Improving Urban Resilience by Augmenting Blue-Green Infrastructure

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Abstract: Rapid urbanization and climate change have intensified city environmental challenges, including flooding, heat stress, and biodiversity loss. Blue-Green Infrastructure (BGI), which integrates water systems (blue) and vegetated spaces (green), offers a sustainable, multifunctional approach to urban planning that enhances resilience and aligns with global climate adaptation goals. This study investigates the role of BGI in improving urban resilience by analyzing its environmental, social, and economic benefits. Drawing on national and international case studies—including Indore, Bhopal, Portland, and the Netherlands—the paper examines best practices, implementation barriers, and the policy landscape. Through case studies it highlights the importance of context-specific planning, community engagement, and interdisciplinary collaboration. The research will try to find gaps in coordination that hinder BGI mainstreaming and proposes strategic recommendations aligned with Sustainable Development Goals (SDGs 6, 11, 13, and 15). By advocating for integrated design frameworks and international cooperation, the study will establish potentials of BGI as a transformative tool for sustainable urban development in India. The paper aims to achieve how essential it is in Indian context to switch towards sustainable alternatives to enhance BGI in urban public spaces not only mitigates climate risks but also fosters inclusive growth, ecological balance, and long-term urban livability.

Index Terms - **Blue-Green Infrastructure (BGI), Urban Resilience, Sustainable Development Goals (SDGs), Nature-Based Solutions, Climate Adaptation**

I. INTRODUCTION

Urban areas worldwide are increasingly facing challenges associated with rapid urbanization, climate change, and the degradation of natural ecosystems. These challenges often result in issues such as flooding, heat islands, loss of biodiversity, and reduced quality of life. In response, the concept of Blue-Green Infrastructure (BGI) has emerged as a sustainable urban planning approach that integrates water management (blue) and green spaces (green).

Fig 1 Loss in Blue-Green Areas and Rise in Built-Up Areas in Major Indian Cities

Source: *https://www.orfonline.org/research/blue-green-infrastructure-an-opportunity-for-indian-cities*
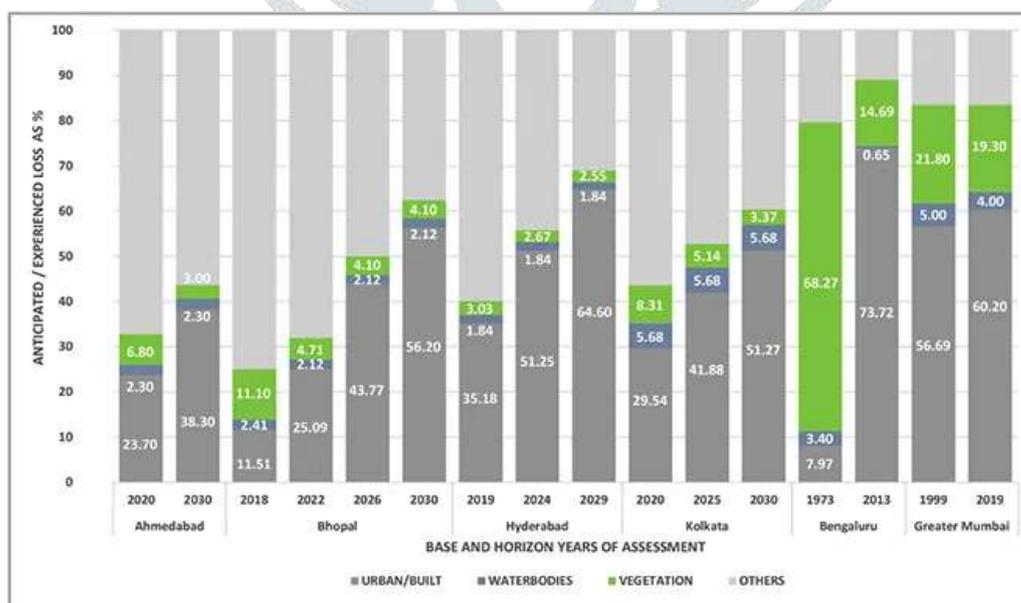
Ecologically Integrated spaces act as "lungs" of the city, promoting ecological connectivity while serving as community hubs that support the well-being of urban residents.

Fig 2 Integrated Urban Public Space

Source: https://www.orfonline.org/research/blue-green-infrastructure-an-opportunity-for-indian-cities

Blue-Green infrastructure refers to urban planning where water bodies and land are interdependent and grow with the help of each other offering environmental and social benefits.

Fig 3 Benefits from Blue Green Infrastructure

Source: https://www.foe.org.hk/en/news/Policy%20Advocacy/earth%20chat/enhancing%20resilience%20and%20sustainability%20with%20blue-green%20infrastructure

The integration of BGI in shaping urban public spaces is becoming an essential aspect of contemporary urban design and planning. Public spaces—such as parks, plazas, streets, and waterfronts— are increasingly being designed with BGI principles to provide recreational opportunities, enhance urban biodiversity, and foster social cohesion.

Fig 4 Blue-Green Infrastructure: A combination of natural elements with engineered systems

Source: Author

1.1 Need of the Study

Four major global risks projected to have a negative decadal consequence-
- Natural disaster
- Extreme weather
- Biodiversity loss
- Climate action failure

Integrating Blue-Green Infrastructure (BGI) with the Sustainable Development Goals (SDGs) is critical for mitigating global risks like climate change, flooding, and biodiversity loss. BGI enhances urban resilience by naturally managing stormwater (SDG

6), reducing heat islands, and sequestering carbon (SDG 13). It promotes biodiversity (SDG 15) and supports sustainable urban development (SDG 11) by providing green spaces that reduce disaster vulnerability. By fostering ecosystem-based solutions, BGI reduces reliance on grey infrastructure, thus contributing to long-term environmental sustainability and the global risk reduction agenda outlined in the SDGs.

Fig 5 SDGs for Blue-Green Infrastructure

Source: https://sdgs.un.org/goals

The need for Blue-Green Infrastructure (BGI) in shaping urban public spaces is driven by a combination of environmental, social, and economic challenges that cities worldwide are increasingly facing. Cities are key contributors to climate change having less than 2% of earth's surface but consume 78% of world's energy and produce 60% of all greenhouse gases. By 2050, one in every two Indians is expected to live in cities.

Extreme weather events in India –

- Drought
- Cyclone
- Forest fires
- Heatwaves
- Floods

The need for Blue-Green Infrastructure (BGI) in shaping urban public spaces is driven by a combination of environmental, social, and economic challenges that cities worldwide are increasingly facing. So, below are few points mentioning the need of blue green infrastructure as an emerging topic to fulfill sustainable development goals.

1. Gray infrastructure often lacks the capacity to handle heavy rainfall events, causing urban flooding and waterlogging.
2. UHI effect, increased energy consumption, heat-related illnesses, and reduced overall comfort in cities.
3. Exposure to natural elements has been shown to reduce stress, enhance mood, and foster social interaction.
4. Evaluation of existing barriers will lead to solution that will enhance public spaces.

1.2 Aim

The study aims to understand blue-green infrastructure, assess its potential, identify barriers, and strategic planning needs for urban resilience through SDG-aligned collaboration.

1.3 Objectives

1. To understand the concept and applications of blue-green infrastructure (i.e. blue and green interfaces, their types, interactions, elements, principles and components of BGI etc).
2. Study national and international case studies.
3. Explore collaboration opportunities with international agencies aligned to UN SDGs (6, 11, 13, 14, 15).
4. Identify a city and give a way forward for augmenting the BGI of that city.

1.4 Scope and limitation

Scope:

1. To study concepts and applications of-
- Urban vulnerability
- Climate resilience
- Blue-green infrastructure
- International funding opportunities
- Nature-based solutions.
2. Exploring case studies of cities that have successful BGI implementation, highlighting best practices, innovative solutions, and lessons learned that can be adapted to other urban contexts.
3. The study will cover aspects of environment management, water resource and management, land use, policy framework, governance, and physical and social infrastructure to evaluate existing situations and understand possible strategies.
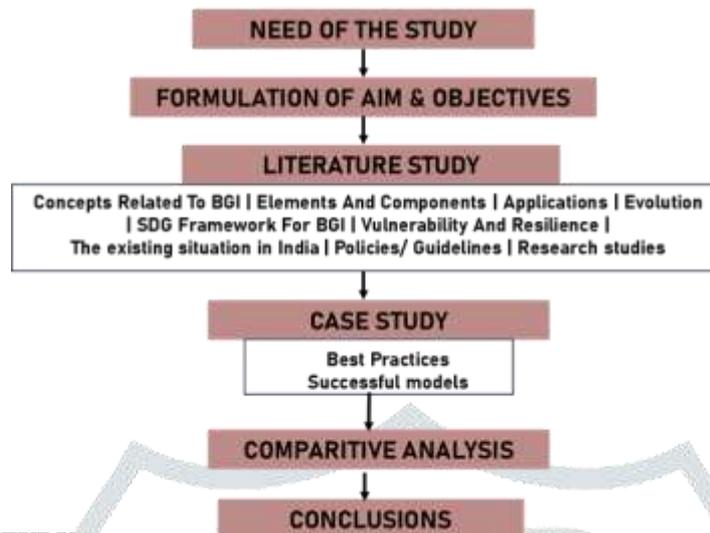
Limitation:

1. The study will only be limited to urban areas.

1.5 Research questions

How can preserving or augmenting blue-green infrastructure in a city enhance urban resilience?

