PLANNING INTERVENTOINS TO DEVELOP BLUE GREEN INFRASTRUCTURE ON THE VERGE OF WATER SENSITIVITY:
A CASE OF LUCKNOW, UTTAR PRADESH

Thesis submitted in partial fulfillment of the requirements forthe award of the degree of

MASTER IN URBAN AND REGIONAL PLANNING

By

Ar. Paritosh Kumar Yadav

1210106011

Under the Guidance of
(Mrs. Shalini Diwakar)

SCHOOL OF ARCHITECTURE & PLANNING,
BABU BANARASI DAS UNIVERSITY
FAIZABAD ROAD, LUCKNOW, U.P. - 226028

2022-2023

BABU BANARASI DAS UNIVERSITY, LUCKNOW

Report of MURP Thesis/Dissertation Evaluation

Name of Student: PARITOSH KUMAR YADAV Roll No. 1210106011

Department: School of Planning & Architecture_

Thesis Title: PLANNING INTERVENTION TO DEVELOP BLUE GREEN INFRASTRUCTURE ON THE VERGE OF WATER SENSITIVITY CASE OF LUCKNOW.

Thesis Supervisor(s): Mrs. SHALINI DIWAKAR

Remarks: Satisfactory/Not Satisfactory (in case of not satisfactory give comments)

____

____

____

________________________	________________________
Sign of Thesis Supervisor	Sign of External Examiner
________________________	________________________
Sign of Head of Department	Sign of Dean of School

____

Convener

BABU BANARASI DAS UNIVERSITY, LUCKNOW

CERTIFICATE OF THESIS SUBMISSION FOR EVALUATION

(Submit in Duplicate)

1. Name : **Paritosh Kumar Yadav**

2. Enrollment No. : **12101060011**

3. Thesis title: **PLANNING INTERVENTION TO DEVELOP BLUE GREEN INFRASTRUCTURE.**

4. Degree for which the thesis is submitted: **Masters in Urban & Regional Planning**

5. Faculty of the University to which the thesis is submitted
School of Architecture and Planning

6. Thesis Preparation Guide was referred to for preparing the thesis. ☐ YES ☐ NO

7. Specifications regarding thesis format have been closely followed. ☐ YES ☐ NO

8. The contents of the thesis have been organized based on the guidelines. ☐ YES ☐ NO

9. The thesis has been prepared without resorting to plagiarism. ☐ YES ☐ NO

10. All sources used have been cited appropriately. ☐ YES ☐ NO

11. The thesis has not been submitted elsewhere for a degree. ☐ YES ☐ NO

12. Submitted 2 spiral bound copies plus one CD. ☐ YES ☐ NO

(Signature of the Candidate)
Name: PARITOSH KUMAR YADAV
Roll No: 1210106011

BABU BANARASI DAS UNIVERSITY, LUCKNOW

CERTIFICATE OF FINAL THESIS SUBMISSION

(To be submitted in duplicate)

1. Name : **Paritosh Kumar Yadav**

2. Enrollment No. : **12101060011**

3. Thesis title: **PLANNING INTERVENTION TO DEVELOP BLUE GREEN INFRASTRUCTURE.**

4. Degree for which the thesis is submitted: **Masters in Urban & Regional Planning**

5. School (of the University to which the thesis is submitted)
School of Architecture and Planning

6. Thesis Preparation Guide was referred to for preparing the thesis. ☐YES ☐NO

7. Specifications regarding thesis format have been closely followed. ☐YES ☐NO

8. The contents of the thesis have been organized based on the guidelines. ☐YES ☐NO

9. The thesis has been prepared without resorting to plagiarism. ☐YES ☐NO

10. All sources used have been cited appropriately. ☐YES ☐NO

11. The thesis has not been submitted elsewhere for a degree. ☐YES ☐NO

12. All the corrections have been incorporated. ☐YES ☐NO

13. Submitted 4 hard bound copies plus one CD.

(Signature(s) of the Supervisor(s))

Name(s): Mrs. Shalini Diwakar.

(Signature of the Candidate)

Name: Paritosh Kumar Yadav
Roll No 1210106011
Enrollment No.: 12101060011

Acknowledgment

Above all, I wish to express my sincere appreciation and thanks to my Guide Asst. Ms. Shalini Diwakar. For her continuous support over these 6 months, whose support has helped me a lot to complete this thesis. I am extremely grateful to Asst. Prof. Mr. Saurabh Verma for their reviews and for effective suggestion, ideas to complete this research. A special thankyou to all the School of Architecture, BBDU planning faculty for their enormous support and guidance.

I would like to thank every one of my colleagues, senior and friends, "Shishir Verma, Kirti Saxena, Ankur Sachan", for all the difficulties and funny moments at SAP, BBDU, Lucknow, being there to stand with me. Thanks to all of my BBDU, Lucknow friends for spending time with them all along the course. I don't have any worthy words to express my thanks, but my heart is still full of the favors that every person has received.

Ultimately, I would like to thank the Almighty God, the eternal authority who is clearly the one who has always driven me to work on the right direction of life. This Master's thesis project couldn't become a reality without his goodness. Next to him are members of my family, whom I am so deeply indebted to have brought up to this stage with love and encouragement.

Abstract

Urbanization, the most common and inevitable phenomenon for the economic development of a city and has its share of adverse effects too, one of which is urban flooding. According to the World Bank statistics in 2015, 32.7% of the population of India resides in urban areas. The residing population requires development of infrastructure which leads to the increased demand for land resulting in consequences such encroachment of land that is seldom known or used. Most often these lands are seasonal water bodies (wetlands) that have been dried up for a while. When these smaller acts of negligence occur in a city level, it experiences escalation in impervious surfaces in the natural drainage areas, resulting in urban flooding and various climatic hazards. A marsh is a type of a wetland, which is categorized under the palustrine type that is defined as the wetlands which is fed by inland water bodies and is populated predominantly by herbaceous vegetation. Although the marshlands are a unique type of ecosystem, they stand out to be easy alternatives for vacant lands since they are conventionally considered to be wastelands and most of the times the benefits they provide are disregarded. One of the important ecosystem service that a marshland provides is flood retention, i.e., it acts as a natural reservoir that stores the excessive flood water during the times of heavy run-off and releases the water that has been stored during dry seasons.

TABLE OF CONTENTS

DRAFT REPORT

CHAPTER 1 INTRODUCTION

1. Introduction:

Blue-green infrastructure refers to the integration of water management and other environmental features into the design of urban and suburban areas. It is a concept that has gained significant attention in recent years as a sustainable solution for addressing the complex challenges faced by cities and towns in managing water resources. The goal of blue-green infrastructure is to create more livable and sustainable communities by integrating the built and natural environments.

2. Need for study:

The importance of studying blue-green infrastructure lies in its ability to provide a range of benefits to urban and suburban communities. Blue-green infrastructure projects such as green roofs, rain gardens, permeable pavements, sponge areas and constructed wetlands can help to manage storm water and improve water quality. Additionally, these projects can reduce the heat island effect, improve air quality, and promote biodiversity.

As urbanization continues to increase, the demand for sustainable solutions that can manage the impacts of urbanization on the environment is becoming more pressing. Blue-green infrastructure offers a holistic approach to address these challenges, by not only managing water resources but also providing other benefits such as improved air quality, biodiversity, and recreational spaces.

The main concepts related to blue-green infrastructure include:

Green roofs, which are vegetated roofs that absorb and retain storm water and reduce the heat island effect.

Rain gardens, which are shallow depressions filled with plants and soil that can capture and filter stormwater, permeable pavements, which allow water to permeate through the surface and recharge the groundwater.

Constructed wetlands, which are man-made wetlands that can treat and clean storm water before it is discharged into natural water bodies.

Overall, blue-green infrastructure represents an innovative approach to addressing the challenges of urbanization and promoting sustainable development. Its ability to provide multiple benefits while managing water resources make it an important area of study.

3. Aim & Objective:

The aim is to analyze the need of integration of Blue Green Infrastructure with urban development to make cities future proof or hazard resilient.

Objectives

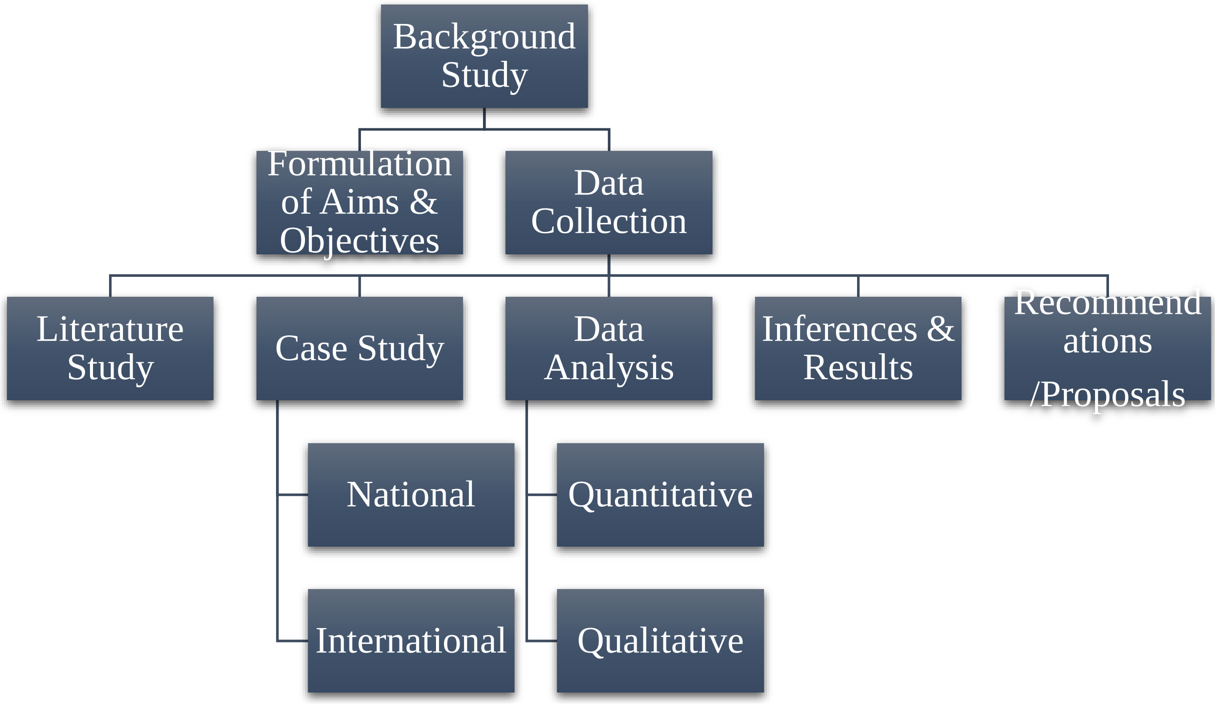
a) Understand the requirement and importance of BGI in urban context of Lucknow.

