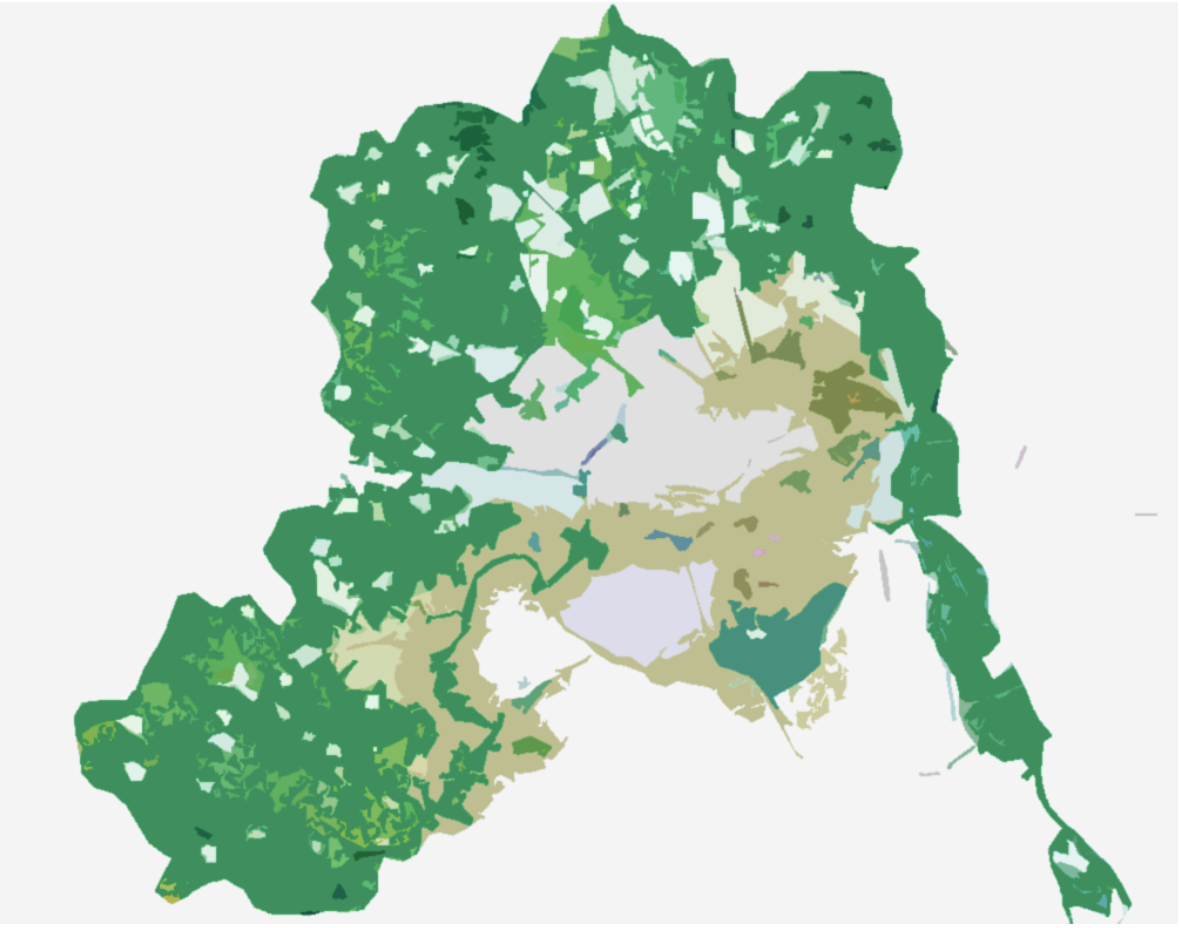
Sponsored Thesis Project Competition on

"RE-IMAGINING URBAN RIVERS"

Season- 3



Project Title : Unpacking the catalyzing potential of geographical urban voids around the natural drains in the fabric of Bhubaneswar

Creator : Monali Biswal, Masters in City Planning

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to my thesis guide Prof. Haimanti Banerji for her guidance, support, and encouragement throughout the entire research process. Her expertise and insight have been invaluable in shaping my research and guiding me towards its successful completion.

I would also like to thank all the professors and other faculty members of the Architecture and Regional Planning department of IIT Kharagpur for their time and effort in reviewing and providing feedback on my thesis. Their constructive criticism and suggestions have helped me to refine my work and improve its quality.

I am also grateful to Dr. Uday Bhonde, senior program specialist, NIUA and to Students Thesis Competition by NIUA for their support and resources, which have been crucial in facilitating my research.

Finally, I want to thank my family and friends for their love, support, and encouragement during my academic career. Their unwavering belief in me has served as a motivational and inspirational force, and I am deeply grateful for their presence in my life.

Thank you all for your contributions to this thesis and for being a part of this journey.

ABSTRACT

Natural drains and their voids have been under a lot of developmental stress which has led to their disconnect from the city fabric. The clear stormwater drains now carry the load of anthropogenic activities and are highly polluted due to combined sewer overflows. Holistic river centric city planning can be the key to reintegrate the neglected drains of the city. This involves cleaning the natural drains, regulating the source of pollution as well as restoring the degrading ecosystem in a sustainable manner. The study aims to identify the causes and consequences of urban voids specifically around the natural drains and to develop strategies to revitalize these spaces using nature-based solutions and placemaking strategies thereby fostering a dialogue between nature people and events.

Keywords- urban voids, natural drains, ecosystem, placemaking, nature-based solutions

“This is the result: the city that they speak of has much of what is needed to exist, whereas the city that exists on its site, exists less.”

(Calvino, 1978)

Table of Contents

List of Figures

List of Tables

List of Abbreviations

NIUA - National Institute of Urban Affairs

NMCG - National Mission for Clean Ganga

SLUSI - Soil and Land Use Survey of India

NbS - Nature-based solutions

IUCN - International Union for the Conservation of Nature

CWs - Constructed wetlands

FWS - Free water surface

SSF - Subsurface flow

VF - Vertical flow

HF - Horizontal flow

BMC - Bhubaneswar Municipal Corporation

BDA - Bhubaneswar Development Authority

BSCL - Bhubaneswar Smart City Limited

SPCB- State Pollution Control Board

WATCO- Water Corporation of Odisha

CITIIS- City Investments to Innovate, Integrate and Sustain

FE & CC- Forest, Environment and Climate Change Department

CGWB – Central Ground Water Board

SWAB - Scientific Wetland with Active Biodigester

SDGs - Sustainable Development Goals

LQC - Lighter, Quicker, Cheaper

NPCA - National Plan for Conservation of Aquatic Ecosystems

1. Introduction

Cities are complex systems with their own ecosystems and metabolism " (Batty, Cities as Complex Systems: Scaling, Interaction, Networks, Dynamics and Urban Morphologies., 2009)". The dynamic cities are a home to millions. They have variegated functions having infrastructure, housing and many public services. The city's fabric consists of masses and voids.

