STORMWATER INFRASTRUCTURE DECISION-MAKING: ON THE HURDLES OF GOING GREEN

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ABSTRACT

Stormwater runoff has been a major issue for urbanised areas. The traditional response to tackle stormwater flooding and pollution is to construct a network of well-connected drainage to direct the runoff outside the city boundaries. However, such an approach shifts the problems downstream without restoring natural processes that are essential for achieving healthy ecosystems.

This paper looks at the stormwater decision-making challenges from a Green Infrastructure perspective, with a focus on the interconnected nature of urban infrastructure system. A number of examples from around the world together with local examples have been studied to better understand the knowledge gaps that have been hindering our progress toward a widespread and systematic implementation of GI.

The institutional barriers, including path dependence and lack of collaborative decision-making were found to play a key role in defining the way forward. In addition, the true value of water is often neglected, leading to decisions being made largely based on economic assessments considering the market price of water. It is essential that further research programmes investigate developing effective frameworks for capturing and implementing the wider benefits of GI, including social, environmental and cultural ones.

KEYWORDS

Stormwater, Green infrastructure, Decision-making barriers

PRESENTER PROFILE

Arash Farjood is a post-doctoral researcher at the Centre for Infrastructure Research at the University of Auckland. Arash currently works on a two year contract helping Watercare identify research priorities. This paper has been written outside of this contract and does not express the views of Watercare or any other organisation.

1 INTRODUCTION

The traditional stormwater system collects the surface water (runoff) and delivers it to a location downstream through a network of pipes and channels. In a combined sewer system, where sewage and runoff goes into one pipe, the combined sewage should ideally end up in a treatment plant to be treated before being discharged to the environment. However, sometimes during wet weather, the network reaches its capacity, resulting in the mixed sewage and untreated runoff polluting the receiving environment. There has been an increasing concern about the issue of combined sewer overflows (CSOs) around the world. As a result, a number of engineered solutions have been put in place to address the issue, including separating stormwater network from sewer network, retention tanks to store the excess runoff, and tunnels to store and direct the runoff to the treatment plants.

The green infrastructure concept introduced a new solution to the old problem; to mimic the natural processes and value the runoff as an invaluable resource. In Auckland, although the concept of green infrastructure as a sustainable development approach is widely accepted, the implementation in practice has not been well succeeded (Boyle et al., 2013). This paper attempts to address some of the barriers that have been hindering the success of GI. Firstly the interconnectivity between urban infrastructures, including water infrastructure, will be discussed by introducing the concept of Urban Infrastructure Systems (UIS). Next, it will focus on the stormwater GI, benefits and barriers. The last section will briefly review the state of Auckland in regard to the GI implementation.

2 URBAN INFRASTRUCTURE SYSTEMS

For sustainable development of cities, it is imperative that we optimise the investments in infrastructure such that the society's comfort and wealth increases with minimum impacts (Pandit et al., 2015). In the context of urban environment, infrastructures are highly interconnected and interdependent; e.g. water distribution and treatment network requires a functional system of energy, transportation, and telecommunication networks.

To better understand the interdependency between stormwater infrastructure and other city infrastructure, it is worthwhile to introduce here the concepts of system thinking and Urban Infrastructure Systems (UIS). von der Tann et al. (2016) defined a system as "an entity assembling a number of components which form a coherent whole and act together for a common purpose … as opposed to the traditional mechanical paradigm or engineering attitude". A system thinking approach considers the processes between the elements of the system, instead of places or subject matter. An important aspect of systems thinking is defining and managing the 'boundaries' of the system, which then determines the properties of the system (von der Tann et al., 2016). For example, if the aim of a system is sustainable management of urban environment, for which innovative thinking and creativity is fundamental, the boundaries need to be set such that the system allows for innovative thinking and creativity, instead of traditional engineered solutions (von der Tann et al., 2016).

The UIS is defined by Pandit et al. (2015) as "the framework that connect and integrate the flows of capitals (social, cultural, financial, natural, technological and human) in the context of urban systems." They continue that the "UIS enable people, energy, water, materials, and money to flow into, within, and out of cities and are durable features of the urban landscape that can persist for decades to centuries. Also, UIS have far reaching local, regional and global impacts that result from waste generation, and resource and energy demands."

Pandit et al. (2015) identified six main components of UIS as: (1) socio-economics, (2) three waters infrastructure, (3) energy systems, (4) transportation infrastructure, (5) land-use, and (6) the natural environment. They explained that it is the interactions between these components that characterise the UIS. For example the land use determines the water, energy and transportation demands.

