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Green infrastructure to enhance urban sustainability

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***Abstract*---**Green infrastructure is one of the main design strategies that must be developed within the urban plans of any city, its essential role in achieving the principles of sustainability and enhance its social, economic and environmental pillars. It contributes to increasing the quality of life within urban cities, areas and vitality, as well as making it an important attraction for residents and investors and Stepping stone for spreading and enhance sustainability within the built environment. Therefore, the research problem emerged in the "Knowledge deficiency of the importance of green infrastructure in enhance urban sustainability within the built environment". Through, The research hypothesis, "Green infrastructure is one of the most important design strategies within the built environment to enhance urban sustainability by increasing the quality of life socially, economically and environmentally." The aim of the research "Utilizing green infrastructure to strengthen social, economic and environmental axes of sustainability and raise awareness of the importance and key role of this urban-level design strategy for cities". The research addressed green infrastructure within the two axes of the conceptual framework and the applied framework as well as the selection of four global cities as applied projects for green infrastructure plans to Enhance urban sustainability among its three main social, economic and environmental pillars. Then a set of indicators and design vocabulary of green infrastructure has been drawn to enhance urban sustainability, and then a set of conclusions.

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Keywords---green infrastructure, urban sustainability, built environment, enhance sustainability pillars.

Introduction

Green infrastructure is one of the basic design strategies that must be set within the urban plans of any city, because of their instrumental in the realization of the principles of sustainability and the strengthening of their social, economic and environmental pillars, It contributes to increasing the quality and vitality of life within urban cities and areas, as well as making it an important attraction for residents and investors and a starting point for spreading and promoting sustainability within the built environment.

The Concept Of "Urban Green Infrastructure"

Green infrastructure is a way of (re- generating) a variety of urban ecosystem services in cities, Duvall defines it as "an interconnected network of green spaces that preserve the values and functions of nature's ecosystem and provide the benefits associated with society". (Duvall, P, Lennon, M, & Scott, M, 2018), as well as green infrastructure, it enhance coherence, harmony and harmonious between different uses of urban land within the green areas level, this creates a green network of infrastructure able to enhance d interaction, social resilience and environmental. Green infrastructure is a coherent framework for ecosystem service concepts and tools through a deeper understanding of ecology and its functioning (Zari ،2007)

In 1999, the Conservation and Forest Service Fund of the United States Department of Agriculture formed a working group of government agencies and NGOs to develop a programme that would help make green infrastructure an integral part of local and regional plans and policies. This group put forward the definition "green infrastructure is the natural life support system, which is a coherent network of waterways, wetlands, forests, wildlife habitats and other natural areas; green corridors, parks, other protected land, plantations and forests; and wilderness and other open spaces that support local species, maintain natural environmental processes, conserve air and water resources, and contribute to the health and quality of life of communities. " (Benedict & McMahon, 2002)

Due to biodiversity loss and degradation of natural resources at the urban level, the need for the central role that green space networks have to play in cities and city areas has increased. In May 2013, the European Commission published a strategy to strengthen the green infrastructure necessary for the functioning of cities and regions and to mainstream it into the European Union policy areas. The strategy refers to the potential of green spaces to make a significant contribution to sustainable development and the achievement of their objectives and strategies, and shed light on the importance of green infrastructure solutions in cities and addressing the major urban challenges faced by cities. (Commission, Green Infrastructure (GI) — Enhancing Europe's Natural Capital - COM(2013), 2013a) for example :

1. adaptation to climate change
2. protection of biodiversity
3. promotion of a green economy
4. greater social cohesion