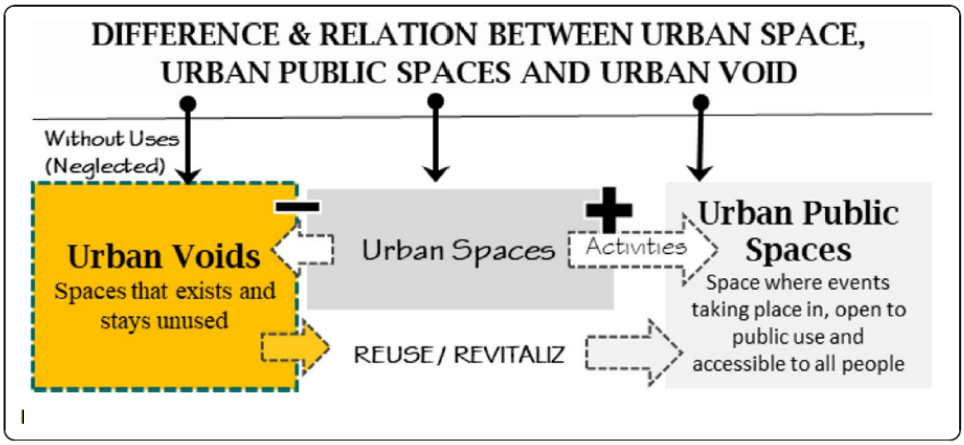


Figure 1: "Difference and relation between urban space, urban public spaces and urban void. (Hashem, Wahba, & Nasr-Eldin, 2022)"

The city fabric consists of masses and voids. There are positive and negative spaces between these designed and built spaces and the entire combination is known as urban space. The proposition of urban space is a cultural indication, emerging from the conflict between the state, community and the local economy and the incorporation of contemporary ideas of property rights. The urban space consists of voids and positive spaces that are primarily recreational. When these negative spaces/ voids are designed to infuse activity such as museums, libraries, parks, etc they become public spaces. "Public spaces," as defined by (UN-Habitat- Training Module Public Space, 2018), are the areas between buildings that are accessible to the general public and principally comprise of four types- a) streets and pedestrian paths, b) public opens spaces such as parks, playgrounds, gardens, water bodies and waterfronts, c) public facilities such as community centres, libraries, etc and d) public commercial spaces such as markets, haats and others. The operation of a city, its prosperity, and its liveability, along with the urban health, social interactions, labour markets, and the urban environment, are all known to be widely influenced by these places. On the other hand, "urban voids" are low quality physical urban spaces which are in neglect. The voids are created as a result of faulty planning or development process. The difference and the relationship between the urban voids, urban public spaces and urban spaces are as illustrated in the given figure 1.

This thesis focuses on transforming these urban voids or the negative spaces specifically around natural drains, making them a functioning part of the city. These spaces are also known as terrain vague, lost spaces, in-between spaces, urban voids, derelict spaces, leftover space, anti- spaces and

many more. Urban voids or the anti- spaces are the unwanted urban areas that don't make any positive contribution to their environment or the users. They are poorly defined, having no boundaries that can be measured and thereby fail in connecting elements in a coherent way and need to be redesigned. The undefined spaces or voids exist primarily due to lack of proper master plan and planning approaches resulting in underutilisation of the space. According to (Trancik, Finding Lost Space, 1990), these spaces are lost and have very low human activities. These spaces disrupt the urban tissue and do not belong to public or private realm. If neglected, these spaces can cause many social, economic and environmental issues such as reduction in property values and lowering the environment quality of the city. The urban voids have a huge potential to be reshaped and redefined as per the needs of the users.

The transformation will involve the natural drain as well as the voids surrounding the drain. The urban voids have a huge potential to be reshaped and redefined as per the needs of the users. Activating these lost spaces can benefit the community.

1.1 Need for study

As per (The World Bank, 2020), about 56% of the world's population are living in urban areas. By 2050, this trend will continue and the urban population living in the cities are expected to increase by more than double the current state. With increase in population, cities face many challenges to meet the demand for housing, transport network and other infrastructure and basic amenities. The increasing pressure on the cities will affect the quality of life. Cities are competing to become more liveable. Public open spaces and other recreation areas are important factors to ensure wellbeing and liveability in a city.

Odisha has recorded about 31% urban population growth which is comparable to that of 36% of India as per (BDCP,2019). The urban cover of Bhubaneswar has grown with 83% in the years between 2000 to 2014 (Swain, et al., 2017). Bhubaneswar has become crowded with limited urban spaces and resources and it has become very difficult to increase public spaces.

The cities that are overcrowded have limited urban spaces and resources. The natural drains and rivers of the Indian cities have faced this development strain and have become highly polluted within the last few decades. This calls for a paradigm shift towards river centric urban planning focusing on the deteriorating water bodies and their riparian zones. This thesis will be focusing on reintegrating the natural drains and their voids into the urban fabric using nature-based solutions.

Urban resources and spaces are finite in these crowded cities, and increasing public spaces is a highly challenging and demanding task. To address these issues, a change in the traditional urban planning is necessary, along with the pursuit of fresh possibilities and creative solutions to the problem of creating better urban places.

1.2 Aim

To **trace, analyse and design geographical voids around natural drains** withing the city and to provide a vision for transforming and reintegrating both, the drains and their voids into urban fabric using **placemaking process, thereby fostering a dialogue between spaces, people and the events**.

1.3 Objectives

- **Delineating Natural Drains**
  - To identify the geographical urban voids around natural drains and select action areas based on analysis.
- **Environmental Measures**
  - To restore the degrading ecosystem (both wetland and upland).
  - To improve the quality of water in drains.
  - To protect from urban floods.
- **Placemaking Measures**
  - To transform the geographical voids as the urban common using placemaking strategies.
  - To formulate strategies involving public participation for placemaking process.
- **Economic Measures**
  - To open new avenues in revenue generation and economic upliftment of the informal sector.

1.4 Scope and limitations

The scope of the thesis involves including the overall integration of water and the natural ecosystem with the public realm. In order to reintegrate into the public realm, all the aspects ranging from treatment to revitalisation strategies will be under consideration. The study also involves identifying, analysing and prioritising the natural drain and its void for revitalisation.

This thesis focuses only on geographical voids only around the natural drains within the city and the voids considered are within a specific time frame. Policy integration with the interventions will be a challenge.

1.5 Methodology

The methodology followed for the thesis is as per the following figure which involves four stages that is (i) Preliminary study phase, (ii) Literature review, (iii) Data inventory, collection and analysis, and (iii) Formulating proposals. Figure 1 illustrates the various processes employed at each stage to reach the final outcome of the thesis.

The research methodology includes a review of literature, case studies, and interviews with key stakeholders involved in urban planning and development. The study identifies several factors that contribute to the creation of urban voids around natural drains, including inadequate planning and zoning regulations, socio-economic changes, and environmental degradation as well as techniques for wastewater treatment and placemaking to activate the voids.