It needs to be emphasised that UIS components are interconnected and require a functional network of systems, e.g., transportation, power supply, telecommunication, etc., to be operable. Traditionally, each component has been designed and optimised in isolation in a "stove-pipe manner" without much concern for the interdependencies between them (Pandit et al., 2015). This not only makes the system prone to failure, but often results in waste of resources and suboptimal solutions (Pandit et al., 2015). Understanding and considering these interdependencies in decision-making is vital for increasing the resilience of UIS. Of interest to this paper, is the interaction between water and energy, known as Water-Energy Nexus (WEN), which has gained prominence in recent years. This will be briefly explained in the following section.

2.1 WATER-ENERGY NEXUS

The generation of power consumes water, and energy is required to convey, treat and distribute water. This interconnection is strategically of significant importance to urban infrastructure decision makers. Peter H. Gleick was among the pioneers of shaping the concept of Water Energy Nexus in the modern age. In his "Water and Energy" paper (Gleick, 1994), he stated that "The supply and use of both water and energy resources are intricately connected, and we can no longer consider the formulation of rational energy policy and water policy to be independent." This interconnectivity will be illustrated by some examples in here.

The impact of electric vehicles on the water demand in the metropolitan Atlanta, Georgia region, USA, was studied by Yen et al. (2011). Their modelling showed that if all the personal transportation was electric, the water demand to produce hydroelectricity for transportation only, would be almost equal to the current domestic demand. In Georgia, only 2% of the power is generated by hydroelectric plants. If alternative sources of energy are not developed or energy efficiency gains not achieved, this increase in power demand can be interpreted as additional stress on water sources, especially for a hydropower-reliant country like New Zealand. In addition, the interrelations between water and energy can also vary widely with the demographics, climate and geography of the regions; long, dry summers when both energy and water demand increase, further strains the co-dependency between water and energy (Pandit et al., 2015).

Wastewater, traditionally considered as a 'wasted' material, is now being valued a source of energy and reusable products. In Auckland, Watercare is producing about half the power required by its Mangere Wastewater treatment plant from biogas, and plans to run its Rosedale and Mangere wastewater treatment plants entirely on self-generated electricity by 2025 (Watercare, 2016). This will also be a step toward reducing the region's dependence on hydropower.

Stormwater can also be used as a source of energy. The feasibility of micro-hydropower turbines integrated in stormwater ponds network mitigate flooding in Lisbon, Portugal was studied by Ramos et al. (2013). By using the stored water in the stormwater ponds and innovative thinking, the runoff became a new energy source, providing a wide range of benefits for the society and the environment. Their study demonstrated that there exists many opportunities within the existing stormwater network for moving toward a smart water management system.

These examples illustrate that the wider functions of infrastructure systems cannot be evaluated without understanding how material and energy flows among its components. Traditional engineering approaches aimed to provide technologies to solve specific problems, often resulting in fragmented applications. Understanding the interconnectivities can foster development of cross-disciplinary technologies and inventions for a more efficient use of the resources.

3 STORMWATER GREEN INFRASTRUCTURE

The urban stormwater has been widely managed through the traditional "big-pipe design" approach (Pandit et al., 2015). Water engineers have learnt and mastered designing complex networks of pipes and tunnels to collect and divert the runoff from urbanised areas; the problem which in the first hand is a caused by urbanisation and the disruption of the natural hydrology and ecology.

An alternative to the conventional approach is to mimic the natural processes through green infrastructure (GI). The GI includes principles of water sustainable design (WSD) (also known as WSUD, SUDS or LID) and can be defined as an interconnected landscape of waterways, upland and riparian habitat, and vegetated areas that mimic, maintain, or restore natural hydrological and ecological processes (Holloway et al., 2014).

The GI is a demonstration of interconnectivity of UIS through the interrelationships between stormwater management and several other social, environmental, and economic achievements. Although the main aim for implementation of GI might be to improve the quality and reduce the quantity of stormwater runoff, increasing interest is forming on its extensive co-benefits. In the following section, some of these benefits of GI will be further explored.

3.1 ECONOMIC BENEFIT

Literature suggests that GI can lead to increasing the value of nearby properties (Mell et al., 2016; Pandit et al., 2013). The increase in property values can be associated with the higher demand for properties that are in 'green zones', and have easier access to 'green spaces'. Nunns et al. (2016) studied the relationship between apartment sales prices and their closeness to parks in Auckland. The results of their modelling showed a positive relationship between the apartments' sales prices and their proximity to the parks and the (Figure 1).