1.6 Methodology

2 LITERATURE STUDY

2.1 Evolution of the Concept

Blue-Green Infrastructure (BGI) evolved as a concept in response to increasing climate hazards and urbanization challenges. Traditional grey infrastructure, relies on engineered solutions, and proved inadequate for addressing issues like flooding, heat waves, and biodiversity loss. BGI integrates natural elements (green) like parks and trees with water bodies (blue) to create multifunctional urban spaces that enhance resilience, promote environmental justice, and improve quality of life.

1. Environmental Foundations (1970s-1980s): Early planning aimed at reducing the negative effects of urbanization on natural ecosystems and maintaining ecosystem services.
2. Green Infrastructure Development (1990s-2000s): Emphasis on urban greening and sustainable landscapes led to formalizing Green Infrastructure (GI) approaches for enhancing biodiversity, water management, and resilience. (National Afforestation and Eco-Development Board (NAEB), Green India Mission)
3. Introduction of BGI (Late 2000s): Recognizing the interconnected role of water and green spaces, BGI emerged through integrated, multifunctional natural systems.
4. Alignment with SDGs (2015): BGI gained international traction with the UN Sustainable Development Goals (SDGs), especially SDGs 6, 11, and 13, linking it to global climate adaptation and resilience goals.
5. Comprehensive Resilience Tool (2020s): BGI now includes digital planning tools and a focus on equity, aiming to provide climate resilience and improve quality of life.

2.2 Applications of Blue–Green Infrastructure

1. Urban Resilience and Climate Adaptation: Eg: Jakarta, Indonesia, has implemented mangrove planting along its coastlines to counteract the impacts of rising sea levels and provide natural flood protection.
2. Stormwater Management: Eg: New York's Green Infrastructure Program incorporates permeable surfaces and green roofs to manage rainwater, reducing combined sewer overflow events.
3. Urban Heat Island Mitigation: Eg: In Singapore, extensive green rooftops and walls are part of the city's strategy to keep urban temperatures lower and improve air quality.
4. Improving Quality of Life: Eg: The Los Angeles River revitalization project includes green spaces along the river, offering recreational areas and access to nature for the community.
5. Economic and sustainable Development: Eg: Copenhagen's "climate-resilient neighborhoods" include rainwater management parks that enhance property values and attract business investments.
6. Water Quality Improvement: Eg: The Cheonggyecheon Stream project in Seoul, South Korea, restored a natural waterway, improving water quality while creating a recreational and green space in the city center.
7. Biodiversity Enhancement: Eg: London's Thames River restoration created habitats for various species and introduced green corridors that link natural areas, supporting urban biodiversity.

2.3 BGI for Various Types of Regions

Blue-Green Infrastructure (BGI) can be adapted and applied to different types of regions—each with unique climatic, environmental, and socio-economic conditions. To achieve healthy connected networks of spaces across cities and regions, multiple ecosystem services can help raise adaptive capacity of cities and hence improve urban resilience.

1. Coastal Regions- solutions like mangrove restoration, constructing artificial wetlands, restoring vegetative cover can protect coastal areas. Eg. The Sundarbans region in India uses mangroves to protect coastal areas.
2. Flood-Prone Regions (Floodplains and River Valleys)- floodplain restoration for water absorption, green buffers along rivers improves stormwater management and increase biodiversity. Eg. Room for the River project, Netherlands.

3.   Mountainous and Hilly Regions- terracing of agricultural fields, riparian buffers along streams and agroforestry can prevent sediment runoff, improve water quality and prevent landslides etc. Eg. Green India Mission promotes agroforestry

4.   Tropical Rainforests- forest restoration by afforestation and stopping illegal logging and implementing rainwater harvesting systems and preventing human encroachment. Eg. Amazon rainforest in Brazil has the initiative REDD+ (reducing emissions from deforestation and forest degradation)

5.   Urban Areas with High Density and Pollution (Industrial Regions)- creating parks and green roofs, rain gardens, bioswales etc to improve air and water quality, cool urban environment and restore water table. Eg. Chandigarh Horticulture Masterplan has incorporated parks, green corridors and rainwater harvesting to tackle pollution.

6.   Desert and Semi-Arid Regions- implement water–efficient landscaping such as xeriscaping and drought-tolerant plants in urban areas, rainwater harvesting in tanks, ponds, or artificial wetlands and agriculture techniques like mulching, smart sensors for soil moisture monitoring and agroforestry. Eg. Al Ain in UAE uses Aflaj irrigation system which minimizes evaporation and supports groundwater recharge.

2.4   Urban Vulnerability

"The exposure of Indian cities to climate extremes, worsened by poor environmental governance and infrastructure gaps." (Source: TERI Discussion Paper on Urban Climate Resilience, 2020)

"The conditions and factors that make urban populations, especially the marginalized and impoverished, more susceptible to harm during crises, exacerbated by rapid urbanization and inadequate infrastructure" (Source: UN-Habitat's Cities and Climate Change Initiative)

"Urban vulnerability relates to the characteristics of people and places that influence their exposure to hazards and their capacity to respond." (Source- World Bank)

"The degree to which urban systems are susceptible to the impacts of climate change, which combines climate hazards with socio-economic characteristics of urban populations. It reflects both physical exposure and social sensitivity to these hazards." (Source: IPCC Fifth Assessment Report, 2014)

Hence, factors that define urban vulnerability are-

•   Environmental & Climate Change Impacts -Disasters, rising temperature, deforestation, GHG emissions
•   Rapid Urbanization- unplanned growth, loss of blue and green, stress on resources, UHI
•   Inadequate Infrastructure- dependency on gray infrastructure, poor maintenance
•   Socioeconomic Disparities- marginalized communities, low-income access to resources, information & infrastructure

2.5   Climate Resilience

"The ability of a system to prepare for, recover from, and adapt to climate-related stressors and shocks while reducing vulnerability to climate impacts. (Source: World Bank Climate Resilience Program)

Resilience refers to "the capacity of social, economic, and environmental systems to cope with a hazardous event or trend, respond positively, and adapt while maintaining essential functions, identities, and structures." (Source: UNFCCC Glossary)

Climate resilience is "the capacity of individuals, communities, institutions, businesses, and systems to survive, adapt, and grow regardless of the chronic stresses or acute shocks they experience due to climate change." (Source: Resilient Cities Framework, Rockefeller Foundation)

"The ability of a system to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions." (Source: IPCC Special Report on Global Warming of 1.5°C, 2018)

Factors that improve climate resilience are-

•   Robust Infrastructure- Designing and retrofitting infrastructure to withstand extreme weather events, risk reduction
•   Ecosystem Services- Stormwater management, air quality improvement, and biodiversity support Governance- promote collaboration among various stakeholders, establishment of clear policies and frameworks
•   Financial Resources- investment in climate resilience initiatives, economic diversification
•   Data and Monitoring Systems- assess vulnerabilities, data-driven approach, ensure they remain effective under evolving climate conditions.

3   LITERATURE REVIEW

3.1 Study 1- Blue-Green Infrastructure: An Opportunity for Indian Cities by Sayli Udas Mankikar, Berjis Driver (2021)

It explores the emerging concept of blue green infrastructure, and analyses existing plans and projects in India and globally. identify opportunities in the blue green space to help India's cities respond to climate hazards, promote equity and resilience, and catalyze economic transitions for sustainable urban futures.

Learnings

•   Indian cities are increasingly vulnerable to climate risks, with rapid urbanization leading to significant losses in green and blue spaces. effective blue-green infrastructure initiatives that can be adapted to Indian contexts.
•   Implementation challenges of blue-green infrastructure.
•   Establishing a national framework for blue-green infrastructure is essential to guide local initiatives and ensure effective implementation across various levels of governance.
•   Successful blue-green projects require active participation from local communities, fostering a sense of ownership.

Keywords: Climate risks, Urbanization, Integration of blue and green, Sustainable urban planning, Adaptive Management

3.2 Study 2- A systematic review on urban blue-green infrastructure in the south Asian region: recent advancements, applications, and challenges by Aman Gupta (2024)

The study aims to assess the present status of research on urban blue-green infrastructure (BGI) in lower-middle-income countries of the South Asian region. research seeks to identify knowledge gaps in the existing literature regarding BGI. highlight the challenges faced in implementing and designing BGI networks, including governance issues.

Learnings

•   The benefits of nature-based solutions, and the role of green infrastructure in mitigating urban heat island effects and air pollution.

•   Highlights a significant lack of governance frameworks and comprehensive methodologies for implementing BGI emphasizing the importance of interdisciplinary collaboration among various stakeholders.

•   Enhance resource sharing, knowledge exchange, and unified approaches to urban sustainability.

•   Integrate BGI with existing grey infrastructure for overall urban resilience.

•   Create policies that specifically address climate adaptation through BGI.

Keywords: Fund allocation, Governance. stakeholder participation, social inclusion, nature-based solutions, integration with gray infrastructure.

3.3 Study 3- The potential of Blue-Green infrastructure as a climate change adaptation strategy: a systematic literature review by Tamer Almaaitah; Madison Appleby (2021)

The study evaluates published studies on the effectiveness of Building Blue Green Infrastructure (BGI) in reducing urban heat island effects and stormwater management, addressing challenges like coordination, funding, and lack of risk reduction frameworks.

Learnings

•   literature shows a slightly greater focus on stormwater management compared to UHI mitigation, highlighting the dual benefits of BGI in urban environments.

•   emphasizes the need for context-specific designs.

•   identifies lack of multilevel coordination among stakeholders, budget constraints, and the absence of risk reduction frameworks.

•   highlights the need for further research to explore the performance of BGI, particularly at smaller urban scales

Keywords: context specific planning, research, and monitoring, UHI, stormwater management, integration with gray infrastructure

3.4 Study 4- Towards climate-resilient cities: Overcoming the barriers of blue-green infrastructure mainstreaming by Pia Bollingerfehr (2022)

It analyses how BGI can be effectively integrated into urban planning and policy processes to enhance climate resilience. seeks to identify the specific barriers that municipalities face in the mainstreaming of BGI. Examining strategies and actions that can facilitate the integration of BGI into urban development and climate adaptation efforts.

