MALAYSIA ARCHITECTURAL JOURNAL

Malaysia Architectural Journal

Journal homepage:
https://majournal.my/index.php/maj
e-ISSN : 2716-6139

Urban Connectors: Blue, Green and Grey as Catalysts for City Liveability in the Built Environment

Ar. Mustapha Kamal Zulkarnain[1*], Siti Fatimah Ilani Bilyamin[2]

[1] Fellow Pertubuhan Akitek Malaysia, Malaysia
[2] Senior Lecturer, UTMSPACE, UniversitiTeknologi Malaysia Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received: 30 April 2024
Received in revised form
Accepted: 15 October 2024
Available online: 23 June 2025

Keywords:

Urban Connectors; Blue Connectors; Green Connectors; Liveability; Connectivity

ABSTRACT

In urban development, urban connectors, encompassing blue (water-based) and green (nature-based) elements as well as grey connectors enhance city liveability. This paper explores their significance for professionals in the built environment. Blue connectors, like rivers and waterfronts, offer benefits such as attractive community spaces, active transportation promotion, and sustainable storm water management. Real-world cases inspire replication. Green connectors, such as parks and urban forests, improve aesthetics, well-being, and air quality. Case studies emphasize the need for preservation and expansion. Blue and green connectors foster city connectivity. Multimodal networks reduce traffic congestion, promote walkable neighbourhoods, and healthier lifestyles. Realizing urban connectors' potential demands interdisciplinary collaboration. Architects, planners, policymakers, and stakeholders must integrate these elements into urban design for vibrant, sustainable cities. In summary, urban connectors, both blue and green, enhance city liveability. This paper encourages built environment professionals to embrace them, creating cities that harmonize with nature and enhance residents' quality of life.

1. Introduction

In the rapidly evolving landscape of urban development the integration of urban connectors encompassing both blue (water based) and green (nature-based) elements as well as grey connectors with digital technology and artificial intelligence (AI) have the potential to revolutionize city liveability. Addressing professionals in the built environment this paper delves in to the transformative power of combining urban connectors with digital solutions.

By leveraging digital technology and AI, cities can enhance the functionality and efficiency of blue connectors, such as rivers and waterfronts. Smart sensors and monitoring system can provide real-time data on water quality, flood risk and usage patterns, enabling proactive management and

* *Corresponding author.*
E-mail address: mkbz@amk.com.my

maintenance. Augmented reality and interactive platforms can engage citizens in the preservation and utilization of blue connectors, fostering a sense of ownership and community involvement.

Similarly, green connectors can be optimized through digital tools and AI. Smart irrigation systems and sensor networks can ensure efficient water usage and maintenance of urban green spaces. Al-powered algorithms can analyse data on air quality, temperature and noise levels to design and optimize the distribution of green connectors, creating microclimates and improving urban biodiversity

Integrating digital technology and AI with urban facilities will enhance connectivity and accessibility within cities. Intelligent transportation systems can optimize traffic flow, prioritize public transportation and promote multimodal options, reducing congestion and carbon emissions. Smart wayfinding applications and navigation tools can assist pedestrians and cyclists in navigation urban connectors, encouraging active transportation modes.

Furthermore, digital platforms can facilitate citizen engagement and participation in the planning and design of urban connectors. Crowdsourcing platforms and virtual reality simulations enable inclusive decision-making processes, ensuring that the diverse needs and preferences of residents are considered. Data-driven analytics and predictive modelling can inform evidences-based urban design, fostering sustainable and equitable city development

This paper aims to inspire professionals in the built environment to embrace the potential of digital technology and Ai in enhancing the liveability of cities through urban connectors. By combining the power of blue and green elements with digital solutions, we can create cities that are more sustainable, resilient, and inclusive. Let us harness the transformative capabilities of digital technology and AI to build cities that prioritize the well-being of both people and the environment.

2. Literature Review

In the context of rapid urbanization and the challenges it presents to cities worldwide, the concept of Urban Connectors emerges as a novel approach to enhance city liveability through the integration of Blue (water-related) and Green (nature-related) infrastructure, supported by digital technology and artificial intelligence (AI). By harnessing the power of AI and advanced digital solutions cities can optimize their resources, improved urban planning, and create sustainable environments that promote a better quality of life for their residents.