b) Integration of Blue Green Infrastructure approach with respect to latest government policies.

c) Find the public opinion and adaptive scale for to cater the environmental concerns using Blue Green Infrastructure strategies.

d) To plan and deliver at a local level while recognising that this will inevitably extend at times across administrative boundaries.

4. Methodology



CHAPTER 2 LITERATURE REVIEW

2.1 Urban Water Management Challenges in China

Since the 1980s, China has witnessed rapid urbanization, a sharp growth in urban population and a dramatic expansion of urban land. The rapid development of cities tends to bring serious water issues. Large areas of absorbable green space in growing cities have been converted to impermeablepavements. The urban stormwater drainage systems in Chinese cities are considered insufficient, as the construction of current drainage systems in some cities, like Beijing and Wuhan, can be traced back to the Qing Dynasty[1]. Those drainage systems are seriously degraded and cause severe water pollution in rivers, streams and other water bodies. It is also estimated that the drainage systems in half of all Chinese metropolises do not meet the national flood prevention standards.

Figure 1.1 Historical Flooding in Wuhan (KANG Dan, permissions from the Wuhan Urban and Rural Construction Bureau)

China is also particularly vulnerable to floods. It experienced 15 floods from the year 2004 to 2014[3]. Floods usually lead to severe property damage and loss of life, and according to statistics, up to 1% ofannual Gross Domestic Product (GDP) is washed away annually[4]. The extreme storm events are even increasing due to climate change, with more and more frequent flooding events. To resolve urban water issues and adapt to climate change, China has raised the urban water management challenges as a priority for national development, exploring shifting the paradigm from the conventional engineering-based approaches to a holistic and systematic nature-based model for urban water management.

2.2 Chinese Sponge City Programme

Inspired by concepts used worldwide, including "Low Impact Development" (the USA), "Water Sensitive Urban Design" (Australia), "Sustainable Urban Drainage Systems" (the UK) and "Low ImpactUrban Design & Development" (New Zealand), the "sponge city" concept was developed in China to reshape the relationship between people, water and the city. In 2013, Chinese President Xi Jinping pointed out that cities should be built to retain rainfall and make use of natural forces to accumulate,infiltrate and purify rainwater like a sponge in a new type of urbanization[6]. Since then, the concept of"sponge city" has gradually entered the public view.

In 2015, the State Council of China issued the Guideline on Promoting the Construction of Sponge Cities[7] (hereinafter called "National Guideline" for short), which would enable urban areas and infrastructure, like parks, streets and buildings, to "act like sponges". The sponge city concept refers to a way of urban management that allows cities to naturally absorb, store and purify rainwater to resolve waterlogging issues, prevent urban flooding, improve water storage and discharge capacity, enhance water quality, and alleviate heat island effects through nature-based and grey solutions.

According to the National Guideline, the sponge city program sets the targets at 20% of the urbanarea that should be constructed to meet the sponge city standards of absorbing and utilizing 70% of the rainfall in situ by 2020 and 80% of the urban area by 2030. To meet the targets, six measures - "infiltration, retention, storage, purification, utilization, and drainage" - are taken to minimize the impact of urban development and construction on the environment. The construction of sponge citiesshould emphasise conservation, restoration and rehabilitation of original urban ecosystems to build "resilience" for cities. Preserving rivers, lakes, wetlands, ponds and other aquatic ecosystems as well as forests and grasslands to the maximum extent possible and maintaining the natural hydrological characteristics are the basic requirements for sponge city construction. Three principles are pointed out in the National Guideline: adhere to the ecology and natural cycle; adhere to guiding anddeveloping through planning; and adhere to governmental guidance and social participation.

The municipal governments are suggested to follow the guideline and establish their sponge city work plan and standards. The construction of sponge cities shall be carried out in both new urban districts and old city districts in coordination with the renovation of dilapidated buildings and shantytowns.

Guided by the Ministry of Housing and Urban-Rural Development (MOHURD), the Ministry of Finance and the Ministry of Water Resources, the Sponge City pilot program selected 16 pilot cities in 2015, followed by another 14 pilot cities in 2016.

Figure 1.2 Pilot Cities in Chinese Sponge City Programme

2.3 National Guidance on Municipal Sponge City Plans

To promote the construction of sponge cities, in 2016, the MOHURD published the Temporary Provisions on Specialized Planning of Sponge City Programme[12] to guide municipal government and planning sectors on the compilation of sponge city plans. In accordance with the Provisions, the municipal sponge city specialized plan is the foundation of the sponge city construction programme and an important part of urban planning. The municipal sponge city plan is suggested to follow the principles in the National Guideline to minimize the impact of urban development on the natural environment.

The municipal sponge city plan can be formulated separately or with the urban comprehensive plan. The sponge city planning area should be, in principle, consistent with the city planning area (designated in the urban master plan by the municipal government). At the same time, the sponge city plan should adhere to the urban comprehensive plan, and should take account of the integrity of the rainfall catchment area and the ecological elements, such as mountains, water, forests, croplandsand lakes. While compiling or revising the urban master plan, the core index of sponge city programme

- volume capture ratio of annual rainfall - should be incorporated into the comprehensive plan.

In addition, the municipal urban and rural planning department should collaborate with other departments, including construction, municipal administration, gardening and water affairs departments to consolidate the municipal sponge city plan, ensuring the municipal specialized plans, like urban roads and green space plans, are consistent with the sponge city plan. After approval, the sponge city special plan is published by the municipal government. Relevant planning data and surveydata as requisite background materials, such as meteorological, hydrological, geological, and soil materials, should be collected prior to the compilation of the sponge city plan. In the process of compiling sponge city plans, listening to and accepting the opinions from relevant departments, experts and the public extensively is important.

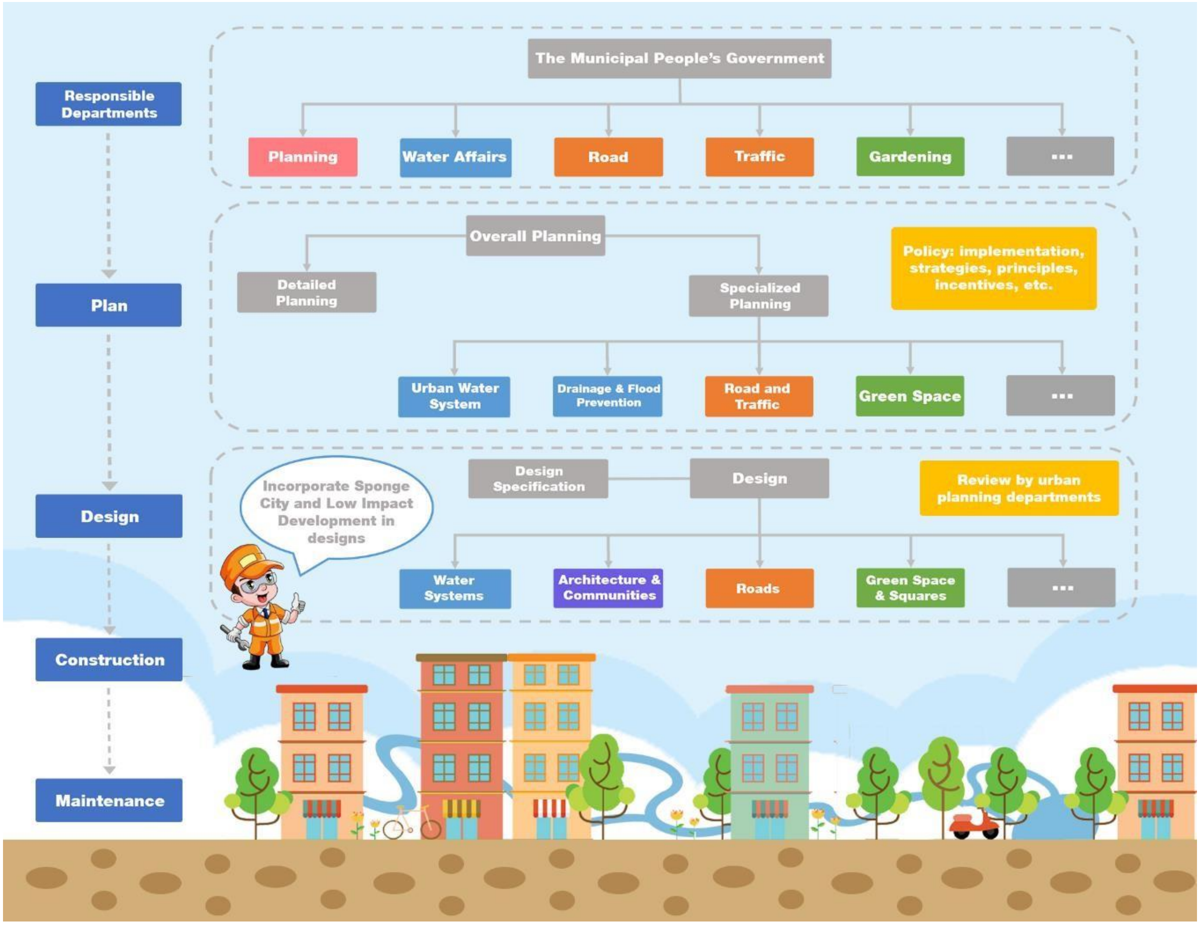


Figure 1.3 Coordinating Different Departments in the Municipal Sponge City Programmes