Learnings

•   The research identifies key barriers to the mainstreaming of Blue-Green Infrastructure (BGI) in urban policy

•   Four enabling mechanisms are proposed to overcome barriers: synergy exploitation, organizational learning, policy entrepreneurship, and funding mechanisms crucial for overcoming the identified barriers.

•   emphasizes the need for better integration of climate adaptation policies at all levels of governance. engaging various stakeholders, such as water authorities and urban planners, to create a cohesive approach.

Keywords: resource availability, policy integration, Governance, climate adaption, water management, adaptive management

3.5 Study 5- Assessment of Blue and Green Infrastructure Solutions in Shaping Urban Public Spaces—Spatial and Functional, Environmental, and Social Aspects by Kinga Kimic, Karina Ostrysz (2021)

The study evaluates 19 BGI solutions effectiveness in urban public spaces, categorizing them based on their potential contributions to sustainable design, providing insights for urban planners and designers.

Learnings

•   The study identified and evaluated 19 bgi solutions based on spatial, functional, environmental, and social aspects, highlighting the need for a multi-faceted approach in urban planning.

•   Findings emphasize the necessity of a comprehensive approach to planning.

•   BGI solutions play a crucial role in enhancing urban ecosystems by improving water retention, flood control, and biodiversity enhancement, which are essential for resilient urban environments.

•   Successful implementation of bgi requires conscious planning and design, as well as community engagement to maximize their benefits and address potential barriers.

Keywords: Surface requirements, water retention, biodiversity factors, cost factor, multi-faceted approach

3.6 Study 6- Blue–green architecture: A case study analysis considering the synergetic effects of water and vegetation By Friederike Well, Ferdinand Ludwig (2020)

The primary aim of the study is to analyze the synergetic effects of integrating blue (water) and green (vegetation) elements in urban architecture. The analysis focuses on identifying successful strategies and potential areas for improvement.

Learnings

•   Buildings can serve as critical interfaces for blue-green systems, and their design should incorporate both water management and vegetation to improve urban microclimates and resource efficiency.

•   The analysis revealed that many projects overlook potential synergies between water and vegetation during the planning process.

Keywords: synergistic effects, integrated planning, urban landscape, resource efficiency, urban microclimate

3.7 Comparative Study

Table 1 Comparative analysis of Literature Review

LITERATURE STUDY TOPIC	AGENCY/ AUTHOR	YEAR	OBJECTIVE	FINDINGS	PARAMETERS/ KEYWORDS
Blue-Green Infrastructure: An Opportunity for Indian Cities	Sayli UdasMankikar, Berjis Driver	2021	This study explores blue green infrastructure in India and globally, identifying opportunities to help cities respond to climate hazards, promote equity, and catalyze sustainable economic transitions.	Indian cities face climate risks due to rapid urbanization, causing significant loss of green and blue spaces. Implementing effective blue-green infrastructure initiatives is crucial to mitigate these challenges.	climate risks, urbanization, integration of blue and green, sustainable urban planning, adaptive management
A systematic review on urban blue-green infrastructure in the south Asian region: recent advancements, applications, and challenges	Aman Gupta;	2024	The study evaluates urban blue-green infrastructure research in South Asian lower-middle-income countries, identifying knowledge gaps and challenges in implementation and design, including governance issues.	The study highlights the need for comprehensive governance frameworks and methodologies for implementing Bio-Growth Infrastructure (BGI) and integrating it with existing grey infrastructure to mitigate urban heat island effects and air pollution.	fund allocation, governance, stakeholder participation, social inclusion, nature based solutions
The potential of Blue-Green infrastructure as a climate change adaptation strategy: a systematic literature review	Tamer Almaaitah; Madison Appleby;	2021	The study evaluates the effectiveness of Building Green Infrastructure (BGI) in reducing urban heat island effects and stormwater management, addressing challenges like coordination, funding, and lack of risk reduction frameworks.	Literature highlights stormwater management and UHI mitigation benefits of Building Green Infrastructure (BGI) in urban environments, but lacks coordination, budget constraints, and risk reduction frameworks.	context specific planning, research and monitoring, UHI, stormwater management, integration with gray infrastructure.
Towards climate-resilient cities: Overcoming the barriers of blue-green infrastructure mainstreaming	Pia Bollingerfehr	2022	This study explores the integration of Building Green Infrastructure (BGI) into urban planning and policy to improve climate resilience, identifying barriers and strategies for successful implementation.	Four enabling mechanisms are proposed to overcome barriers: synergy exploitation, organizational learning, policy entrepreneurship, and funding mechanisms. The text emphasizes the need for comprehensive climate adaptation policies at all governance levels, involving stakeholders like water authorities and urban planners to develop a cohesive approach.	resource availability, policy integration, governance, climate adaption, water management, adaptive management
Assessment of Blue and Green Infrastructure Solutions in Shaping Urban Public Spaces—Spatial and Functional, Environmental, and Social Aspects	Kinga Kimic, Karina Ostrysz	2021	The study evaluates 19 BGI solutions' effectiveness in urban public spaces, categorizing them based on their potential contributions to sustainable design, providing insights for urban planners and designers.	The study underscores the importance of a comprehensive planning approach, highlighting the role of Building-Ground-Infrastructure (BGI) solutions in enhancing urban ecosystems and supporting biodiversity.	Surface requirements, water retention, biodiversity factors, cost factor

Source: Author

4 INITIATIVES AND OPPORTUNITIES

4.1 Initiatives in India

First discussion in 4th five year plan (1969-1974) on Green Infrastructure then the Environment Ministry was setup in 1980 later renamed As Ministry Of Environment forest And Climate Change (MOEFCC) in 2014 for protecting environment and climate. Ministry Of Water Resources And Ganga Development was set up to look after the development in blue infrastructure. In 2008, National Action Plan On Climate Change (NAPCC) was set up in response to 'UN Framework Convention On Climate Change' and UNs 'Green Economy Initiative'.

NAPCC includes 12 missions.

- National Mission for Green India
- National Solar Mission
- National Water Mission
- National Mission for Sustainable Agriculture
- National Mission on Sustainable Habitat
- National Mission for Enhanced Energy Efficiency
- National Mission for Himalayan Ecosystem
- National Mission on Strategic Knowledge on Climate Change
- National Wind Mission
- Mission on Health (to deal with climate change impacts on human health)
- National Coastal Mission
- Waste-to-Energy Mission.

There are two national flagship missions under the Government of India-

- Smart Cities Mission
- AMRUT

Other Initiatives related to or indirectly support blue and green infrastructure-

- National Mission For Clean Ganga (NMCG)
- Swacch Bharat Mission urban
- Urban Greening Guidelines 2014 (MOHUA)
- Green India Mission (GIM)
- Wetlands (conservation and management) rules, 2017

- National River Conservation Plan (NRCP)
- SDGs (localization initiatives)
- EIA guidelines
- Integrated Watershed Management Programme (IWMP)
- National Environment Policy (2006)

Table 1 Acts and policies

ACTS/POLICIES/PROGRAMMES	AUTHORITY	GOAL W.R.T. BGI	APPLICABILITY
NAPCC	Prime Minister's Council on Climate Change, MOEFCC	To mitigate and adapt to the impacts of climate change through eight core missions, including water and forest conservation, sustainable habitats, and enhancing energy efficiency.	various sectors such as energy, water, renewable energy and agriculture
AMRUT	MOHUA	Enhance QOL through urban infrastructure, including water supply, sewerage, and green spaces.	Basic Services Urban Greenspaces Sustainable Urban Development Stakeholder Participation
Smart Cities Mission	MOHUA	To promote sustainable urban development, including green infrastructure, smart water management, eco-roofs, and sustainable urban drainage systems.	Core Infrastructure Technology Utilization Community-Centric Approach
Urban Greening Guidelines 2014	MOHUA	To increase urban green cover by planning and developing parks, urban forests, and green belts in urban and peri-urban areas.	Tree Protection Space Allocation Biodiversity Enhancement Community Involvement
Green India Mission	MoEFCC	To increase forest and tree cover, restore degraded ecosystems, and improve biodiversity and ecosystem services	Reforestation Targets Community Participation Convergence with Other Missions Sustainable Livelihoods
Wetlands(conservation and management) rules, 2017	MoEFCC and respective State Wetland Authorities.	To conserve wetlands for ecological balance and biodiversity protection, regulate activities affecting wetlands, and prevent their degradation.	Regulatory Framework State Wetland Authoritiy Participation and Awareness Prohibition of Harmful Activities restoration of wetland ecosystems.
National environment policy (2006)	MoEFCC.	To ensure environmental sustainability through conservation, restoration of natural resources, and integrating environmental concerns into economic and social development policies.	Sustainable Development Stakeholder Engagement Monitoring Mechanisms Legal Frameworks
National River Conservation Plan	MoEFCC and respective State Governments.	To reduce pollution in major rivers through measures like sewage treatment, effluent control, and development of riparian green zones.	pollution Abatement Sewage Treatment Stakeholder Coordination Community Engagement

