Green(ing) Infrastructure

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Introduction

The development and maintenance of infrastructure is crucial to improving economic growth and quality of life (WEF 2013). Urban infrastructure typically includes bulk services such as water, sanitation and energy (typically electricity and gas), transport (typically roads, rail and airports), and telecommunications. The focus of this chapter will be on greening bulk services and roads.

Despite the importance of infrastructure to economic growth and social wellbeing, many countries struggle to meet the increasing demand by growing cities for infrastructure services (ULI 2007; WEF 2013), especially in developing countries including South Africa (SAICE 2006), and many consumers struggle to afford the increasing costs associated with the services they use (National Treasury 2012).

The South African Institute for Civil Engineers (SAICE), in their assessment of infrastructure in South Africa rated bulk services like water, sanitation and solid waste management in major urban areas and national and local energy distribution networks as 'fair', while bulk national water infrastructure, non-urban solid waste management, non-national roads, and non-urban electricity distribution were rated as 'poor' (SAICE 2006). In South Africa almost two-thirds of the R76.6-billion owed to municipalities by consumers is owed by households (National Treasury 2012) due, in part, to the state of the economy and substantial increases in tariffs.

While infrastructure undoubtedly can lead to an improvement in the quality of life of users, in many instances this contribution comes at the expense of environmental quality. The expanding network of roads, for example, covers many thousands of kilometres of land – in excess of 747,000 km in South Africa (SAInfo 2013) – with significant impacts on the ecosystem resulting in diminishing ecosystem services, as does the damming of rivers (McCully 2001). Road surfaces also decrease the ability of the land to absorb rain water resulting in an increase in runoff. Bulk services require energy to pump water to reservoirs and buildings, and to pump effluent away from buildings for both sewerage and storm water (Cohen, Nelson, and Wolff, 2004). The energy required is mainly generated by the burning of fossil fuels such as gas, oil, and coal, with a concomitant release of greenhouse gases.

Green infrastructure seeks to perform those functions in a manner that, at the very least, minimises its impact on the natural environment and, at best, enhances the quality of the natural environment.

Definition

Green infrastructure can be defined as the design and development of infrastructure that works with natural systems in the performance of its functions. Green infrastructure recognises the importance of the natural environment in land use planning decisions with particular regard to supporting the interconnected life support functions provided by the network of natural ecosystems (EPA 2007).

Greening infrastructure, on the other hand, can be defined as infrastructure that indirectly reduces the negative environmental consequences of infrastructure development in its operation. Examples of greening infrastructure would be emission-free energy-generating infrastructure such as solar and wind.

Green infrastructure terminology

As stated earlier, green infrastructure essentially makes use of and/or mimics natural processes: in this sense green infrastructure focuses mainly on water management in general, and storm water management in particular.