2.1 Blue Infrastructure as an Urban Connector

Blue infrastructure refers to water-related systems that can mitigate the effects of urbanization on water resources and improve overall city liveability or life. Examples include water bodies, green space with sustainable water management, rainwater harvesting systems, and wastewater treatment plants. AI and digital technology play a vital role in maximizing the effectiveness of these solutions.

2.1.1 Smart Water Management

AI-driven sensors and data analytics can monitor water quality, consumption patterns, and detect leaks or contamination in real time. This enables efficient water distribution, reduces wastage and ensures a stable water supply for urban residents.

1. Neutral ESM and climate
2. Mobile water testing kits to support water justice
3. Precision allocations and hydraulics for sustainable integrated resources management
4. Intelligent water pipe leak and sewer blockage diagnosis
5. High fidelity virtual forensics and testing of new technology
6. Predictive pump station maintenance and upgrade schedule
7. Rapid optimization of treatment plant performance

8. Advanced water sensitive urban design with urban digital twins
9. Smart water –saving devices and decentralized services
10. Automated detection of public health hazards and illegal activities
11. Intelligent dam safety planning and disaster decision-making
12. Enhanced Earth observation and real-time hydrological analysis

2.1.2 Flood Prediction and Mitigation

AI model analyse historical weather data, water levels and other factors to predict potential flooding events accurately take proactive measures, such as opening flood barriers or issuing early warnings to residents.

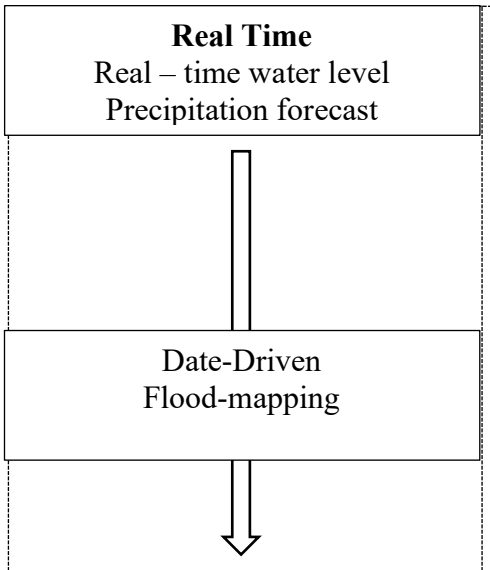

Fig. 1. These two figures have been placed side-by-side to save space

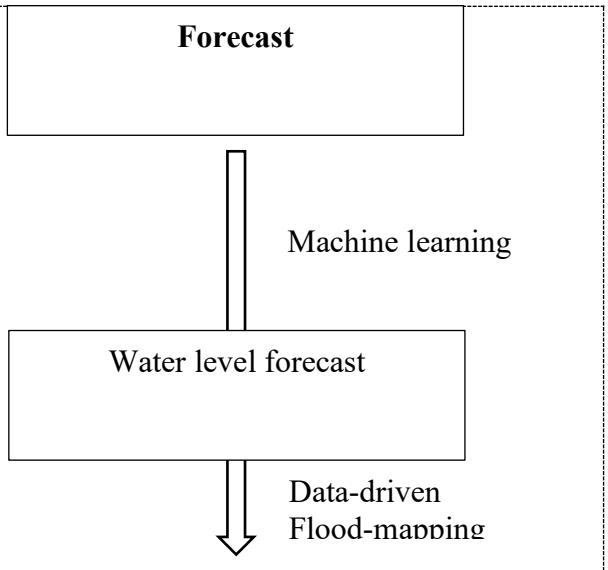

Fig. 2. These two figures have been placed side-by-side to save space

2.1.3 Water Conservation and Reuse

AI-powered algorithms can optimize water Reuse Strategies, identifying suitable opportunities for recycled water in irrigation, industrial processes, or non-potable uses, thus reducing freshwater demand.

2.2 Green Infrastructure as an Urban Connector

Green infrastructure involves strategically planned natural areas within urban settings, promoting biodiversity, reducing pollution, and enhancing the overall urban ecosystem. Integrating AI and digital technology with green initiatives can yield various benefits:

2.2.1 Smart Urban Planning

AI algorithms can assist city planners in designing optimal green spaces, parks, and urban forests, considering factors like accessibility, ecosystem benefits and spatial distribution. There are three (3) participants in urban planning explain the terms below:

1. Government & Private Sectors

- Digital Cities

2. Government, Private Sectors & Communities
   - Intelligent Cities
3. Government, Private Sectors & Communities
   - Smart Cities

2.2.2 Air Quality Improvement

AI-powered monitoring system can track air quality in real time, identifying pollution hotspots and triggering interventions to reduce harmful emissions and improve public health.

