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Blue-green infrastructure (BGI) in planning for urban neighbourhood: A case of Indian cities

Merin Sara Rajan[1], Prof. Anjana Murali[2]
[1]M. Plan Student (Urban Planning), Dept. of Architecture, TKM College of Engineering, Kollam, India
[2]Assistant Professor,Dept. of Architecture, TKM College of Engineering, Kollam, India.

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ABSTRACT:Climate change is a rising threat to human comfort and environmental justice in urban settings. The major contributor to climate change is cities. [1] Global cities have incorporated nature-driven solutions as a counteract to conventional infrastructure practices by harnessing blue elements (such as seas, rivers, lakes, etc.) alongside green elements (such as trees, parks, gardens, etc.), often referred to as BGI. The study was driven based on a research question, what is the relevance of Blue-Green Infrastructure in planning for Indian urban neighbourhoods. A framework for BGI is developed using indicators, elements, standards, focusing on development controls of India to assess and help India's cities respond to climate hazards, and promote equity and resilience for sustainable urban futures.

KEYWORDS: Blue-Green infrastructure, nature-driven solution, blue elements, green elements.

I. INTRODUCTION

Urbanization presents environmental dilemmas such as changes to local hydrology and unprecedented biodiversity loss that negatively impact the quality and availability of local water resources, overcrowding, and inaccessibility to nature. Effects on nature and people are first experienced in cities, as cities form miniatures with extreme temperature gradients, and by now, about half of the human population globally lives in urban areas. [2] Climate change has substantial influence on ecosystem functioning and well-being of people.

However, Blue-Green Infrastructure (BGI) have the potential to counteract these pressures. They can foster and simplify implementation actions in urban landscapes by taking into account the services/benefits provided by nature. BGI is an approach recognised globally with capitalises on the benefits of working with urban green spaces and naturalised water-flows. [3]Blue-green infrastructure is a defined by the European Commission as a 'strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem service'. It plays a vital role in reducing air pollution, mitigating climate change, and providing various ecosystem services. BGI provide nature based solutions in counter to the conventional grey infrastructure practices and helps to provide balanced development with nature.

NEED FOR BGI

Several Indian cities have witnessed a decline in green and blue features due to rapid urbanisation, with studies on land-use transitions indicating environmental losses. [4] One in every two Indians is expected to live in cities by 2050, creating high densely populated neighbourhoods. In attempts to address these challenges, growing attention is being paid to Nature-Based Solution often approach through the concept of green and blue infrastructure, which can be incorporated in Comprehensive land-use planning and urban settlements.

AIM

To develop approaches in planning blue-green infrastructure for the urban neighbourhoods of Indian cities.

OBJECTIVES

1. To understand the concept of Blue-Green Infrastructure and its elements in city planning.
2. To identify the key challenges of BGI planning in urban neighbourhood of Indian cities.
3. To examine various approaches of BGI on urban neighbourhood implemented in developed and developing counties.

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4. To develop a framework of Blue Green Infrastructure in urban neighbourhood of Indian cities.

LIMITATION

- The study is based on secondary data. Validation of derived BGI framework in planning for Indian cities is required through primary study such as reconnaissance/ field survey, and focus group discussion.

II. METHODOLOGY

The theoretical study definesthe terms Blue Infrastructure, Green Infrastructure, and BGI.Also studies about evolution of BGI, it's role in Sustainable Development Goals, its elements, benefits and its application on different scales. For understanding it's application best practices from developed and developing countries is look into. Finally concludes with thedeveloped BGI framework using elements, indicators, standards to assess Indian cities.

III. LITERATURE REVIEW

Definition:

[1] Green infrastructure refers to green elements, like trees, lawns, hedgerows, parks, fields, forests, etc. [5] Blue infrastructure refers to water elements, like rivers, wetlands, canals, ponds, floodplains, water treatment facilities, etc. (Root-Bernstein 2020)

Evolution of green infrastructure (BGI) globally:

[6] In 1980's the concept of GI evolved in USA with the development of greener or bluer rainfall drain management. The first GI project was implemented during 21st century.

Evolution of green infrastructure (BGI) in India:

First mentioned in an early discussion of environmental policy of the Fourth Five Year Plan (1964-69). Under the response of UNFCC India formulated the National Action Plan on Climate Change (NAPCC – 2008) with 12 missions that deals with agriculture, sustainable water, forestry, and habitat management. In addition, two flagship projects in 2015 Smart Cities Mission, AMRUT also focuses on improving urban living by integrating blue and green components.