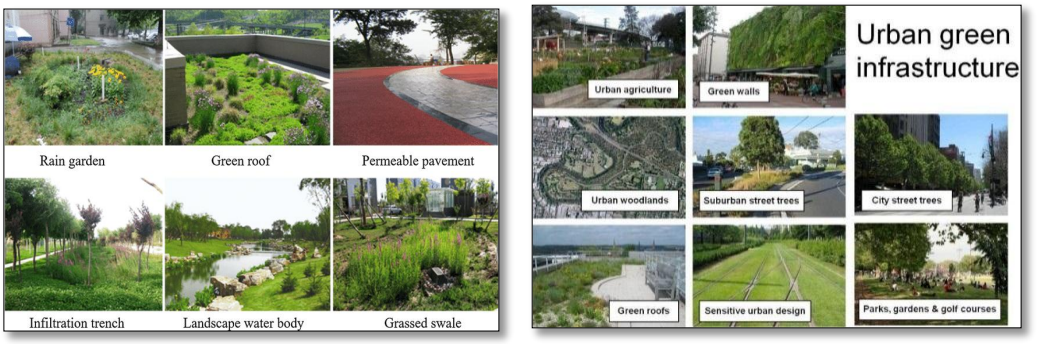

Figure 1. Type of urban green infrastructure

Principles and strategies of green infrastructure

Green infrastructure is multi-scale, multi-purpose and multi-disciplinary, as it aims to connect different spatial levels, from urban areas to individual sites. All types of green and blue urban spaces, regardless of ownership and origin, can be considered part of a green infrastructure network. as well as ideally promoting synergy in partnership between local authorities and other stakeholders from different areas. (Hansen, 2017)

Green infrastructure principles are fundamentally interrelated, as improved communication within the green network can lead to increased provision of ecosystem services and integration of structures with other structures, which in turn enhance multiple functions. Green infrastructure is a strategic approach aimed at developing networks of green and blue spaces in urban areas ,which are designed and managed to deliver a wide range of ecosystem services and other advantages at all spatial scales, As follows is a set of its design principles:

1. Green and grey integration - combine of green and grey infrastructure: combining green and grey infrastructure planning, any integration and coordination of urban green spaces with other infrastructure, such as transport systems and utilities.
2. Communication - establishment of green space networks: Includes establishment and restore of communications to support and protect processes, functions and benefits that individual green spaces cannot provide on their own.
3. Multifunctionality - Providing and enhancing multiple functions and services: combining different functions to enhance the capacity of green urban areas as a space to provide multiple benefits.
4. Social inclusion _ Collaborative and participatory planning are cooperative processes, socially inclusive , spaces open to all and include knowledge and needs of various sides. (Benedict & McMahon, 2002).

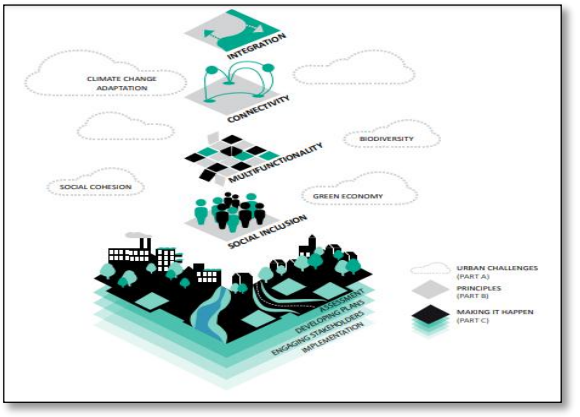

Figure 2. Shows the four basic principles

Green infrastructure components

The green infrastructure consists of a set of elements:

1. Core areas: Consist of the largest natural or semi-natural spaces connected to each other in networks by small green and blue infrastructure elements called "stepping stones."
2. Stepping-stones: These elements are the smallest, such as fencing, street trees, riverbanks, green surfaces and insulating biodiversity strips in agricultural areas, marshes and ponds can be physically or functionally linked to core areas.
3. Urban Corridors or links: Corridors areas that connect areas around water Corridors such as trees, green spaces and waterways, in addition to their environmental function, can provide valuable services to people. (Benedict & McMahon, 2002)

