NATURAL ASSETS IN INFRASTRUCTURE PROJECTS

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Abstract

In the drive for financial and environmental sustainability natural assets can be used in parallel with or to replace some traditional approaches and hard assets. An infrastructure project to reduce risk of flooding that may, for example, have previously used hard assets like a dam or a levee built from materials trucked into the site might instead use vegetated wetlands. In many cases these natural solutions come with lower capital and operating costs and they can mitigate urban heat islands and support resilience to the impacts of climate change. Natural assets also bring additional benefits, they can enhance recreational opportunities, purify air, improve soil quality and enhance habitat. Collectively the interaction of urban green infrastructure components can help to conserve biodiversity and restore ecological processes. Canada and in particular the state of British Columbia have become leaders in this emerging area of asset management practice. This paper reviews some leading examples of the application of natural assets in urban green infrastructure.

Introduction

The Institute of Public Works Engineering Australasia (IPWEA) is the peak association for public works professionals across Australia and New Zealand. IPWEA was established to enhance the quality of life for communities via continuous improvement and best practice in all aspects of public works, services, infrastructure planning, delivery and operations. IPWEA provides services to members and advocates on their behalf. Our core business is to provide tools and resources to support all asset intensive organisations manage their assets and for local government to maintain the high level of service the community demands.

We are aware that as the human population grows beyond 8 billion our consumption of natural resources continues to grow exponentially. The World Bank estimates that infrastructure now accounts for approximately 70% of global greenhouse gas emissions and half of all resources used and waste created globally. Add to that the projection that 60%-70% of the 2050 infrastructure is not yet built, and it becomes obvious that the infrastructure sector has enormous potential to reduce the impacts of climate change and demand on water and other raw materials.

One approach to reducing infrastructure resource inputs is to include nature-based solutions such as natural assets and green infrastructure to support or in some cases replace hard infrastructure. The benefits of green infrastructure (GI) and the ecosystem services it can provide are extensive and include stormwater runoff reduction and treatment, air and water quality improvement, mitigation of urban heat island effects, reduction of energy consumption in buildings, sequestration and storage of carbon, protection of wildlife habitat and improvement in human health and well-being (Green Infrastructure Network, 2023; US EPA, 2021). A range of GI assets and the value, benefits and services provided, the threats and challenges natural and green infrastructure must address, and how we might include green infrastructure in traditional infrastructure approaches are considered in this paper and presentation through examination of some case study examples.

Traditional infrastructure assets and their management

The ISO 55000 standard defines an asset as “something that has potential or actual value to an organization”. Traditional infrastructure assets are physical assets that contribute to meeting the needs of major economic and social facilities and services. They are typically large, interconnected networks or portfolios of composite assets and include a variety of classes including road and road related assets (road pavements, road surfaces, bridges, culverts, footpaths, kerb and channel/gutter, stormwater drainage systems (pipes, open channels, pits, inlet structures, stormwater treatment and water sensitive urban design systems) recreation facilities (passive parks, active sports fields), buildings, (public, community and sporting buildings), water supply and sewerage assets.

Assets are managed at the component level. A component is part of an item of property, plant or equipment that has a significant cost in relation to the total cost of the asset. It has an independent physical or functional identity and specific attributes such as different life expectance, maintenance regimes, risk or criticality. The components of assets may be separately maintained, renewed or replaced individually so that the required level and standard of service from the network of assets is continuously sustained. Generally, the components and hence the assets have long lives and need to be managed throughout the asset life cycle from planning and design through acquisition and deployment, operation and maintenance, and finally decommissioning and disposal / recycle.

Infrastructure asset management is the systematic process of managing an asset through each of its life cycle stages. A range of measures are considered in infrastructure asset management, including: cost; risks; efficiency; durability; safety; customer satisfaction; quality; capacity; reliability; responsiveness; environmental acceptability; availability; functionality; sustainability and other performance attributes (ISO 55000:2014). In most jurisdictions there are legal and financial requirements that must be met in the management of infrastructure assets.

Natural and green infrastructure assets

Natural assets, green infrastructure or urban green infrastructure are terms that refer to natural resources or ecosystems that are intentionally managed to provide multiple benefits for the environment and for human well-being. They can be applied at different scales, from individual buildings to entire landscapes, and can include various forms.