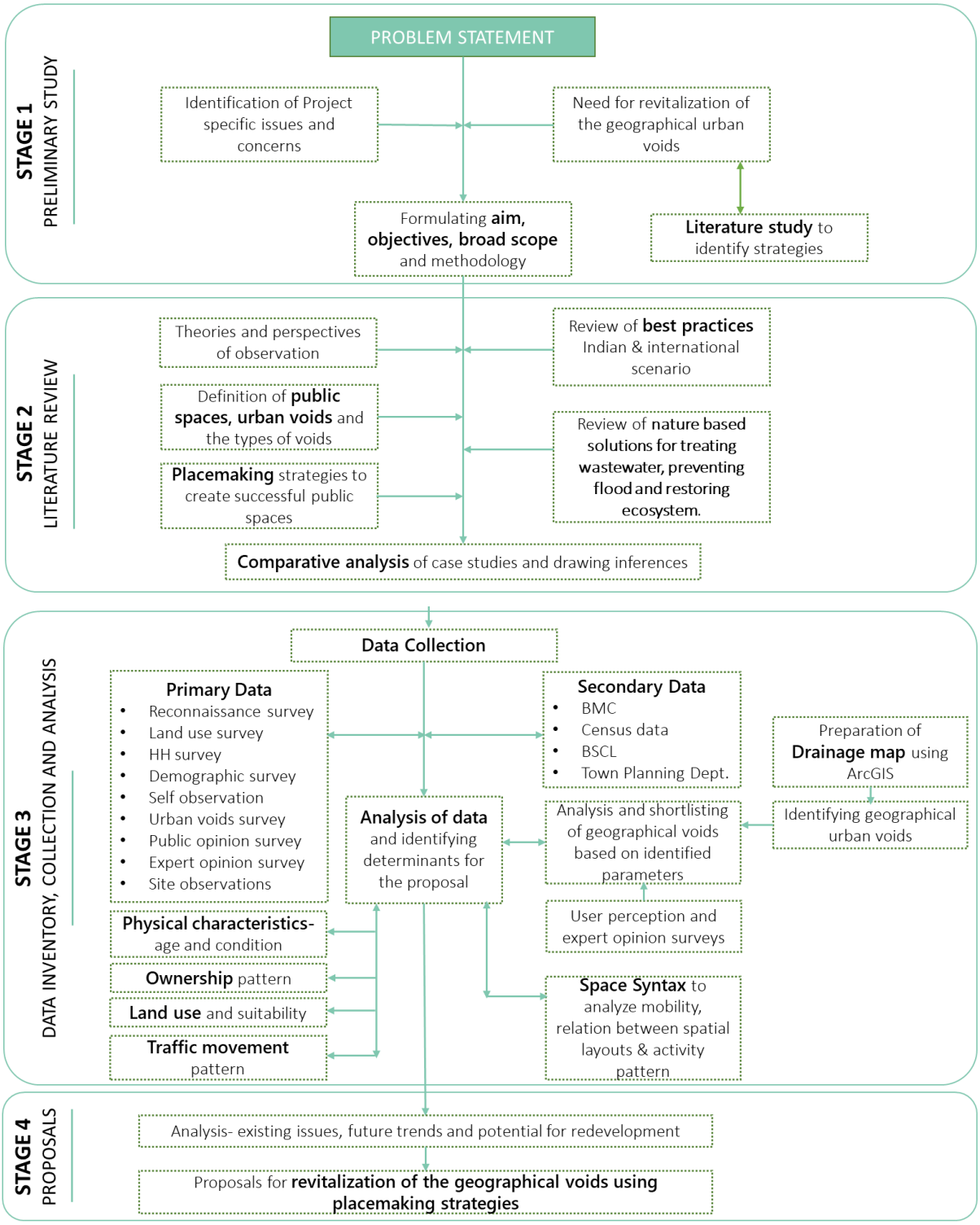


Figure 2. Methodology followed for the thesis

2. Literature Review

2.1 Urban Voids

Urban Voids are the residual spaces of the city that rupture its fabric. They are often neglected or forgotten in the eyes of the people. Most of the times, they are an outcome of faulty planning process when cities are planned in isolation with no regards to the urban fabric. According to (Trancik, Finding Lost Space, 1990), "Urban voids are the undesirable urban areas that are in need of redesign making no positive contribution to the surroundings. They are ill-defined, without measurable boundaries and fail to connect elements in a coherent way." These lost spaces or urban voids can be along residential edges, along railways, car parking areas, under and around elevated highways, highway edges that are being planned but without maintenance, abandoned military courts, abandoned waterfronts, deteriorated parks and unused plazas. Trancik contends that the fault for creating the voids is caused by cars, urban rejuvenation, the liberalisation of the public spaces and functional segregation of the contemporary movement and uses.

Urban voids can be presumed as a space which doesn't have public realm and permeability as shown in the figure. Permeability refers to both physical and social permeability. Physical permeability is associated with a barrier such as a railway line or highway inside the city at the city level, or a slum which is at the area level. Social permeability can be an outcome of presence of ghettos which becomes a barrier.

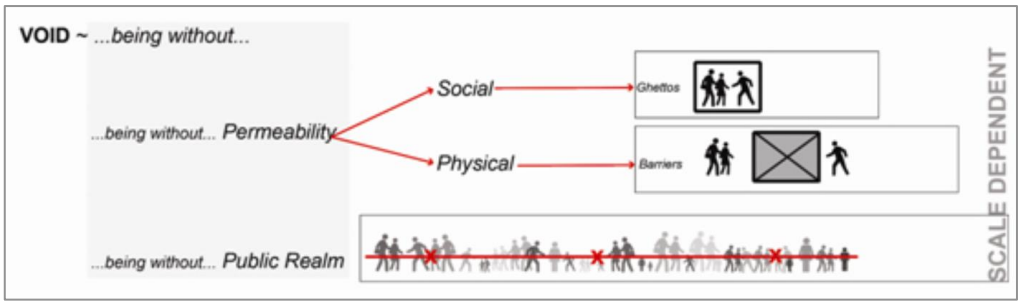


Figure 3: Understanding Urban Void (Nipesh, 2012)

These voids have distinct morphology depending on various aspects such as time, legislation, ownership and their context. As asserted by (Nipesh, 2012), "The urban voids form distinct spaces outside a programmed urban norm". In particular, in the fluctuating, dynamic and ever-changing networks, we should think of the leftovers as the areas that provide an alternative to the predictable zones of consumption and hold potential for urban wildness and biodiversity.

2.1.1 Origin of Urban Voids

The deliberation about the urban voids began in the late 19th century, with architects realising the ability to shape space and not just buildings. This spatial perception was brought about by technological revolution and the breakthrough in arts and science. (Pluta, 2017)

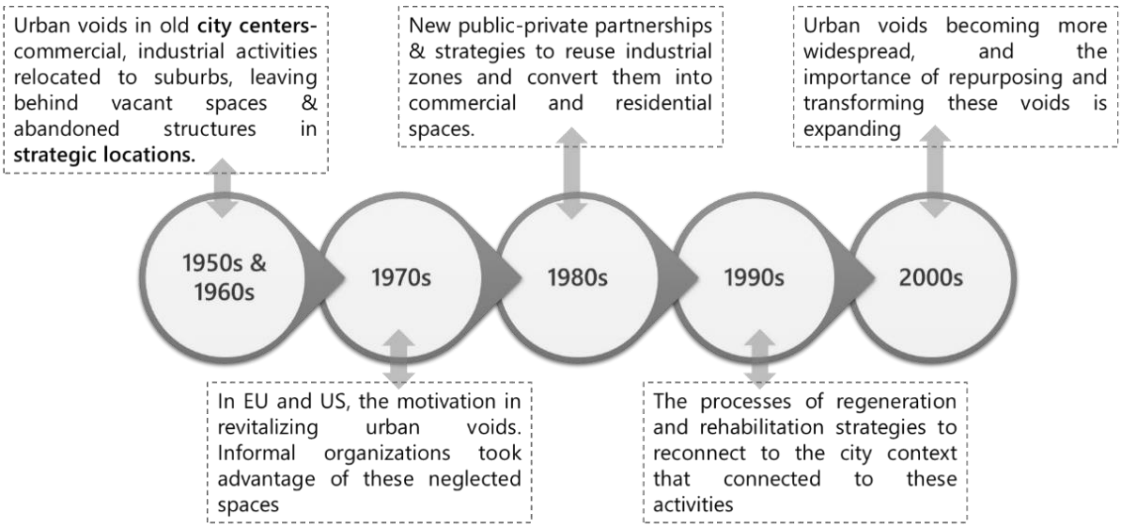


Figure 4: Timeline of urban voids

2.1.2 Categories of Urban Voids

On the basis of formation, urban voids are generally of two types for the Indian context that is planning and functional voids (Katkar, 2021).

a. **Functional voids** – these are the voids created by defunct buildings and have legal aspect such as they are either under litigation or are government property which needing bureaucratic process to go through any functional change. They are mostly found in old city areas and generally associated with time, technological and socio-cultural or political factors.
b. **Planning voids** – These are the voids generated due lack of holistic approach to city planning and are most prominent out of all voids. Faulty planning creates dead pockets in the urban fabric. The planning voids are further categorised as geographical voids, residual voids, large scale plots and infrastructure voids.
    a. **Geographical voids** – These voids are created when planners don't respect geographical features of the city such as river, nullah, contoured land, etc. though these areas are reserved for conserving nature, but with passage of time they get degraded or misused and become unwanted place. These voids run throughout the city and are linear which can be used to create vistas enhancing the aesthetics and identity of the city.
    b. **Residual voids** – These are odd size unconventional pockets left out in the city. In India, city planning follows land use plan and plotting is done by assigning typical shapes. This results in creating residual voids in between buildings or near the edges.
    c. **Large scale plots** – In the Indian context, cities are planned for the projected population and density after 25 years. Occasionally, parcels of land are kept for future development, which leads to these plots of land becoming dysfunctional.
    d. **Infrastructure voids** – These are created when elevated infrastructural projects disturb the homogeneity of parts of the city. Examples include areas under flyover.