3. Overview of Wuhan Sponge City Programme

To start the initiative of sponge city construction, Chinese Sponge City Construction Programme selected 30 pilot cities in 2015 and 2016. Wuhan was among them. Municipal governments are suggested to follow the sponge city guiding package provided by the national government and establish their sponge city work plan and standards. The package is essential in the planning and design of sponge city projects, including the National Guideline, index systems[9,10], technical guides[13], and others.

3.1 Background and Primary Problems

Wuhan, the capital city of Hubei Province, is well-known as the "city of one hundred lakes" located in central China. Wuhan city occupies a total of 8494 km2 with 812km2 of built-up area. The abundant water resources and extensive water systems shape beautiful landscapes and nice city views and make the city liveable. The water systems, consisting of 165 rivers, 166 lakes, over one hundred water channels and hundreds of reservoirs, cover 25% of the entire municipal area. Two main rivers, the Yangtze River and

Han River, merge here on the floodplain. Wuhan is also one of the most populated metropolises in China with nearly 11 million residents, thus, ensuring a good urban living environment is critical.

Figure 2.1 East Lake, Wuhan, China (Stephen Fang / Unsplash)

However, water management and flood prevention in Wuhan is challenging. Predominantly due to its geographical location and unevenly distributed precipitation, Wuhan has suffered from waterlogging for years[15]. The built-up area of Wuhan is located in the low-lying area and the elevation of the urban area is usually lower than the flood level. The annual precipitation of Wuhan is 1257mm, with 70% of the rainfall falling in April to September. The flood season of the Yangtze River and its tributaries coincides with the rainstorm period, which restrains urban discharge capacity. In most times, the rainfall was pumped to the outer river by pumping stations during the long-lasting flood season.

On top of the waterlogging issues, water pollution caused by urbanisation also deteriorates the water management system. Sewage pipes and stormwater pipes are mixed and misconnected, resulting in incomplete sewage collection, and thus the sewage water is discharged into the urban water channels, forming black and malodorous water bodies. Besides, the overexploitation of groundwater and the heat island effect are also problems that need to be addressed in urban management. Therefore, it is urgently needed to develop an effective system for water management and waterlogging prevention.

4. Principles & Requirements

As one of the first batch of sponge pilot cities, the Sponge Cities programme therefore became the primary means used in Wuhan to address its water management problems. After consulting the National Guideline and design guidelines from Beijing, Nanning and Shenzhen, Wuhan released the Guideline for Wuhan Sponge City Planning and Design (Trial) (hereinafter referred to as “Wuhan Guideline”) in 201519. The guideline was jointly compiled by Wuhan Planning and Research Institute, Wuhan Municipal Water Affairs Bureau, Wuhan Municipal Land resources and Planning Bureau, Wuhan Urban and Rural Construction Committee, Wuhan Municipal Landscape and Forestry Bureau and other municipal departments. The planning principles for sponge city projects in Wuhan are consistent with the National Guideline: adhere to the ecology and natural cycle; adhere to guiding and developing through planning; and adhere to governmental guidance and social participation.

5. Objective and Construction Goals

In addition to the main objectives, Wuhan has set up four construction goals for sponge city programme based on the local condition to alleviate waterlogging problems:

1. Light rain shall be able to seep through the ground
2. Heavy rain shall not cause waterlogging
3. To lessen water pollution
4. To alleviate heat island effect

To accomplish the construction goals, Wuhan has defined the principal construction requirements as follows: The sponge projects must achieve 60%-85% (17.6-35.2mm/d) of the volume capture ratio of annual rainfall, achieve a capacity to resist 50-year storm effectively (303mm/d), and eliminate black and malodorous water bodies to meet water quality standards.

6. Planning

In this section, we look deep into the Wuhan Plan[21] to understand the top-level design and strategies used to promote the implementation of Wuhan sponge city programme. The foundation of the WuhanPlan includes national policies and regulations, municipal regulations, national standards, sponge city technical guides and relevant municipal plans.

6.1 Concept and ideas

The overall concept of Wuhan sponge city construction is the systematic and whole-process controlled water management with a combination of blue, grey and green infrastructure and a combination of engineering and non-engineering measures[15]. The Wuhan sponge city programme has also established a multi-level system based on the runoff process with a double orientation of problems and targets (see Figure 2.3). The runoff process starts with precipitation as the source and finishes with the outflow of water from rivers. Problem-oriented strategies should be applied with systematic governance in the existing built-up area; target-oriented strategies should be applied with high standards of control and construction in the new development area.

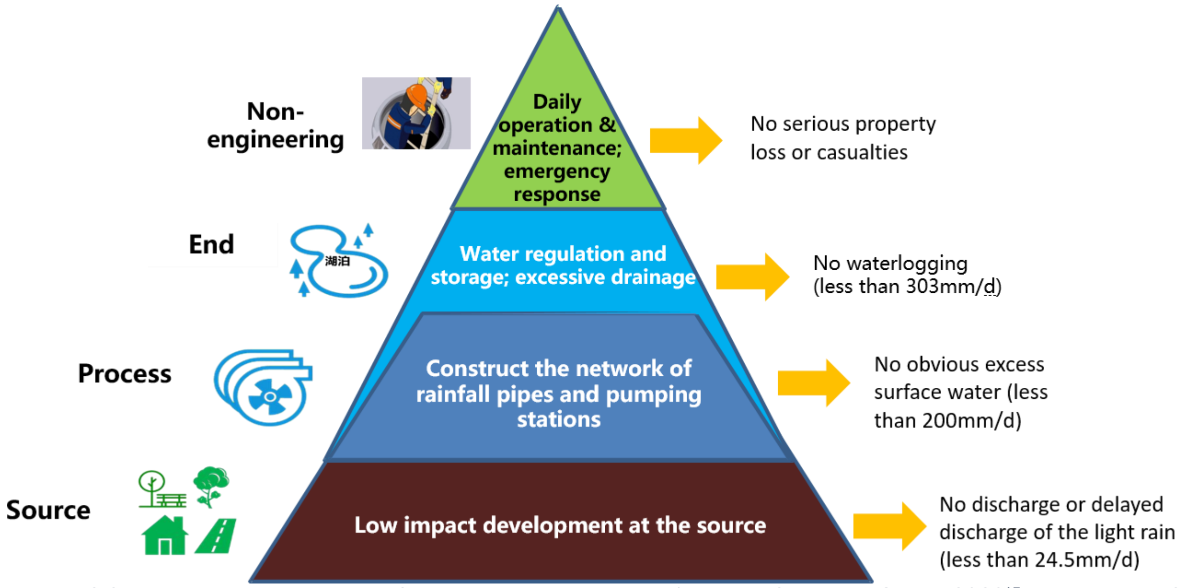


Figure 2.3 The management ideas of sponge city construction (adapted from KANG Dan 2020[15], permissions from the Wuhan Urban and Rural Construction Bureau)

6.2 Integrating the sponge programme into urban plans

The Wuhan sponge city programme is not a construction project that exists separately from other urban plans but is interdependent with them, especially the Wuhan Comprehensive Planning20 and the ecological planning framework. It also needs the cooperation of different departments, such as water affairs, landscape and road traffic, to be planned and implemented.

6.3 Wuhan sponge city construction index system

Table 2.1 List of Wuhan Sponge City Construction Index System (adapted from WPDI, 2016[21])

Index Type	No.	Index Name	Category	Index Value		Notes
				2020	2030	
Water Ecology	1	Water retention rate of natural lakes	Concept	100%	100%	
	2	Volume capture ratio of annual rainfall	Concept	20% area reach standards	80% area reach standards	Zoning by construction
	3	Proportion of natural shoreline of rivers and lakes	Measure	≥50%	≥80%	
	4	Proportion of water bodies meeting quality standards	Target	80%, and no black and odorous water	95%, and no water below grade 5 (V standard)	

Water Environment	5	Reduction of non-point source pollution in the upper part of watersheds	Measure	≥50% (Calculate by TSS*)	≥50% (Calculate by TSS)	
	6	Number of combined sewer overflows	Measure	≥10 times/year	≥10 times/year	Mixed flow outlets
Water Resources	7	Utilization rate of rainfall resources	Measure	Consumption of rainfall is not less than 5% of tap water	Consumption of rainfall is not less than 5% of tap water	Introductory
	8	Utilization rate of regenerated wastewater	Measure	≥20%	≥20%	Introductory
Water Safety	9	Flood control standard	Target	Resist 200-year storm event	Resist 200-year storm event	
	10	Waterlogging control standard	Target	Resist 20-year storm event	Resist 50-year storm event, 100-year storm event for key areas or facilities	
	11	Rate of discharge pumping station meeting standards	Measure	85%	100%	
	12	Levee compliance rate to the standard length	Measure	100% for the main levee, 90% for back levee	100% for the main levee and back levee	
	13	Rate of stormwater main pipes (canals) meeting standards	Measure	70%	95%	
	14	Proportion of permeable hardened pavement in new projects	Measure	≥40%	≥40%	

6.4 Zoning

The entire sponge city construction area covers 3261km2 in the urban development area of Wuhan. As one Chinese idiom said "applying appropriate medicine according to the symptom", it is important to adopt problem-oriented strategies. Likewise, the purpose of zoning is to classify different zones, determine the construction routes and indexes, and form the sponge city zoning maps for Wuhan on the basis of the water-related problems in each district. Therefore, the goal and sponge indexes of each subregion should be differentiated from other subregions.