Green infrastructure (GI) includes natural assets (such as air, water, soil and both natural and restored ecosystems such as wetlands, forests, lakes, rivers, mangroves, coastal dunes, living shorelines, meadows and pastures) as well as hybrid or enhanced assets that combine engineered and nature-based elements. These include urban forests, bioswales, storm water ponds, parks and gardens, street trees, rain gardens, roadside verges, vegetable patches, bikeways and pedestrian trails, green roofs or walls, rain gardens, cemeteries and community gardens (Figure 1).

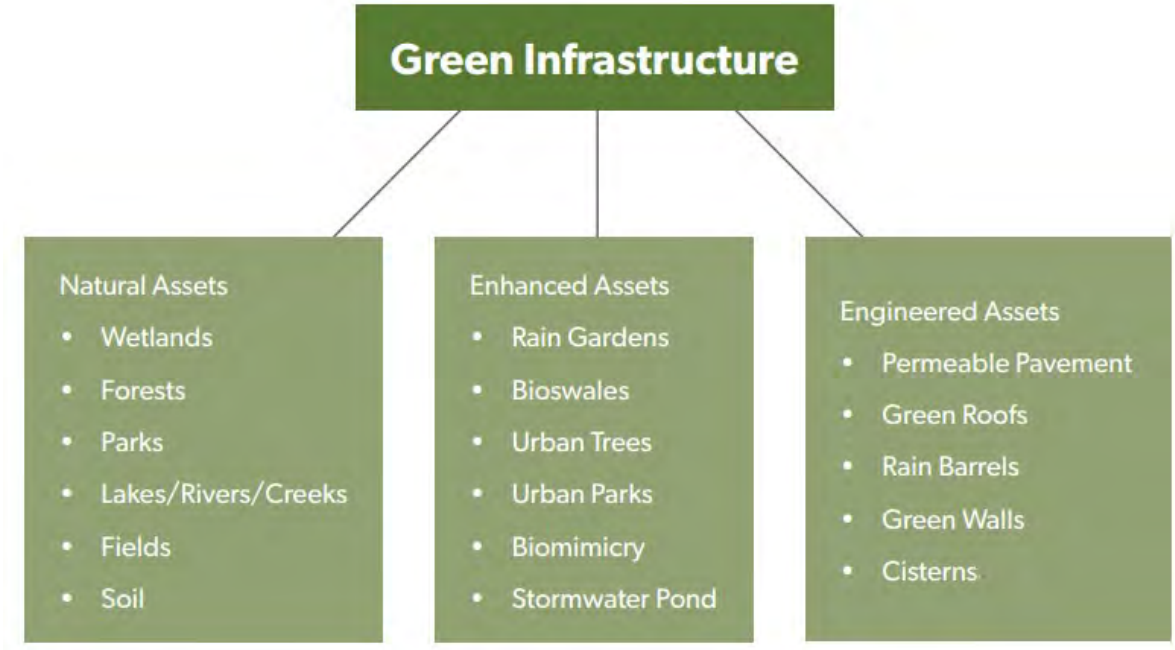

Figure 1: Green infrastructure examples (Source: MNAI, 2023).

The inclusion of GI in urban landscapes is usually intended to enhance the quality of life of citizens, ti improve resilience, or to conserve, restore and support natural ecosystems and biodiversity which provides ecosystem services (Jun Ying et al., 2022). Globally, ecosystem services from GI have been estimated using a range of

methods such as market prices, revealed preferences, or stated preferences, to provide benefits of US $125-140 trillion per year - more than 1.5 times the size of global GDP (Nature4Climate, 2023). However, these benefits are often undervalued or ignored in conventional economic accounting and decision making, leading to the degradation and loss of natural capital and biodiversity. Natural or green infrastructure assets have not traditionally been included in asset managers' portfolios.

Value and benefits of green infrastructure assets

To provide community services cost-effectively and sustainably now and in the future, governments continually seek ways to improve the management of their critical assets that supply essential services. GI assets have the potential to provide a range of services of benefit to humans. Emerging evidence shows that identifying, measuring and managing natural assets, and creating green infrastructure as part of an overall asset management strategy can save capital and operating costs and reduce risk when compared to engineered alternatives. In addition, natural assets can be long-lived or perpetually self-regenerating and are often more resilient and adaptable to climate change (MNIA, 2023). Additional benefits of GI include the provision of clean air, food and water, enhanced pollination, reduced pollution, stormwater management, carbon sequestration, noise reduction, biodiversity conservation, improved human health and well-being, recreational and economic opportunities, and strengthened cultural and aesthetic values.