Role of BGI in Sustainable Development Goals:

BGI is directly outlined in SDGs 6, 13, 14,15 and also indirectly accelerates other goals (SDGs 1, 2, 3, 11, 8, 9, 10) through the development of green employment prospects.

Elements of BGI in planning:

Elements identified from various secondary sources:
[7] Runoff troughs, grassed swales, infiltration trenches, vegetated swales, bio retention basins
[8] District park, neighbourhood park, tot lots, playgrounds, green belt (buffers), rivers and floodplains, green strip, lakes and wetlands, major recreational spaces, canals
[9] Green roofs, swales, parks, sports grounds, urban agriculture, green corridors, ponds and lakes, wetlands, waterways
[10] Water, Clustered trees, Street trees, Shrub, Mixed, Grasslands

Benefits of BGI in planning:

Multiple benefits for elements in BGI are identified in different secondary source, and they are:
[9] The benefits provided for environment are biodiversity/species protection, connectivity, heat island effect, flood protection, water retention, soil protection, air quality, drought, water purification, resource, inefficiency, water management. The benefits provided for people are active recreation, health and well-being, better conditions for pedestrians, aesthetic. BGI also enhances tourism creating economic benefits.

[11] The benefits provided in mentioned paper for environment are biodiversity,UHI mitigation, flood mitigation , surface flood risk reduction, air quality, drought, water quality, noise reduction, resource inefficiency, water management, outdoor air evaporative cooling. The benefits for people are provision of healthier environment, well-being, promotion of culture, better conditions for pedestrians, enhanced scope for socialising, aesthetic. Other benefits includehigher property value, buildings more comfortable, job creation, tourist attractions, and food production are focusing on providing better economic growth.

Spatial Planning intervention of BGI

For successful BGIplanning, interventions need to carry out in different scales of planning and application. Subsequently, green-blue infrastructure planning will be for a complete urban area or catchment but require to consider possible interference at various scales and their cumulative impact. [9] The application can be at the global level, macro-level (macro-regions), mezzo level (in the river basin and cross border), and micro-level.

Best Practices of BGI

a) Active, beautiful, clean waters (ABC Waters) Programme, Singapore

Main climatic issue faced by city is urban flooding. The city has extensive network of drains, canals, rivers. ABC Waters aim to improve water quality, and enhance liveability through transforming canals, rivers and reservoirs into beautiful recreational spaces. Elements they have used are Green roofs, Balconies, Planter Boxes and Vertical Green, Sedimentation basins, wale/buffer, Vegetated swales, Bioretention swale, Bioretention basins (rain gardens), Constructed wetlands, Cleansing biotopes. And maps developed are Blue Map, Parks and Waterbodies Plan, Park Connector Network

b) Rain city strategy, Vancouver, Canada

Main climatic issue faced by city is urban flooding due to extensive rainfall and combined sewer system. The aim is to protect and improve urban water quality, urban resilience, sustainable water management, and liveability from BGI. And have developed Topography & Areas of Average Annual Precipitation, Historical Stream Locations, Geology and Soils, Infiltration Potential, Combined Sewer Map, Land Use Map, Impervious Area Map to analyse the condition of blue green element and come up with BGI network plan as the solution.

c) Cloudburst Management Plan, Copenhagen, Denmark

Being a coastal town increased risk from flooding due to the rising sea level combined, extreme precipitation events. The plan aims at blue-green solutions to address urban resilience issues. They developed Cloudburst Toolbox with eight types of intervention for roads, parks and squares aimed at mitigating urban flooding. The Finger Plan to easily access recreational space, forests and lakes, with quicker transportation. And also Copenhagen Climate Adaptation Plan Incorporate BGI within the urban landscape. Toolbox includescloudburst roads, retention alleys, green streets, stream restoration, cloudburst pipes, floodable parks, wet plazas, urban canals, urban creeks, retention boulevards.

IV. DEVELOPING BGI FRAMEWORK

Classifying benefits under BGI

For developing the framework first step is to classify the benefits. Through various secondary studies, all the identified benefitswere grouped based on the type of benefit they provide. And they are categorised into three indicators, ie. Environment response, Social cohesion, Economic Prosperity.

- Environment response provide benefits to environment like consist of biodiversity conservation, improving air and water quality, Reduce noise pollution, Urban heat island effect, runoff, energy consumption, and soil erosion.
- Social cohesion provides benefits to people through enhancing socialisation by providing better pedestrian conditions, and recreational facilities.
- Economic prosperity in BGI is achieved through enhancing food production.