Source: Compiled By Author

4.2 International Funding Opportunities

Table 3 International Funding Opportunities

INTERNATIONAL INITIATIVE / POLICY	YEAR OF ESTABLISHMENT	COUNTRIES IMPACTED	GOAL	SDG ALIGNMENT	PROGRAMMES AND PROJECTS	PROGRAMES AND PROJECTS IN INDIA
Global Environment Facility (GEF)	1991	Over 140 countries	To address global environmental challenges by funding biodiversity conservation, sustainable land management, and climate resilience projects, particularly in developing nations.	SDG 6, 13, 15	Funds projects such as urban wetland restoration, natural water management, and ecosystem conservation, often integrating BGI into urban planning.	Integrated Coastal Zone Management Project (ICZMP), Sustainable Cities Integrated Approach Pilot, Biodiversity Conservation and Rural Livelihoods Improvement
Green Climate Fund (GCF)	2010	Developing nations across Asia, Africa, and Latin America	Provide financial support for climate adaptation and mitigation projects in vulnerable nations, focusing on nature-based solutions.	SDG 6, 11, 13	Funds BGI initiatives such as flood management systems, rainwater harvesting, and green roofs to enhance urban climate resilience.	Climate Resilient Agriculture in Maharashtra, Enhanced Climate Resilience of India's Coastal Communities (AP, MH, Odisha), Solar Irrigation Expansion
United Nations Development Programme (UNDP)	1965	Projects in multiple developing countries	Promote biodiversity conservation and ecosystem-based urban planning to enhance resilience to climate change and sustainable development.	SDG 11, 13, 15	"Nature for Development" Urban forestry, riverbank stabilization, and green belt creation within cities to mitigate urban heat and flood risks.	Biodiversity Finance Initiative (BIOFIN), Urban Heat Island Reduction Delhi
The World Bank	2017	Over 50 cities worldwide, particularly in Asia and Africa	Strengthen urban resilience to natural disasters and climate risks through sustainable urban drainage and green	SDG 6, 11, 13	"City Resilience Program (CRP)" Supports projects that integrate BGI in urban resilience planning, including green corridors, sustainable drainage	Amritsar Urban Resilience Project, Mumbai Flood Control and Climate Resilience, Smart Cities Mission

European Union (EU) Initiatives	2021, 2019	Europe and developing regions worldwide	Advance sustainable urban growth, reduce pollution, and restore ecosystems through green infrastructure and climate adaptation projects.	SDG 11, 13, 15	"Horizon Europe" and "Green Deal" Provides grants for BGI research and implementation, focusing on urban sustainability initiatives like floodplain restoration and urban greening.	EU-India Urban Partnership on Smart and Sustainable Urbanization, International Urban and Regional Cooperation (IURC), Waste Management and Circular Economy Initiatives
Asian Development Bank (ADB)	1966 (Climate initiatives intensified in recent decades)	Primarily in Asia-Pacific	Support climate adaptation in Asia, integrating BGI to protect urban and coastal areas from natural disasters.	SDG 6, 11, 13	"Climate Resilience and Green Infrastructure Projects" projects like mangrove restoration, urban wetland development, and green corridors for biodiversity.	Chennai-Kanyakumari Industrial Corridor, Kolkata Environmental Improvement Investment Program, Sustainable Coastal Protection and Management Project
ICLEI – Local Governments for Sustainability	1990	500+ cities and towns globally, including several in developing countries	Empower local governments with resources for sustainable urban ecosystems, promoting practices like urban greening and eco-mobility.	SDG 11, 13	Through "Cities with Nature" and "Resilient Cities," ICLEI helps cities develop BGI projects that integrate biodiversity and climate resilience into urban planning.	Urban Biodiversity and Ecosystem Services in India (UBESI), EcoMobility Alliance, 100 Resilient Cities (partnership with Rockefeller Foundation)- surat, chennai
UN-Habitat	1978 (Urban resilience efforts have been a focus in recent decades)	Developing nations globally	Enhance urban resilience to climate hazards, focusing on flood management, water conservation, and urban cooling in rapidly urbanizing areas.	SDG 6, 11, 13	"Urban Resilience Programme" BGI-focused projects like flood control through sustainable drainage, waterway restoration, and green infrastructure for urban cooling.	Cities Investment Program (CIP)- bhopal and jaipur, Water and Sanitation for the Urban Poor (WSUP), Urban Cooling and Heat Resilience Project in Ahmedabad

Source: Compiled By Author

3   Literature study- Inferences

Table 2 Barriers in Implementing BGI

IDENTIFIED BARRIERS	EXPLAINATION	KEY ISSUES
Cognitive	These barriers relate to the psychological aspects of decision-making and awareness regarding climate adaptation and BGI	• Lack of awareness about the necessity of BGI • Absence of a sense of urgency • High levels of uncertainty regarding future climate conditions
Organizational & Institutional	These barriers occur from the internal structures and processes within organizations that is delay in policy making or lack in coordination for the integration of BGI	• Fragmentation and poor coordination among different departments and stakeholders • ingrained practices and resistance to change. • Vague responsibilities and accountabilities
Social & political	These barriers arise from the varied social needs and political influence that shape decisions on adopting Blue-Green Infrastructure (BGI).	• Insufficient political commitment to climate adaptation. • Public resistance due to misunderstandings about their benefits. • Conflicts between different political interests and priorities
Resource availability	These barriers occur due to the availability of financial, human, and physical resources necessary for BGI projects.	• Limited financial resources • Shortage of skilled personnel with expertise Physical constraints, such as land availability.
BGI related	These barriers are specific to the characteristics and definitions of BGI itself.	• Ambiguity in the definition of what constitutes BGI, leading to inconsistent interpretations and applications • Ecological and physical challenges like land and water related to the implementation of BGI • Existing reliance on traditional grey infrastructure
Time related	These barriers relate to the timing and urgency of implementing BGI measures.	• Delays in decision-making and planning • The need for long-term planning can conflict with short-term political cycles and priorities.

Source: Bollingerfehr et al., n.d. Compiled By Author

1. Effective blue-green infrastructure (BGI) implementation in Indian cities requires comprehensive governance frameworks that coordinate efforts among various stakeholders.
2. Create policies that specifically address climate adaptation through BGI.
3. A cohesive, multi-level policy approach is required to support urban resilience, biodiversity, and sustainable ecosystem management.

4. The programs and initiatives dealing with sustainable habitat, water, and agriculture and sustainability are multisectoral, overlapping and multi-departmental in nature leading to lack of coordination and functional division.
5. Buildings can serve as critical interfaces for blue-green systems, and their design should incorporate Nature-based solutions
6. Due to varied geographies and topographies in India the need for context-specific designing and planning is crucial.
7. Addressing BGI implementation barriers—such as lack of coordination and funding constraints can be mitigated.
8. Local governments can be financially and technically empowered with economic diversification and collaboration through international organizations such as United Nations.

6. Case Studies

6.1 Kahn riverfront development, Indore

The Kahn Riverfront Development in Indore is an initiative aimed at restoring and rejuvenating the polluted and encroached Kahn River while incorporating Blue-Green Infrastructure (BGI) principles to address urban environmental challenges. Initiated under the Indore Smart City Mission in 2016, as part of urban rejuvenation efforts. Includes both immediate pollution mitigation and long-term ecological restoration. Aims to develop landscaping and open spaces for city level recreational space and accommodate local markets. Implementing authority is Indore Municipal Corporation (IMC), with technical guidance from environmental consultants and urban planners. Policies and funding aligned with the Smart Cities Mission and AMRUT (Atal Mission for Rejuvenation and Urban Transformation).

The Kahn River, a tributary of the Shipra, rises from a hill near village Umaria about seven miles south of Indore. It flows through the city of Indore. It is to be mentioned that there are 02 rivers namely Saraswati River & Kahn Rivers in flowing in the area and other 10 are the tributary nalas

Fig 2 Kahn River watershed and before development situation

Source: Kahn & Saraswati Riverfront Development, Smart City Indore Report

6.1.1 Issues

1. The Khan River is heavily polluted due to untreated sewage from the city of Indore. Approximately 314 outfalls discharge sewage directly into the river, leading to high levels of Biological Oxygen Demand (BOD) and fecal coliforms, making the water unsafe for bathing and irrigation.
2. Industrial effluents from various industrial areas, contribute significantly to the pollution load in the Khan River. This includes both domestic and industrial wastewater, which often exceeds permissible limits
3. Encroachments and slum formation along the riverbanks have led to habitat degradation and reduced biodiversity. The removal of natural vegetation and the construction of structures along the river have disrupted the ecological balance also makes the area disaster prone.
4. The existing sewage treatment plants (STPs) in Indore are insufficient to handle the volume of wastewater generated.
5. The pollution of the Kahn River has implications for groundwater quality in the surrounding areas. Contaminants from the river can seep into groundwater, posing health risks

Hence, improving public health, restoring the local ecosystem, enhancing biodiversity, and Addressing the pollution and degradation of the Kahn River is vital for enhancing urban resilience against climate change impacts. Blue-green infrastructure can help manage stormwater, reduce flooding, and mitigate the urban heat island effect. A clean and healthy river can boost local economies by enhancing property values, attracting tourism, and providing recreational opportunities. It can also support agriculture by providing safe irrigation water.

Fig 3 Slum Scenario Around River

Source: Kanh & Saraswati Riverfront Development, Smart City Indore Report

6.1.2 Mitigation strategies

- Construction of CETPs and actions against industries under water act.
- Prohibition on burning of agro-residues and wastes
- Laying of sewage networks and trapping outfalls at source in all areas of the city and constructing STPs
- Carrying assessment of ground water survey for quality and to identify over exploited and critical blocks. To ensure rain water harvesting by the industrial commercial and other institutions and groundwater recharging with only clean water
- Plantation in Flood plain Zone (FPZ), prioritizing soft edges in riparian zones
- Ghat redevelopment
- thick plantation all along the river bank and around the city streets with various species plants in order to improve the environment and to stop the further encroachment along the bank and to reduce the soil erosion.
- Prohibition of disposal of municipal plastic and biomedical waste particularly in drains

6.1.3 Expected Improvement and impacts

- Noticeable reduction in water pollution levels due to improved waste management systems. Groundwater recharge and improvement of water quality in wells/pumps.
- Revival of biodiversity, urban rejuvenation, environmental and stabilization of urban ecosystems.
- Enhanced public spaces fostered recreational activities and improved the quality of life.
- Increased property values in areas adjacent to the river.
- Reduced instances of urban flooding through sustainable planning.
- Visual improvement of surrounding areas and clearance of encroachment.
- Cleaning of water and riverbed promotes aquatic life.
- Enhanced opportunities for tourism purposes.