2.1.3 Values of Geographical Urban Voids

Geographical urban voids have many potentials and values which can be used to reconnect them to the city fabric (Hashem, Wahba, & Nasr-Eldin, 2022).

a. **Environmental Value** - Geographical voids have several environmental benefits and improve the quality of life of communities. They help in preserving natural habitat and stormwater management. These underutilised spaces have the potential to be used as green infrastructure and promote the environmental health.
b. **Social Value** - These voids provide exceptional opportunities by giving a host of social opportunities having the ability to compensate for the scarcity of open spaces in densely packed cities. These voids play an important role in social interaction and engaging communities facilitating many socio-cultural events.
c. **Economic Value** – Geographical voids have the ability to reinforce city's economic structure and generate employment opportunities. They promote the informal sector's economy. Revitalisation of the voids leads to increase in the value of nearby properties.
d. **Historical and Cultural Values** – These voids have the ability to preserve the historical memory reflecting the culture, identity and character of the city over the years. They add adding personality and uniqueness to a community and support a host of cultural activities if revitalised.
e. **Visual and Aesthetic Values** – Geographical voids are the gaps in the urban fabric and may have negative impact if not planned for properly. Revitalisation of the voids creates a strong urban tissue, improves visual appearance of the city and adds to the identity of the city. it also increases the economic worth of current assets.

2.1.4 Management of Urban Voids

a. Partnership Model

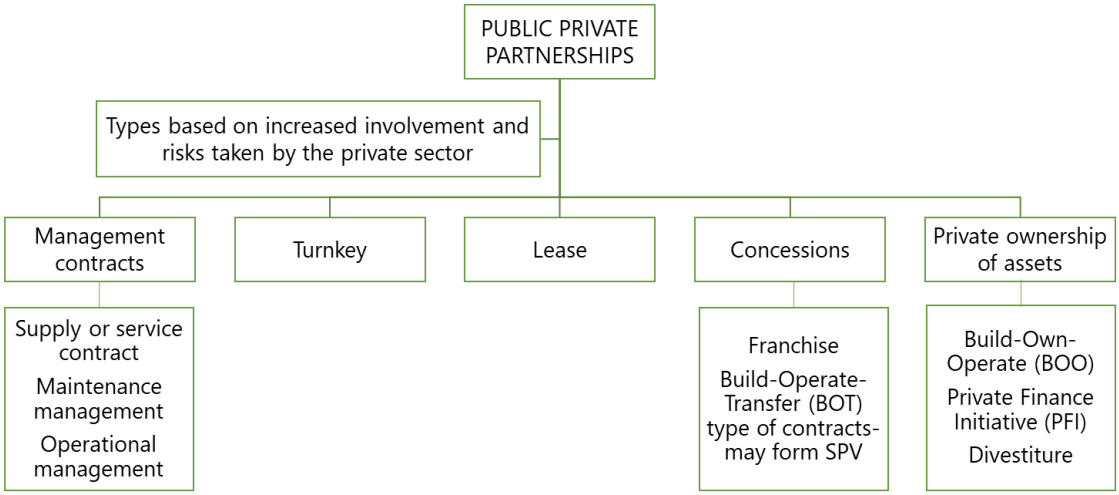


Figure 5: Types of public private partnerships

b. Fiscal Management

- Debt Tools
- Value Capture Mechanisms
- Credit Assistance
- Direct Fees
- Grants

c. Ownership Pattern

Voids have the following ownership pattern, which plays an important role before planning interventions near the natural drains.

- **Public / Government / State ownership**- Assets that a government or state has and that are accessible to all of its inhabitants.
- **Personal ownership**- Also known as individual ownership, refers to the possessions and assets that belong to an individual.
- **Common ownership**- Assets and property held in common by all members of society are known as having common ownership (or non- ownership).
- **Communal ownership**- When a community owns property jointly.
- **Collective ownership**- Assets and property that are owned collectively by a group of persons who manage their usage and reap the benefits of their operations.
- **Private ownership**- It is a subset of collective property in which a group of owners jointly own productive property that is used by workers, often in order to make a profit.
- **Cooperative ownership**- When people who utilise and run a piece of property also own it (or social ownership).

2.1.5 Placemaking

Placemaking is characterized as a multifaceted strategy for the administration, planning, and creation of public areas. In order to create public places that support people's health, happiness, and well-being, it makes the most of a community's resources, inspiration, and potential.

As per **(What is Placemaking?, 2007)**, "Placemaking facilitates creative patterns of use, paying particular attention to the physical, cultural, and social identities that define a place and support its ongoing evolution." It goes beyond just advocating for improved urban architecture.

Figure 6: What is placemaking?

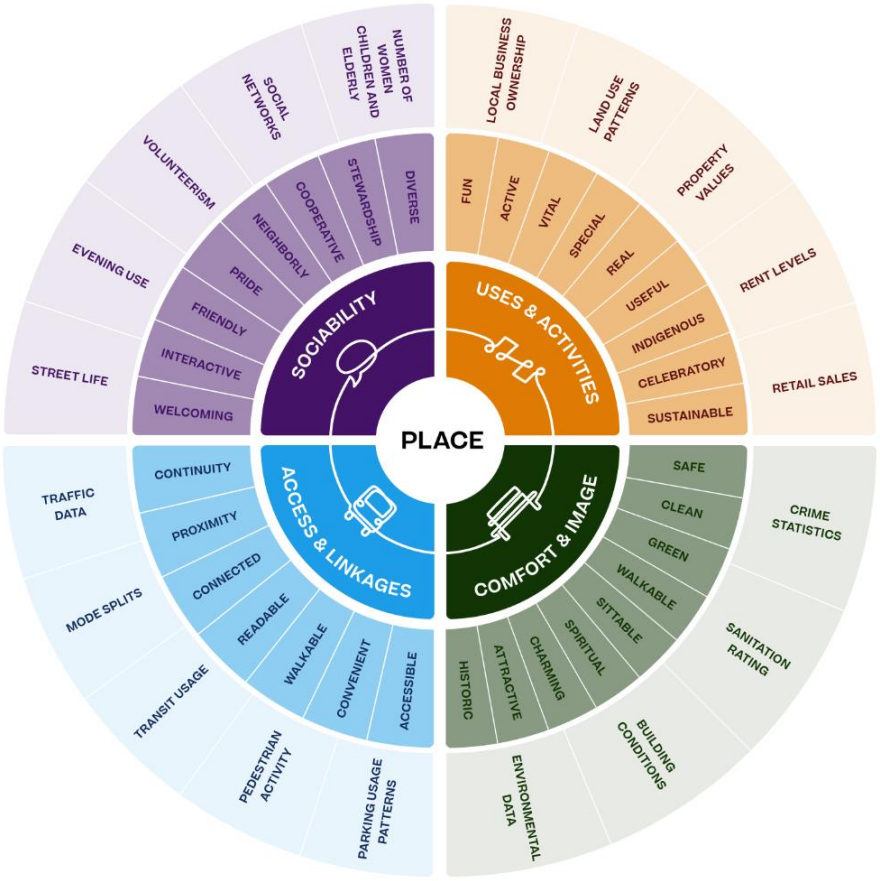


Figure 7: Place Diagram (What is Placemaking?, 2007)

Placemaking inspires people to cooperatively recreate and remodel public spaces as the pulsating centre of every neighbourhood. Placemaking is a collaborative approach that aims to improve shared value in public areas while enhancing the connection between people and the places they share.

2.2 Guidelines

2.2.1 Placemaking Guidelines (NIUA)

NIUA, Bhopal has proposed the following ten principles of placemaking.

1. **Image and Identity**- Site specific design strategy to ensure each site has unique identity.
2. **Attractions**- Interest points that attract crowds to the area and spend time.
3. **Streets as public spaces**- The streets are critical public spaces.
4. **Triangulation**- Locating elements next to each other in a way that fosters activity.
5. **Power of 10**- Every place should provide 10+ things to do layered to create synergy.
6. **Amenities**- Basic amenities to make the experience more comfortable.
7. **Flexible design**- Flexibility through well thought out plans and programming.
8. **Seasonal strategy**- Adaptable to all seasons for maximum useability of the space.
9. **Accessibility & connectivity**- Facilitating pedestrian movement and inclusivity.
10. **Safety**- A safe space encourages a sociable environment for interactions and activities.

