Green Infrastructure Retrofit in High Density Urban Environments: Mechanisms for Delivery

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Abstract

Green infrastructure (GI) retrofit into high density urban environments can be delivered via a number of funding and governance mechanisms. The most appropriate mechanism is dependent on required delivery timelines, the City’s overarching political and regulatory environment, the types of outcomes required and the receptiveness of beneficiaries to providing in-kind funding or ongoing management.

Analysis from GI retrofit projects in Melbourne, New York and Wales planned and delivered at various scales shows that an integrated approach to delivery that links and connects policy across ‘silo-driven’ cultures can achieve long-term benefits.

Though contexts may vary, approaches to implementing new GI should always use the resources, delivery mechanisms and policy context that is currently in place.

INTRODUCTION

It is increasingly clear that the retrofitting of GI is becoming increasingly common in high density urban environments around the world. From increasing tree canopy cover in Melbourne’s streets, parks and iconic laneways, to retrofitting 578 rain gardens into New York City streets, to installing sustainable urban drainage features into Welsh schools as part of a catchment wide intervention.

At the core of many GI projects is improved stormwater management, and water itself can be the integrator that highlights the interdependencies between individuals, settlements, their hinterlands and global systems. A shared stakeholder interest in water management can be the key to facilitating collaborative, holistic approaches to policy, planning and design.

The drivers for water-focused GI type projects differ from location to location and stakeholder to stakeholder. These include reducing flows into combined sewer systems to reduce associated spills from high rainfall events, improving water quality and flow patterns in receiving waterways, reducing property damage and inconvenience associated with urban flooding, improving the overall amenity and functionality of our cities, reducing energy and carbon usage, supporting the health and wellbeing of residents, improving habitat and biodiversity outcomes and enhancing resilience to climate change (see Figure 1). Other residual benefits such as improved air quality and microclimate are also increasingly being documented and understood.

Delivering this type of infrastructure into highly populated settlements differs significantly from installing these types of infrastructure into green or brownfield developments. Key issues for delivery include: competition for limited space, the costs associated with working in high-density environments, clashes with existing services, public health and safety, educating residents about the functional requirements of these different looking types of infrastructure as well as involving them in the design process, and determining and then funding the party responsible for long term maintenance. However, all of these projects are delivered with one key consideration in mind, namely, making better places.

Lessons learnt from planning for and delivery of these types of projects in various developed cities in the UK, Australia and the USA show that there are a number of ways these types of infrastructure can be delivered and land uses targeted. This may be done by incremental opportunistic installations sequenced to take place with other infrastructure upgrades, large scale streetscape retrofits which are centrally funded, and a suite of projects at various scales which form part of a larger initiative.

Regardless of who is delivering the intervention and its primary purposes, all GI projects will produce a wide variety of direct and indirect benefits, and in order to be successfully delivered, require a number of elements to be considered at the outset. This include a shared vision coupled with a commitment to multidisciplinary collaboration and the use of innovative funding models.
CASE STUDY ASSESSMENT METHODOLOGY

Previous research conducted by Arup (2014) as part of the ‘Cities Alive’ initiative laid out the case for GI in our cities (see Figure 1) while also acknowledging that the delivery of GI in urban environments is complex.

A comprehensive framework was developed (see Figure 2) to guide delivery of successful GI initiatives and the following key requirements identified:

- **Overarching vision** - All delivery should be underpinned by and contribute to a large-scale strategic vision. This vision should identify the assets, opportunities, risks and vulnerabilities for a given context.
- **Collaboration** - Increasingly, GI is being seen as a concept which unites a range of disciplines and interests, and that facilitates collaborative working. Crucially, in the context of GI, competing priorities can often complement each other.
- **Evidence** - Preparation of a GI project should be underpinned by evidence. The aim is to ensure that interventions are appropriate to their context. Evidence is particularly important to understand the value of a city’s natural resources to enable future planning for enhancement potential.
- **Tools and Design Stage** - Planning plays a vital role in the delivery of projects and will be triggered in many interventions involving new and existing development. Designers working in multidisciplinary teams should seek to ensure that GI and its subsequent maintenance are integral to individual projects, and always linked into the wider vision and framework for that city.
- **Management** - Management and maintenance of GI should always be a key consideration from the outset of a project. This is crucial for the longevity of a project and for securing the full potential of interventions.
- **Funding** - Traditionally, local authorities provided funding for the delivery and management and coordination of GI. Increasingly, this type of funding is more difficult to secure, leading to new, creative and innovative ways for funding and use of available resources. Considering funding for maintenance and management from the outset will help deliver long-term benefits. Cost reduction and recognition of the value of existing assets are also important.
- **Importance of city leadership** - Demonstrating the value of GI and the variety of scales and types of interventions possible is crucial. Political champions are important in setting and promoting a vision whereby GI adds to the quality of a city and differentiates its offer by attracting investment. Professionals negotiating to achieve new or improved assets should understand the economic context in which they are working and promote the multiple benefits of GI.

The following case studies were analysed to determine how these various initiatives respond to the criteria for success.

### Urban Forest Strategy, Melbourne Australia

The City of Melbourne (CoM) has increasingly recognised the vital role which biodiversity and the natural environment play in the health and wellbeing of its cityscapes. To help drive sustainable urban development, Council has implemented a range of strategies to support GI delivery, including the Urban Forest Strategy and Growing Green Guide.

The City recognises that the integration of GI within traditional built form can provide a range of environmental and eco-system benefits by enriching air quality, improving water quality, supporting healthy biodiversity and reducing stormwater runoff.

Melbourne is renowned for its iconic laneways; many of which were transformed from forgotten backstreets into vibrant and bustling cultural hubs through a series of precinct activation projects in the early 1990’s. The success of Melbourne’s laneways, along with the emergence of ‘laneway culture,’ is now cited internationally as a best practice in urban revitalisation.

As part of the evolution of Melbourne's tree canopy a number of complimentary programmes have been developed targeting council and non-council owned land. Delivery of opportunities will be incremental and opportunistic, based on leveraging other asset management activities taken to optimise delivery of GI into existing work programmes.

### Newtown Creek GI, Brooklyn, NY, USA

The NYC Department of Environmental Protection (NYCDEP) is leveraging the use of GI to reduce combined sewer overflows (CSOs) and to meet and exceed the water quality standards of NYC’s waterways. The NYC Economic Development Corporation (NYCEDC) is managing the delivery process on behalf of the NYCDEP to achieve the goals set forth in the NYC GI Plan.

Retrofitting the public right of way with 578 “Bioswales” or “Stormwater Green Streets” within 531 acres of the Newtown Creek watershed in Brooklyn, NY is a core component of achieving this goal.
Site selection and design needed to be completed within one year, and construction completed within three years. Rollout is underway with specific tasks to achieve this goal including civil engineering, tributary analysis, site selection, mobile data collection, GIS data management, detailed engineering design and design services during construction.

**Dwr Cymru Welsh Water’s Rainscape Initiative, Wales**

Dwr Cymru Welsh Water (DCWW) is responsible for the sewer network across Wales. The organisation is using GI, branded Rainscape, rather than traditional grey infrastructure solutions to manage surface water. The issues being addressed include: network flooding, spills from CSOs, high wastewater treatment and pumping costs, and general hydraulic under-capacity in the system.

Stebonheath Primary School previously contributed 59l/s into the combined sewer network (1 in 5 AEP). The school grounds offered little in the way of green space and localised flooding was common. A GI scheme at the school brought with it the potential to turn an otherwise bland playground into a green, vibrant, and exciting educational resource.

Collectively, 100m$^3$ of sustainable attenuation volume has been constructed at the site, limiting peak flows into the sewer system to just 6 l/s (1 in 5 AEP).