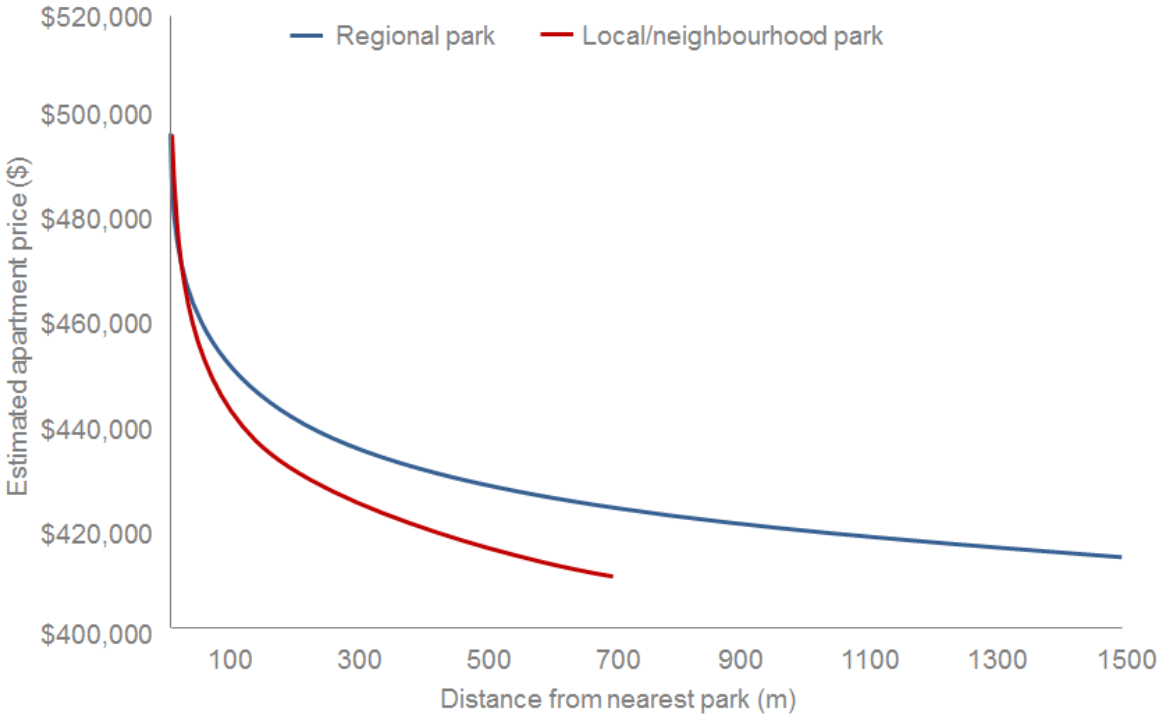

Figure 1 – Estimated apartment sales prices as a function of distance from the nearest regional or local neighbourhood park (figure recreated from (Nunns et al., 2016))

3.2 SOCIAL EQUITY

One of the key social benefits of GI is its contribution to increasing the social equity. The promotion of social equity through GI can occur in two ways: (1) through active participation of the wider community in the project, and (2) through the outcomes of greening. These benefits include providing outdoor recreation opportunities and the opportunity to connect with nature, improved public health resulting from improved environmental conditions, improved aesthetic quality and opportunity for cultural expression, and production of local resources (McEwen et al., 2013). Also many of the jobs created by GI projects can be filled by entry level, historically disadvantage citizens (McEwen et al., 2013).

3.3 INFRASTRUCTURE RESILIENCE

Urban infrastructures are under the stress of the increasing population growth rates and are expected to be constantly providing high quality services. Thus, natural events that can cause disruptions in a system's operations need to be well studied and the impacts be minimised through forward looking planning. The significant damage caused by natural disasters such as Hurricane Katrina flood in the US in 2005, the Japan's Tsunami in 2011, the Christchurch and Kaikoura earthquakes in 2011 and 2016, and the Millennium drought in Australia in the last decade, to name a few, are reminders that our water infrastructure are vulnerable to natural disasters, even in the developed countries. It is estimated that if a major earthquake occurs in Wellington, it would take 6-12 months for some areas to be reconnected to the water network (Cousins et al., 2010).