2.2.2 Wetland & Waterbodies Management Guidelines (NMCG)

The geographical voids taken into consideration for the thesis are the natural drains of the city. in order to reconnect the voids to the city fabric, it is important to take into consideration the guidelines for wetlands.

The current research was started by the National Mission of Clean Ganga for addressing the problems raised, by developing a toolkit for the management of wetlands and waterbodies in urban areas. The toolkit's goals are to safeguard the natural systems that maintain urban water resources, mainstream water body conservation into urban planning, also providing a step-by-step procedure for identifying, prioritizing, and creating an action plan for protecting urban water bodies (Urban Wetland/Water Bodies Management Guidelines - A Toolkit For Local Stakeholders, 2021).

Figure 8: Stage 1- Identification of urban wetlands/ water bodies for conservation " (Urban Wetland/Water Bodies Management Guidelines - A Toolkit For Local Stakeholders, 2021)"

The various steps involved in identification of the urban water bodies are as follows:

A) Mapping the City Level Information

1. Administrative boundaries (Planning Boundary, Municipal Boundary, & Ward Boundary)
2. Natural Resources (Existing & Proposed Land Use)
3. Natural Resources (Existing Land Cover)
4. Natural Resources (Temp, Humidity, Geology, Soil, Hydrogeology, Ground water Level)
5. Infrastructure (Drainage & Sewerage Network)
6. Economic Base (Economic Activities & Agriculture Practices)

B) Delineating Catchment Area & Zone of Influence of Water Bodies

7. Delineation of identified Basin (From Contour or Govt websites like CWC, SLUSI, BHUVAN)
8. Prioritized Watersheds (Based on Parameters)
9. Zone of Influence & Catchment Area (Delineation or Identification)
10. Prioritized Micro-Watersheds with the Prioritized Watersheds (Delineation of watershed-Based on criticality)

C) Mapping of Urban Water Bodies

11. Historical Dataset of Satellite Imagery (Past 15 years) (From Landsat images-For Identification of Encroachment & Trends)
12. Documentation of Existing conditions of Water Bodies (with Characteristics)
13. Classification of Existing Water Bodies (Based on size, Characteristics & Ownership)
14. Prioritization of Existing Water Bodies (Based on Hydrological Criteria & Scientific Criteria)

2.3 Nature Based Solutions

Nature-based solutions are what the International Union for the Conservation of Nature (IUCN) refers to as "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, providing human wellbeing and biodiversity benefits at the same time." These are responses to societal issues that draw inspiration from natural processes. Nature-based solutions can be applied to treat wastewater by developing engineered systems that mimic the functioning of natural ecosystem to their advantage, which reduces dependence on mechanical systems. Natural elements such as soil, plants, bacteria, porous media, etc are used to remove various pollutants from wastewater such as organic matter, suspended solids, nitrogen, phosphorous and pathogens. Nature-based solutions are often viewed as sustainable and cost-effective approaches, offering numerous benefits for both the environment and people.

2.4 Wastewater Treatment Using Constructed Wetlands

Constructed wetlands (CWs) are wetlands that have been planned, developed, and maintained to mimic particular natural processes for the treatment of wastewater. These technologies, which mostly use plants, substrates, soils, microbes, and water, use a variety of jobs involving physical, chemical, and biological techniques to remove several pollutants or improve the freshness of the water. They are used to treat municipal wastewater, wastewater from oil refineries, drainage from agricultural operations, acid mine drainage, etc. According to certain data, subsurface constructed wetlands in Africa are estimated to cost approximately US $5 per individual for wastewater treatment, whereas mechanical wastewater treatment methods such as activated sludge systems cost roughly US $50 per individual (Hassan, Chowdhury, & Prihartato, 2021).

Wetlands are typically characterized by soil that is saturated with water for an extended period, leading to anaerobic conditions. Wetlands can be found in various forms, such as natural freshwater and saltwater wetlands, as well as constructed wetlands that are used to treat contaminants. Constructed wetlands utilize a complex system of processes that involve water, soil, plants, animals, microorganisms, and the environment to remediate contaminants. Different techniques are employed in constructed wetlands, including biodegradation, phytoremediation, and natural attenuation. Wetlands primarily undergo physical processes like filtration and

sedimentation, chemical processes like adsorption and precipitation, and biological processes like biodegradation and plant assimilation.

Most wetlands are identified by having a large concentration of vascular plants. The dense vegetation helps to decelerate the flow of water, generating microenvironments that offer sites for sorption of contaminants and attachment of microorganisms. Microbes are crucial in the breakdown of contaminants and the transfer of contamination between the environment and plants. Typically, a group of microorganisms, known as a microbial consortium, is responsible for the degradation and transformation of contaminants. The efficiency of contaminant degradation is dependent on the presence of microorganisms necessary for the process, as well as suitable environmental conditions that facilitate their growth and activity.

2.4.1 Classification of Constructed Wetlands

The diagram in Figure 9. illustrates the general layout of different types of constructed wetlands (CWs). These CWs are typically classified into two types based on their hydrologic processes, namely free water surface (FWS) CWs and subsurface flow (SSF) CWs. FWS structures mimic natural wetlands by allowing wastewater to flow over the surface of polluted substrates, while SSF structures allow wastewater to pass through the substratum horizontally or vertically to promote plant growth. SSF structures can be further classified into vertical flow (VF) and horizontal flow (HF) CWs based on the direction of wastewater flow.

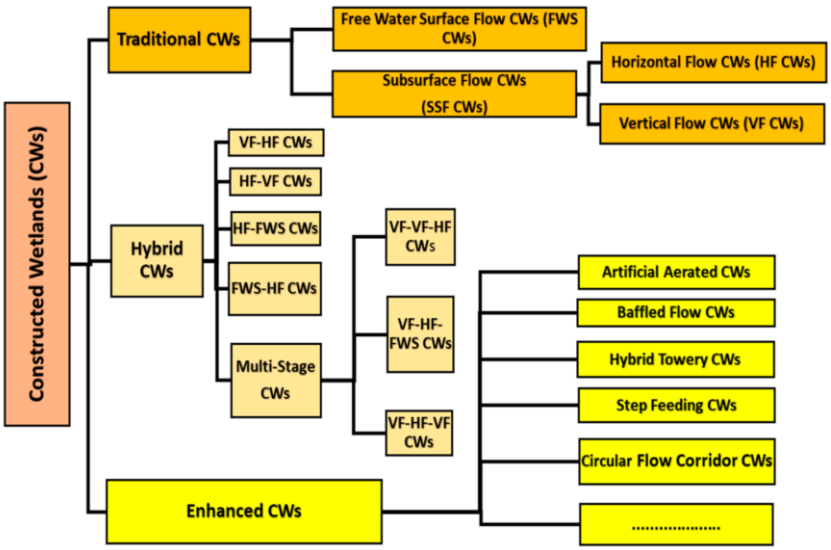


Figure 9. Classification of CWs for wastewater treatment

Hybrid CWs, which are composed of multiple wetland technologies, are commonly used for wastewater treatment and recovery. These hybrid CWs can be a combination of VF, HF, and FWS CWs, such as VF-HF CWs, HF-VF CWs, HF-FWS CWs, and FWS-HF CWs. Additionally, multiple-stage CWs with more than three steps are utilized. To improve the efficiency of wastewater treatment, different types of augmented CWs, such as manmade ventilated CWs,

baffled flow CWs, hybrid tower CWs, step feeding CWs, and circular flow corridor CWs, have been developed in recent years.

Surface Flow Wetlands

A surface flow (SF) wetland is comprised of a shallow basin, a medium such as soil to support plant roots, and a water control structure that maintains a shallow depth of water. The water level is higher than the substrate level. SF wetlands resemble natural marshes and can offer aesthetic and wildlife benefits as well as water treatment. The upper layer in SF wetlands is aerobic, while the deeper waters and substrate are usually anaerobic. SF wetlands are typically used for stormwater treatment and treating mine drainage and agricultural runoff. They are also referred to as free water surface wetlands or aerobic wetlands for mine drainage treatment.