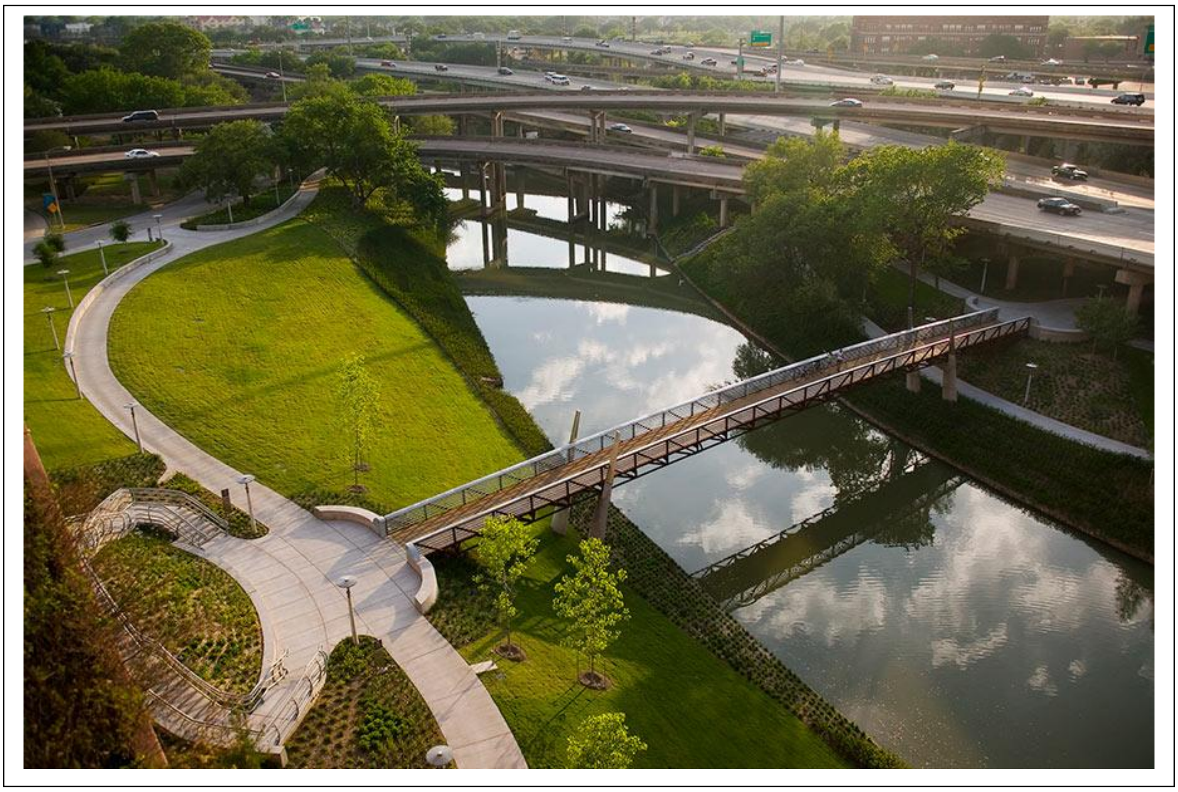

Figure 1: SWA Groups Buffalo Bayou Promenade created recreational areas along the waterway and incorporated flood mitigation infrastructure (Gendall 2013).

To better understand the concept of green infrastructure some generally used terms are described below.

Biodiversity – Encompasses the number, abundance and distribution of all species of life on earth. It includes the diversity of individual species, the genetic diversity within species and the range of habitats that support them. Biodiversity also includes humans and human interactions with the environment (Dale, Thomson, Kelly, Hay, and MacDougall, 2011).

Bioinfiltration – Bioretention systems are soil-and plant-based facilities systems employed to filter and treat runoff from developed areas. Bioretention systems are designed for water infiltration and evapotranspiration, along with pollutant removal by soil filtering, sorption mechanisms, microbial transformations, and other processes (American Rivers , 2012). See above comment

Blue space – is any piece of open water, public or private, usually within or adjoining to an urban area (Dale et al , 2011).see comment above

Coherence – A coherent ecological network is one that has all the elements necessary to achieve its overall objectives. The components are chosen to be complementary and mutually reinforcing so that the value of the whole network is greater than the sum of its parts (Dale et al, 2011).

Ecology – is the study of plants (flora) and animals (fauna) and the relationship between them and their physical environment (Dale et al, 2011).

Ecosystem – A biological community and its physical environment (Dale et al, 2011).

Ecosystem services – The multitude of resources and processes that are supplied by natural ecosystems (Dale et al, 2011).

Green infrastructure – is an approach to wet weather management that uses natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services. As a general principle, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspire, and/or recycle storm water runoff (American Rivers et al, 2012). In this capacity it is a strategically planned and delivered network of natural and man-made green (land) and blue (water) spaces that sustain natural processes. It is designed and managed as a multifunctional resource capable of delivering a wide range of environmental and quality of life benefits for society (Dale et al, 2011).

Green infrastructure systems – include tree boxes, vegetated swales, vegetated median strips, cisterns and rain water tanks, land conservation and reforestation, rain water harvesting, green roofs, riparian buffers, parks and greenbelts, permeable pavement, wetland and floodplain construction, rain gardens, bio infiltration practices and ecological sanitation systems (City of Philadephia 2009).

Greening infrastructure systems – includes the generation of electricity from renewable sources such as wind, water and solar.