**DISCUSSION AND RESULT ANALYSIS**

Analysis of these projects examines how they address the key components which are considered crucial for GI project delivery:

**Overarching vision**

Melbourne: The CoM’s “Total Watermark: City as Catchment” sets a clear vision and associated targets for stormwater management within the city catchment noting “our vision is a healthy city in a healthy catchment. We want the whole of Melbourne’s community – residents, workers and businesses, to think about water and its role in our future, to help create a healthy city in a healthy catchment.”

The strategy notes that rapid climate change is resulting in less, but more intense bursts, of rainfall and that the city must ensure that it uses the right water for the right purpose while minimising flood risk.

The strategy sets a number of targets at the 2018 and 2030 timescale including a 30% reduction in Total Nitrogen contributed to the waterways from the municipality of Melbourne’s catchment (baseline year 2000). This vision and strategy along with CoM’s Urban Forest Strategy has driven council programs such as Greening Melbourne’s Laneways and the Greens roofs, walls and façade programmes across the city.

New York City: In 2010, NYC developed its GI Plan which presented a comprehensive framework and strategy for implementing GI in the city. The vision encapsulated within this Plan has since been used to develop a process to deliver GI across the city.

The GI Plan was a key part of PlaNYC, which was a sustainability initiative released in 2007 by Mayor Michael Bloomberg, which was intended to strengthen the economy, adapt to climate change, and enhance quality of life to create a “Greener, Greater New York.”

Wales: DCWW’s vision is to lead the way in developing and using new, innovative solutions to manage the amount of surface water entering its sewers.

DCWW have branded this initiative RainScape and developed a 20-year strategic delivery plan, which uses retrofit GI measures to separate or attenuate surface water before it enters the sewer. The plan is supported by targets and budgets including a commitment to invest more of up to around £80 million by 2020 to support the core goals of:

- Reducing the risk of sewer flooding and pollution, whilst also helping to increase capacity in the sewer network; and
- Supporting economic development and protecting customers against climate change.

**Collaboration**

Melbourne: working across departments and using existing asset management systems to incorporate GI will be crucial to the success of GI delivery. From treating trees as assets and valuing them for insurance purposes to ensuring that future GI interventions are visible in asset management software, the city is proactively assessing and mapping opportunities and making this information available to the delivery arm of Council.

CoM has also worked collaboratively with surrounding councils, Melbourne Water and Government agencies in the development of its WaterMark and Urban Forest Strategies.

New York City: The design of GI is truly a multi-disciplinary effort encompassing civil engineering, landscape architecture, geotechnical engineering, traffic engineering, environmental engineering, etc. Moreover, any work within the Public Right-Of-Way requires collaboration amongst multiple agencies.

In New York City, the Department of Transportation (DOT) manages streets and sidewalks, while
NYCDEP manages stormwater and combined sewer runoff, and the Department of Parks and Recreation (DPR) manages trees and landscape within public lands. In addition to these city agencies, utility agencies are very prevalent in terms of electric, natural gas, cable television, telephone, fibre optic, fire department communication, etc.

To guide collaboration NYC DEP developed the GI Design Standards. This required input from DOT in terms of sidewalk treatment and appropriate siting criteria to ensure unimpeded access for pedestrians and cars. DEP also needed input from DPR on the appropriate trees and planting species within the design standards to ensure performance during rain events. Regulatory coordination was also required to ensure that approvals and permits for GI work within the Public Right-of-Way were acceptable by all regulatory agencies.

DEP developed a program to deliver GI across the city using area-wide contracts. With DEP undertaking ownership of the area-wide contracts, they sought partnerships with other city agencies to manage and administer the area-wide contracts. Such organisations include not only DPR but the Economic Development Corporation (EDC) and the Department of Design and Construction (DDC). In addition to the area-wide contracts which focus on Public Right-of-Way installations, DEP have also partnered with other public agencies such as the Schools Construction Authority and the NYC Housing Authority to implement GI within other NYC properties.