Table 1
AI for Clean Air - Drones –in Air Quality Monitoring and the future Prospects of AI

1	2	3	4	5	6
Monitor Air-pollution	Predict Air Quality	Collect & Analyze data	Pattern Identification	Equipment Maintenance Insight	Policy Making

2.2.3 Biodiversity Conservation

AI can help identify endangered species and support Conversation efforts through tracking monitoring and protecting biodiversity-rich areas within the city.

Preserve local biodiversity in an urbanizing environment and protect important and rare species	Create stepping stones or corridors for natural populations	Connect people and nature and provide environment education	Provide ecosystem services	Fulfil ethical responsibilities	Improve human well-being

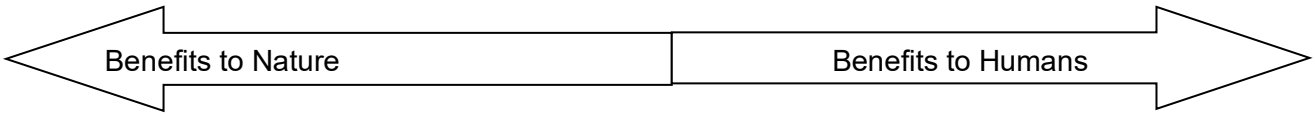

Fig. 3. Benefits of connectors to nature and human

2.3 The Synergy between Blue and Green Connectors

The combination of blue and green infrastructure can create a synergistic effect further enhancing city live ability:

2.3.1 Water and Green Space Integration

Blue infrastructure, such as water bodies, can be integrated into green spaces, creating aesthetically pleasing landscapes and providing recreational areas for residents.

1. Climate Resilience: Together blue and green infrastructure can make cities more resilient to climate change impacts, mitigating the effects of extreme weather events and flooding while reducing the urban heat island effect.
2. Community Engagement: AI-powered platforms can engage citizens in the design and maintenance of blue and green initiatives, fostering a sense of ownership and promoting sustainable practices.

2.4 Grey Infrastructure as an Urban Connector

Grey infrastructure in cities refers to the conventional built structures and systems such as roads, bridges, tunnels, and utility networks like water supply and sewage systems. While traditionally seen as purely functional, these elements can also serve as urban connectors, linking different parts of the city and facilitating movement and interaction among residents. Here's how grey infrastructure acts as urban connectors:

2.4.1 Transportation Networks

Roads, highways, and bridges are vital components of urban connectivity, enabling people to travel between neighbourhoods, workplaces, and recreational areas. Efficient transportation networks reduce commute times and improve accessibility, fostering economic activity and social interactions.

2.4.2 Utility Systems

Water supply, sewage, and electrical grids form the backbone of urban infrastructure. These systems not only provide essential services but also connect communities by ensuring reliable access to resources. Modernizing these networks with smart technology can enhance efficiency and resilience, further strengthening urban connectivity.

2.4.3 Communication Infrastructure

Telecommunication networks, including internet cables, cell towers, and Wi-Fi hotspots, facilitate digital connectivity in cities. These systems enable instant communication and access to information, fostering collaboration and innovation among residents, businesses, and institutions.

2.4.3 Public Spaces and Amenities

Parks, plazas, and recreational facilities serve as important connectors within urban environments, offering spaces for social interaction and community engagement. Well-designed public spaces enhance the quality of life and promote a sense of belonging, encouraging people to gather and interact.

2.4.4 Mixed-Use Developments

Mixed-use developments integrate various functions within a single area, such as residential, commercial, and recreational spaces. By bringing diverse activities and amenities into close proximity, these developments promote walkability and social interaction, creating vibrant urban hubs.

2.4.4 Multi-modal Transportation Hubs

Transportation hubs, such as airports, train stations, and bus terminals, serve as major connectors within cities and regions, linking different modes of transportation and facilitating inter-city and

international travel. These hubs also often serve as focal points for economic activity and urban development.

2.4.5 Redevelopment Projects

Redevelopment projects, such as waterfront revitalization and brownfield redevelopment, can transform underutilized or blighted areas into vibrant urban spaces. By reimagining the built environment and creating new connections between neighbourhoods, these projects contribute to the overall connectivity and vitality of the city.

