

Recommendations for Smart Green Urbanization in Dhaka Megacity: Enhancing Efficiency with Limited Resources

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Abstract

Dhaka, the capital of Bangladesh, is one of the world's most densely populated megacities, with rapid urbanization. The city is facing considerable challenges, such as a lack of available land, environmental deterioration, and limited financial resources. The highly impermeable areas and the gradually diminishing green spaces in the city are causing Dhaka to experience the effects of ultra-urbanization. An environmentally conscious, economically viable, spatially efficient, and contextually relevant approach to smart green urbanization in Dhaka was the focus of this research. The research revealed that vertical green infrastructure, intelligent water management, smart rainwater harvesting, and ecologically sustainable solutions that are both practical and cost-effective are all necessary measures. Global case studies and literature reviews corroborate these findings. Urban planners, lawmakers, and engineers can use these findings to facilitate Dhaka's adoption of sustainable urban development.

Keywords

Smart Urbanization, Green Infrastructure, Vertical Greenery, Smart Water Management, Rainwater Harvesting, Sustainable Development

1. Introduction

The infrastructure in Dhaka has not been able to keep up with the city's growth, which has led to overcrowding, informal settlements, and environmental stress [1]. With over 20 million people living there and limited room to grow horizontally, traditional urban growth is impossible. Climate change is also likely to im-

pact the city, potentially leading to flooding and heat islands [2]. This article discusses smart green urbanization tactics that maximize resources while minimizing use. It provides Dhaka with a plan for sustainable development. A sustainable approach to city development known as “smart green urbanization” combines cutting-edge technology with eco-friendly methods to create livable, efficient, and resilient metropolitan areas. It prioritizes green activities like waste reduction, renewable energy, green spaces, smart water management, and climate resilience while highlighting the use of smart infrastructure such as digital monitoring systems, energy-efficient buildings, and intelligent transportation networks. Through data-driven planning and environmentally mindful design, the objective is to improve urban life quality, reduce environmental impact, and guarantee long-term sustainability [3]. Smart systems decrease reliance on overexploited groundwater sources while promoting sustainable urban development through the reduction of stormwater runoff and the improvement of water availability for domestic and agricultural purposes. The concept of rainwater management systems (RMS) broadens the traditional framework of rainwater harvesting by integrating stormwater control and urban resilience strategies. RMS are engineered to fulfill various functions, including water supply and flood mitigation, utilizing decentralized, frequently dual-tank systems that address rainfall management at the source [4]. Comprehensive frameworks for developing water-smart cities highlight the importance of integrating rainwater harvesting with greywater reuse, managed aquifer recharge, and socio-economic assessments to promote long-term sustainability [5]. These innovations illustrate the potential of smart rainwater harvesting as a fundamental component of resilient and sustainable water management systems in response to climate change and urbanization.

2. Urban Challenges in Dhaka

Dhaka has more than 47,000 people living in each square kilometer, which puts a lot of stress on land, water, and public services [6]. Urban sprawl has caused wetlands and farmland to disappear, and informal communities do not have the essential services they need [7]. Water scarcity is made worse by taking too much groundwater and polluting surface water sources [8]. The loss of green spaces has worsened air pollution and health concerns [2]. The city’s ability to carry out large-scale infrastructure projects is further limited by financial constraints [9].

3. Methodology

This review draws on data from government publications, peer-reviewed journals, and case studies from cities with similar socioeconomic and spatial limitations. Some of the criteria for evaluation include land efficiency, environmental impact, cost-effectiveness, and scalability [10] [11]. We propose these suggestions with Dhaka’s distinctive metropolitan surroundings in mind. For instance, Singapore and Dhaka are both heavily populated cities that have rapidly become more urbanized in recent decades. Both cities have a tropical monsoon climate, which is

characterized by hot, muggy weather and abundant rainfall during the monsoon season. They are also low-lying cities that are susceptible to flooding and sea level rise. Similarly, like Dhaka, Pune has experienced rapid population growth and faces challenges such as air pollution, transportation congestion, and infrastructure development. Pune and Dhaka reflect the larger patterns of urbanization in developing countries.