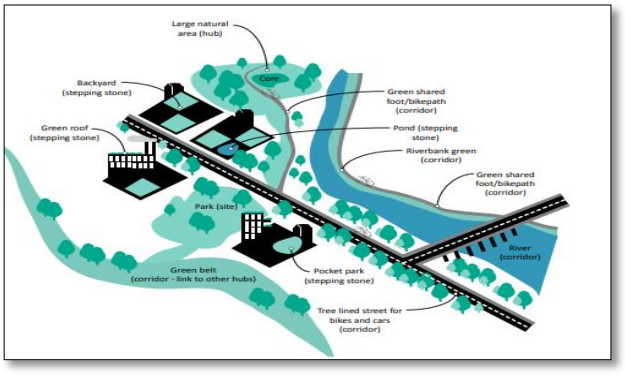

Figure 3. Shows the components of green infrastructure

Benefits of consolidate green infrastructure into the built environment

There are many benefits of using the green infrastructure within the built environment, as it provides a mechanism for balancing environmental, economic

and social factors; Provides a framework for integrating diverse natural resource management and growth activities into a comprehensive ecosystem approach; Ensures that both green spaces and development are placed where they are more convenient; which identifies vital ecosystem areas before development; Identifies opportunities to restore and strengthen systems that operate normally in urban areas; provide a unified vision for the future. as well as addressing environmental, social and economic needs, It contributes to enhance healthy communities and sustainable transportation , Enhance the improvement of public health and psychological well-being ,Enhance local economic and investment projects, Enhance interaction and social communication , creating a balance between residential and natural areas, as well as creating high-quality environments and reducing pollution, Storm Water Management and reducing energy consumption costs. (Commission, Building Green Infrastructure for Europe, 2013)

Green infrastructure must be considered as multi-functional, with different types providing different services/benefits depending on local needs and circumstances, Its including:

- Wildlife space and protection
- providing access to nature
- Recreation and social interaction
- reducing flood risks
- improving landscapes (including those within our settlement)
- Reducing the adverse effects of climate change

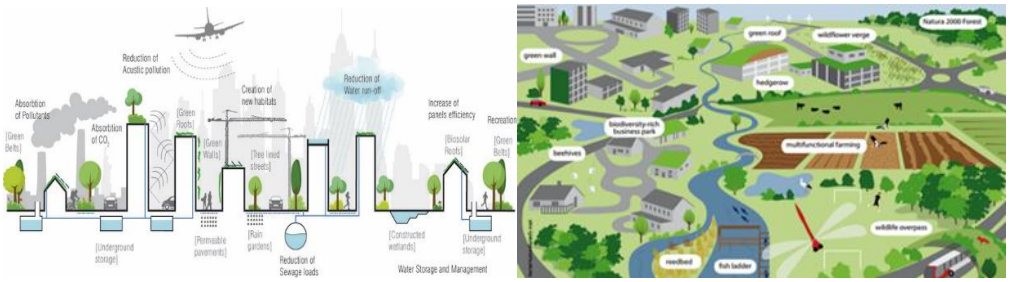

Figure 5. shows the types of benefits or services provided by green infrastructure

The European Commission adopted the Green Infrastructure Strategy in 2013 to "Enhance the deployment of green infrastructure in the European Union in urban and rural areas" to support biodiversity conservation objectives against the backdrop of rapid urbanization and landscape fragmentation. Green infrastructure preserves and restores ecosystems and ensures the continuity of their services and provides habitats and resources that species need to survive. Geographical indicator scattered across and across cities can serve as core habitats or stepping-stones for species.

Figure 6. Benefits of Green Infrastructure (European Commission - Technical Information on Green Infrastructure, 2013

Applied Framework for Green Infrastructure within the Built Environment

Green infrastructure must be designed to link elements to a system that works as a whole, rather than as separate and unconnected parts, where green spaces need to be planned to include environmental, social and economic benefits, functions and values and thus Enhance sustainability and its pillars. through linking and integrating green space elements into each level of the built environment with a strategic, diverse and most important vision and must build on knowledge of professional disciplines such as landscape environment, urban and regional planning ,landscaping, and implemented according to a participatory scheme that sets the community as the basis and the main beneficiary. This includes community organizations, landowners and the private sector.