Wide implementation of GI can result in decentralisation of the system elements, consequently increasing the resilience of the system. Instead of a network of connected pipes there will be separate devices operating as a system, where failure of a part would have limited impact on the rest of the system. For example, Rainwater Harvesting Systems (RWHs), in addition to reducing the runoff volume and intensity, can play a key role in the case of an unforeseen disaster by providing emergency water to the affected areas. After Christchurch's earthquake, people were encouraged to collect rainwater in buckets on rainy occasions. Rainwater tanks and domestic greywater recycling system would have been extremely useful on this occasion, had they been installed (Boyle et al., 2013).

However, it has been argued that while event-driven approaches can be successful in the short-term, their fate remains in uncertainty. A review of Melbourne's response to the Millennium drought in Australia (Low et al., 2015) revealed that the uptake of rainwater tanks slowed down once the water became more abundant and the fear of drought was eased (Figure 2). This highlight the need for a well-thought planning a

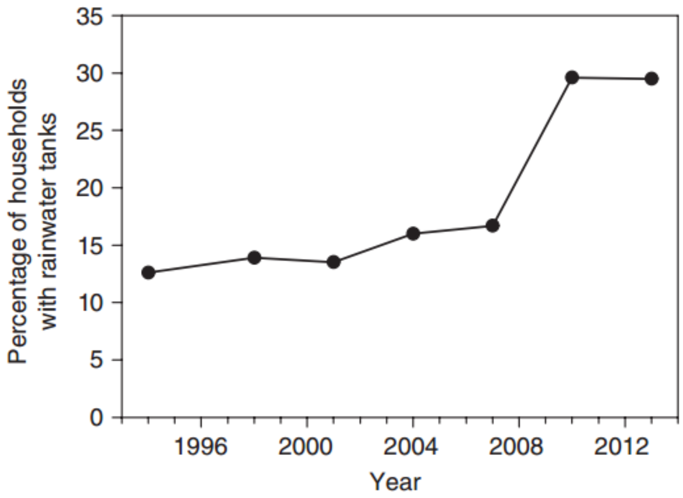

Figure 2 – Portion of households with rainwater tanks surveyed by the Australian Bureau of Statistics. (Picture reprinted from Low et al (2015))

3.4 ENVIRONMENTAL BENEFITS

While taking on a greening policy can satisfy compliance requirements, the environmental benefits of the GI extend beyond compliance. Green infrastructure, in addition to mitigating flooding and CSOs, will contribute to long-term environmental and public health protection, reducing heat islands within urban areas, and creating a wide range of opportunities for current and future generations (Boyle et al., 2013).

In New York City the decision makers agreed on a plan to reduce the CSOs through a cost-effective combination of grey and green infrastructure. The "NYC Green Infrastructure Plan" is projected to cost approximately $2.4 billion less than the grey infrastructure plan it replaced. It was also agreed to defer or postpone $3.4 billion in grey infrastructure spending for additional storage tunnels and holding tanks. It is expected that the water quality in New York City's harbour will be higher than it would have been under the traditional "grey" plan at a lower cost to New Yorkers (NYC, 2010).

In the city of Philadelphia, installing green infrastructure was proposed at a scale unprecedented in the U.S. To address the city's frequent runoff and CSO problem, the city adopted a 20 year plan, called "Green City, Clean Waters", which relies heavily on green stormwater management practices and is expected to not only reduce runoff, but also to restore and preserve stream corridors, and upgrade treatment plants discharges (Madden, 2010).

Despite the increasing awareness about these benefits, there still exist gaps between theory and implementation of GI. The next section will look into some of these issues.

4 BARRIERS TO IMPLEMENTATION OF GI

Barriers to GI can occur in many forms, including institutional, economic, social, and environmental barriers. The US EPA lists the barriers to GI in three categories as follows (EPA, 2011):

1. Barriers Confronting Municipalities, including:
    a. Perception that performance is unknown
    b. Perception of higher costs
    c. Perception of resistance within regulatory community
    d. Perception of conflict with principles of smart growth
    e. Perception of conflict with water rights law
    f. Unfamiliarity with maintenance requirements and costs
    g. Conflicting codes and ordinances
    h. Lack of government staff capacity and resources
2. Barriers Confronting Developers, including:
    a. Scepticism about long-term performance
    b. Perception of higher costs
3. Design Challenges

Some of the institutional, economic and social barriers will be further explored in the following sections.

4.1 INSTITUTIONAL BARRIERS

The organisational standards and values influence how policies are created and implemented, leading to further strengthening the conventional paths and limiting policy reform ideas. Among the institutional barriers to change, is the concept of path dependency; the idea that certain technologies constrain subsequent choices. Institutional path dependence is considered the fundamental determinant of feasibility or affordability of reforms (Marshall and Alexandra, 2016).