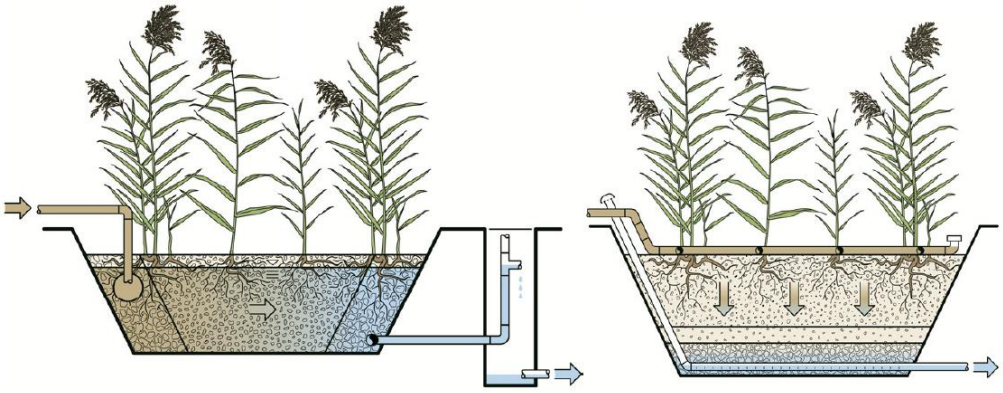


Figure 10. Schematic diagram horizontal flow (left) and vertical flow (right) treatment wetlands

The advantages of SF wetlands are their low capital and operating costs, and their construction, operation, and maintenance are uncomplicated. However, the main disadvantage of SF wetlands is that they usually require more land area than other systems.

Subsurface Flow Wetlands

Subsurface flow (SSF) wetlands are constructed with a sealed basin that contains a porous substrate such as rock or gravel. The water level in these systems is designed to remain below the top of the substrate.

In the United States, horizontal flow paths are commonly used, while in Europe, vertical flow paths are also employed. SSF systems are known by different names, such as vegetated submerged bed, root zone method, microbial rock reed filter, and plant-rock filter systems. SSF wetlands are best suited for treating wastewaters with low solids concentrations and relatively uniform flow conditions due to hydraulic constraints imposed by the substrate. These systems have mainly been used to reduce 5-day biochemical oxygen demand (BOD5) in domestic wastewaters.

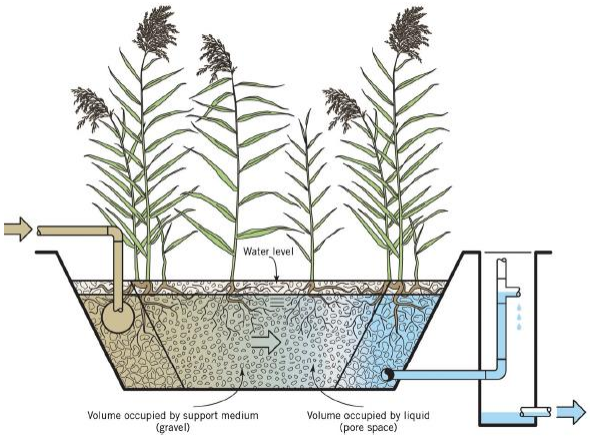


Figure 11. Schematic diagram showing subsurface flow constructed wetland

Advantages of SSF wetlands include greater cold tolerance, minimized pest and odour problems, and potentially greater assimilation capacity per unit of land area compared to SF systems. SSF wetlands have some drawbacks in comparison to SF wetlands. They are relatively more costly to construct, making them more suitable for small flows. Additionally, they may be more difficult to regulate, and their maintenance and repair costs are typically higher than those of SF wetlands.

Hybrid Wetlands

Single stage systems rely on a single area for all treatment processes, while hybrid or multistage systems use separate cells for different types of reactions. For example, effective treatment of mine drainage may require a sequence of wetland cells with varying conditions to promote aerobic and anaerobic reactions. The removal of ammonia from agricultural wastewater may also require multiple cells with different conditions.

2.5 Case studies

2.5.1 Cheonggyecheon Stream Restoration, Seoul, South Korea

Figure 12: Before and after the restoration of "Cheonggyecheon river in Downtown Seoul (South Korea: Restoration of the Cheonggyecheon River in Downtown Seoul, 2022)"

- **Population**: 10.1 million
- **Biome**: Freshwater
- **Extent**: Length- 5.8 km, Area- 292,000 sqm
- **Context**: Mixed-Use
- **Cost**: 345.2 million USD
- **Funding**: Seoul Metropolitan Government

Project Statement: The downtown area which was the economic centre of Seoul was in decline from the past two decades with increasing pollution and rise of slums. The elevated highway that covered the stream was an important artery for transport and logistics. The overpass however decline with time and various concerns of safety were raise. The 10-lane motorway and the 4-lane elevated highway along the Cheonggyecheon stream, which transported nearly 170,000 cars daily, were demolished by the Seoul Metropolitan Government. This brought about a significant paradigm shift from an auto-centric development-oriented landscape to one valuing the people's quality of life.

Project Goals:

- To enhance environmental conditions & quality of life in the downtown area
- To establish a focus having historical value and is visually appealing
- To spark economic growth over a long time by captivating tourists and the investors
- To restore both sides of the city separated by road infrastructure.
- To restore a decrepit public space and create a waterfront

Figure 13: Conceptual site plan by Seoul Development Institute (Cheonggyecheon Stream Restoration Project, 2022)

Implementation:

- **Revival of historical values**- In order to successfully justify the project, restoring the historical values of the place at the same time ensuring safety from flood was priority.
- **Flood prevention and safety measures**- The city set the aim for 200 years interval of flood recurrence to ensure safety of the citizens.
- **Sewerage treatment**- Adopting double-box system where the sewage is treated in a combined system and the highly-polluted first rainfall is segregated into a separate pipeline & treated at the treatment facilities

- **Water supply and its quality**- Water sources in the area include the Han River and groundwater released from local metro stations. (Seoul Urban Renewal: Cheonggyecheon Stream Restoration, 2022).

Stakeholders:

The key stakeholders involved for the coherent implementation of the project are (Case Study: Cheonggyecheon; Seoul, Korea, 2022):

- **"Public Organisations**- These include Central Government, Seoul Municipality, Seoul Metropolitan Government and Cultural Heritage Administration
- **Citizen Associations and Unions**- Citizen's Committee
- **Private Groups and Partnerships**- Cheonggyecheon Research Group
- **Designers and Engineers**- Seoul Development Institute urban design team, Dongmyung Eng, Daelim E&C"

Project Outcomes:

- **Environmental**
  - Flood protection for up to 200 years of flood while having the capacity for sustaining flow rate of 118mm/hr.
  - Increased the biodiversity of the area by about 639% from before the restoration to after the end in 2008
  - Reduced urban heat island effect (-4.5%) due to daylighting of the stream that was previously covered. It was also affected by the increase in vegetation, reduction in vehicular travel and increased the wind speed.
  - Reduced air pollution caused by small particulate matter by 35% and minimised respiratory diseases.
- **Social**
  - Increased pedestrian activity by 76% and social interaction
  - From 2003 and 2008, helped Seoul's bus and subway ridership rise by 15.1% and 3.3%, respectively.
  - Attracts 64,000 visitors every day on average. 1,408 of them are international visitors who provide the Seoul economy up to 2.1 billion won ($1.9 million) in visitor expenditure.
- **Economic**
  - There was about 30–50% increase in land prices for homes within 50 metres of the restoration project which is double that of rate increases in other parts of the city.
  - The number of enterprises expanded in the Cheonggyecheon region by 3.5% between 2002 and 2003, which was twice as fast as company growth in downtown Seoul. Additionally, the area's working population increased by 0.8%, compared to a 2.6% decline in downtown Seoul.