6.2 Bhoj Wetland Project, Bhopal

Bhojtal, a large man-made lake bordering the city of Bhopal (Madhya Pradesh state, central India), is important for the city's water supply, connoted the lifeline of the city. consists of two man-made lakes, the Upper Lake and the Lower Lake. The Upper Lake has a surface area of 36 km2 and catchment area3 of 361 km2 while the Lower Lake has a surface area of 1.29 km2 and catchment area of 9.6 km2. The Upper Lake was an important source of water providing more than 40% of the drinking water demand for an estimated population of 1.8 million in Bhopal City. The Lower Lake was used mainly for recreation. Despite the dry though not arid and markedly seasonal climate, soil impermeability hampers infiltration into the complex geology underlying the Bhojtal catchment. Rural communities in the catchment are nonetheless high dependent on underlying aquifers.

6.2.1 Project overview

1. In 2002 Bhoj wetland declared as Ramsar site.
2. Time Period: 1995–2004
3. Authority: Government of Madhya Pradesh with financial support from the Japan Bank for International Cooperation (JBIC)
4. Target Area: Upper and Lower Lakes of Bhopal (Bhoj Wetlands)

Fig 4 Bhoj Lake Watershed Basin
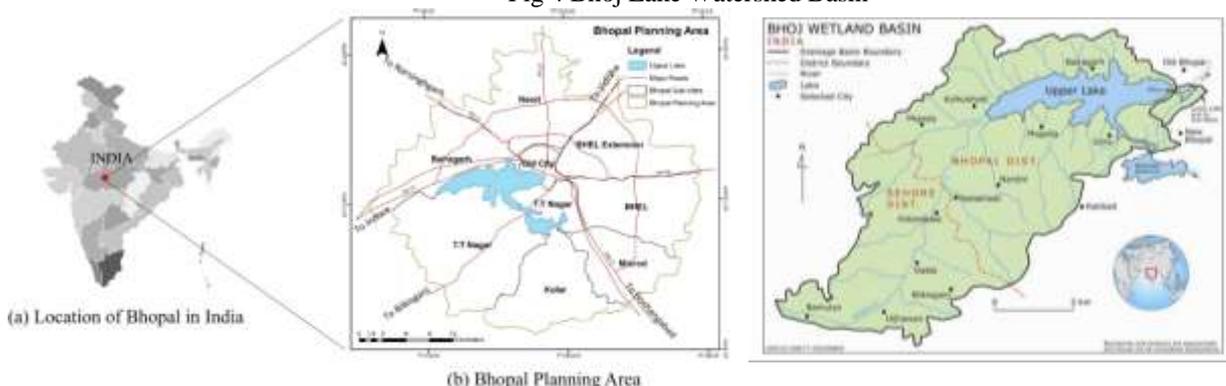
Source: https://link.springer.com/article/10.1007/s12524-023-01728-7, Report: Lake Bhopal Conservation and Management Project

The objective of the project was to promote improvement of overall environmental conditions of Bhoj Wetland and improvement of water quality of the Upper and Lower Lakes by implementing several pollution control and environmental conservation measures within the two lakes and their catchment, thereby contributing to the conservation of the lakes and improvement of overall health and sanitary conditions of the local people.

6.2.2 Issues
- Pollution from untreated sewage and industrial effluents.
- Loss of water holding capacity due to siltation and encroachment.
- Eutrophication caused by nutrient enrichment, leading to algal blooms and biodiversity loss.
- Unauthorized construction in the lake's catchment area.
- The lakes provided water for drinking, agriculture, and recreation, making their degradation a public concern.
- The vegetative cover of Bhopal declined from 92% in 1977 to 21% in 2014, with further predicted declines to 11% by 2018

Fig 5 Pictorial Summary of Bhoj Wetland Project

Source:

https://www.sciencedirect.com/science/article/abs/pii/S0048969720315746

6.2.3 Mitigation strategies
- Installation of water oxygenation systems, Weed removal, aquaculture and Dredging and desilting of lakes for water quality improvement
- Deepening and widening of the spill channel
- Fringe area protection by Delineating buffer area (demarcated as 'No Construction Zone'); Upper Lake: 50m from the Full Tank Level (FTL); Lower Lake: 33m from FTL
- The promenade is developed as a recreational site. Permitted activities in these areas include agriculture and grazing
- Buffer plantation areas having Plant species are tolerant to flooding and drought condition, and have medicinal properties created in along the western, northern and southern fringe of the upper lake.
- Extensive plantation in the immediate catchment area to control soil erosion to filter pollutants and reduce stormwater runoff.
- Land is developed as a buffer zone with gardens and parks.
- Sewage treatment systems and solid waste management systems build to prevent pollution

6.2.4 Impacts
- Enhanced water quality in the lakes.
- Better biodiversity preservation with restoration of aquatic habitats.
- Increased community awareness about lake conservation.
- Integration of scientific studies into policy decisions for long-term sustainability.
- Urban cooling and climate regulation by restoring green buffers.
- Revival of fishing and eco-tourism supported local livelihoods.
- Improved public health due to reduced waterborne diseases.

6.3 Hoeksche Waard And Room For The River, The Netherlands
The Room for the River program in the Netherlands, launched in 2006, is a nature-based approach to flood management. It aims to reduce river flooding due to climate change, sea-level rise, and urbanization. Over 30 projects have been completed, including the Hoeksche Waard area, which demonstrates how flood-prone areas can be transformed to accommodate water safely while supporting biodiversity and human use.

Location: Netherlands, Europe
Area: 325.8 sqkm
Population: 4 million approx.
Agency: funded by the Dutch government, 19 partners including the provinces,
   municipalities, regional water authorities
Time Period: 2006-2015
No. Of Projects: 30 across country

6.3.1 Concept

The Room for the River program is based on the concept of Blue-Green Infrastructure (BGI), which combines natural water management with green spaces to create multifunctional landscapes. Instead of traditional flood defenses like high concrete dikes, the program aimed to work with nature, using floodplains, wetlands, vegetated embankments, and side channels to absorb, retain, and safely redirect floodwaters.

Fig 6 Conceptual Room for The River Strategies
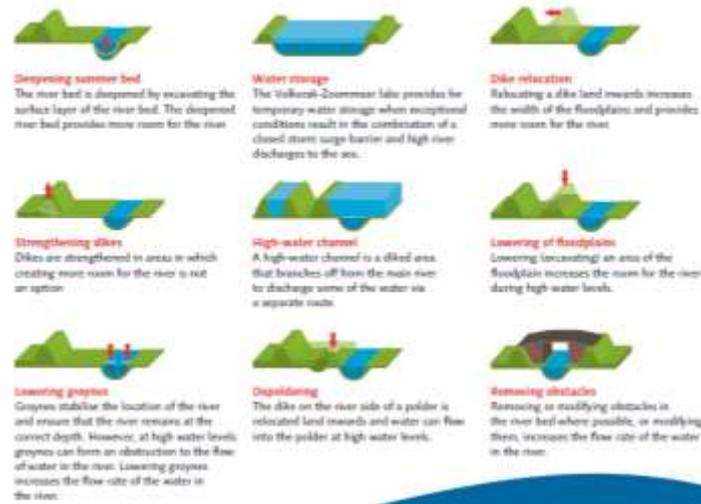
Source: https://www.researchgate.net/figure/Nine-approaches-of-river-restoration-by-reconstruction-of-the-floodplains-and-the-river_fig1_303669431

6.3.2 Example - Nijmegen

- Widening river channels and expanding floodplains to hold more water during high-flow events.
- Creating secondary channels to divert floodwaters away from urban centers.
- Introducing green embankments and restoring wetlands, which act as natural sponges and support local biodiversity.
- Designating controlled flood areas in agricultural lands to temporarily store excess water during extreme weather events

The 'Room for the River' plan at Nijmegen. The green line indicates the current line of the protective dike. The red line shows the position of the proposed relocated portion of dike. In the bottom image, the new river channel is shown in blue and the new island in yellow/green. The white arrows represent the bridge connections planned for the island

Fig 7 Nigmegen River Widening
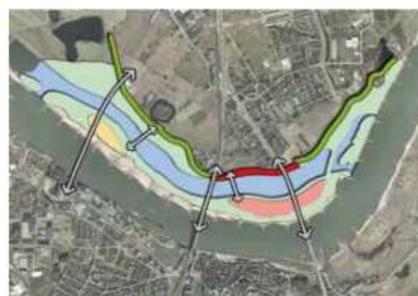
Source: https://www.baca.uk.com/nijmegen.html, https://www.preventionweb.net/files/workspace/7935_casestudy6.pdf

6.3.3 Project goal

1. The Room for the River program was launched to reduce flood risks along the Dutch rivers Rhine, Meuse, Waal, and IJssel by allowing rivers to flow more freely
2. Manage higher water levels across four rivers and prevent flooding in cities along the rivers, improve river retention capacity during flood events.
3. Room for the River approach is to restore the river's natural flood plain.

Hoeksche Waard's Role: Part of this broader initiative, Hoeksche Waard aimed to manage water levels through managing water levels to protect crops, improving soil health with buffer zones, and enhancing biodiversity for natural pest control, demonstrating BGI's benefits for rural, agricultural areas.