4. Global Case Studies

Dhaka may learn a lot from several cities. Singapore is known around the world for its creative use of vertical greenery in city planning. The PARKROYAL on Pickering Hotel is a great example of this. This hotel has a “hotel-in-a-garden” design that includes many green walls, sky gardens, and cascading planter terraces. This design increases biodiversity, lowers the urban heat island effect, and makes the air cleaner [2]. The skyscraper has over 15,000 square meters of greenery, more than double the land it sits on. This project shows how vertical green infrastructure can work in crowded cities [2]. The project also includes systems that save energy, collect rainwater, and let in fresh air, which fits with Singapore’s larger smart city aspirations of making the city more livable and sustainable [1].

Pune and Ahmedabad: The Smart Cities Mission in India started in 2015 and is a major urban revitalization effort that aims to encourage sustainable and equitable urban growth in 100 cities. Pune and Ahmedabad are two cities that stand out as models of how to use smart mobility, energy-efficient buildings, digital government, and green public areas to solve problems [9]. These cities have used retrofitting and redevelopment plans to enhance infrastructure without moving many people, which makes them especially useful for cities like Dhaka that are densely populated and have limited budgets [1]. For example, Pune has added smart traffic systems, streetlights that run on solar power, and forums for citizens to get involved. Ahmedabad, on the other hand, has focused on building up the riverfront, creating green corridors, and managing garbage smartly [10]. The mission stresses scalability, cooperation between the public and private sectors, and planning that puts citizens first. This makes it a model that other developing countries with similar urban problems can use [7].

The Green City Kigali project in Kigali shows how to build economical, long-lasting homes utilizing passive architecture and materials from the area [12].

High-density urban neighborhoods in Tokyo are purposefully planned with compact, mixed-use zoning that combines commercial, residential, and recreational sectors. By improving walkability and land efficiency, this urban design strategy reduces the need for lengthy commutes and supports environmentally friendly modes of transportation. The city’s focus on transit-oriented architecture and vertical building makes better use of its limited land resources while creating thriving, livable neighborhoods [13].

The Thammasat University Rooftop Farm (TURF) in Bangkok is one of the largest urban rooftop farms in Asia and a great example of how to grow food in

a city in a way that is beneficial for the environment. The farm is over 22,000 square meters and combines traditional rice terrace cultivation with modern green infrastructure to help with food poverty, urban heat, and stormwater management [1]. The sloped design allows rainwater to flow over each terrace, watering the crops and reducing runoff and flooding. The design is especially useful in areas like Dhaka that are prone to flooding [2]. TURF grows organic vegetables and herbs for the university and the surrounding community. The operation supports local food systems and reduces the carbon impact of transporting food [1]. The farm also serves as a public learning area, where people can learn about ecology and how to combat climate change. Its versatile design shows how unused urban rooftops can be turned into useful, climate-adaptive spaces in crowded cities [7].

Villanova University embodies numerous attributes of a smart campus through its incorporation of sustainable infrastructure, cutting-edge technology, and data-driven systems. The university has adopted sustainable building methods, with LEED-certified structures and advanced stormwater management systems, thereby enhancing environmental sustainability. Moreover, intelligent energy solutions, including real-time monitoring and automatic building controls, improve operational efficiency. These initiatives not only diminish the campus's carbon footprint but also function as a practical laboratory for students and academics involved in smart city and sustainability research [14]. Green stormwater infrastructure (GSI) is an essential element of Philadelphia's sustainable smart urbanization strategy. Incorporating green stormwater infrastructure elements for community enhancements can significantly mitigate the heat island effect, peak stormwater flow, and the marginal costs associated with stormwater management while improving recipient water quality. As a crucial component of a green city program, varied drainage infrastructure was established at Villanova University to facilitate runoff and mitigate the heat island effect in the newly constructed dormitories, referred to as "The Commons." The research site was converted into a landscape that supports green stormwater infrastructure (GSI), and the reconfigured environment, featuring rain gardens and grassland, demonstrates reduced maximum and average temperatures [15].