Wales: The use of GI interventions by a water company for this purpose is unique in the UK. The assembled project team, which comprised of DCWW (the client), Arup (the designer) and Morgan Sindall plc (the capital delivery partner), worked collectively to address key challenges such as planning policy, a lack of real life examples and design guidance, and delicate construction within an existing Victorian built environment.

Formal Memorandums of Understanding between key stakeholders on two of the initial projects were useful to legitimise the input from each party and clarify expectations. Multi-organisation steering groups also enabled issues to be highlighted and resolved and provided a forum for communication. Attendees are empowered to take action to assist the project’s progress. Discussions on Legal issues over ownership and maintenance, often blockers to these types of schemes, were started early and followed up at every steering group meeting to ensure resolution and long term adoption and maintenance agreements with CCC have been formed.

Evidence

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New York City: Currently DEP are managing several area-wide contracts across the city to deliver thousands of bioswales within city streets. To get to this point in their program, DEP started by implementing pilot projects to develop design standards to ensure they were achieving the performance necessary to management stormwater and also to ensure the standards met the requirements of all city agencies. Since 2011, DEP has increased its knowledge and understanding on the technical aspects, costs and benefits of GI.

In 2012, DEP publicised the 2012 Pilot Monitoring Report to present the progress and monitoring results from their pilot projects. DEP’s monitoring program focused on the functionality of the GI practices and the impact to runoff rates and volumes along with water and soil quality and establishing maintenance requirements. As more evidence was attained from their pilot and demonstration programs, the program was adapted and then expanded by an order of magnitude to gain city-wide implementation.

DEP continue to research the co-benefits of GI and have noted that more than 100 references have been reviewed to support their internal co-benefit analysis which will help to demonstrate the cost savings and social benefit GI will provide NYC.

Wales: Following extensive catchment-wide investigations, data collection and hydraulic modelling undertaken between 2010 and 2011, a suite of over one hundred GI schemes were identified for implementation as part of a long term catchment strategy to address flooding and river pollution in Llanelli (see Burry Inlet Investigations, UK Water Projects 2012).

The selection of three priority pilot schemes was based on a multi-criteria analysis comprising key indicators such as surface water reduction, resolution of flooding, whole life costing, ease of construction and carbon footprint. The three chosen projects, Queen Mary’s Walk, Stebonheath School and Glevering Street are all located in central Llanelli and are each serviced by a public combined sewer network.
The sites are considered typical of the urban environment that has evolved within the catchment resulting in a highly impermeable response to storms where rainfall quickly arrives within the sewer network. With the Rainscape project being a first on this scale in the UK, locally based evidence was not always readily available before construction. Consequently, data collection that could feed into other UK schemes has been a priority on this project. For each scheme constructed, a full ecosystem services assessment pre and post construction has been carried out. Also, flow monitoring in the sewer network has been completed to assess the flow removal. Early indications show flow removal rates compared to that of beforethe schemes show in excess of 70% peak and volume flow reductions.

**Tools and Design Phase**

Melbourne: Melbourne Water as the drainage authority in the City has produced a series of guidance documentation to assist local authorities in GI delivery. This includes a comprehensive WSUD Guidelines (2013) produced in conjunction with the CoM and costing data to help ensure that this type of infrastructure is adequately costed into future capex and operational budgets. Software tools such as MUSIC allow for ready assessment of GI types to understand pollutant removals, while standard engineering drawings produced by surrounding municipalities such as the City of Moreland ensure consistency of delivery.

An opportunities assessment framework has been developed for CoM to identify GI opportunities at the laneway scale. This drew on a multidisciplinary team of environmental and civil engineers and environmental scientists, landscape architects, water sensitive urban design specialists, horticulturalists and arborists, urban designers and transport planners. Each discipline’s contributions help ensure all aspects are considered in the framework.

New York City: NYCDEP, along with their partner agencies, have developed tools to enable other city agencies and consultants to deliver GI to their required standards. For example, standard construction details and geotechnical investigation procedures have been developed by DEP and widely available for use. DOT have prepared site selection criteria to ensure that the GI practices within the Public Right-Of-Way remain clear of pedestrian accessibility requirements, emergency egress and a myriad of street furnishings. Similarly, the DPR have identified tree species and prepared planting palettes that are based on varying land use typologies of the city environment.