6.3.4 Issues addressed

- Flood risks
- Ecological Degradation
- Climate change adaptation
- Public perception of water management

6.3.5 Mitigation strategies

- Floodplain Expansion and Dike Relocation
- Wetland Restoration and Natural Flood Retention
- Controlled Overflow Zones
- Public Parks and Recreation Spaces
- National level coordination and adaptive policy framework

6.3.6   Impacts

Environmental Impacts

The project aims to reduce flood risks by creating more river space, benefiting around 4 million people near rivers. It also boosts biodiversity by restoring wetlands and floodplains, providing habitats for native flora and fauna. Additionally, it improves water quality through natural filtration processes.

Socio-Economic Impacts

The flood mitigation measures improved community safety by reducing flood risks for residents and businesses in flood-prone areas, while also generating economic benefits through new recreational areas and eco-tourism activities, but also posed challenges for affected individuals.

Global Impacts

The project established a global model for adaptive flood management strategies, integrating nature-based solutions into urban policies for sustainable and climate-resilient urban planning.

6.4   Grey To Green Initiative, Portland, US

The five-year 'Grey to Green' initiative facilitated the implementation of the Portland Watershed Management Plan (2005), with larger goals of protecting natural resources, restoring critical ecosystems, and implementing stormwater solutions integrating urban areas with the natural environment.

The initiative aimed to transition from traditional "gray" infrastructure, like pipes and drains, to "green" infrastructure that incorporates natural elements for water management. This shift aligns with Portland's commitment to environmental sustainability and resilience, enhancing the urban landscape through methods that integrate blue-green infrastructure (BGI).

Location: Portland, Oregon, US
Area: 375.5 sqkm
Population: 0.6 million approx.
Agency: Portland Bureau of Environmental Services (BES) with various stakeholders
Time Period: Launched in 2008

Projects: Green Streets, Tree Planting, Ecoroofs, Invasive Species Removal and Native Plant Restoration, Downspout Disconnection Program, Land Acquisition for Flood Management

Fig 8 Portland City

Source: https://www.researchgate.net/figure/Blue-green-infrastructure-for-stormwater-management-Tanner-Springs-Park-in-Portland_fig9_324695178

Why Portland Is A Green City?
- In Portland, rainwater now greens the city instead of polluting the rivers.
- Portland is America's clean energy hub and home to leading renewable companies.
- Portland has one of the lowest-carbon transportation networks in the US

6.4.1 Concept

Portland's strategy emphasized the installation of bioswales, green roofs, rain gardens, and other green infrastructure systems across the city. These green spaces capture, filter, and slow down stormwater runoff before it enters the city's sewer system, reducing the risk of overflow during heavy rain.

1. Bioswales And Rain Gardens: component of green streets designed to capture and infiltrate stormwater runoff from streets and other impermeable surfaces. Can transform awkward street intersections into safe pedestrian crossings
2. Green Streets: transform impervious street surfaces into landscaped green spaces that capture stormwater runoff and let water soak into the ground as plants and soil filter pollutants.
3. Eco Roofs: Incentives and policies encouraged the installation of green roofs on public and private buildings, lightweight, thermal insulation, reduce runoff, urban wildlife habitat. Constructed 398 eco-roofs covering an area greater than 11 acres.
4. Tree Planting: 30,000 planted street and yard trees capable of capturing 18million gallons of stormwater annually, 867 new street planters added. A city-wide tree planting effort to increase canopy cover, which intercepts rainfall and provides shading.
5. Rainwater Tank System: rain catchment system for roof rainwater used to filter and store rainwater.
6. Invasive Species Removal And Native Plant Restoration: 7,400 acres of land treated for invasive plant species. The city worked on removing invasive plant species from urban green spaces and replanting native vegetation to restore local biodiversity.
7. Land Acquisition For Flood Management: 406 acres of natural land parcels acquired, and indigenous vegetation restored on up to 4,100 acres in consultation with private and public property owners. acquired land in flood-prone areas to restore natural floodplains and wetland areas.
8. Downspout Disconnection Program: This program encouraged property owners to disconnect their downspouts from the sewer system, redirecting stormwater into rain gardens or other infiltration areas.

Fig 9 Concepts
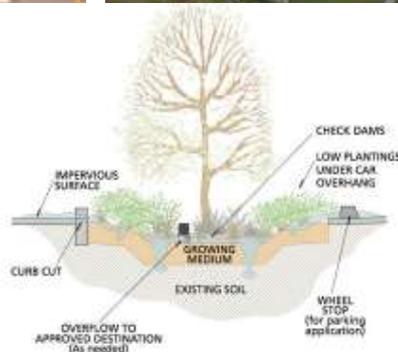
Source: Google images

6.4.2 Issues addressed
Stormwater Management
Water Quality
Urban Heat Island Effect
Biodiversity Loss

Fig 10 Floodplain Restoration Project strategy

Source: https://us.nextdoor.com/agency-post/or/portland/bureau-of-environmental-services/west-lents-floodplain-restoration-project-update-july-3-2024-correction-344803499/

6.4.3 Mitigation strategies
Expansion of Green Infrastructure
Green Roof Incentives
Community Tree Planting Programs
Public Engagement and Education
Performance Monitoring

Fig 11 Rainwater Harvesting System

Source: https://www.slideshare.net/slideshow/portland-oregon-48432553/48432553
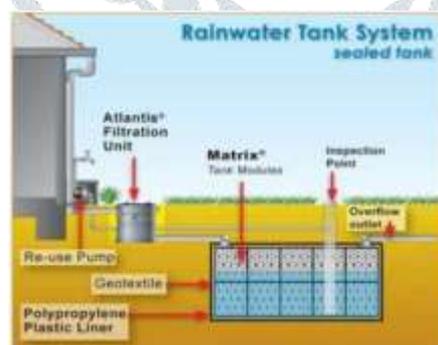
6.4.4 Impacts
Environmental Impacts
The project focuses on stormwater management, habitat restoration, and urban heat island mitigation through bioswales, rain gardens, eco-roofs, native vegetation restoration, and tree planting, aiming to divert over 76 million gallons of stormwater runoff annually.

Socio-Economic Impacts
Green infrastructure enhances community well-being by providing access to green spaces and improved recreational opportunities. It reduces stormwater management costs through natural filtration and water absorption, and creates jobs in urban forestry, construction, and maintenance.

Global impact
Portland's innovative designs and policy innovation have established it as a global leader in sustainable urban planning, enhancing the integration of existing infrastructure with a hybrid model**.**

6.5 Case Study Comparative Analysis

Table 3 Case Study Comparative Analysis

CASE STUDY	AUTHORITY	SCHEME/POLICY	PROGRESS	SCALE	ISSUES	STRATEGIES	FINDING
KAHN RIVERFRONT DEVELOPMENT, INDORE	Indore municipal corporation and Indore smart city	Smart Cities Mission and AMRUT	ONGOING	local area, city level	Pollution and Industrial Discharges Encroachment and Habitat Loss Urban Disaster Vulnerability Impervious Infrastructure Challenges Health and Biodiversity Risks	CETP Installation Rainwater Harvesting Outfall Trapping at source Floodplain Plantation Solid Waste Treatment and planned disposal	BGI improves river health, enhances environmental sustainability, and promotes community engagement through recreational spaces, but concerns arise about long-term sustainability due to urban growth's focus on gray infrastructure.
BHOJ WETLAND PROJECT, BHOPAL	Government of Madhya Pradesh	Wetland Conservation Program UNDER GOI	COMPLETED	local area, city level	Untreated Sewage and Effluents Reduced Water Holding Capacity Eutrophication and Water Degradation Unauthorized Construction Growth Groundwater Depletion and Decline	Spill Channel Widening Buffer Zone Delineation Flood-Tolerant Planting Park and Garden Buffers Sewage Treatment Systems	Improved water quality, catchment restoration, and groundwater recharge have reduced pollution and improved livability in cities, but wetland challenges persist due to urban population growth, improper maintenance, and coordination issues.
HOEKSCHE WAARD AND ROOM FOR THE RIVER, THE NETHERLANDS	funded by the Dutch government, 19 partners including the provinces,municipalities, regional water authorities	Room for the River program	completed	regional level	Frequent floods Ecological and Habitat Preservation Climate Adaptation Water Management Improvements Community Safety and Livelihoods	Floodplain Expansion and Dike Relocation Interconnected Irrigation Waterways Green Embankments Restoration Soil Health with Buffers Natural Pest Control	BGI protects farmlands, enhances biodiversity, coexists with urban areas, and improves climate resilience by restoring natural river dynamics.
GREY TO GREEN INITIATIVE, PORTLAND, US	Portland Bureau of Environmental Services (BES) with various stakeholders	Portland Watershed Management Plan (2005)	completed	city level	Stormwater and Water Quality Management Urban Heat Island Biodiversity and Ecosystem Protection Aging Infrastructure Challenges Adapting to Weather Changes	Tree Plantation and Invasive Species Removal Flood Management Land Acquisition Bioswales and Rain Gardens Renewable Energy Transition	demonstrated the efficacy of nature-based solutions, urban areas can serve as ecological havens., Investment in green infrastructure proved cost-effective compared to upgrading traditional grey infrastructure, collaborative urban planning and regulatory measures

Source: Compiled by Author

7 Case Study- Inferences

1. The strategies implemented in the Khan Riverfront Project demonstrate potential for replication in other medium-sized cities facing similar environmental challenges.
2. The use of natural processes for wastewater treatment and habitat restoration proves cost-effective and environmentally sustainable in the case of Bhoj Wetland Project. Measures like desilting, catchment treatment, and wetland buffer creation demonstrated the potential of holistic water management in preserving aquatic ecosystems.
3. The Hoeksche Waard case highlights the significance of blue-green infrastructure in safeguarding farmers' interests, a crucial aspect to be explored in India, where agricultural land is abundant. This also presents an opportunity to develop small and medium towns that have an abundance of agricultural land.
4. The Portland effort emphasizes the value of targeted retrofitting and sustainable benefits. It recommends a thorough inventory of blue-green infrastructure components that may prove valuable in urban India that can be climatically separated for optimal viability and lower maintenance costs. Portland's approach has inspired similar nature-based solution initiatives as it exemplifies a replicable model.
5. The projects show how hybrid approaches—combining grey infrastructure upgrades with nature-based solutions—can be leveraged to achieve sustainable urban development goals.
6. Benefits that can be achieved—health; energy and carbon sequestration(process of capturing CO2) and community livability.