The rules of zoning take consideration of primary issues, area size, distribution of liability and drainage outlets. The following three levels are established for delineation of sponge subregions: The first level is divided by the outlet of the river, focusing on the coordinating management of external flood and waterlogging and capacity building of waterlogging prevention. The second level considers the receiving water body, focusing on the coordinating management of drainage and dispatch. At the third level, the construction characteristics, drainage system, water issues and administrative management of the area are considered, with the emphasis on the coordination of construction and management. As a result, Wuhan delineated 4 main sponge districts and 171 subregions in total in the sponge city planning area.

Index name		Value	Control type
Ratio of permeable pavements	New projects	≥40%	Mandatory
	Renovation projects	≥30%	Introductory
Ratio of depressed green areas	New projects	≥25%	Mandatory
	Renovation projects	≥25%	Introductory
Utilization rate of rainfall resources		≥5%	Introductory
Ratio of green roof		≥30%	Introductory

Controlling indexes[21]

Adjusted values of volume capture ratio of annual rainfall in architectures and communities[21]

c	Adjust values in various land-use types						
	Residential	Industries	Public management and public service	Business service	Public infrastructure	Logistics and storage	Transportation infrastructure
Renovation	0	0	0	-5%	-5%	0	-5%
New	+5%	+5%	+5%	-5%	0	+5%	-5%

Adjusted values of volume capture ratio of annual rainfall in urban roads[21]

Road width of boundary lines（m)	Adjust values	
	Renovation projects	New projects
10≤B＜20	-5%	0%
20≤B＜40	0%	0%
B≥40	0%	+5%

6.5 Safeguard measures

Concerning the discrepancy between planning and implementation in real-life, Wuhan introduced strategic safeguard measures to ensure the completion of sponge city projects. As suggested by the

Wuhan Plan, a whole-process control mechanism should be established. In combination with the demonstration project, the municipal government should refine the Management Measures for Wuhan Sponge City Construction23, and formulate policy documents with clearer responsibilities and more rational routes. To better implement the sponge city concept, relevant governmental sectors are required to develop an annual evaluation system and to summarize the problems experienced during project implementation. Another measure is to link sponge city construction with the awarding of governmental honour for companies and institutions and set the promotion of sponge city construction as a prerequisite for all administrative units. Meanwhile, developing policies for active publicity, open information and public monitoring allows social supervision of the construction of sponge cities.

It is important to discover an effective and sustainable financial security system for the sponge city programme. The municipal and district governments are encouraged to establish a special investment fund used for construction or subsidy and reward of sponge city projects and explore a mechanism to link stormwater fees and the sponge sites.

6.6 Design

To implement the Wuhan Plan, sponge city projects are being developed on the ground, focusing mostly on waterlogging prevention at the preliminary stage of construction, from 2015 to 2020. The Design Guide for Wuhan Sponge City Construction24 was published in 2019 and suggested that with the objective of preventing waterlogging in the urban areas, various measures and strategies have been utilized collectively.

As part of the Wuhan urban comprehensive ecological plan, 166 lakes were designated in the conservation plan to ensure the water regulation and storage capacity of the lakes, particularly during the flooding season. Grey infrastructure is applied for flood prevention and process control, including the construction of embankments to prevent external water flooding and the repair of pipes and pumps to increase water discharge capacity. Green and blue infrastructure plays a key role in waterlogging prevention. Source reduction strategies, like "infiltration" and "retention", are combined with low-impact development, to reduce the drainage of rainfall and relieve drainage pressure on the urban pipe networks. The Wuhan sponge city programme also implements non-engineering strategies for daily operational management and maintenance. The management measures emphasize the regular maintenance of pipes and pumping stations and emergency response to enhance disaster response capacity and reduce the property loss and casualties to the maximum extent.

Figure 2.5 The rain garden in Huazhong University of Science and Technology, Wuhan (KANG Dan, permissions

from the Wuhan Urban and Rural Construction Bureau)

6.7 Sponge Infrastructures

The sponge infrastructures are suggested to be designed under the guidance of the national technical guide for sponge infrastructures. The sponge infrastructures used in Wuhan sponge projects include rain gardens, green roofs, permeable pavements, grass swales, bio-retention facilities, depressed green spaces, pervious concrete pavements, constructed wetlands, rainwater-fed wetlands, infiltration-removal wells, infiltration basins, infiltration manholes, infiltration trenches, rainwater storage modules, pervious asphalt pavements, vegetation buffer zones, wet ponds, artificial soil infiltration facilities and ecological embankments.

The design of sponge infrastructures in each project should be applied according to the different sponge indexes to maximize the sponge effects. Table 2.5 illustrates how the six technical measures are incorporated into the design of sponge infrastructure while fulfilling the sponge goals.

The Framework of National Building Standard Design System for Sponge City Construction (adapted from MOHURD, 2016[25])

	Sponge infrastructures	Infiltration	Retention	Storage	Purification	Utilization	Drainage
Nature-based solutions	Green roofs						
	Sunken green areas						
	Infiltration ponds						
	Bio-retention facilities						
	Grass swales						
	Rain gardens						
	Stormwater wetlands						
	Wet ponds						
	Retention ponds						
	Detention basins						
	Vegetation buffer zone						
Grey solutions	Permeable pavements						
	Underground rainwater tanks						
	Water storage modules						
	Seepage wells, seepage pipes, seepage canals						
	Rainwater drainage facilities						
	Rainwater purification facilities						
	Green area irrigation						
	Artificial soil filtration						

6.8 Project Implementation

Demonstration Projects

To initiate the citywide sponge city projects, Wuhan implemented demonstration projects of sponge city construction in 2015 and issued "Wuhan Sponge City Pilot Implementation Plan" in 2016. A "2+N" mode was designated for sponge demonstration projects to construct 38.5km^2 of sponge-like areas. "2+N" mode refers to the two demonstration areas, Qingshan (23 km^2) and Sixin (15.5 km^2), and 288 pilot projects with the emphasis on the renovation of the old town area and development of the new city area. The pilot projects consist of various types, such as roads, green space and residential quarters. Started in 2015, the construction of demonstration projects lasted for three years and attracted CNY 11 billion (EUR 1.4 billion) of investment. Case studies in the demonstration areas, such as Nangan Channel Sponge Project - the first PPP (public-private partnership) project in Wuhan, and the Gangcheng No.2 Middle School (Figure 2.7) which has achieved great success, are analyzed in Part

3. Demonstration projects as the prototype of sponge city construction accumulated experience and laid the foundation for promoting larger-scale construction across Wuhan city.

Before and after sponge construction of demonstration project - the Gangcheng No.2 Middle School in Qingshan district, Wuhan (Kang Dan, permissions from the Wuhan Urban and Rural Construction Bureau)

The success of demonstration projects has proved the potential of nature-based solutions and grey solutions in urban water management and waterlogging prevention. Sponge construction has realized the natural absorption, purification and utilization of rainfall through various sponge infrastructures, enhancing the harmonious relationship between water and city. After the completion of demonstration projects, sponge projects have been implemented across Wuhan city. See more details about sponge projects and their achievements in Part 3.

6.9 Operation and Maintenance

Wuhan sponge city projects are operated and maintained both by the government and enterprises, depending on the main responsible body of each project. To comply with and implement the national technical guide, Wuhan released The Technical Guide for Operation and Maintenance of Sponge City Infrastructures in Wuhan Residential Quarters (trial)[26] in 2017. Key points of this technical guide include that the sponge infrastructures should be maintained and supervised regularly by their owners or entrusting parties; the owner of sponge infrastructures should develop a standard manual for operation; and that the maintenance personnel should record the maintenance status of the infrastructure and evaluate annually. Specific requirements for the operation and maintenance of each sponge infrastructure are also specified in the document, which serves as the standard reference for sponge infrastructure.

6.10 Achievements

Until 2020, Wuhan sponge city construction programme has achieved a series of results. Practically, the standardization and localization of sponge technologies throughout the sponge city construction process is critical. Wuhan finished the compilation of local technical standards in 2019 and also encouraged enterprises to establish sponge construction standards.