Rooftop farms in Bangkok exemplify the transformation of unused urban spaces into productive green areas that promote food security, decrease urban heat, and improve air quality. This strategy might be implemented in Dhaka to mitigate its restricted green spaces and escalating temperatures, while fostering community involvement and enhancing local food production. Likewise, Villanova's GSI project demonstrates that the incorporation of natural systems such as rain gardens, permeable pavements, and bioswales into urban infrastructure can proficiently manage stormwater, mitigate flooding, and enhance water quality. Considering Dhaka's susceptibility to waterlogging and monsoon-induced flooding, implementing nature-based solutions could markedly improve the city's climate resilience and urban livability.

5. Smart Green Urbanization Strategies

5.1. Vertical Green Infrastructure (VGI)

Vertical green infrastructure (VGI) improves urban sustainability and quality of life by adding plants to the built environment [2]. Vertical greening systems, also referred to as these systems, use a mix of technologies to cover walls, screens, and building facades with plants [16]. VGI has several benefits for the environment, society, and economy. For example, it reduces the urban heat island effect, improves air quality, and enhances building insulation [1] [16]. As part of VGI [11], corporate and office buildings might incorporate rooftop farming, green facades, living walls, and green roofs. In Dhaka, where there is limited horizontal space, vertical greenery can be added to homes, businesses, and institutions to create microclimates, save energy by insulating buildings, and manage stormwater flow [2] [6]. Some self-supporting living walls can be used as green barriers or dividers [16]. Lemongrass, basil, and mint are all excellent choices for rooftop gardens since they have pleasant scents, grow quickly, and are easy to maintain. Lemongrass can be used for many purposes, such as making tea and repelling mosquitoes [11].

5.2. Low-Cost Green Infrastructure

Low-cost green stormwater infrastructure (GSI) can help address Dhaka's high population density and lack of green space by focusing on solutions that are simple to use, require little upkeep, and are led by the community [1]. One effective approach to achieving these goals is to add more plants to balconies and rooftops. Most people agree with this; it is simple to do, and the government may encourage it by offering tax breaks [7]. Public education is very important to encourage people to use these green spaces, which help lower city temperatures, clean the air, and increase biodiversity [2]. Another idea is to turn trash-filled areas in cities into small "pocket parks" and clean up polluted bodies of water to create communal gardens, which also help with managing stormwater [17]. Planting trees along city roadways and in the middle of the street can improve air quality and provide shade. Bioswales along the side of the road can also help with drainage at minimal cost [18]. Community support and partnerships between the public and private sectors can facilitate the gradual implementation of these improvements. This makes them ideal for Dhaka's crowded urban environment [1] [9]. Rain gardens, bioswales, and permeable pavements are some inexpensive green infrastructure options. Rain gardens are shallow, vegetated basins that absorb water runoff from roofs and pavements. Bioswales are gently sloped, vegetated channels that clean and convey stormwater. Permeable pavements are surfaces, such as sidewalks and parking lots, that allow water to seep through. These systems are inexpensive to install and maintain, beautify cities, improve air quality, and increase biodiversity. In Dhaka, where space is scarce and funding is limited, community-based implementation of small-scale GSI projects can provide immediate benefits while also helping the city become more resilient to climate change and more sustainable over time. [1] [17].