7.1 Critical analysis of the case studies based on the parameters

Critical analysis of the case studies based on the parameters identified from the literature study. The table below shows whether these parameters were addressed and how

Table 4 Case Study Analysis Based on Parameters

Parameter	Bhoj Wetland Project	Gray to Green Initiative, Portland	Room for the River, Netherlands
Sustainable Urban Planning	Addressed partially through conservation efforts but limited urban integration. Focused on wetland ecosystems.	Strongly addressed by incorporating green spaces, ecological restoration, and stormwater management.	Addressed comprehensively with large-scale river management projects improving resilience.
Integration of Blue and Green	Partially addressed by restoring wetland areas and vegetation around the lake.	Extensively integrated through bioswales, green streets, and tree planting.	Fully integrated by combining wetlands, dike relocation, and buffer zones for flood management.
Integration with Gray Infrastructure	Minimal integration; focus remained on ecological conservation rather than infrastructural adaptation.	Strongly emphasized integrating nature-based solutions with gray infrastructure like storm drains.	Balanced integration by adapting gray infrastructure with dike and waterway reconfigurations.
Nature-Based Solutions	Addressed through wetland restoration and vegetation; limited innovation.	Core principle with extensive use of natural stormwater systems and habitat restoration.	Fully addressed by restoring floodplains, wetlands, and natural water retention systems.
Stakeholder Participation	Limited stakeholder involvement; primarily government-driven project with moderate community engagement.	Strong community participation with public-private collaborations and resident input.	High stakeholder participation with farmers, local communities, and regional authorities.
Context-Specific Planning	Addressed; focused on lake-specific issues like eutrophication and biodiversity loss.	Addressed; tailored to urban-specific challenges like UHI and water quality in Portland.	Strongly addressed; site-specific flood and land-use planning for the Netherlands' needs.
Urban Heat Island (UHI)	Not directly addressed as the focus was on aquatic ecosystems and water quality.	Directly addressed through increased urban greenery and tree cover.	Indirectly addressed by improving green spaces and floodplain ecosystems.
Stormwater Management	Addressed through wetland hydrology restoration and reduction of runoff pollution.	A primary focus with rain gardens, bioswales, and green roofs mitigating runoff.	Addressed by creating buffer zones and flood retention areas.
Policy Integration	Addressed under environmental policies like Ramsar Convention but lacked comprehensive urban policy integration.	Strong integration with urban planning policies and environmental guidelines.	Fully integrated into national and regional flood management policies like the Delta Plan.

Source: Compiled by Author

8 Tools And Strategies

8.1 Nature – Based Solutions

1. Green Roofs and Green Walls: Green roofs and walls involve the installation of vegetation on building rooftops and walls, which helps manage stormwater, reduce urban heat, enhance aesthetics, and improve air quality. They provide insulation and can enhance biodiversity by creating habitats for various species

2. Rain Gardens: Rain gardens are designed to capture and absorb rainwater runoff from impervious surfaces. They consist of native plants and soil that filter pollutants and promote infiltration, reducing the volume of stormwater entering drainage systems. Eg. Sponge city concept

3. Bioswales: Bioswales are landscape elements designed to concentrate or remove debris and pollution out of surface runoff water. They are typically vegetated, shallow, and can effectively manage stormwater while enhancing the aesthetic value of urban areas

4. Permeable Pavements: Permeable or porous pavements allow water to infiltrate through the surface, reducing runoff and promoting groundwater recharge. This solution helps mitigate flooding and can be used in parking lots, walkways, and streets

5. Wetlands and Ponds: Constructed wetlands and ponds can be integrated into urban landscapes to treat stormwater, provide habitat for wildlife, and enhance recreational opportunities. They play a crucial role in water quality improvement and flood control

6. Tree Canopy and Urban Forestry: Increasing tree canopy cover in urban areas can help mitigate the urban heat island effect, improve air quality, and enhance stormwater management through increased evapotranspiration and promote rainfall. Eg. Sponge city concept

7. Water Squares: Water squares are multifunctional public spaces that can temporarily store rainwater during heavy rainfall events. They serve as recreational areas during dry periods and help manage stormwater effectively

8. Infiltration Trenches: These are excavated trenches filled with gravel or other permeable materials that allow stormwater to infiltrate into the ground, reducing runoff and promoting groundwater recharge.

8.2 Identified Tools

1. Integrated Planning Frameworks: Establishing comprehensive planning frameworks that incorporate both blue and green elements from the early stages of urban development is essential to ensures that water bodies and vegetation are interdependent and provide environmental and social benefits.
2. Multi-Functional and integrated Design Approaches: Designing BGI to serve multiple functions—such as stormwater management, biodiversity enhancement, and recreational spaces—can maximize their benefits. This includes integrating features like green roofs, rain gardens, and permeable pavements
3. Monitoring and Evaluation Tools: Implementing monitoring frameworks for BGI in terms of hydrological and ecological benefits is crucial. Tools that provide real-time data can help in adaptive management and decision-making. For example: water quality checks or moisture control meters
4. Cost-Benefit Analysis Frameworks: Conducting thorough cost-benefit analyses to evaluate the economic viability of BGI projects can help secure funding and support. This includes assessing the long-term benefits of BGI in terms of health, environmental quality, and economic growth.
5. Digital Data Governance and Inventory Systems: Creating a digital inventory of existing infrastructure and BGI elements can facilitate better planning and integration. This tool can help identify gaps and opportunities for growing needs and population
6. Policy and Regulatory Support: Developing policies and regulations that encourage the integration of BGI into urban planning promoting comprehensive strategy planning. This includes establishing guidelines for the design and implementation of BGI projects
7. Interdisciplinary Collaboration: Promoting collaboration among various sectors (e.g., urban planning, environmental management, and public health) can enhance the effectiveness of BGI initiatives.
8. Partnering with international agencies: Taking technical support, financial assistance and learnings from places which have successfully implemented BGI projects

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3.1Population and Sample

KSE-100 index is an index of 100 companies selected from 580 companies on the basis of sector leading and market capitalization. It represents almost 80% weight of the total market capitalization of KSE. It reflects different sector company's performance and productivity. It is the performance indicator or benchmark of all listed companies of KSE. So it can be regarded as universe of the study.Non-financial firms listed at KSE-100 Index (74 companies according to the page of KSE visited on 20.5.2015) are treated as universe of the study and the study have selected sample from these companies.

The study comprised of non-financial companies listed at KSE-100 Index and 30 actively traded companies are selected on the bases of market capitalization.And 2015 is taken as base year for KSE-100 index.

3.2 Data and Sources of Data

For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE - 100 Index is taken from yahoo finance.

3.3 Theoretical framework

Variables of the study contains dependent and independent variable. The study used pre-specified method for the selection ofvariables. The study used the Stock returns are as dependent variable. From the share price of the firm the Stock returns are calculated. Rate of a stock salable at stock market is known as stock price.

Systematic risk is the only independent variable for the CAPM and inflation, interest rate, oil prices and exchange rate are the independent variables for APT model.

Consumer Price Index (CPI) is used as a proxy in this study for inflation rate. CPI is a wide basic measure to computeusualvariation in prices of goods and services throughout a particular time period. It is assumed that arise in inflation is inversely associated to security prices because Inflation is at lastturned into nominal interest rate andchange in nominal interest rates caused change in discount rate so discount rate increase due to increase in inflation rate and increase in discount rateleads todecreasethe cash flow's present value (Jecheche, 2010). The purchasing power of money decreased due to inflation, and due to which the investors demand high rate of return, and the prices decreased with increase in required rate of return (Iqbal et al, 2010).

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I. RESEARCH METHODOLOGY

The methodology section outline the plan and method that how the study is conducted. This includes Universe of the study, sample of the study,Data and Sources of Data, study's variables and analytical framework. The detailsare as follows;

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Exchange rate is a rate at which one currency exchanged with another currency. Nominal effective exchange rate (Pak Rupee/U.S.D) is taken in this study.This is assumed that decrease in the home currency is inverselyassociated to share prices (Jecheche,2010). Pan et al. (2007) studied exchange rate and its dynamic relationship with share prices in seven East Asian Countries and concludethat relationshipof exchange rate and share prices varies across economies of different countries. So there may be both possibility of either exchange rate directly or inverselyrelated with stock prices.Oil prices are positively related with share prices if oil prices increase stock prices also increase (Iqbal et al, 1012).Ataullah (2001) suggested that oil prices cause positive change in the movement of stock prices. The oil price has no significant effect on stock prices (Dash & Rishika, 2011).Six month T-bills rate is used as proxy of interest rate. As investors arevery sensitive about profit and where the signals turn into red they definitely sell the shares. And this sensitivity of the investors towards profit effects the relationship of the stock prices and interest rate, so the more volatility will be there in the market if the behaviors of the investors are more sensitive. Plethora (2002)has tested interest rate sensitivity to stock market returns, and concluded an inverse relationship between interest rate and stock returns. Nguyen (2010) studies Thailand market and found thatInterest rate has aninverse relationship with stock prices.