Sjöstedt (2015) explains that the path dependence determines the chosen options along the timeline of development, increasing the value of the chosen path over time, and thus determining much of the future development trajectories. (Brown et al., 2013) suggested that one of the key challenges facing stormwater managers, as well as city infrastructure decision-makers, is the "limited knowledge and guidance regarding how to effectively address the significant issue of path dependency". This in turn limits innovation in strategies and policies, thus hindering the transformation from the traditional stormwater management paradigm to adopting green infrastructure.

It is worthwhile to note that the institutional path dependence does not mean that potential paths are predetermined by historical circumstances, but rather that a range of dynamics and factors shape prospective institutional innovations, i.e. path dependency is dynamic (Sjöstedt, 2015).

In addition, successful policy reforms require the right expertise and skills that are often multi and cross disciplinary. Historically, a narrow expertise would be sufficient for a successful management practice, while in the modern era broader knowledge and experience is fundamental. For example, in reviewing drought and water policies in

Australia, Kiem (2013) found that individual irrigators with a broad knowledge of the water system and risk management principles would gain higher benefits from water trading, compared with local 'family-farm' operations.

4.2 ECONOMIC VALUATION

The cost-benefit analysis of GI has proven difficult, because GI provides a diverse range of benefits that may not be easily defined or quantified, whereas grey infrastructure tends to provide a specific, defined function and thus well-defined benefits. Mell (2013) argued that one of the underlying barriers in implementation of green infrastructure is the "difficulty of incorporating both the tangible and intangible benefits associated with environmental resources into robust estimates of economic values". The complexity of incorporating value of natural resources suggest that "any attempt to value nature may potentially be undermined by a lack of robust economic evidence compared to other built infrastructure valuations" (Mell et al., 2016).

This could be one of the main reasons for the limited dialogue between city infrastructure decision makers and the GI planners. It is therefore vital for the environmental analysis models to incorporate the wider effects of GI into the cost-benefit analyses. The lack of understanding about 'how urban greening might generate economic value' may be another reason for the uninspiring investment in green infrastructure.

4.3 PUBLIC PERCEPTIONS

"The values of urban greening projects are related to the way that people interpret the form, as well as the utility, of the physical environment" (Tyrväinen, 2001). The public participation and community development components proved to be essential for the success of GI projects (Raymond et al., 2016).

Mell et al. (2016) demonstrated that the "nature of a green investment has a strong relationship with perceived values and willingness to pay." Through a number of surveys he found that the surveyed residents of city of Sheffield, UK, recognised the higher benefits that they would gain from GI developments compared with the traditional engineered grey infrastructure. He suggested that this public support remarkably enhanced the progress of the proposed GI projects.

In another example from the UK, the South West Water proposed a number of environmental friendly investments for their pricing submission in 2013 (South West Water, 2013). The proposed integrated management approach included reducing supply interruption and discolouration (for drinking water), using sustainable drainage to reduce the risk of flooding (for stormwater), and reducing odours from sewage treatment (for wastewater). These improvements required the highest increase in water price among the other water companies in the UK. However, the plan received a remarkable 84% support from the customers, and South West water was awarded the "enhanced status" by Ofwat.

These examples indicate that public perceptions can play a fundamental role in urban water management. While from an organisation's perspective an investment option might not be economically justifiable, public might be willing to pay more for 'environmentally friendly" options. Thus, understanding people's values and perception should form the basis of the planning and decision-making process.

4.4 DISINTEGRATED WATER MANAGEMENT

The linkage between the three waters, their source of extraction and the environment they discharge into is often overlooked by policy makers of different authorities, or by the decision makers within organisations. Such a fragmented system can lead to uncoordinated decisions, reflecting individual responsibilities that are not sufficiently linked (Bressers and Lulofs, 2010). There could be significant benefits from moving towards a more integrated model of water decision-making, regardless of which organisations are responsible for which parts of the water cycle. By looking at water as one system, holistic evaluation becomes possible, leading to a more efficient and sustainable use of resources.

For example, domestic RWHs may not be economically justifiable in a fragmented water management framework; from a stormwater perspective, RWHs would be too costly to be designed to address the flood issues; from a water supply perspective, they would not be effective for a long dry period; and from wastewater perspective it would not reduce the quantity of wastewater flows. Cost-benefit analyses of RWHs are often based on the market price of water, while increasing awareness is now being given to capturing the economic value of the wider benefits that RWHs can offer, e.g., reduced risk of flooding, increased resilience of the water network, etc. (Boyle et al., 2013).