The performance of 2020

In the summer of 2020, Wuhan has showcased the great ability of flood control and waterlogging prevention developed from the construction of sponge cities[15]. Wuhan suffered from multiple rounds of intense precipitation during the rainy season of 2020. The rainy season lasted from June 8 to July 19, in total 42 days, which is the longest rainy season in this century, and cumulative precipitation was 1.3-2.1 times more than other years. In some areas of Wuhan, the total amount of the rainfall in the rainy season was 1109.5mm. The daily precipitation even reached 472.3mm and the hourly precipitation reached 88.3mm. The flood level of the outer river was more than 4m above the average elevation of the urban surface, which could potentially inflict severe flooding in Wuhan. On July 7, the Yangtze River reached the warning line of 27.30 m, and was close to exceeding the protective safety level. However, on 12th of July, the flood peak, which was 28.77m ranking the fourth in history, went through Wuhan "quietly". No serious floods occurred in Wuhan thanks to the multi-level flood prevention and water management system.

Although the heavy rainstorm event in the summer of 2020 caused serious flooding and property losses in most provinces in Southern China, Wuhan, whose rainfall amount in the rainy season of 2020 ranked the first among metropolises, has not seen serious waterlogging and floods. The occurrence of some waterlogging points in the urban area did not cause a serious impact on the city and could be effectively dealt with.

Compared to the storm event in 2016, despite a strong rainstorm hitting Wuhan again, the construction of sponge projects effectively increased the discharge capacity and efficiency[15]. The number of waterlogging points reduced from 162 to 30 (more than 90% of the waterlogging points disappeared when rain stopped). The maximum duration of waterlogging shortened from 1 month to 6 hours and the area of waterlogging points was significantly reduced. The impact of waterlogging on traffic and the public was greatly alleviated, which demonstrated huge potential and capability of the sponge city programme.

6.11 Finance.

The construction of sponge city projects is costly, thus, there has to be an effective fund-raising and allocation mechanism to attract investment and distribute funds. As one of the sponge pilot cities in China, Wuhan received national funds of CNY 500 million (EUR 64 million) each year from 2015 to 2017, as the financial support to implement the municipal sponge city construction. The Municipal Government of Wuhan is responsible for receiving the national funds, preparing municipal funds, inviting social investment, allocating funds to the district government, and setting up management regulations for the use of funds. District governments, the main responsible bodies for project implementation, get funds from the municipal government and arrange their own funds for sponge projects. The Wuhan municipal government also encourages the participation of social capital and the application of the PPP model. For example, demonstration projects constructed without government investment are rewarded 30% of the fund if they started before October 2015 and 15% if they started after that date.

6.12 Lessons Learned and Future Visions

The Wuhan Sponge City Programme has obtained experience in many regards. The success of the sponge programme depends on the systematic and whole-process controlled water management. The combination of non-engineering measures and engineering measures, which include blue and green infrastructure to “let nature do the work” and grey infrastructure to reduce excessive rainfall, constitutes the top-level design of sponge cities as well as coordination with other urban plans, realizing the integration of multiple planning programmes.

Sponge city construction requires collaboration between government and different departments, rather than being a duty for one single department. The programme has clearly defined responsibilities for every engaging department and has established a specific leading group for Wuhan sponge pilot projects, which consists of leaders from different participating departments. Wuhan municipal and district governments coordinate the construction of sponge cities. The Municipal Urban and Rural Construction Bureau is responsible for the overall planning and promotion of the sponge city programme. The Municipal Gardening Bureau takes charge of the implementation of the sponge city concept in green space projects, while the Municipal Water Affair Bureau takes responsibility for the implementation of the sponge city concept in the water-related projects. The Municipal Planning Bureau is accountable for sponge city management control and project acceptance.

Localization is another reason behind the success of the sponge programme. Due to different natural and social-economic conditions in different cities, identical strategies would not lead to the same results. The implementation of sponge city projects must be context-specific. The localized strategies applied in the programme include but are not limited to the sponge index system for the design of sponge infrastructures and zoning, the local technical standards throughout the entire project process from planning, design, and implementation to maintenance, and the development of the local sponge industry union. The Wuhan sponge monitoring and evaluation platform is another illustration of the localization strategy, which has been established to integrate information management, monitoring and performance evaluation into one system. Since the programme allows the local government to address water management challenges, strong national policies, fiscal and regulatory mechanisms and clarified national technical standards also back up the implementation of sponge projects.

A cost analysis3 conducted by the University of Leeds showed that the use of sponge measures with a focus on nature-based solutions in Wuhan sponge city demonstration areas have saved around CNY 4 billion (EUR 509 million) compared to the conventional approach to upgrade the drainage system based on grey infrastructure. This reveals the potential of nature-based solutions.

Going down to the specific projects in Wuhan, the implementation of sponge projects have enlightened deeper application of the sponge city concept and replication in other cities. The Nangan Channel sponge project, namely the first PPP project in Wuhan, is a good example. The project reused recyclable resources, like the industrial wastes generated in iron production, to achieve sustainable development. Meanwhile, the project exported experiences learned by telling stories about Wuhan's

water management and by communicating with other cities, experts and well-known enterprises about the PPP model, sponge technology application and other aspects. It also invited experts for technical consultation and cooperated with research institutes for research and standard formulation to enhance the application capability of sponge technology. As a result, this project accumulated rich and useful materials for the formation of sponge city construction that can be used for reference and replicated in Wuhan.

6.13 Challenges and Future Prospects

Having discussed the successful experience gained through the Wuhan Sponge City Programme, the following section will focus on challenges and further improvements for the programme. The sponge index system of Wuhan was categorized into water ecology, water environment, water resources and water safety, suggested by the national government. However, the system lacks consideration of other factors, especially social aspects.

Although climate change has been considered in the calculation of water drainage capacity and waterlogging prevention, it requires more attention to climate regarding different climate scenarios. Other environmental factors that have not been included in the evaluation of sponge projects include biodiversity, carbon emission reductions and air quality, to mention a few. They could be possibly applied in the multidimensional assessment in the long term. Aside from ecological factors, to ensure the sustainable development of cities, social factors should be taken into account as well, since nature- based solutions offer multiple social benefits. The accessibility to public green areas, mental health, aesthetics, etc., can be potentially included as sponge indicators for environmental and social co- benefit.

The engagement of citizens is sometimes considered in the implementation process of sponge city projects, but it should be strengthened. Public participation and stakeholder engagement is one key component of urban management that could not only fulfil social needs but facilitate project processes and compensate for the conventional top-down management. Local residents should be seen as stakeholders in the sponge city programme and there should be a mechanism for non- governmental stakeholders to be involved in the design and later maintenance of sponge projects. The opinions of property owners, residents and other stakeholders should be fully understood and considered. As one main function for sponge project areas is for recreational activities, such as running and playing sports, the participation of residents can identify their needs, raise awareness of urban nature, and recognise the value of sponge areas[3].

To scale up, the national government should encourage the formation of sponge city networks at both national and international level for open conversations in exchange of experience, good practices and innovations, enabling sponge-related knowledge to be institutionalized[3]. Different sectors should also actively seek more innovative solutions to technological development and governance strategies that support the implementation of nature-based solutions. Opportunities like training, capacity building and research could be given for better implementation and management of sponge projects. Moreover, financial incentives, such as tax deduction, could be offered to ensure social participation in urban green infrastructure and the shared burden of the costs of sponge projects.

In summary, the Chinese Sponge City Programme, which integrates nature-based solutions into cities and leverages the power of nature, is the momentum for moving Chinese cities towards a holistic, nature-based and climate-smart urban water management.

CHAPTER 3 CASE STUDY

3.1 Introduction

Background

In March 2013, Atkins, supported by the Development Planning Unit of University College London and the Indian Institute of Human Settlements, were commissioned by the Climate Development Knowledge Network (CDKN) to undertake action planning with the city authorities of Bangalore and Madurai, focused on developing future proofed urban strategies in the cities. In Madurai, we have been working closely with Madurai Municipal Corporation who has been the client for the project as well as Dhan Foundation who are delivery partners for the project.

The key objective of the project is to help both cities to develop an action plan which charts a clear way forward, via the development of policies and other interventions, to help them respond to climate hazards and promote a transition to a low carbon economy while reducing poverty and catalysing economic development. A special emphasis is placed on supporting and enhancing locally owned policy processes.

Overall approach to the project

The project has been undertaken over two key stages at the city level, which is consistent with the future proofing approach developed by Atkins and UCL, with later stages disseminating the lessons learned (see Figure 1.1 on page 4). This report is the final action plan for Madurai which provides a basis to address the climate risks and development needs of the city.

At the conclusion of the urban diagnostic stage, stakeholders in the city converged on the view that the plan should focus on future proofing Madurai’s blue-green infrastructure to build resilience to climate change impacts facing the city. This is essentially a plan for managing an interconnected set of challenges relating to water resources management (surface and ground water), water supply, water quality, sanitation, waste management, flooding and preservation of natural ecosystems in the context of the urban development trajectory of the city and its changing climate.

The plan develops a series of city wide proposals as well as showing how such a plan could be developed at the local level.