In essence, grey infrastructure plays a crucial role in shaping the physical and social fabric of cities, serving as the connective tissue that binds together diverse communities and activities. By investing in resilient and sustainable infrastructure, cities can enhance their connectivity and adaptability to meet the evolving needs of urban populations. Blue, green, and grey infrastructures each play important roles in creating liveable cities and enhancing urban connectivity. Let's explore how these different types of infrastructure contribute to the development of more liveable urban environments. Grey infrastructure, as mentioned earlier, encompasses traditional built structures and systems such as roads, bridges, and utility networks. While essential for urban connectivity, grey infrastructure alone may not always create the most liveable cities. However, when integrated thoughtfully with blue and green infrastructure, it can contribute to a more holistic approach to urban development. Blue infrastructure refers to the network of natural and constructed water bodies, including rivers, lakes, wetlands, and canals, as well as engineered water features like storm water management systems and green-blue corridors.

2.5 Blue Infrastructure for Liveability

Incorporating blue infrastructure into urban planning offers several benefits for liveability:

2.5.1 Flood Mitigation

Properly managed water systems can reduce the risk of flooding, protecting communities and infrastructure from water-related disasters.

2.5.2 Water Quality Improvement

Natural water bodies and green-blue corridors help filter and purify water, enhancing overall water quality and ecosystem health.

2.5.3 Recreation and Aesthetics

Blue spaces provide opportunities for recreation, relaxation, and aesthetic enjoyment, contributing to residents' well-being and quality of life.

2.5.4 Biodiversity Conservation

Wetlands, green-blue corridors, and other water features support diverse ecosystems, fostering biodiversity and ecological resilience within urban areas.

Green infrastructure consists of natural and semi-natural elements such as parks, urban forests, green roofs, and permeable surfaces. Integrating green infrastructure into urban design offers numerous advantages for liveability. Vegetation helps mitigate the urban heat island effect by providing shade, evaporative cooling, and reducing surface temperatures. Trees and vegetation absorb

pollutants, improve air quality, and reduce noise levels, creating healthier and more pleasant urban environments.

Green infrastructure features like rain gardens and vegetated swales help absorb and filter storm water, reducing runoff and alleviating pressure on grey infrastructure. Parks, greenways, and urban green spaces provide opportunities for recreation, social interaction, and community engagement, enhancing residents' quality of life. By integrating blue, green, and grey infrastructure in urban planning and design, cities can create more resilient, sustainable, and liveable environments. This integrated approach fosters connectivity between people, nature, and built systems, promoting healthier, happier, and more inclusive communities. Additionally, by prioritizing the preservation and enhancement of natural resources and green spaces, cities can ensure long-term environmental sustainability and resilience in the face of climate change and urbanization pressures.

Achieving the goal of creating more liveable cities through the integration of blue, green, and grey infrastructure faces several issues, constraints, and challenges. These challenges can vary depending on the specific context and characteristics of each city, but some common ones include limited space and land use conflicts. Urban areas often face constraints related to limited available land and competing demands for land use. Balancing the need for infrastructure development with the preservation of green spaces and natural habitats can be challenging, especially in densely populated cities where space is at a premium. Implementing green and blue infrastructure projects may require significant upfront investment, which can pose financial challenges for cash-strapped municipalities. Funding constraints, budget limitations, and competing priorities may hinder the implementation of long-term sustainable infrastructure solutions. Political will and institutional capacity play crucial roles in driving sustainable urban development initiatives. However, bureaucratic red tape, fragmented governance structures, and conflicting interests among stakeholders can slow down decision-making processes and impede the implementation of integrated infrastructure projects. Designing and implementing integrated blue, green and grey infrastructure projects require multidisciplinary expertise, including urban planning, landscape architecture, civil engineering, and environmental science. A shortage of skilled professionals and technical expertise may hinder the effective planning, design, and management of complex infrastructure systems.

Ensuring that infrastructure projects benefit all segments of the population and address the needs of marginalized communities is essential for creating inclusive and equitable cities. However, achieving meaningful community engagement, addressing social disparities, and balancing competing interests and priorities can be challenging, particularly in diverse and heterogeneous urban environments. Urban areas are increasingly vulnerable to the impacts of climate change, including extreme weather events, sea-level rise, and heatwaves. Integrating blue and green infrastructure to enhance resilience and adaptability to climate-related risks requires proactive planning, risk assessment, and implementation of nature-based solutions. Many cities have existing grey infrastructure systems that are outdated, inefficient, or in need of repair and retrofitting. Integrating green and blue infrastructure into established urban environments often requires retrofitting existing infrastructure, which can be technically challenging and costly.