5 GREEN AUCKLAND

A "green Auckland" is a goal desired by the Auckland Plan (Auckland Council, 2012). It states that we must recognise the need for considering "environmental values in all that we do", that "the interaction between the environment and people is understood and considered in our everyday behaviour and choices." It also emphasises on the need for Water Sensitive Design approaches to prevent flooding and environmental problems.

The Auckland Plan also recognises that a significant investment in Auckland's infrastructure will be required to support the future growth. This can provide an opportunity for creating a more integrated, sustainable, and resilient infrastructure systems. The Thirty Year New Zealand's Infrastructure Plan (NIP) emphasised on the need for "investigating options to support long-term integrated regional infrastructure plans…" and states that "… in the future, we will need larger productivity gains which more effective infrastructure can contribute towards" (NIU, 2015).

In Auckland a combination of a wide range of GI, e.g. bio-retention swales, permeable carparks, and rain garden have already been adopted. A benchmarking study conducted by the Cooperative Research Centre for Water Sensitive Cities (Ferguson et al., 2014) reviewed Auckland's progress towards becoming a water sensitive city, and suggested that that there were many gaps in our stormwater management approach that are yet to be addressed. The report stated that "A lack of strategic alignment across key stakeholders is the overarching challenge for further progress towards a Waterways City." Although this report may not be a complete reflection on the state of stormwater management in Auckland (Bentley and Miguel, 2014), it highlighted the need for a higher degree of collaboration between the decision-makers.

The Auckland Council's Healthy Waters has been developing a Green Infrastructure Policy (Mayhew et al., 2016), with the main purposes to:

- Direct the SWU's approach to the use and management of GI in undertaking its functions;

- Encourage the use of GI for stormwater management in public and private development where stormwater infrastructure is to be vested in/managed by Council; and
- Guide SWU involvement in wider Council planning and management programmes for GI.

The challenge of economic evaluation of the GI benefits can be observed in this policy. Mayhew et al. (2016) stated that "the Policy has adopted a simplified assessment process to determine where these benefits outweigh the additional costs (if any) of utilising a GI option. This involves a tiered approach depending on the scale of the project. For small to moderate projects, an additional cost percentage (of up to 10%) has been determined as a conservative estimate of the additional benefits of GI. For larger and major projects, a more detailed assessment is required to better define the specific benefits associated with a project to determine whether these benefits are sufficient to justify any additional cost."

6 CONCLUDING REMARKS

That the Green Infrastructure has advantages over grey Infrastructure is well documented, and guidelines been published. However, full implementation of the GI is yet to be achieved due to a number of barriers.

The experience of greening of the cities around the world, specifically for the city of Philadelphia, has shown that transformation from traditional thinking can be a tedious process and requires dedicated and well-reputed individuals to push for the shift. It also requires organisations to be open to increasing the risk acceptance. Some of the reasons that have hindered this process are the organisations' traditional paths, lack of extensive understanding about the benefits of the change, and lack of collaboration between the key decision-makers and city developers.

It was also highlighted that because of the complex and multivariate nature of GI benefits, there is a need for multi-disciplinary approach for the economic valuation of social, environmental, cultural, and other benefits of GI. This requires a forward looking and collective approach, taking into account the interdependent nature of services that GI offers. In addition, robust models are needed for capturing the economic value of the wider benefits of a GI. As of yet, however, the research in this area has been sporadic and further research would be merited.

Decision-makers must bear in mind that public support would significantly facilitate implementation of their decisions. Thus, it is imperative that public values and perception should be understood and the decision be aligned with those. The example of water price plan of South West Water in the UK, demonstrated that consulting the community can lead to better decisions.

Although the main driver for GI in Auckland might be better management of stormwater, the wide array of benefits it provides, derives the need for more collaboration between the different authorities. As discussed in this paper, fragmented decision-making often hinders success. With a better understanding of the interrelations between GI and other urban infrastructures, together with a higher level of collaboration between the decision-makers, the society can profit from the variety of benefits that GI offer. There are new regulations and policies that have opened up windows for change (e.g. the Auckland Plan and the National Policy Statement for Freshwater Management), and can provide a unique opportunity to be innovative and forward thinking to overcome the hurdles discussed in this paper.

DISCLAIMER

The views expressed in this paper are those of the author and do not reflect those of Watercare or any other organisation.

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