Street trees, parks and urban forests can: reduce air pollution by filtering particulate matter and absorbing gaseous pollutants such as nitrogen dioxide and ozone, lower ambient temperatures and the urban heat island effect by providing shade and evaporative cooling, reduce building heating and cooling costs and energy consumption, improve human health by reducing respiratory disease, increase property values, provide a sense of scale within the built environment, and offer ecosystem benefits. Natural and green assets can improve resilience against extreme weather events and climate change impacts by reducing greenhouse gas emissions, enhancing carbon sequestration, lowering urban temperatures, increasing water retention and infiltration, and reducing sea level rise and riverine flood risk.

Coastal assets such as mangroves, dune systems and artificial reefs can reduce coastal flooding and erosion, sequester carbon, support fisheries and tourism, provide habitat for many species, provide tourism and recreation opportunities and reduce the impacts of sea level rise. It is estimated that if today's mangroves were lost, 18 million more people would be flooded every year (a 39% increase) and annual damages to property would increase by 16% (US $82 billion).

Urban green spaces and wetlands can enhance water retention and infiltration, reducing surface runoff and flooding. They can also improve water quality by filtering pollutants and nutrients from storm water before returning it to rivers and underground aquifers prior to reuse. Natural and green infrastructure can also provide habitats and corridors for various species of plants and animals, increase urban biodiversity and enhance ecological resilience. GI can increase opportunities for physical activity, social interaction, relaxation and the enjoyment of nature – all of which improve human mental health and well-being by reducing stress, enhancing mood and cognitive function. From an asset management perspective green infrastructure can also come with lower capital and operating costs, and generate economic value by increasing property values, rental rates, sales revenues, employee retention, and customer satisfaction. (This summary of benefits was compiled from MNAI (2018); Moore (2000); Bolund & Hunhammar (1999); Ma, Henneberry, Privitera, & Mastrucci (2021); Donovan & Butry (2010); Jim & Chen (2006); Tyrväinen, Mäkinen, & Schipperijn (2007); Nature4Climate (2023)).

Threats and challenges for green infrastructure assets

Despite their value and benefits, GI assets face several threats and challenges that have the potential to undermine their provision and diminish the quality of ecosystem services delivered. These include lack of recognition, valuation and financing, degradation and loss of natural habitats, competing land uses and development pressures, and insufficient data and knowledge regarding their safety, performance, benefits, maintenance, operation and management. More specifically GI assets face the following threats and challenges.

Education, expertise and knowledge:

- lack of awareness and knowledge of the multiple benefits and values of GI among policy makers, practitioners, and the public
- loss of expertise from local government and lack of horticultural input to decision making
- lack of data and tools for the valuation of ecosystem services and disservices, life span, performance, benefits, costs
- lack of capacity and skills to implement and manage green infrastructure effectively and efficiently
- inadequate data and evidence to support design and evaluation of GI interventions

Policy and finance:

- poor coordination and integration among different sectors and stakeholders involved in GI planning and management
- failure of legal and institutional frameworks to incentivize, support and regulate the use of GI
- lack of understanding of GI ecosystem service interactions, e.g. increasing tree cover at the cost of reduced solar radiation
- insufficient funding and financing mechanisms to support the development and maintenance of GI.

Hard infrastructure developments:

- loss of public and private open space
- inner city re-development and urban sprawl that reduce the availability and connectivity of green space, affecting their ecological functions and services
- overhead cables; communications and power distribution company policies and poor practices for power line clearing
- underground infrastructure including cables, plumbing and drainage
- competing demands between GI and other land uses or interests creating conflicts over the allocation and management of green spaces (e.g. development Vs green space and trees).

Environmental threats:

- unmanaged pests and diseases
- the changing climate
- exposure to various sources of pollution and disturbance that can degrade the quality and health of green spaces and their biotic components, e.g. air pollution can damage vegetation and reduce photosynthesis, herbicide use, chemical fertilizers
- thresholds or tipping points beyond which irreversible or undesirable changes may occur, e.g. biodiversity loss or climate change may reduce ecosystem resilience and stability and compromise ecosystem services

The above threats and challenges were compiled from Moore (2000), Jun Ying et al. (2021), Nature4Climate (2023), Green Infrastructure Network (2023), US EPA (2021), Saleh & Weinstein (2016), Sutton-Grier et al. (2015).