Inadequate data availability, monitoring, and evaluation systems can hinder evidence-based decision-making and effective management of urban infrastructure projects. Addressing knowledge gaps and investing in data collection, monitoring, and evaluation efforts are critical for informing policy decisions and optimizing the performance of integrated infrastructure systems. Addressing these challenges requires a holistic and collaborative approach involving governments, civil society, the private sector, academia, and local communities. By prioritizing sustainability, resilience, and equity in urban planning and development, cities can overcome these constraints and move towards creating more liveable and vibrant urban environments for current and future generations.

3. Methodology

Yes, several cities around the world have made significant strides in utilizing blue, green, and grey infrastructure as urban connectors to create more liveable and sustainable urban environments. While no city is perfect, and there's always room for improvement, these cities serve as examples of successful integration of these infrastructure components:

3.1 Copenhagen, Denmark

Copenhagen is renowned for its commitment to sustainability and liveability. The city has integrated blue infrastructure by revitalizing its waterfront areas, creating harbour baths for swimming, and implementing climate-resilient urban design. Copenhagen also boasts extensive green infrastructure, with parks, green spaces, and bicycle lanes that promote active transportation and enhance quality of life.

3.2 Portland, Oregon, USA

Portland is renowned for its comprehensive approach to urban planning and sustainable development. The city has invested in green infrastructure through initiatives like the Green Streets Program, which incorporates vegetated swales and storm water management features into streetscapes. Portland also prioritizes active transportation infrastructure, such as bike lanes and pedestrian-friendly streets.

3.2 Melbourne, Australia

Melbourne has been recognized for its efforts to create a more liveable and environmentally sustainable city. The city's green infrastructure includes extensive parklands, urban forests, and green corridors that enhance biodiversity and provide recreational opportunities. Melbourne's blue infrastructure initiatives focus on water-sensitive urban design, with projects like rain gardens, wetlands, and water-sensitive urban streetscapes.

3.4 Vancouver, Canada

Vancouver is known for its commitment to sustainability and natural beauty. The city has integrated blue infrastructure through initiatives like the False Creek Seawall, which provides a scenic waterfront promenade for walking, cycling, and recreation. Vancouver's green infrastructure includes urban parks, greenways, and green roofs that contribute to the city's liveability and environmental resilience.

3.5 Singapore

Singapore is a global leader in green urbanism and sustainable development. The city-state has maximized its limited land area by incorporating green roofs, vertical gardens, and park connectors into its urban fabric. Singapore's blue infrastructure includes reservoirs, rain gardens, and canal networks designed for flood control, water management, and recreational purposes.

These cities demonstrate that with strategic planning, investment, and community engagement, it is possible to leverage blue, green, and grey infrastructure as urban connectors to create more liveable, resilient, and sustainable cities. By learning from these examples and sharing best practices, cities around the world can work towards achieving similar goals and improving the quality of life for their residents.

In Malaysia, several cities have made efforts to integrate blue, green, and grey infrastructure to enhance liveability and sustainability, although there is still room for improvement. Here are a few examples:

3.6 Kuala Lumpur

Malaysia's capital, Kuala Lumpur, has implemented various initiatives to enhance urban connectivity and sustainability. The city has developed green spaces such as KLCC Park and Perdana Botanical Gardens, providing residents with recreational areas and improving air quality. Additionally, Kuala Lumpur has invested in public transportation infrastructure, including the Mass Rapid Transit (MRT) system, to improve mobility and reduce traffic congestion.

3.6 George Town, Penang

George Town, the capital city of the state of Penang, has taken steps to preserve its cultural heritage while promoting sustainable development. The city's historic core is a UNESCO World Heritage Site, and efforts have been made to enhance pedestrian infrastructure and promote non-motorized transportation. George Town also features green spaces like Penang City Park and the Penang Botanic Gardens.

3.7 Putrajaya

Putrajaya, Malaysia's federal administrative capital was designed with sustainability and green principles in mind. The city features extensive greenery, parks, and landscaped areas, including the Putrajaya Botanical Garden and Wetlands Park. Putrajaya also incorporates blue infrastructure elements such as lakes and water features, which serve both aesthetic and functional purposes.