Figure 7. Demonstrates the mechanisms and levels of application of green infrastructure within the built environment and its importance in promoting urban sustainability

Case studies

Each city must have a green infrastructure strategy and a practical plan to achieve this. Four green infrastructure strategic plans have been selected within four large cities and face significant challenges through these plans that have overcome their challenges and achieved social, economic and environmental gains, thereby enhancing the urban sustainability of their cities.

Figure 8. Illustrates the key aspects of green infrastructure within the built environment and its enhanced urban sustainability

Green Infrastructure Plan (Green City, Clean Waters in Philadelphia)

The Philadelphia city plan includes a comprehensive green infrastructure approach estimated to cost only $1.2 billion over the next 25 years, compared to more than $6 billion for "grey" infrastructure, a term used for concrete tunnels created to carry water. The Green City, Clean Waters in Philadelphia project in 2011, the city entered into a 25-year agreement with the U.S. Environmental Protection Agency to address stormwater problem and its suffering from stormwater management. Philadelphia receives more than 1 million gallons of rain per acre annually. The city has created more than a thousand "green" acres to restore natural rainfall cycles and systems in the region. From simple to complex, these green acres can absorb billions of gallons of rain annually, with the added advantage of creating external landscape for the public to enjoy. Philadelphia's plan envisions transforming the city into an oasis of rain gardens, green roofs, tree views and porous sidewalks, which advocates say are cheaper than tunnels and make the city nicer and more liveable with higher property values and better community health. It has built hundreds of underground storage projects, rain gardens, farming basins, storm water drainage trenches, porous sidewalk projects, and green basins and roofs that reuse or intercept stormwater and leave it to absorb or evaporate. Within this plan, it is expected that:

- Employment of 250 persons per year in green jobs.
- Avoid or absorb up to 1.5 billion pounds of CO2 emissions through green infrastructure each year, equivalent to removing nearly 3,400 vehicles from roads.
- Improve air quality due to all new trees, green roofs and parks

- Communities will benefit socially and healthy.
- The city estimates that 20 deaths due to asthma will be avoided, and at least 250 working or school days will be missed.
- Urban extreme heat deaths can also be reduced by 250 over 20 years.
- Philadelphia expects an increase of up to $390 million in property values near parks and green areas over the next 45 years.

Figure 9. The three Main axes of the Philadelphia plan's benefits.

These benefits are achieved within three core axes

1. Environmental: Using plants in green tools benefits our environment, reducing Co2 and filtering pollutants like those from cars improves air quality. Trees block humans and buildings, providing energy that can be used for air conditioning and reducing heat impact. GSI packages are planned for the city's hottest areas, including north and west Philadelphia. Native plants and flowers support important wildlife, including pollinators, such as bees, and larger species, such as birds. Green infrastructure helps our city prepare for climate change.
2. Economic: Investing in green tools boosts Philadelphia's economy, creating and maintaining green storm water tools creates local jobs. Studies have also shown that the creation of tree-surrounded streets and green spaces near residential streets can increase the property value. The presence of clean rivers attracts and Enhances recreation, pumping millions of dollars of tourism into our local economy. Already, Schuylkill alone generates $589.9 million in economic impact, supports 6,154 jobs, and creates $37.7 million in tax revenue for the region each year.

Figure 10. shows the Schuylkill project

3. Social: Creating healthier communities, restoring our waterways provides better spaces for hiking, cycling, boating, fishing and enjoying nature. Living in green space encourages spending time outside, which means more exercise and time with neighbors. Collaboration with local people to preserve and beautify neighbourhoods through programs is beneficial to

communities. Research indicates that greening Philadelphia's neighborhoods Enhances social justice, as well as reducing crime and local tension.

