urbanisation and spiralling rates of consumption has resulted in a spike in research on ways in which urban areas can be made more sustainable. One of the key impediments to sustainable urban development remains the management of urban stormwater. The Integrated Urban Metabolism Framework provides a platform in which different disciplines would be able to contribute, foster dialogue and establish a learning loop in which successful mainstreaming of WSUD depends. Apart from this interdisciplinary approach, the process of knowledge transfer from concept to practical application is also an imperative to support this dialogue and the learning loops that facilities this paradigm shift for better outcomes on the ground. It is hoped that this would hasten the journey of urban areas to arrive at an adaptive, resilient and most of all, sustainable form of urban development.

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