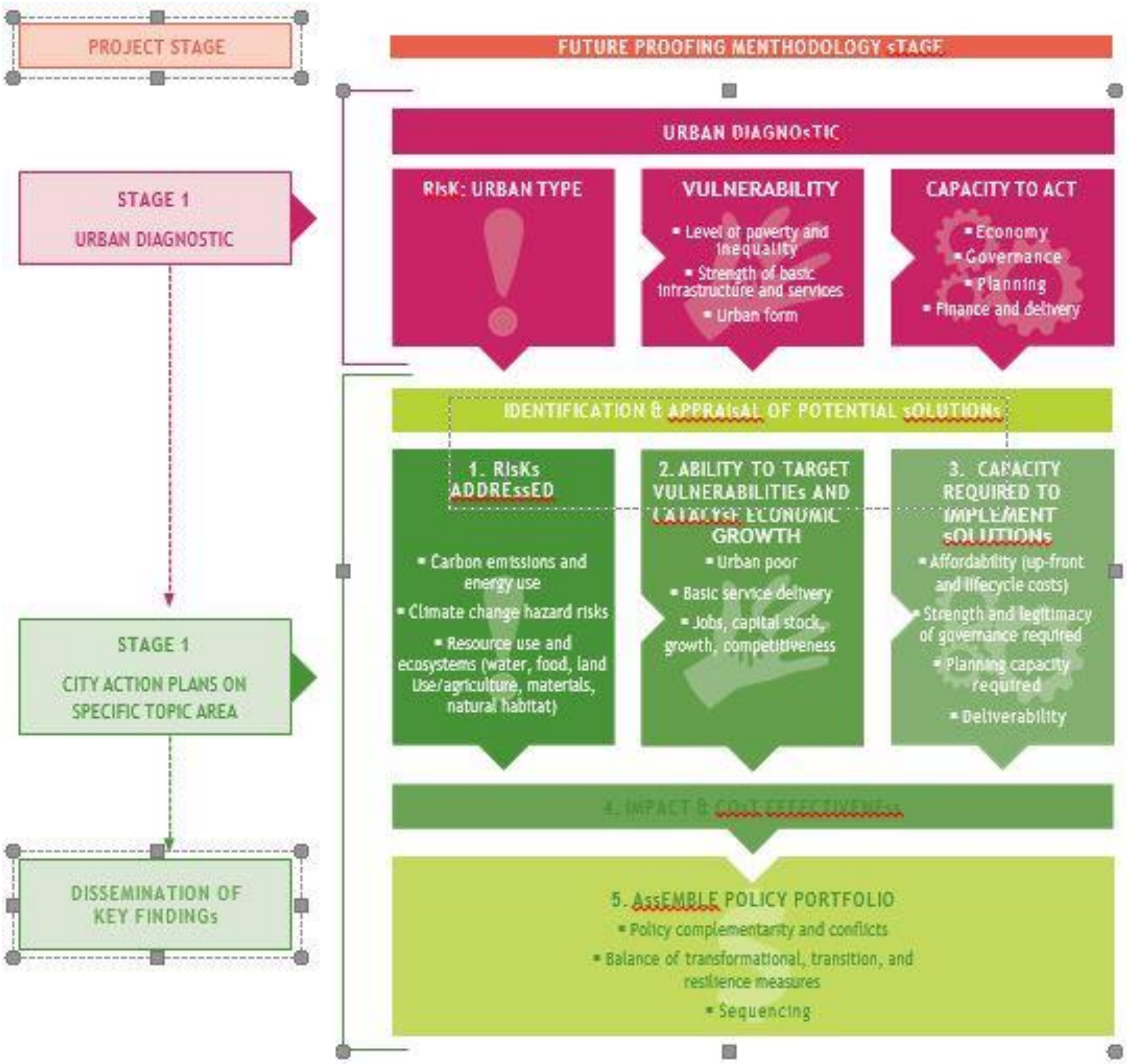


Figure 1.1 Overall approach to this project

Action planning in Madurai

The approach

Over a period of around one year, a series of action plan proposals have been shaped and supported by a range of stakeholders in the city. Initial discussions took place early in the project about the issues and challenges Madurai is facing which provided the impetus for collective action.The process of action planning has been used to develop, deepen and share understanding between different stakeholders, as well as exploring and initiating discussion of what the opportunities could be for the city to address its existing vulnerabilities and adapt to climate risks which are expected to impact the city.

- Building platforms for engagement - state level dialogues were essential in gaining commitment to address the project. In addition, multiple mechanisms were used during the action planning process to engage local stakeholders.
- Reviewing the current position and creating an urban diagnostic allowed for the first time the

critical issues to be seen as interlinked, rather than a collection of sector focused issues and initiatives which previously have proved difficult to implement in isolation from each other.

- Using the action planning process to clarify and examine the implications of the existing situation for vulnerable communities through a multifaceted programme of research, interviews and visits to hotspot areas around the city where the climate risks and vulnerabilities are most evident including an in depth case study of the Kiruthumal corridor.
- Bringing together stakeholders to engage and consider the priority issues. The process provided a safe place for debate and discussion to between community organizations and government bodies.
- Exploring and selecting the range of different actions which can be mobilised to reduce vulnerability and adapt to climate risks - developing the social capital of the city can help deliver early results and complement policy-legal and government actions regarding infrastructure projects which may take longer to realize.

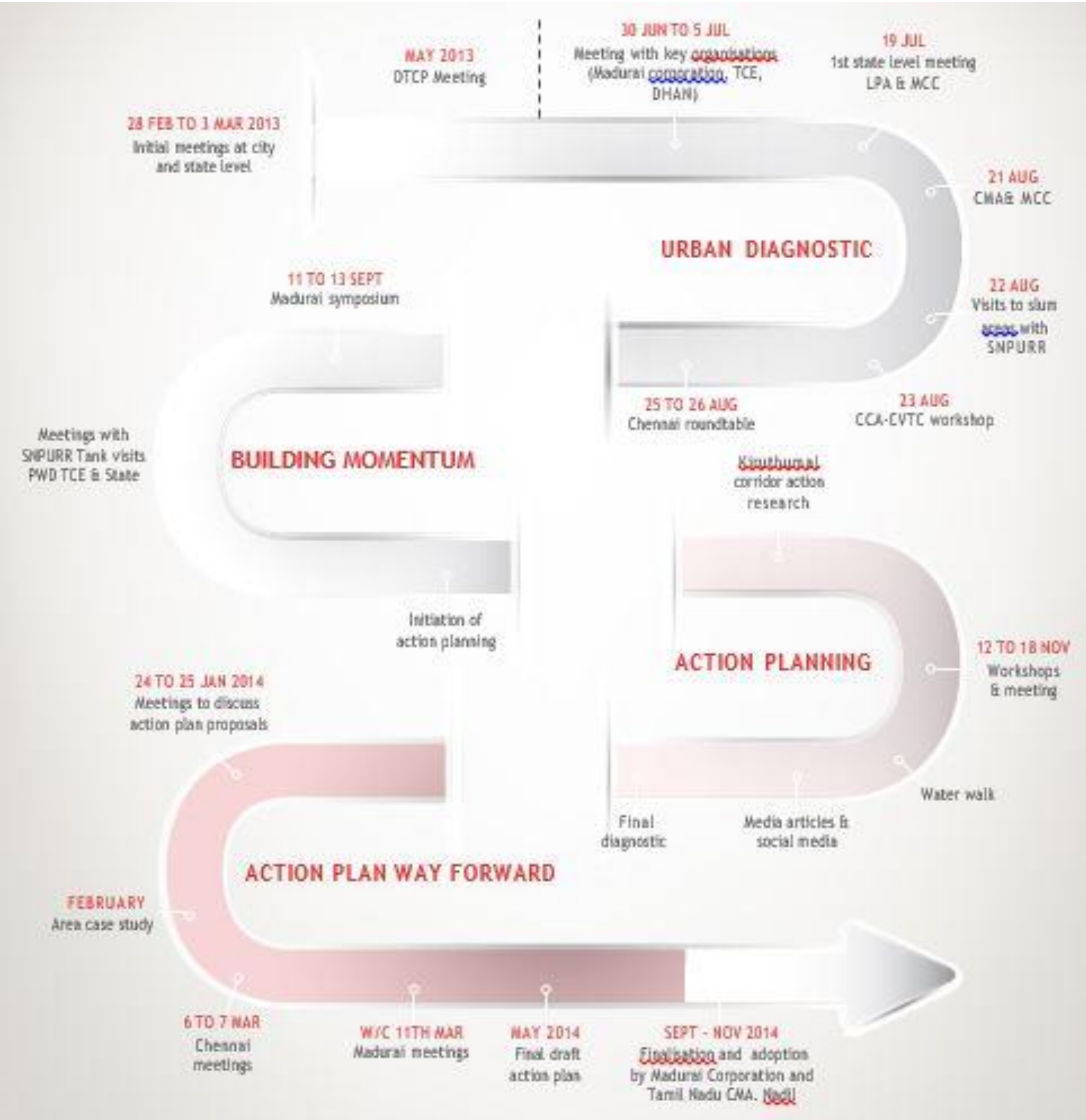


Figure 1.2 - Action plan timeline

What is the 'Future proofing' approach?

In order to tackle the risks to its future growth, as well as to meet the demand for adequate infrastructure and basic services, Madurai could benefit from a new approach to urban development: a 'future proofing' approach.1 Future proofing is about identifying and developing solutions which can respond to the risks associated with issues such as climate change, resource scarcities, and damage to vital ecosystems but in a way which catalysis broader economic development, improves access to basic services, and tackles urban poverty.

Future proofing is about taking an integrated approach to tackling some of the city's deep rooted urban problems. For example, water supply issues are generally approached solely from the perspective of identifying water engineering solutions, with the potential impacts on vulnerable groups, patterns of development, food security and flooding poorly understood.