Grey infrastructure – In the context of storm water management, grey infrastructure can be thought of as the hard, engineered systems to capture and convey runoff, such as gutters, storm sewers, tunnels, culverts, detention basins, and related systems (American Rivers, 2012).

Green roof – Employs vegetated roof covers, with growing media and plants covering or taking the place of bare membrane, gravel ballast, shingles or tiles. A green roof system is an extension of the existing roof which involves a high quality water proofing and root repellent system, a drainage system, filter cloth, a lightweight growing medium and plants (American Rivers, 2012).

Green space – is any piece of open land, public or private, usually within or adjoining to an urban area (Dale et al, 2011).

Green streets – Green streets are defined as a streetscape designed to integrate a system of storm water management within its right of way, reduce the amount of runoff into storm sewers, make the best use of the tree canopy for storm water interception as well as temperature mitigation and air quality improvement (American Rivers, 2012).

Hard engineering – The controlled disruption of natural processes to achieve a desired solution by using masonry, concrete or steel structures (Dale et al, 2011).

Impervious Cover (Or, impervious area, imperviousness) – Any surface that cannot be effectively (easily) penetrated by water, thereby resulting in runoff. Examples include pavement (asphalt, concrete), buildings, rooftops, driveways/roadways, parking lots and sidewalks (American Rivers, 2012).

Rain garden – A rain garden is a strategically located low area planted with native vegetation that intercepts runoff. Other terms include mini-wetlands, storm water gardens, water quality gardens, a storm water marsh, a backyard wetland, a low swale, a wetland biofilter, and a bioretention pond. Rain gardens are designed to direct polluted runoff into a low, vegetated area where the pollutants can be captured and filtered (American Rivers, 2012).

Resilience – The persistence of natural systems in the face of changes in ecosystem variables due to natural or anthropogenic causes (Dale et al, 2011).

Soft engineering – Working with natural processes and using natural or semi-natural materials to achieve a desired solution (Dale et al, 2011).

Storm water (or, Runoff) – Storm water runoff is precipitation that becomes polluted once it flows over driveways, streets, parking lots, construction sites, agricultural fields, lawns, and industrial areas. Pollutants associated with storm water include oils, grease, sediment, fertilizers, pesticides, herbicides, bacteria, debris and litter. Storm water washes these pollutants through the storm sewer system into local streams and drainage basins. In addition, because impervious surfaces prevent precipitation from soaking into the ground, more precipitation becomes runoff, and the additional volumes and velocities of storm water can scour streams and river channels, creating erosion and sediment problems (American Rivers, 2012).

Street trees – When properly designed traditional tree plantings along street and road edges can capture, infiltrate, and transpire storm water. These functions can be expanded by incorporating trees into more extensively designed "tree pits" that collect and filter storm water through layers of mulch, soil and plant root systems where pollutants can be retained, degraded and absorbed (American Rivers, 2012).

Green Infrastructure Functions

Green infrastructure systems are therefore those systems that can replace traditional grey infrastructure by utilising and/or mimicking natural systems.

It involves the integration of all aspects of the design and construction in civil engineering projects to deliver a strategically planned network of natural and man-made green (land) and blue (water) spaces that sustain biodiversity and natural processes. Well-designed green infrastructure has the potential to have many different functions, as it can provide a broad range of ecosystem services with benefits to the economy and society.

Figure 2: De Urbanisten’s Watersquare Project in Rotterdam is a sunken plaza that doubles as a catchment system to manage storm water (Gendall 2013).

Green storm water management

Traditionally storm water is managed through a system of impervious surfaces, open channels, trenches and pipes that carry it away from buildings and ground surfaces to a suitable area for discharge or treatment.

Figure 3: Ballard Roadside Rain Gardens, Seattle, Washington (Robbins 2013).

Often it will be discharged to the nearest watercourse or stream if available although it will find its way into a watercourse eventually. Conventional storm water management poses three challenges: first, any pollution caught up in the storm water will be discharged into a stream, river, lake or dam, creating a significant environmental problem for ecosystems along the way; secondly, as the urban footprint increases, so too does the area of impervious surfaces thereby diminishing the absorption potential and increasing the flooding potential especially areas where climate change may result in higher rates of precipitation; and thirdly, the ability to replenish the water-table is diminished, a problem that may become acute as a growing population increases its groundwater withdrawal.