Asset management for green infrastructure

Harnessing GI assets in the service of urban areas is an innovative and promising concept that can enhance the liveability and sustainability of cities. With effective monitoring, maintenance and rehabilitation, natural and green assets can provide service and add value for decades in ways that many engineered assets cannot match. However, GI requires careful planning, monitoring and evaluation to ensure that it delivers the desired outcomes for different stakeholders. The management of green infrastructure requires a cross-disciplinary approach that involves policy makers, planners, designers, engineers, researchers, horticulturists and potentially ecologists and hydrologists. It also requires a clear understanding of the multiple advantages and challenges of green

infrastructure and the threats posed by rapid environmental and social change in urban environments and in the changing climate.

As with traditional assets, managing GI assets requires a systematic process of planning, operating, maintaining and upgrading green infrastructure to deliver its environmental, social and economic benefits and services. GI assets require regular monitoring and maintenance to ensure their optimal performance and longevity. Incorporating GI assets into traditional asset management systems requires that the GI components be properly valued and managed.

Initial steps require GI assets to be integrated into established asset management policy and practise via high level strategic planning. Next, an inventory of key GI assets must be compiled, including the services they provide. An assessment of asset value and condition can then be undertaken to compare service provision against engineered options. Doing this requires comprehensive information in an asset management system for each component (specimen, swale, length of stream) and / or asset (forest, wetland, dune system) including its identity, location, age, condition, value and management (maintenance and renewal) schedule. A corresponding financial management plan is also required to ensure funding for the assets and understanding of return on investment. Asset management for GI can be implemented within an organization by:

- communicating and engaging with stakeholders on the benefits of their GI assets
- identifying the current state and value of their GI assets
- assessing risks and opportunities associated with their GI assets
- prioritizing and allocating resources for their GI assets
- tracking and reporting on the performance and impact of their GI assets

Green infrastructure has the potential to provide a win-win solution to achieving sustainability goals and improving human health, well-being, and environmental quality. However, overcoming the challenges and bringing about wider adoption of GI assets into asset management will require:

- improved acceptance of GI as a mainstream alternative or addition to hard assets
- cross-sectoral partnerships and stakeholder engagement in GI decision-making processes
- increased biodiversity within GI projects
- development of robust methods for valuing GI benefits and costs across different spatial and temporal scales and improved economic valuations for GI
- optimised spatial configuration and composition of GI for multiple benefits
- identification and development of metrics, models and tools for the planning and assessment of GI
- turning research into policy and implementation

Several frameworks and guidelines have been developed or are under development to assist with the mainstream expansion of GI:

- International Capital Market Association Green Bond Principles and Sustainability Bond Guidelines, which provide standards for issuing bonds to finance GI projects (ICMA, 2023)
- HSBC Global Asset Management Green Impact Investment Guidelines, which outline eligible green activities and impact reporting expectations for bond investors (HSBC, 2020)
- US Environmental Protection Agency (EPA) Stormwater Asset Management Framework, which helps municipalities plan, track and manage their stormwater GI projects (EPA, 2022)
- CIRIA Asset Management of Blue Green Infrastructure Guiding Principles Project, which is developing best practices for managing BGI assets that combine water and vegetation features (CIRIA, 2023)
- The Green Infrastructure Ontario Asset Management Framework is currently developing a roadmap for developing an asset management plan for GI in Ontario and includes a suite of resources and reports (GIO, 2021)

In Canada, the Natural Assets Initiative (NAI) is now providing scientific, economic and municipal expertise to support and guide local governments in identifying, valuing and accounting for natural assets in their financial

planning and asset management programs and developing leading-edge, sustainable and climate-resilient infrastructure. They have been able to develop resilient, long-term infrastructure alternatives at substantial savings and to incorporate this information into mainstream asset management systems (MNAI 2023).