Key lessons learned:

- Ingenious envisioning- the vision behind demolishing one of the busiest transport corridors of Seoul was an innovative step.
- Participatory approach- in order to streamline the process, participation from the community, local traders and entrepreneurs was vital.
- Pertinent system adapted for implementation and efficient project management
- Political leadership- In order to successfully implement such a ground breaking project, strong leadership with clear vision and ability to get the approval of the locals was most important.
- The triangular project implementation structure, which included an administrative agency to carry out the work, a research organisation to lend expertise, and a citizens' committee to solicit input from the general public, was successful (Seoul Urban Renewal: Cheonggyecheon Stream Restoration, 2022).
- Similar initiatives have been encouraged to be undertaken in Korea and other parts of the world as a result of the successful completion.

2.5.2 Houtan Park, Shanghai

- **City population:** 384333
- **Date of Design:** 2007 – 2009
- **Date of Completion:** 2010-15
- **Size:** 14 hectares
- **Client:** Shanghai World Expo Land Development Co., Ltd.
- **Landscape Architect:** Turenscape

Project Statement: On the Huangpu Riverfront in Shanghai, Houtan Park is a regenerative living landscape that was constructed on a brownfield of a former industrial site. A comprehensive restorative design strategy is used to treat contaminated river water and restore the deteriorated waterfront in a visually appealing manner. Key elements of this strategy include the constructed wetland in the park, ecological flood control, reclaimed industrial structures and materials, and urban agriculture.

Project Goals:

- To build a sustainable Expo that can handle a huge influx of tourists and then convert it into a long-term public waterfront park after the Expo.
- To design a green expo that showcases green technology for park design, water treatment, and flood control.
- To transform from a temporary waterfront park to a permanent one.
- To restore the polluted environment from the remains of the industry.
- To improve quality of water and flood control.

Figure 14: The view before park construction and after the construction (Shanghai Houtan Park, 2022).

Planning and design: The planning revolved around the concept of *"Landscape as a Living system"* (Yu, 2010)

- **Constructed wetlands and regenerative design**: Reinvigorated waterfront acts as a living machine to filter water that is contaminated and also helps in flood prevention.

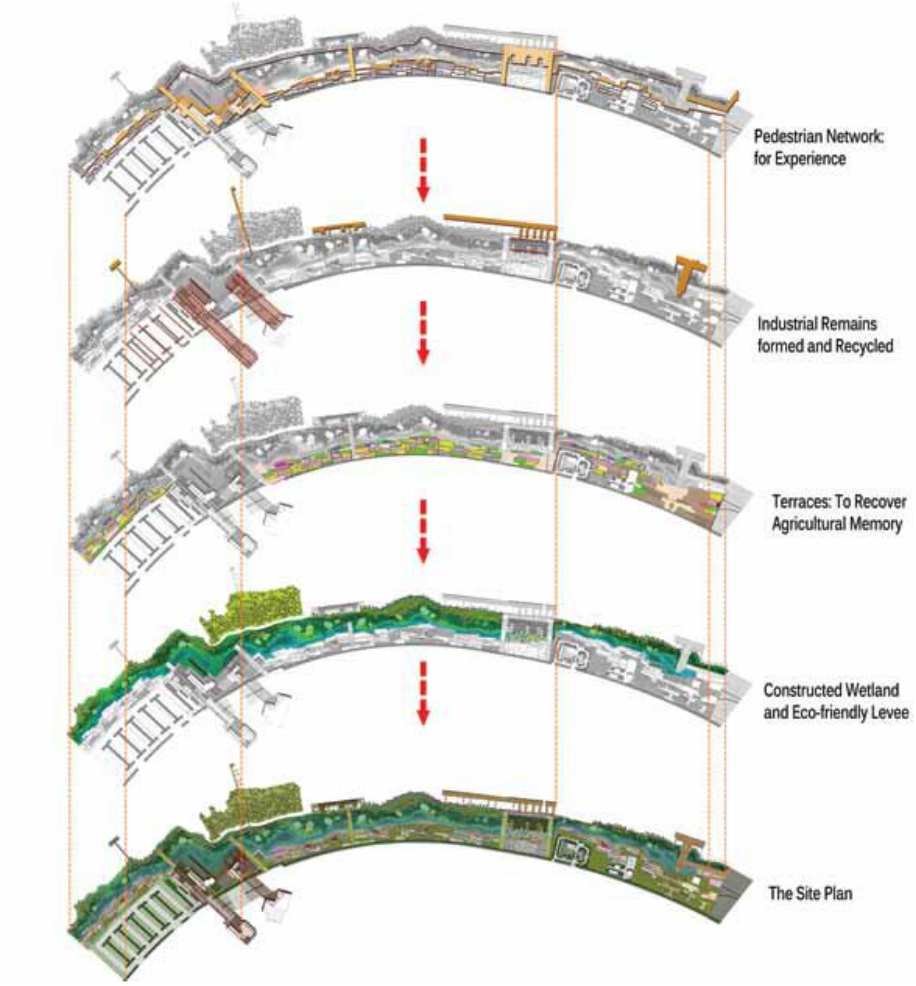


Figure 15: Layering and integration of various functions and ecosystem services of the park (Yu, 2010)

- **Memory and Prophecy**: The post-industrial eco-civilization and the site's layers of agricultural and industrial history.

- **Path Network**: A network of routes connects the park's three main sections, which are an environmentally regenerated landscape, urban agriculture, and industrial spirit.

Project Outcomes:

- **Environmental**
  - Enhances the water's quality by cleaning up to 634,000 gallons of contaminated river water per day from grade V which is not suitable for human contact to grade II that is for landscaping.
  - Increases the biodiversity of the site with about 93 plant species and more than 200 animal species.
  - Successfully exhibited futuristic cutting-edge design and construction methods
- **Social**
  - 590,500 visitors had the opportunity for entertainment and education during the 2010 Shanghai World Expo.
  - Residents of the city and tourists from all over China and the world continue to enjoy these advantages owing to the park.
- **Economical**
  - Water treatment technology utilised in the water features reduces water bills by $116,800 annually.
  - Reusing 37 tonnes of steel and about 34,000 post-industrial bricks from the site reduced trash and cost an estimated $17,300 was an added advantage (Shanghai Houtan Park, 2022).

2.5.3 Gorla Maggiore water park, Lombardy, Italy

- **City population:** 3063361
- **Date of Design:** 2008-13
- **Size:** 30000 sqm.
- **Construction Cost:** €820,510
- **Operation Cost (annual):** €3,500.00
- **Type of solution:** Treatment wetlands for combined sewer overflow (CSO-TW)

Project goals

The main objective is to prevent flooding while simultaneously limiting pollutants. Thus, pollution and flood management are addressed by the green infrastructure. Green spaces development, restoring of the degraded ecosystems as well as managing of blue areas such as rivers, ponds, etc. are also the focus of this project.