Classifying elements under BGI

Based on type of benefits each element provided it is classified under the three indicators Environment response, Social cohesion, Economic Prosperity. Elements under each indicator are:

- Environment response: Forest, water bodies, surface and ground water reservoirs, ecological corridor, urban canopy
- Social cohesion: park, tot lots, playgrounds, green loop, urban squares, sports grounds, water squares, street trees
- Economic prosperity: Urban agriculture, Gardens (Kitchen garden, community garden), Aquaponics, Aquaculture

Table 1Developed Framework for BGI

INDICATOR	ELEMENTS	SUB - INDICATORS	ASSESSMENT CRITERIA	SOURCE
Environmental Response	Forest	Proportion of natural areas in the city	Total Area of Natural Areas) ÷ (Total Area of the City) × 100	[12]
	Water bodies	Propagation of wildlife, fisheries, Coastal Regulation Zone	pH:6.5 - 8.5 Dissolved oxygen: 4 mg/l or more Free ammonia (as N): 2mg/l or Less	[12]

	Ecological corridor	Counter habitat fragmentation	(1/A total)(A12+A22+A32+…+An2)	[12]
	Green roof	UHI Vol. of runoff water captured	Reduction of heat by 1.5°C, 1.9°C& Volume credit, V=As Dp (MMWR) As = the surface area Dp = the depth of the media MMWR = moisture content	[15]
	Green belt	Two rows of tall trees Width: 5-10m	33% of the existing land area 1500-2000 trees per hectare	
	Rainwater harvesting	Runoff water quantity (on roof) =	Annual rainfall (in mm) X Area of roof (in sq m) X Runoff coefficient for the roof	[13]
	Swales, Runoff troughs	Water quality	25 - 50% reduction in particulate pollutants	
	Unbuilt areas	Regulation of quantity of water	(Total permeable area) ÷ (Total terrestrial area of the city)	[12]
	Pavements	Cool Permeable pavements types		
	Infiltration trenches	Water runoff	Q= 10 C i A Q - runoff in m3/hr; C - coefficient of runoff i - intensity of in mm/hr A - area drainage district	[12]
	Riparian buffers	width	75-ft: low-intensity land-use area 50–ft: high-intensity land-use area	[14]
	Rain garden	Size	5 to 10 percent size of the impervious surface, 10-20m 2 for a rain garden drains	[12]
	Bio retention basin	Quantity of water	Area: 1 acre, Depth: 1 foot, Capacity: Approx.330,000 gallons	[16]
Social Cohesion	Park (10- 12 sq.m per person)	Small Towns	1.0 to 1.2 ha /1000 ppl	[12]
		Medium Towns	1.4 to 1.6 ha / 1000 ppl	
		Large City, Metropolitan and Megapolis	1.2 to 1.4 ha / 1000 ppl	
	Urban squares (multi - purpose ground)	Sub-city level	8 Ha	
		District level	4 Ha	
		Community level	2 Ha	

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	Street trees	Perc. Of Tree cover	(Tree canopy cover) ÷ (Total terrestrial area of the city) × 100	
	Sports grounds	Residential unit play area	5000 sq	
		Neighbourhood Play area	1.50 ha	
		District Sports Centre	8.00 ha	
		Divisional Sports Centre	20.00 ha	
Economic prosperity	Urban agriculture	Growing Space Potential	No. of residence x $2m^2$ (assuming avail. area)	[17]
	Aquaponics	Seafood (sustainable fishery)	Production over the years	

Merits of developed BGI framework:

The developed framework is to evaluate blue green asses, its current condition in a city. So that cities can improve their green and blue elements, and reach optimum standards. Since the framework is developed majorly using Indian standards, it is applicable throughout the country for assessment.

Limitations of developed BGI framework:

The framework requires primary and secondary survey for its complete validation. Various maps are required to analyse the yearly change of these elements.

V. CONCLUSION

Blue Green Infrastructure (BGI) in spatial planning is recommended as a natural solution for climate issues faced in urban areas. It can be an alternative to conventional grey infrastructure practices having pragmatism of cost affectivity.

A systematic framework using standards to assess existing condition of Blue Green elements in an urban area was lacking in the studies. So the paper has developed a BGI framework which helps to assess Indian cities based on the various measurable standards. The framework requires graphical and measurable data of decadal changes for validation. The application should be carried out in all the levels for its successful implementation. The study is limited to secondary data collection and analysis.

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