3.8 Iskandar Malaysia

Iskandar Malaysia, located in the southern state of Johor, is a flagship economic development corridor that aims to be a sustainable and liveable metropolis. The region incorporates green spaces, waterfront promenades, and eco-friendly developments to enhance quality of life. Iskandar Malaysia also prioritizes connectivity through infrastructure projects such as the Iskandar Malaysia Bus Rapid Transit (IMBRT) system.

While these examples highlight efforts to integrate blue, green, and grey infrastructure in Malaysian cities, there are still challenges to overcome, including urban sprawl, traffic congestion, and environmental degradation. Continued investment in sustainable urban planning, infrastructure development, and community engagement is essential to further improve liveability and sustainability in Malaysian cities.

4. Findings

Artificial intelligence (AI) plays a crucial role in equipping and enabling the smartness of cities to achieve liveability aspects by optimizing the operation of blue, green, and grey infrastructure. Here's how AI can contribute to creating more liveable urban environments:

4.1 Smart Transportation Management

AI-powered systems can optimize traffic flow, reduce congestion, and improve public transportation efficiency. AI algorithms can analyse real-time traffic data, predict congestion patterns,

and dynamically adjust traffic signals and public transit schedules to minimize travel times and enhance mobility. Smart transportation solutions help make cities more accessible, reduce air pollution, and improve the overall quality of life for residents.

4.2 Optimized Energy and Resource Management

AI technology can optimize energy consumption, water usage, and waste management in urban areas. AI-powered smart grids can dynamically adjust energy distribution based on demand patterns, optimize renewable energy generation, and reduce carbon emissions. Similarly, AI-driven water management systems can detect leaks, monitor water quality, and optimize water distribution networks, contributing to resource conservation and environmental sustainability.

4.3 Predictive Maintenance and Infrastructure Resilience

AI algorithms can analyse sensor data from infrastructure assets such as bridges, roads, and utility networks to predict maintenance needs and prioritize repair efforts. By detecting early signs of deterioration or malfunctions, AI-enabled predictive maintenance systems can help prevent infrastructure failures, reduce downtime, and ensure the reliability and safety of essential urban infrastructure.

4.4 Enhanced Urban Planning and Design

AI tools and algorithms can support urban planners and architects in designing more sustainable, human-centric built environments. AI-driven simulation and modelling software can analyse spatial data, optimize land use patterns, and generate design solutions that prioritize green spaces, pedestrian-friendly neighbourhoods, and mixed-use developments. AI also enables data-driven decision-making in urban planning, allowing policymakers to anticipate the potential impacts of development projects on liveability factors such as air quality, noise pollution, and access to amenities.

4.5 Smart Environmental Monitoring and Management

AI-powered sensors and monitoring systems can track environmental parameters such as air quality, temperature, and noise levels in real-time. By analysing vast amounts of sensor data, AI algorithms can identify pollution hotspots, assess environmental risks, and inform targeted interventions to improve environmental quality and public health. Smart environmental monitoring solutions help cities proactively address environmental challenges and create healthier, more liveable urban environments.

Overall, AI technology holds great potential to enhance the smartness and liveability of cities by optimizing the operation of blue, green, and grey infrastructure, improving resource efficiency, and enabling data-driven decision-making in urban planning and management. By harnessing the power of AI, cities can become more resilient, sustainable, and inclusive, fostering a higher quality of life for residents now and in the future.

5. Conclusions

Urban Connectors, powered by digital technology and AI, offer a promising pathway towards improving city live ability through the integration of blue and green infrastructure. By optimizing water management, enhancing green spaces, and fostering sustainable practices, cities can become more resilient attractive and healthier place to live. Collaborative efforts between governments, private

sectors and communities are crucial to realizing the full potential of Urban Connectors and building cities that are sustainable, inclusive and thriving for generations to come.

Acknowledgement
This research was not funded by any grant.

References

[1] Nadja Kabisch, Horst Korn, Jutta Stadler and Aletta Bonn (2007). Theory and Practice of Urban Sustainability Transitions: *Nature-based Solutions to Climate Change Adaption in Urban Areas*, ISBN 978-3-319-56091-5(eBook)
[2] Robert C.Brears and Limin Hee, (2018). *Blue and Green Cities*, Second Edition, ISBN 978-3-031-41393-3 (eBook)
[3] Peter Rowe, (2019). *A City in Blue and Green: The Singapore Story*, Springer Nature Singapore Pte Ltd. ISBN 978-981-13-9597-0 (eBook)
[4] Prof F. Haghingat, (2015). *Sustainable Cities and Society*, Concordia University, Canada.