Figure 11. Green City, Clean Waters in Philadelphia

New York City Green Infrastructure Plan

New York City's green infrastructure plan is expected to cost $1.5 billion less than similar grey infrastructure approaches, with green storm water management systems alone providing $1 billion, at a lower cost of about $0.15 per gallon. Also, sustainability benefits in New York City range from $139-418 million over the 20 years of the project's life, depending on the measures implemented. In terms of identifying strategies for different land use types, including parks, parking lots, streets and public utilities; An inter-agency working group on green infrastructure and the involvement of stakeholders such as partner agencies and community groups ;use green infrastructure carefully while improving grey infrastructure, which will also be necessary to meet the city's water quality requirements; Monitor and measure performance to manage green infrastructure facilities in an adaptive manner over time. New York's 2012 Green Infrastructure Grants Programme promises in this regard; It is a step towards keeping cities functional, effective and safe. These include green roofs, blue ceilings, assembled ceilings, and farms on roof and porous sidewalks. Sewage systems are being regulated under a city-state agreement as part of the Clean Water Act and set targets for 20 years. In order to maintain effectiveness in these policies, cities need to continue to predict and anticipate climate change with innovative policy strategies and integrate design into green infrastructure.

In addition, New York has committed to updating its green infrastructure plan annually to better track progress and performance. Within this plan, it is expected that:

- That "every entire vegan acre of green infrastructure will provide a range of benefits as follows:
- Total annual benefits of $8,522 in lower energy demand
- $ 166 in CO2 emissions reduction
- $1044 in improved air quality
- $4,725 in increased property value

https://ara.architecturaldesignschool.com/new-york-citys-green-infrastructure-plan

Singapore City Green Infrastructure Plan Garden City Project

Singapore is an inspiring example of being an island that has long faced unique challenges to urban planning and infrastructure, having to sacrifice most of its green spaces for development to support a growing population during the twentieth century. One of the greatest climate risks is the potential for massive droughts, as they have had to import water from neighbouring countries for decades to increase their supply. In the 1970s and again in the early 2000s, Singapore launched massive campaigns to reshape their city to become a leading example of green infrastructure and smart water management, earning its nickname "Garden City." There are three areas where the city stands out when it comes to green innovation: urban planning, water management and clean energy. They are all connected to each other - green buildings, mandatory since 2008, help people save water, cool temperatures naturally and improve air quality. It also provides healthier open spaces for adults and children. In urban planning, Singapore has established a base for new developments in the Marina Bay region where developers must adhere to a 100% green space replacement policy. It is also in the same area where the city created one of the world's largest freshwater reservoirs and allocated 250 acres of green zone called Gardens by the Bay. Many public buildings now have their own green terraces connected to each other. The city aims to achieve 80% by 2030 in the Green Mark environmental performance rating, reducing carbon emissions and energy consumption. In Marina Bay, visitors can find supertres that collect solar energy in the day and night to perform a beautiful light show. Singapore also has an electric car project called Eva Taxi is a cooperative project developed by the local university that will transform public transport while saving energy in terms of water management, Singapore has invested in the reuse of reclaimed water, stormwater harvesting system and desalination. The city is committed to building a community that is aware of the importance of water, and has won many awards for its efforts in public and private water management and serves as a basis for using innovation in the sustainable use of water. As well as the Garden City project where the project has become global, it integrates three main strategies: collecting every drop of stormwater, indefinitely reusing water and desalinating seawater. Two thirds of the city's surface can now collect rainwater and transport most of that water through different tunnels to 18 reservoirs. They have also built a number of seawater desalination plants to treat seawater, as well as several desalination plants under implementation. They have also pushed the idea of liveable density; making green buildings compulsory since 2008 and making all new developments require a plant life. They have one of the largest green walls in the world - an area of 5,300 square meters - and are located at the Singapore Institute of Technical Education College Central. The green space lost has now been returned vertically. Some of Singapore's modern plans include creating approximately 650 km of walking and cycling trails across the city.
https://blog.horyou.com/singapore-garden-city/

Figure 13. Shows Garden City project in Singapore's green infrastructure plan

Infrastructure Plan Project (Green Your Laneway) in Melbourne

Melbourne is characterized by a rich heritage of urban parks and green belts through planning decisions taken with projects aimed at implementing action on climate change, biodiversity and communities' health and well-being. Melbourne's Green Infrastructure Plan includes:

- "Green Guide": which provides practical advice to community and business groups on the planning, design and maintenance of green infrastructure.
- Laneways greening strategy: which depends on Melbourne's commercial revitalization in three decades. The green roads were planned and the demonstration project was developed to showcase the technologies needed to make them more vibrant green spaces for businessmen, tourists and local residents to enjoy.
- Urban Forest Strategy: The strategy aims to plant 5 to 8 million trees over the coming decades for the greater city of Melbourne.