KSE-100 index is used as proxy of market risk. KSE-100 index contains top 100 firms which are selected on the bases of their market capitalization. Beta is the measure of systematic risk and has alinear relationship with return (Horn, 1993). High risk is associated with high return (Basu, 1977, Reiganum, 1981 and Gibbons, 1982). Fama and MacBeth (1973) suggested the existence of a significant linear positive relation between realized return and systematic risk as measured by β. But on the other side some empirical results showed that high risk is not associated with high return (Michailidis et al. 2006, Hanif, 2009). Mollah and Jamil (2003) suggested thatrisk-return relationship is notlinear perhaps due to high volatility.

3.4Statistical tools and econometric models

This section elaborates the proper statistical/econometric/financial models which are being used to forward the study from data towards inferences. The detail of methodology is given as follows.

3.4.1 Descriptive Statistics

Descriptive Statics has been used to find the maximum, minimum, standard deviation, mean and normally distribution of the data of all the variables of the study. Normal distribution of data shows the sensitivity of the variables towards the periodic changes and speculation. When the data is not normally distributed it means that the data is sensitive towards periodic changes and speculations which create the chances of arbitrage and the investors have the chance to earn above the normal profit. But the assumption of the APT is that there should not be arbitrage in the market and the investors can earn only normal profit. Jarque bera test is used to test the normality of data.

3.4.2 Fama-Mcbeth two pass regression

After the test statistics the methodology is following the next step in order to test the asset pricing models. When testing asset pricing models related to risk premium on asset to their betas, the primary question of interest is whether the beta risk of particular factor is priced. Fama and McBeth(1973)develop a two pass methodology in which the beta of each asset with respect to a factor is estimated in a first pass time series regression and estimated betas are then used in second pass cross sectional regression to estimate the risk premium of the factor. According to Blum (1968) testing two-parameter models immediately presents an unavoidable errors-in-the variables problem.It is important to note that portfolios (rather than individual assets) are used for the reason of making the analysis statistically feasible.Fama McBeth regression is used to attenuate the problem of errors-in-variables (EIV) for two parameter models (Campbell, Lo and MacKinlay, 1997).If the errors are in the β (beta)of

individual security are not perfectly positively correlated, the β of portfolios can be much more precise estimates of the true β (Blum, 1968).

The study follow Fama and McBeth two pass regressionto test these asset pricing models.The Durbin Watson is used to check serial correlation and measures the linear association between adjacent residuals from a regression model. If there is no serial correlation, the DW statistic will be around 2. The DW statistic will fall if there is positive serial correlation (in worst case, it will be near zero). If there is a negative correlation, thestatistic will lie somewhere between 2 and 4. Usually the limit for non-serial correlation is considered to be DW is from 1.8 to 2.2. A very strong positive serial correlation is considered at DW lower than 1.5 (Richardson and smith, 1993).

According to Richardson and smith(1993) to make the model more effective and efficient the selection criteria for the shares in the period are: Shares with no missing values in the period, Shares with adjusted $R^2 < 0$ or F significant (p-value) >0.05of the first pass regression of the excess returns on the market risk premium are excluded. And Shares are grouped by alphabetic order into group of 30 individual securities (Roll and Ross, 1980).

3.4.2.1 Model for CAPM
In first pass the linear regression is used to estimate beta which is the systematic risk.
$$R_i - R_f = (R_m - R_f)\beta \qquad (3.1)$$
Where $R_i$isMonthly return of thesecurity, R_f isMonthly risk free rate, R_m isMonthly return of market and βis systematic risk (market risk).

The excess returns $R_i - R_f$ of each security is estimated from a time series share prices of KSE-100 index listed shares for each period under consideration. And for the same periodthe market Premium $R_m - R_f$also estimated. After that regress the excess returns $R_i - R_f$ on the market premium $R_m - R_f$to find the beta coefficient (systematic risk).
Then a cross sectional regression or second pass regression is used on average excess returns of the shares and estimated betas.
$$\hat{R}_i = \gamma_0 + \gamma_1\beta_1 + \epsilon \qquad (3.2)$$
Where λ_0= intercept, $\hat{R}_I$is average excess returns of security i,$\beta_I$isestimated be coefficient of security I and ϵ is error term.

3.4.2.2 Model for APT
In first pass the betas coefficients are computed by using regression.
$$R_i - R_f = \beta_i f_1 + \beta_{i2} f_2 + \beta_{i3} f_3 + \beta_{i4} f_4 + \epsilon \qquad (3.3)$$
Where Ri is the monthly return of stock i,R_f is risk free rate, β_i is the sensitivity of stock i with factors and ϵ is the error term.
Then a cross sectional regression or second pass regression is used on average excess returns of the shares on the factor scores.
$$\hat{R} = \gamma_0 + \gamma_1\beta_1 + \gamma_2\beta_2 + \gamma_3\beta_3 + \gamma_4\beta_4 + \epsilon_i \qquad (3.4)$$
Where$\hat{R}$ is average monthly excess return of stock I, λ = risk premium, β_1 to β_4 are the factors scores and ϵ_i is the error term.

3.4.3 Comparison of the Models
The next step of the study is to compare these competing models to evaluate that which one of these models is more supported by data.This study follows the methods used by Chen (1983), the Davidson and Mackinnon equation (1981) and the posterior odds ratio (Zellner, 1979) for comparison of these Models.

3.4.3.1 Davidson and MacKinnon Equation
CAPM is considered the particular or strictly case of APT. These two models are non-nested because by imposing a set of linear restrictions on the parameters the APT cannot be reduced to CAPM. In other words the models do not have any common variable. Davidson and MacKinnon (1981) suggested the method to compare non-nested models. The study used the Davidson and MacKinnon equation (1981) to compare CAPM and APT.
This equation is as follows;
$$R_i = \alpha R_{APT} + (1 - \alpha)R_{CAPM} + e_i \qquad (3.5)$$
WhereR_i= the average monthly excess returns of the stock i, R_{APT}= expected excess returns estimated by APT, R_{CAPM}= expected excess returns estimated by CAPM and α measure the effectiveness of the models. The APT is the accurate model to forecast the returns of the stocks as compare to CAPMif α is close to 1.

3.4.3.2 Posterior Odds Ratio
A standard assumption in theoretical and empirical research in finance is that relevant variables (e.g stock returns) have multivariate normal distributions (Richardson and smith, 1993). Given the assumptionthat the residuals of the cross-sectional regression of the CAPM and the APT satisfy the IID (Independently and identically distribution) multivariate normal assumption (Campbell, Lo and MacKinlay, 1997), it is possible to calculate the posterior odds ratio between the two models.In general the posterior odds ratio is a more formal technique as compare to DM equation and has sounder theoretical grounds (Aggelidis and Maditinos, 2006).
The second comparison is done using posterior odd radio. The formula for posterior odds is given by Zellner (1979) in favor of model 0 over model 1.
The formula has the following form;

$$R = [ESS_0/ESS_1]^{N/2} N^{K_0 - K_1/2} \qquad (3.6)$$

WhereESS_0iserror sum of squares of APT, ESS_1iserror sum of squares of CAPM, Nisnumber of observations, $K_0$is number of independent variables of the APT and K_1 isnumber of independent variables of the CAPM.As according to the ratio when;
R> 1 means CAPM is more strongly supported by data under consideration than APT.

R < 1 means APT is more strongly supported by data under consideration than CAPM.

IV. RESULTS AND DISCUSSION

4.1 Results of Descriptive Statics of Study Variables
Table 4.1: Descriptive Statics

Variable	Minimum	Maximum	Mean	Std. Deviation	Jarque-Bera test	Sig
KSE-100 Index	-0.11	0.14	0.020	0.047	5.558	0.062
Inflation	-0.01	0.02	0.007	0.008	1.345	0.510
Exchange rate	-0.07	0.04	0.003	0.013	1.517	0.467
Oil Prices	-0.24	0.11	0.041	0.060	2.474	0.290
Interest rate	-0.13	0.05	0.047	0.029	1.745	0.418

Table 4.1 displayed mean, standard deviation, maximum minimum and jarque-bera test and its p value of the macroeconomic variables of the study. The descriptive statistics indicated that the mean values of variables (index, INF, EX, OilP and INT) were 0.020, 0.007, 0.003, 0.041 and 0.047 respectively. The maximum values of the variables between the study periods were 0.14, 0.02, 0.04, 0.41, 0.11 and 0.05 for the KSE- 100 Index, inflation, exchange rate, oil prices and interest rate.

The standard deviations for each variable indicated that data were widely spread around their respective means.

Column 6 in table 4.1 shows jarque bera test which is used to checkthe normality of data. The hypotheses of the normal distribution are given;

H_0 : The data is normally distributed.

H_1 : The data is not normally distributed.

Table 4.1 shows that at 5 % level of confidence, the null hypothesis of normality cannot be rejected. KSE-100 index and macroeconomic variables inflation, exchange rate, oil prices and interest rate are normally distributed.

The descriptive statistics from Table 4.1 showed that the values were normally distributed about their mean and variance. This indicated that aggregate stock prices on the KSE and the macroeconomic factors, inflation rate, oil prices, exchange rate, and interest rate are all not too much sensitive to periodic changes and speculation. To interpret, this study found that an individual investor could not earn higher rate of profit from the KSE. Additionally, individual investors and corporations could not earn higher profits and interest rates from the economy and foreign companies could not earn considerably higher returns in terms of exchange rate. The investor could only earn a normal profit from KSE.

FiguresandTables

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Table 1 Table Type Styles

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V. ACKNOWLEDGMENT

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