Green infrastructure strategies include using rooftop vegetation to control storm water; restoring wetlands to retain floodwater; installing permeable pavement to mimic natural hydrology; and using or capturing and re-using water more efficiently on site. By employing natural processes such as infiltration and evaporation, these approaches prevent storm water from polluting watercourses and water bodies, and/or reducing flooding.

Figure 4: Permeable concrete pavement at the CSIR Innovation Site, designed to hold one hour of rainfall in Pretoria.

Climate adaptation via green infrastructure

Climate change will impact on urban areas in a number of ways, varying from higher rates of precipitation in some areas to higher temperatures in others. The forecast for South Africa is an increasingly hotter climate – increasing by between 4-5°C – with drier conditions generally but a higher rate of precipitation along the KwaZulu-Natal north coast (Conradie 2012).

Since forests and oceans are known to be carbon sinks deforestation is considered to be one of the contributing factors to climate change (Szalay, 2013). Green infrastructure can be a climate change mitigation strategy by replacing lost carbon sinks. Green infrastructure can be a climate change adaptation strategy by reducing the heat island effect in urban areas through shading and evaporative cooling, by reducing the volume of runoff and by increasing natural features that can reduce the effects of storm surges and flooding (Krayenhoff and Bass, 2003; Foster, Lowe and Winkelman, 2012; Gill, 2007).spell out all authors first time referenced

Biophilic urbanism and green infrastructure

Harvard biologist E. O. Wilson popularised the concept of biophilia, describing it as "the innately emotional affiliation of human beings to other living organisms. Innate means hereditary and hence part of ultimate human nature" (Beatley 2011). Beatley argues that humans are at their emotional and physical healthiest, happiest and most productive when working and living in close proximity to nature. There is sufficient evidence, according to Beatley, to support the notion that urban buildings that are green and natural contribute to maximal healing (in the case of health care facilities), and improved learning (in the case of academic institutions). There are many ways in which urban environments can provide access to nature including parks, natural areas, and views of nature through rooftops to roadways to riverfronts.

Beatley offers the following key qualities of biophilic cities:

- Biophilic cities are cities of abundant nature in close proximity to city dwellers;
- In biophilic cities urban dwellers feel a deep affinity with the unique local flora and fauna, and with the climate, topography, and other special qualities of place and environment that serve to define the urban setting; and
- Biophilic cities invest in social and physical infrastructure that helps to bring urban dwellers in closer connection and understanding of nature.

Green infrastructure helps maintain valuable ecosystems services at a broader landscape level, maintain biodiversity by ensuring ecological coherence and connectivity of the whole network, and enhancing landscape permeability to aid species dispersal, migration and movement (EU 2010).

Conclusion

Green infrastructure provides an effective land use management strategy in at least four critical areas:

- Green infrastructure can provide a less expensive and more cost-effective management strategy for storm water runoff and by so doing reduce the financial burden to the local authority, the property developer, and the occupier. A more localised storm water management system reduces the need for an extensive reticulation system of channels, pipes, pumps, and treatment plants.
- Green infrastructure reduces energy demand by reducing the need to collect and transport storm water to a suitable discharge location. In addition, green infrastructure such as green roofs, street trees and increased green spaces reduce the heating and cooling loads on buildings from the shading offered to buildings and impervious surfaces. Harvested precipitation can further reduce energy demands by reducing the demand on the water reticulation system.

- Green infrastructure can reduce the economic costs and risks associated with flooding by reducing runoff volumes and by providing either permanent or temporary holding areas.
- Green infrastructure enhances public health and reduces illness-related costs by reducing the extent of pollutants collected and dispersed throughout the storm water management system.
- Green infrastructure is an effective climate change adaptation and mitigation strategy by reducing anthropological contributions to greenhouse gas emissions and by reducing the negative impacts of climate change on cities and urban dwellers; and
- Green infrastructure contributes to the innate emotional affiliation of human beings to other living organisms and thereby enhancing human quality of life.

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