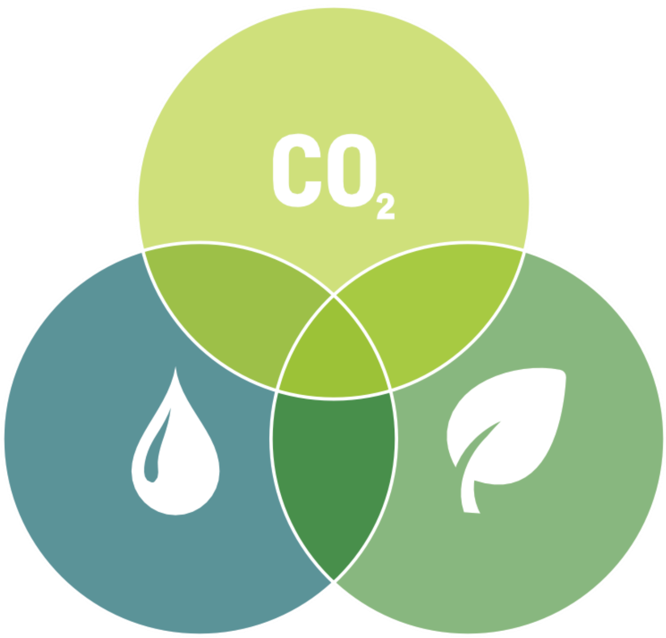
When urban problems are approached in this narrow way, solutions can sometimes be ineffective, opportunities for generating wider benefits are missed, or significant unintended negative consequences can occur.

The future proofing approach considers the growth dynamics of the city in parallel with the range of potential risks which may impact its future development.

The approach involves looking at three groups of interrelated issues:

- climate risks e.g. flooding, extreme heat events
- resource and ecosystem risks within the city and its wider catchment e.g. water scarcity, food security, and damage to vital ecosystems due to urban growth
- energy use and carbon emissions

E.g. from transport, domestic and commercial consumption, industry and waste.



Future proofing approach: integrated assessment framework

Benefits of a future proofing approach

Building a profile - or urban diagnostic of these key risks, in conjunction with assessing the vulnerability and capacity of local institutions and stakeholders to respond to them can help to identify implementable solutions which can deliver multiple economic, social, and environmental benefits. This differs from most current approaches to urban development which tend to focus on targeting one or a few narrowly defined objectives (e.g. city competitiveness, green cities) rather than looking at packages of complementary policies which can meet multiple objectives. The benefits for Madurai of developing this approach include:

- An explicit focus on how the city can respond to four long run challenges - resource security (e.g. water), resilience to climate impacts, the move to a low carbon economy, and protection of ecosystems
- The identification of packages of complementary policies in these areas which can generate multiple environmental, social, and economic benefits, crucial in the context of limited financial resources
- A focus on measures which respond to the needs of the urban poor
- The identification of measures which can be implemented and driven forward by stakeholders within the city given current capacities.

Madurai is the second largest city in Tamil Nadu. One of the oldest continuously inhabited cities in the world, Madurai developed on the fertile plain of the River Vaigai and has been a major religious centre and settlement for two millennia.

Today it is an important educational, industrial and tourism hub, but retains many remnants of its historic origins. The intricate network of rivers, channel, canals, tanks and groundwater forms the city's essential blue-green infrastructure, providing water, drainage and sanitation for domestic, agricultural and industrial use. The city is growing rapidly, and is expected to rise from 1.4m in 2011 to over 2 million people by 2031 (the end date for the upcoming Madurai Master plan). This will lead to further pressures on infrastructure, housing, and basic services.

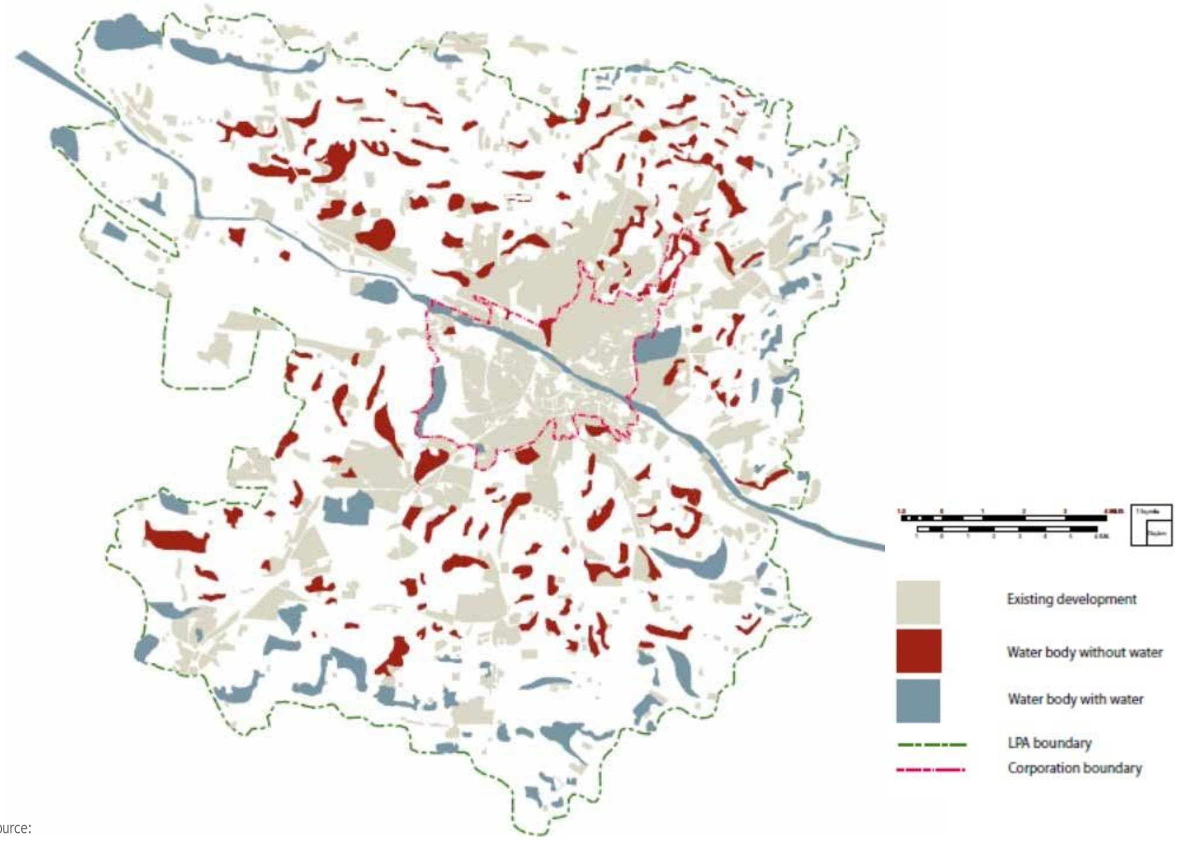
Summary of the urban diagnostic for Madurai

Madurai faces a range of climate hazards - particularly flooding - which already impacts its people and physical infrastructure. Madurai is located in a warm-humid climatic zone, and experiences a hot dry climate with intermittent and irregular rainfall. In recent years, high volumes of rain during the monsoon has caused parts of the city to flood. Areas particularly impacted are the Periyar Bus Stand Area, Railway Colony, and the area close to Madura Coats on the northern bank of the Vaigai River. Other flood prone areas include Simakkal, the area near to Amirtham Theatre, the area near to Tallakulam Perumal Kovil temple, Kattabomman Nagar, Narimedu and the Meenakshipuram-Bibikulam area.1

The areas which are particularly prone to flooding include parts of the city which lie within the natural floodplain of the river and drainage channels. Often slums have become established in these areas which are usually owned by public bodies and lack appropriate flood protection or flood resilient infrastructure. Moreover, much of the network of natural water bodies and tanks which play a key role in storm water drainage and runoff within the city have been encroached upon by development which leads to these areas flooding during heavy rainfall events.

Many of the water bodies which could play a role in providing water for the city are polluted from untreated sewage and pollutants from dumping

An example of one of the water bodies which has fallen into disuse from sand mining which is disrupted the flow of water which would replenish the tank. The tank has then been encroached upon by development which is at high risk of flooding



Source:

Distribution of water bodies in Madurai including those with and without water

Location of slum areas inside Madurai Corporation area

There is an important opportunity for Madurai to consider an integrated urban water management approach to address its water security challenges.

The current strategies employed by the city have not been able to keep pace with demand for drinking water, sanitation, wastewater treatment, and other water-related services. The Government of Tamil Nadu has already indicated that improving access to water will be the highest priority of the regional government.12 Madurai has an opportunity to consider an integrated urban water management approach which offers a set of principles that underpin better coordinated, responsive, and sustainable resource management practices. It is an approach that integrates water sources, water use, water services, and water management.

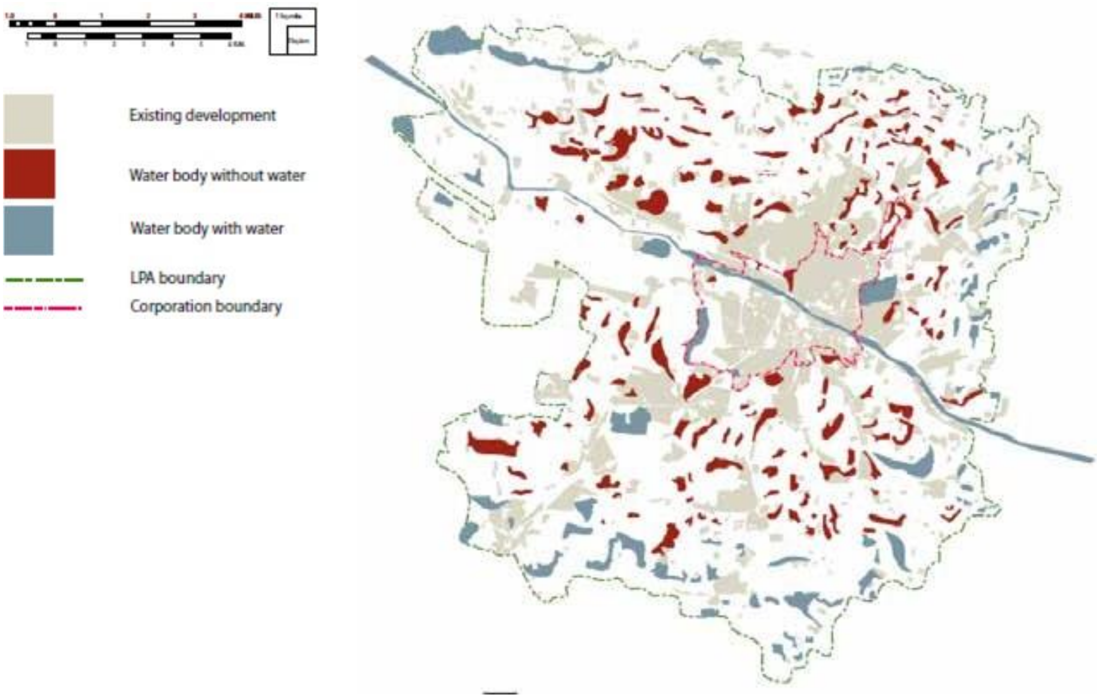
Vulnerability of the city

Not only does Madurai face a wide range of environmental risks, but segments of Madurai's population especially the urban poor - are particularly vulnerable14 to those risks.