These tools are critical in ensuring City requirements are met and in achieving consistency across multiple neighbourhoods. Arup has also developed customised tools to help deliver these projects in a more efficient manner, such as customised mobile data collection tablets for site selection, web-sharing platforms and augmented reality for community outreach.

Cardiff: Detailed software modelling showed that Stebonheath Primary School previously contributed 59l/s into the combined sewer network (1 in 5 AEP). The school grounds offered little in the way of green space, and localised flooding was common.

Design proposals for Stebonheath were refined through interactive sessions with the staff and pupils at the school. The final design consisted of a selection of basins and planters, whereby attenuation volume was maximised through the use of innovative storage products, such as Silva Cell, designed to increase soil void ratios.

Collectively, 100m$^3$ of sustainable attenuation volume has been constructed at the site, limiting peak flows into the sewer system to just 6 l/s (1 in 5 AEP). A key challenge faced at Stebonheath School was the programme. Construction was limited to just six weeks to fit within the summer holiday period. This meant it off-site fabrication; for example, bespoke downpipe timber planters which were delivered to site in two halves, generating 14m$^3$ of attenuation volume within a matter of hours on site.

**Management**

Melbourne: Generally, local government has a lead role in management of catchments of a size of less than 60 hectares. In existing high density urban environments, local governments thus typically take the lead in GI delivery at the street and precinct scale while Melbourne Water take control of regional drainage assets. This arrangement is relatively well defined and understood, and ongoing management arrangements are well documented in existing guidance documentation.

Specialist contractors are emerging with the skills to maintain this type of infrastructure for optimum performance.

New York City: Developing a maintenance program is one of the more critical elements in creating a successful city-wide GI program. DEP have partnered with DPR to plan and implement a maintenance program, and by the end of 2013, Brooklyn, the Bronx and Queens each had one fully staffed five-member GI maintenance crew. DEP will continue to manage this maintenance program by employing a full-time manager.

Wales: Adoption can be a critical barrier for many retro-fit GI projects with cost, responsibility and maintenance often being the three key issues. This
was overcome in Llanelli by working with Carmarthenshire County Council (CCC) from inception. Discussions and agreements started with the GI overall strategy; this then progressed to agreeing to individual detailed site layouts and the use of bespoke technologies.

Long term adoption and maintenance agreements with CCC were negotiated for ongoing functionality. In addition, much of the GI installed at local schools is maintainable by the school pupils instilling a sense of ownership whilst benefiting both the school and DCWW.

Funding

Melbourne: In Melbourne, the goal of the programme is to prompt incremental change and GI rollout to support existing long-term strategies. An innovative funding approach is using existing Asset Management systems and leveraging off the back of existing works programmes (e.g. drainage system upgrades) so that only minor incremental costs associated with GI delivery are attributable. By understanding the additional costs and using them in the economic analysis, the business case for investment becomes much clearer and highlights the opportunities that could be missed if not pursued in a temporal fashion. Operational and maintenance costs are also being increasingly understood and factored into Council budgets and operational plans.

New York: On March 8, 2012, DEP signed an agreement to reduce combined sewer overflows (CSOs) using both green and grey infrastructure. DEP are developing Long Term Control Plans (LTCP) to reduce CSOs and improve water quality to standards set established with the Federal CSO Policy and the US EPA Clean Water Act. Over the next 20 years, DEP is planning on $2.4 billion in public and private funding for GI installations. DEP have prepared studies demonstrating the financial benefits of GI in comparison to traditional grey infrastructure for CSO reduction (which include large underground tunnels or wastewater treatment plant upgrades). Funding will largely come from DEP; however, there has been shared funding across multiple city agencies in terms of the management of design contracts and the maintenance of future GI practices.