In 2017, Melbourne had begun on four "greening your way" pilot projects, a natural transformation of the city's central streets that lack green space to enhance the city's social, economic and environmental benefits and make it more sustainable. With rising temperatures and hot days across Australia, green infrastructure can be a useful tool to help regulate temperatures, support stormwater purification, provide shade, and improve air quality, The City of Melbourne worked closely with business owners, residents and workers to consider what kind of greening suited each road, and three of the four lanes were partially closed to vehicles or made in one direction to improve pedestrian amenities.

Kathy Okey (conservative president of the Melbourne City Environmental) , said" the upgraded green spaces show how corridors can be transformed with plants and trees to help cool the city, and improve air quality". The Green Your Laneway in Melbourne project, where the city chose more than 200 trails in the CBD to convert them into green corridors within the city's plan, focused on a range of high greening possibilities: on side roads using a mix of crates, vertical gardens and climbing plants such as live walls, trees and street art. They also selected a

group of artists to paint nature-inspired public murals to complement other green spaces. Using a combination of stormwater reservoirs, green roofs, green walls and rain parks, they completely transformed these public urban corridors into green reserves in the city center.
https://www.greenerspacesbetterplaces.co

Figure 14. shows Green Your Laneway in Melbourne

The most important design vocabulary learned to apply green infrastructure within the built environment

Through the conceptual framework, we abstract a set of design vocabulary for the application of green infrastructure within the built environment to enhance its sustainability as follows:

Table 1. shows the most important design terms for the application of green infrastructure within the built environment

Design Terms	
Integration	inclusiveness
communication	coherence
multi-functional	Specialized Strategic Vision
collaborative planning	community participatory

The most important indicators of green infrastructure in enhance urban sustainability

Through the proposed plans in four different cities (Philadelphia, New York, Singapore, Melbourne) we abstract a set of indicators that have contributed mainly to enhance urban sustainability of the built environment within its three main social, economic and environmental pillars as follows:

Table 2. shows the most important indicators of green infrastructure in enhance the pillars of sustainability at the urban level

Social	Economic	Environmental
Enhance and improving public health and	Enhance local economic and investment projects	Enhance sustainable transport by reducing the

psychological well-being		use of vehicles and encouraging the movement of pedestrians
Enhancing interaction and social communication	Increasing property values	Create a balance between residential and natural areas by integrating the harmony and intertwined of green spaces into the building spaces
Providing better spaces for hiking, encouraging pedestrians , cycling and enjoying nature	Attracting and enhancing tourism	Create high quality environments and reduce pollution and energy costs
Enhance social justice and reduce crime and local tension.	Create local jobs	Stromwater Management and benefiting from Clean Energy
Enhancing the sense of place and identity		Improving the natural environment and supporting wild life

Conclusion

Cities need the greatest possible of green infrastructure , Green infrastructure covers everything from gardens to street trees and green roofs to a green element or area that helps absorb and contributes to delaying and treating storm water and mitigating flooding and pollution downstream, A comprehensive ecosystem-based approach is an interconnected network of green spaces, waterways, wetlands, forests, wildlife habitats and other natural areas; Green corridors, parks and other protected land. It enhance interaction, social and environmental resilience, increased economic gains and investment opportunities, as well as biodiversity conservation, Enhance adaptation to climate change Support green economy, improve social cohesion .As well as there are also forests in cities. , which are an important component of green urban infrastructure systems. Urban policies are needed to increase the use of appropriate tree species and plants, especially local ones, as they contribute to lower energy costs for heating, cooling and energy saving. Thus increasing the quality of life socially, economically and environmentally and promoting urban sustainability within the built environment.

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