Case study examples

Case studies from different regions of the world illustrate the potential of green infrastructure projects to deliver multiple ecosystem services and co-benefits for urban communities. Examples include:

- In the Netherlands the Hondsbossche Dunes infrastructure project replaced a conventional dike with a soft coastal barrier made of sand. The dunes have improved the safety and security of the area but also created new recreational and ecological opportunities.
- In Indonesia, the World Bank is supporting the government's ambitious target of rehabilitating 600,000 hectares of mangroves by 2024. The project leverages the power of communities to collect national data on mangroves, provides incentives for mangrove protection and restoration, and promotes sustainable livelihoods and blue carbon markets.
- In India the East Kolkata Wetland Complex project is a natural sewage treatment system that covers 3,000 hectares on the edge of Kolkata. It removes phosphorus from wastewater and provides a resource for fish farming and agriculture.
- The City of Adelaide, Australia created a streetscape of vegetated rain gardens within road reserves to capture and filter pollutants and sediments from stormwater runoff. The rain gardens also provide aesthetic benefits, traffic calming effects and habitat for native plants and animals.
- In Comox, Canada the restoration of Brooklyn Creek enhanced its ability to improve water flow as well as spread, retain and infiltrate water to reduce flooding. The restored creek improved fish habitats, portions of urban woodlands and natural areas to enhanced parks and trails.
- The Korea Superconducting Tokamak Advanced Research (KSTAR) facility (Korea Institute of Fusion Energy) has installed a green roof that covers 12,000 square meters and reduces stormwater runoff by 60%.
- The city of Portland, Oregon, has implemented a Green Streets program that uses rain gardens, bioswales and permeable pavements to capture and filter stormwater runoff from streets and sidewalks.
- The city of Singapore has developed a comprehensive greening strategy that aims to increase the urban tree cover from 36% to 50% by 2030 and create a City in a Garden.
- The city of Curitiba, Brazil, has transformed an abandoned quarry into a botanical garden that hosts a variety of native plants and animals and attracts millions of visitors every year.
- In Detroit, Michigan, USA, a former elementary school site was transformed into a four-acre urban farm called Food Field. The farm produces fruits, vegetables, eggs, honey and mushrooms for local markets and restaurants. It also features a solar-powered aquaponics system, greenhouse and composting facility. The farm provides employment opportunities, community engagement, education and green space.
- In Sri Lanka, a project supported by the Food and Agriculture Organization (FAO) integrated urban agriculture and forestry into climate change action plans of six municipalities via the establishment of home gardens, community gardens, rooftop gardens and school gardens to enhance food security, income generation, waste management and disaster risk reduction. It also supported the planting of trees along roadsides, riverbanks and public spaces to improve urban microclimate, air quality and biodiversity.
- In Beijing, China, an eco-corridor was designed to connect the Olympic Forest Park with the surrounding urban fabric. The corridor consists of a series of green spaces that provide habitat for wildlife, recreation for residents and visitors, stormwater management and climate regulation. The corridor also showcases different types of native vegetation and landscape features that reflect the local culture and history.
- In Lugo, Spain, a set of urban forestry and agriculture actions were implemented within the EU LIFE Program to reduce CO_2 emissions and enhance resilience. The actions included planting trees along

streets and public spaces, creating urban orchards and gardens, restoring riparian forests along rivers and streams, and promoting agroforestry practices in peri-urban areas. The actions resulted in increased carbon sequestration, improved water quality and quantity, enhanced biodiversity and social capital.

Conclusion

There is a growing urgency to improve sustainability, reduce demand for natural resources, reduce greenhouse gas emissions and adapt to climate change. As a sector, infrastructure is responsible for 70% of global greenhouse gas emissions and half of all resources used and waste generated. As a result, we have a huge responsibility and opportunity to respond to these challenges in a sustainable way. Embracing nature based solutions such as green infrastructure and natural assets has the capacity to provide a wealth of win-win solutions and provide climate resilient ecosystem services for our urban environments and habitat for biodiverse plant and animal communities.

The benefits of green infrastructure are significant and include stormwater reduction and treatment, air and water quality improvement, mitigation of urban heat island effects, reduction of energy consumption in buildings, storing of carbon, protection of wildlife habitat and improvement in human health and well-being. To capitalise on these benefits we need to communicate them to stakeholders and then embed green infrastructure into asset management systems and processes. This process will ensure that the necessary values, priorities, resources and funds are put in place to mainstream nature-based solutions at a global scale. There is much work currently underway in this space, a number of guidelines have been developed and more are in progress. IPWEA looks forward to playing a part in our resilient and sustainable future.

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