Wales: At the beginning of 2011, DCWW announced a £15m investment, funded through its flooding and pollution budgets, targeting the top ten highest priority schemes capable of reducing peak storm water runoff entering the combined sewer by 25%. Implementation of the strategy is now underway with three constructed GI schemes showing the benefits resulting from a newly integrated, sustainable and resilient approach to water management.

Most recently, DCWW has agreed to a £230m loan facility with the European Investment Bank to cut costs, keep bills lower and continue its investment programme, including its RainScape programme. As cost savings have been demonstrated over traditional grey infrastructure approaches, funding for maintenance will come from existing budgets.

Importance of City Leadership

Melbourne: Proud of its ranking as the world’s most liveable city, Melbourne is consistently exploring ways to enhance its urban environment for residents and tourists alike. City Leadership is committed to enhancing life and liveability in the city and sees the greening of the city as a key component of this. This support is evident both in the language used by elected City leaders, Council officers and supporting policy documents. Overarching strategies such as the Urban Forest strategy are consistently publically supported by the Lord Mayor and other elected representatives.

New York: The 2010 GI Plan established the vision for a sustainable strategy for clean waterways in NYC. The Plan was developed during the tenure of Mayor Michael Bloomberg who was instrumental in pushing forward sustainability for NYC. Mayor Bloomberg led the creation of PlaNYC in 2007 to strengthen the economy, adapt to climate change and enhance quality of life to create a “Greener, Greater New York.” Much of the thinking and influence in the 2010 GI Plan spawned from PlaNYC.

The 2010 GI Plan was prepared by NYC DEP during the tenure of Cas Holloway as NYC DEP Commissioner. Cas Holloway created new initiatives in DEP including appointing DEP’s first Deputy Commissioner for Sustainability, and his leadership helped to facilitate the onset of the Plan. When Cas Holloway departed NYC DEP (to work directly for the Bloomberg administration), Carter Strickland succeeded Holloway as Commissioner and continued to prioritize GI (including launching the $2.4 billion investment across the next 20 years).

Wales: Although initially led by DCWW, the RainScape programme has and continues to be widely supported by a number of organisations such as Natural Resources Wales and Carmarthenshire Council. A number of public launch events for the projects have been held and attended by elected City Leadership, and media coverage has been strong.

CONCLUSION

The idea of bringing GI-led design into a more influential role in the design of cities is a significant opportunity to influence the structure and design of the urban environment to respond to future needs.
It can introduce a new ideology based around an ecosystems approach that can contribute to the health, resilience and prosperity of a city.

Water plays a key role in the delivery of GI through restoration of rivers and waterways, WSUD element retrofit, and vegetation/ tree planting to reduce run-off and manage microclimate. These new elements can form part of larger green grids which can be inhabited by community orchards and edible planting, play areas and recreational space.

Though contexts may vary, approaches to implementing new GI and urban landscape explored in these case studies should always use the resources, delivery mechanisms, and policy context available today while design of GI must always be appropriate to its context and draw on the best available data.

Delivery mechanisms will differ depending on the underlying goals: improving the quality of existing spaces or creating new assets which contribute to the wider network; large scale investment or smaller incremental projects; temporary, phased or permanent interventions. In all of these scenarios, multi-functionality and connectivity are crucial.

Delivery of GI has been somewhat piecemeal in the past. In the future, we should consider GI from the outset of any urban project or strategy. It should not be an independent driver for development, but a solution to a range of issues. Connecting multiple functions and securing benefits will meet a range of existing and future needs.

Acknowledgments

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References


Ellis, C 2014 Retro-fit GI in Llanelli: Implementing the UK’s first large scale retrofit GI strategy providing sustainable flood risk management and pollution reduction www.WaterProjectsOnline.com
Figure 1: The Case for GI © Arup
Figure 2: GI Delivery Framework © Arup
Figure 3: Greening Melbourne's Laneways (© Arup)

Figure 4: Playground at Stebonheath School after scheme implementation (© Arup)
Figure 5: NYCDEP Newtown Creek GI