For example, the urban poor can be expected to be hit first and hardest by climate hazards such as flooding - they do not have the assets to protect themselves against stresses and shocks and poor residents tend to be located in the most vulnerable areas and in poor quality housing as well as in low paid jobs that can be impacted by flooding. Equally, rising resource prices affect the urban poor disproportionately because they spend a larger share of their income on energy, water and food. When parts of the city experience intermittent power outages, many businesses and households rely on fossil fuel powered backup generators but which are unaffordable for the poorest households.

Blue-green infrastructure:a way of integrating

The focus of the Action Plan on future proofing blue-green infrastructure emerged through the process of developing the urban diagnostic and setting priorities for the city (described in Section 1). This approach enables the city to address the priority climate and resource risks (especially water security) by reducing the vulnerability of Madurai's population, infrastructure and urban form.



Understanding water as a system has helped to identifyMadurai's vulnerability and exposure to climate risks.

Water is a system - it flows across the city, it is used for drinking, cooking, washing, fishing, agriculture and industry and then discharged. Seeing Madurai through this lens has been key to reforming the issues and solutions for the city identified in the urban diagnostic. It has helped to identify the importance of two aspects: the role and condition of tanks and channels which have become part of the sewerage system of the city; and the malfunctioning of sewerage and sanitation. The case study of communities along the Kiruthumal River exemplified the interactions of these two issues and how they are intrinsically intertwined and linked to the third issue of water resources - pollution of the river and groundwater means that communities in many areas cannot access clean water, causing a range of health issues.

Introducing the strategy themes

Enabling infrastructure improvements

Sanitation, including sewer system rehabilitation within the existing urban area, is the issue which needs to be tackled most urgently because sustainable change on the other issues cannot be delivered without it. Action to address solid waste management so that channels and sewerage infrastructure does not become blocked can be addressed in parallel. As these two actions take effect for different branches of the network, it will be possible to make sustained progress in rehabilitating channels and tanks. Without separation of sewage, any action will have a limited impact.

As the channels and tank system are restored, it will strengthen drainage systems which will lead to protection from localised flooding during the monsoon, as well as less frequent floods. Action can then shift towards physical interventions to address flood risk along the Vaigai.

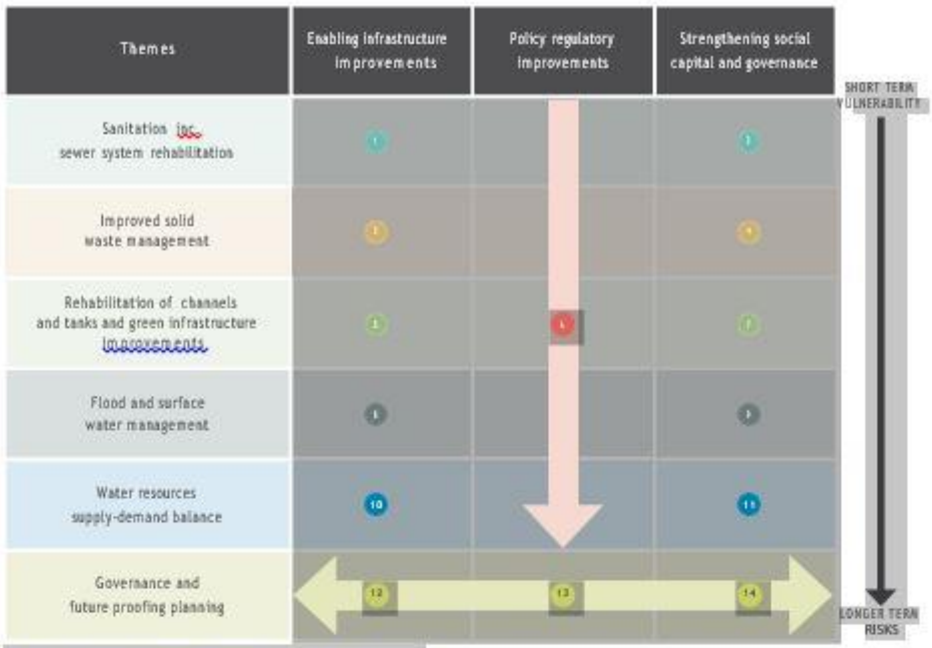


Figure 3.1 - Tackling risk and vulnerability together in Madurai
Tacking risk and vulnerability together in Madurai requires integration action across sectors (see project key on page 32)

implemented around the world. The successes and challenges of these projects vary depending on the specific location and context, but overall, these projects have demonstrated the potential of blue-green infrastructure to address urban and suburban water management challenges and improve the quality of life in cities and towns.

CHAPTER 5 CONCLUSION

Conclusion:

The success of the sponge programme depends on the systematic and whole-process controlled water management. The combination of non-engineering measures and engineering measures, which include blue and green infrastructure to “let nature do the work” and grey infrastructure to reduce excessive rainfall, constitutes the top-level design of sponge cities as well as coordination with other urban plans, realizing the integration of multiple planning programmes.

Sponge city construction requires collaboration between government and different departments, rather than being a duty for one single department. The programme has clearly defined responsibilities for every engaging department and has established a specific leading group, which consists of leaders from different participating departments. Lucknow municipal corporation and district governments coordinate the construction of sponge cities. The Municipal Urban and Rural is responsible for the overall planning and promotion of the sponge city programme. The Development Authority takes charge of the implementation of the sponge city concept in green space projects, while the Municipal Corporation takes responsibility for the implementation of the sponge city concept in the water-related projects. The Niti Ayog will be accountable for sponge city management control and project acceptance.

Localization is another reason behind the success of the sponge programme. Due to different natural and social-economic conditions in different cities, identical strategies would not lead to the same results. The implementation of sponge city projects must be context-specific. The localized strategies applied in the programme include but are not limited to the sponge index system for the design of sponge infrastructures and zoning, the local technical standards throughout the entire project process from planning, design, and implementation to maintenance, and the development of the local sponge industry union. The Wuhan sponge monitoring and evaluation platform is another illustration of the localization strategy, which has been established to integrate information management, monitoring and performance evaluation into one system. Since the programme allows the local government to address water management challenges, strong national policies, fiscal and regulatory mechanisms and clarified national technical standards also back up the implementation of sponge projects.

Challenges and Future Prospects

The following section will focus on challenges and further improvements for the programme.

Although climate change will be considered in the calculation of water drainage capacity and waterlogging prevention, it requires more attention to climate regarding different climate scenarios. Other environmental factors that have not been included in the evaluation of sponge projects include biodiversity, carbon emission reductions and air quality, to mention a few. They could be possibly applied in the multidimensional assessment in the long term. Aside from ecological factors, to ensure the sustainable development of cities, social factors should be taken into account as well, since nature-based solutions offer multiple social benefits. The accessibility to public green areas, mental health, aesthetics, etc., can be potentially included as sponge indicators for environmental and social co-benefit.

The engagement of citizens is sometimes considered in the implementation process of sponge city projects, but it should be strengthened. Public participation and stakeholder engagement is one key component of urban management that could not only fulfil social needs but facilitate project processes and compensate for the conventional top-down management. Local residents should be seen as stakeholders in the sponge city program and there should be a mechanism for non- governmental stakeholders to be involved in the design and later maintenance of sponge projects. The opinions of property owners, residents and other stakeholders should be fully understood and considered. As one main function for sponge project areas is for recreational activities, such as running and playing sports, the participation of residents can identify their needs, raise awareness of urban nature, and recognize the value of sponge areas.

To scale up, the national government should encourage the formation of sponge city networks at both national and international level for open conversations in exchange of experience, good practices and innovations, enabling sponge-related knowledge to be institutionalized. Different sectors should also actively seek more innovative solutions to technological development and governance strategies that support the implementation of nature-based solutions. Opportunities like training, capacity building and research could be given for better implementation and management of sponge projects. Moreover, financial incentives, such as tax deduction, could be offered to ensure social participation in urban green infrastructure and the shared burden of the costs of sponge projects.

In summary, the Lucknow Sponge City Programme, which integrates nature-based solutions into cities and leverages the power of nature, is the momentum for moving Indian cities towards a holistic, nature-based and climate-smart urban water management.

References: Include a list of references used in the research paper.

Remember to use credible sources and to cite them properly. Always be aware of ethical considerations and review your work before submitting.