5.3. Smart Water Management

Because Dhaka is running out of water, it is important to use resources wisely. Smart water management may help with both pollution and ensuring there is enough water. Installing decentralized greywater recycling systems in homes and businesses may purify and reuse water from sinks, showers, and laundry for purposes such as flushing toilets, watering plants, and cleaning roadways [19]. This approach eases the stress on the city's already overloaded sewage and drainage infrastructure and the need for fresh water [1]. Rooftop rainwater harvesting is a beneficial approach for cities that do not have enough water. It can help with the water supply, reduce storm runoff, and recharge groundwater [6]. Dhaka, a city that often experiences water shortages and floods, might benefit greatly from rainwater harvesting as a way to manage its water supply in a more environmentally friendly manner [20]. Dhaka receives a lot of rain every year, and its many roofs and paved surfaces make it easy to collect and store rainwater for non-potable uses, including irrigation, flushing toilets, and cleaning [7]. Rooftop systems for collecting rainwater in homes, businesses, and schools can help people use less groundwater, which is being depleted rapidly [6]. Rainwater storage tanks and recharge pits at the community level help refill aquifers and prevent waterlogging during monsoon seasons [21]. Rainwater harvesting is a cost-effective, decentralized way to improve water security, enhance urban resilience to climate change, and support the goals of sustainable urbanization [1]. Cost-effective rainwater harvesting systems usually consist of simple components such as gutters, downpipes, first-flush diverters, and storage tanks. These can be installed on residential, commercial, and institutional buildings with minimal technical knowledge [22]. Rain barrels may serve as an adaptive strategy for private rainwater gathering initiatives. A rain barrel is a receptacle used for the collection of rainfall. Commonly referred to as a water storage tank, it collects rainwater from your roof that would otherwise be diverted to storm drains and waterways. The harvested water can then be utilized for various purposes, including irrigation of lawns, washing exterior surfaces, and gardening. Rain barrels are typically constructed from plastic, though they may also be fabricated from wood, stone, or clay [23]. Rain barrels collect rainfall and store it for later use. By preventing precipitation from entering the sewer system, rain barrels can help avoid sewer overflows, street flooding, and basement backups. Residents can clean their bikes, tools, and work boots using rain barrel water, as well as wash their cars and water their rooftop gardens [24]. Several municipalities and cities in the USA distribute rain barrels to their citizens through annual sales. Local home and garden supply stores and internet merchants are additional options. Additionally, cisterns are utilized to harvest rainfall. They can be underground or above ground, and they have a larger storage capacity [25].

6. Discussion

The reviewed strategies demonstrate that smart green urbanization is both feasible

and beneficial for Dhaka. Vertical and low-cost green infrastructure can be adapted to the city's dense urban fabric, while smart water management addresses critical resource challenges. Residents of Dhaka city may adopt rain barrel technology due to the prevalence of open rooftops in residential, commercial, and office buildings, which experience regular rainfall during the monsoon season. Community engagement and policy support are essential for successful implementation [9] [22]. Training programs, demonstration projects, and incentives can help to increase involvement, particularly in densely populated areas where infrastructure upgrades are difficult. Involving communities not only ensures the long-term viability of rainwater harvesting systems, but it also boosts social cohesion and resilience in the face of climate change issues. However, several socio-economic and policy-related obstacles must be overcome for smart green urbanization to be successfully implemented in Dhaka. Economically, many people live in makeshift communities without proper infrastructure, making it hard to prioritize long-term goals like sustainability over short-term ones like finding a place to live or a job. Community involvement in green efforts might be hindered by income disparity and a general lack of awareness about environmental issues. Issues with ineffective enforcement mechanisms, disjointed administration, and antiquated urban planning legislation are common policy factors that hinder or delay sustainable development initiatives. Environmental protection and sustainable social and economic growth must be coordinated through comprehensive policy making.

7. Conclusion

Smart green urbanization is a practical approach for Dhaka to address its many problems, turning limited resources into opportunities for new ideas. The megacity can skip over traditional development patterns by using a “minimal resource, maximum efficiency” strategy incorporating green tools. Dhaka's future as a city rests on how well it can come up with new ideas within limits. Smart green urbanization is a technique to achieve sustainable expansion by making the most of land, using nature-based green solutions, cutting expenses, and making cities more livable. Dhaka is a city that offers more opportunities for rainwater harvesting than other cities because of the abundance of rooftops and the monsoon precipitation. Dhaka may become a strong and welcoming megacity with the help of strategic planning, community involvement, and lessons learned from case studies around the world.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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