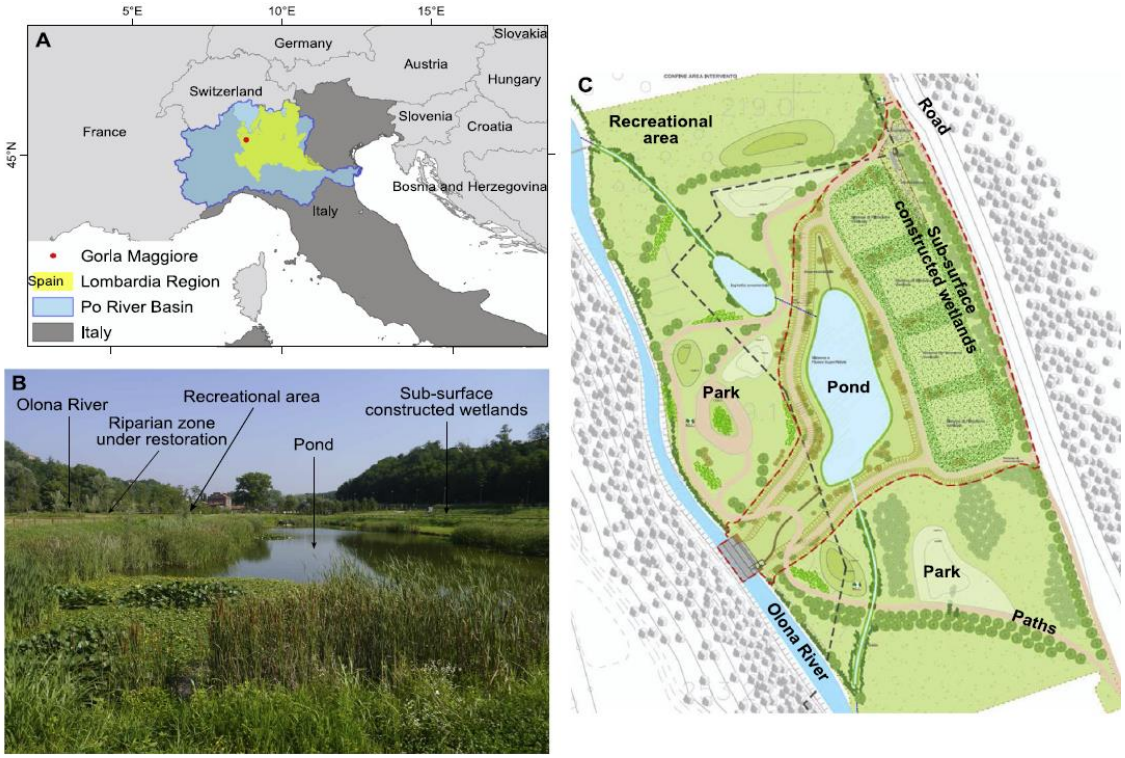


Figure 16. Location and site plan (Reynaud, Lanzanova, Liquete, & Grizzetti, 2017)

Project Objectives

The Gorla Maggiore aquatic park was created with the intention of offering four distinct categories of water-related ecosystem services: firstly, reducing pollution levels discharged into the Olona River from a combined sewer overflow; secondly, preventing floods by collecting rainwater and regulating the flow of water into the river; thirdly, allowing for recreational activities for the local community; and fourthly, supporting biodiversity and wildlife by providing habitats for various species such as birds, macroinvertebrates, and amphibians.

Planning and design

The process for treating the water involves a combination of a vertical-flow treatment wetland and a free water surface treatment wetland for further refining. The CSO-TW is made up of several components, including a CSO separation chamber, a grid and sedimentation tank for preliminary treatment, four VFTW beds for secondary treatment (totaling 3,840 m2), and FWS-TW (3,174 m2) with multiple functions. The FWS-TW is responsible for treating both the first and second flush, increasing biodiversity, creating a recreational space, and serving as a retention basin for hydraulic purposes (with a potential floodable area of up to 7,200 m2).

In accordance with Lombardy laws, the CSO infrastructure was designed to direct a small fraction of the flow (up to 17.5 L/s) to the central wastewater treatment plant, while the first flush fraction (up to 640 L/s) is treated by the vertical-flow beds and the second flush fraction (CSO loads exceeding 640 L/s) is sent directly to the FWS-TW. The system operates by gravity, with a theoretical hydraulic retention time of 36 hours.

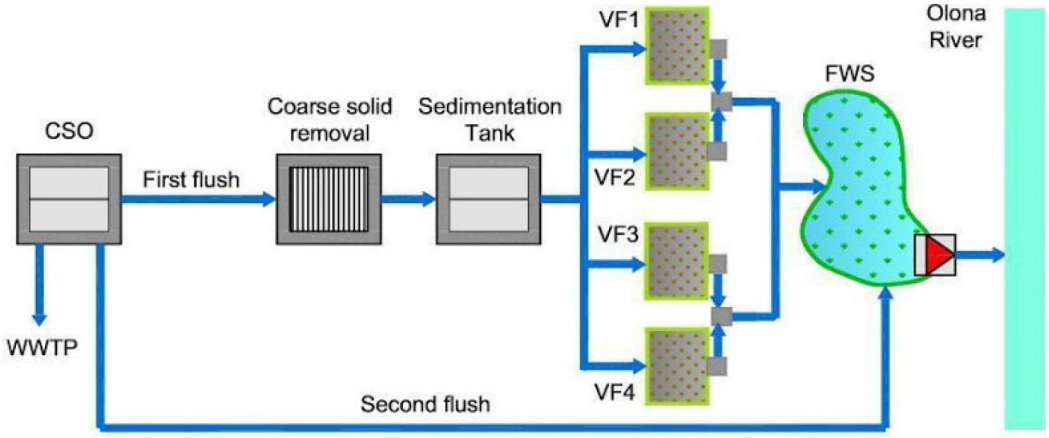


Figure 17. Schematic diagram showing mechanism of CSO-TW (Cross, Tondera, Rizzo, & Andrews, 2021)

Project Outcomes:

- **Environmental**
  - Waste management improved
  - Restoration of degraded marine and coastal ecosystems
  - Water quality improved
  - The stormwater management improved and also better flood control was achieved
  - Biodiversity loss reduced significantly
  - Ecological connectivity increased across the regenerative site and scale

- **Socio-cultural**
  - Encouraged recreational activities and exercise lead to better health and wellbeing of the community
  - Increased support for education and scientific research

- **Economic**
  - Nature based solutions helped in reducing costs for treatment of CSO.
  - Reduction in cost of urban management

2.5.4 Najafgarh Waterway Revitalisation, Delhi

- **City population:** 1.9 crores
- **Implementation status:** Ongoing
- **Scale:** Micro-scale: District/neighbourhood level
- **Project length:** 41km
- **Drainage zones:** Six
- **Monitoring Agency**: National Wetland Authority

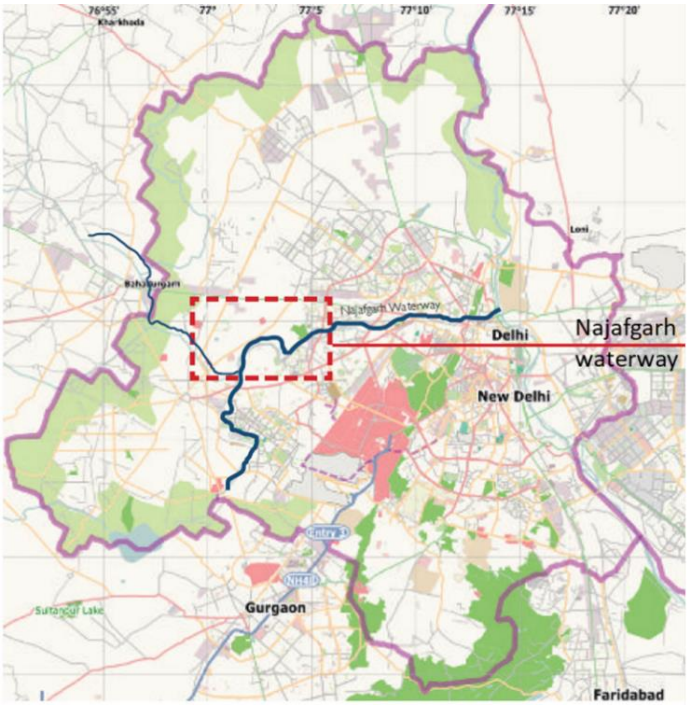


Figure 18: Location of Najafgarh waterway in Delhi (Rewal, Khanna, Mall, & Diptivilasa, 2015)

Project Statement: Delhi has a unique waterscape heritage having a continual natural water system. Najafgarh waterway extends across Central-North, West and South-West parts of Delhi and there is a rising concern for the degrading water and diminishing water in the channel.

Project Goals: The goal is to improve connectedness within the urban fabric by channelling pedestrian traffic inside the city and using the existing rivers, green spaces, historic, and transportation aspects of the city. The aim is to design a pedestrian friendly city.

Project Objectives:

- To create an uninterrupted pedestrian and cycle trail along the waterway
- To restore the degrading riverine ecosystem.
- To create sustainable amenities for the use by public
- To rejuvenate and create places for public interaction and revive the heritage value.
- To create trail for E-rickshaw connecting different parts of the waterway
- To propose alternate transport such as waterway
- Connect river with the people.
- Protect the floodplains from adverse effects of development activities.
- To spread awareness about the degrading waterbodies of Delhi.
- To construct new bridges, reconnecting the urban fabric.
- Use DEWATS system to clean black/grey water for irrigation
- Najafgarh Edge- front Development along its tributaries by developing edge condition

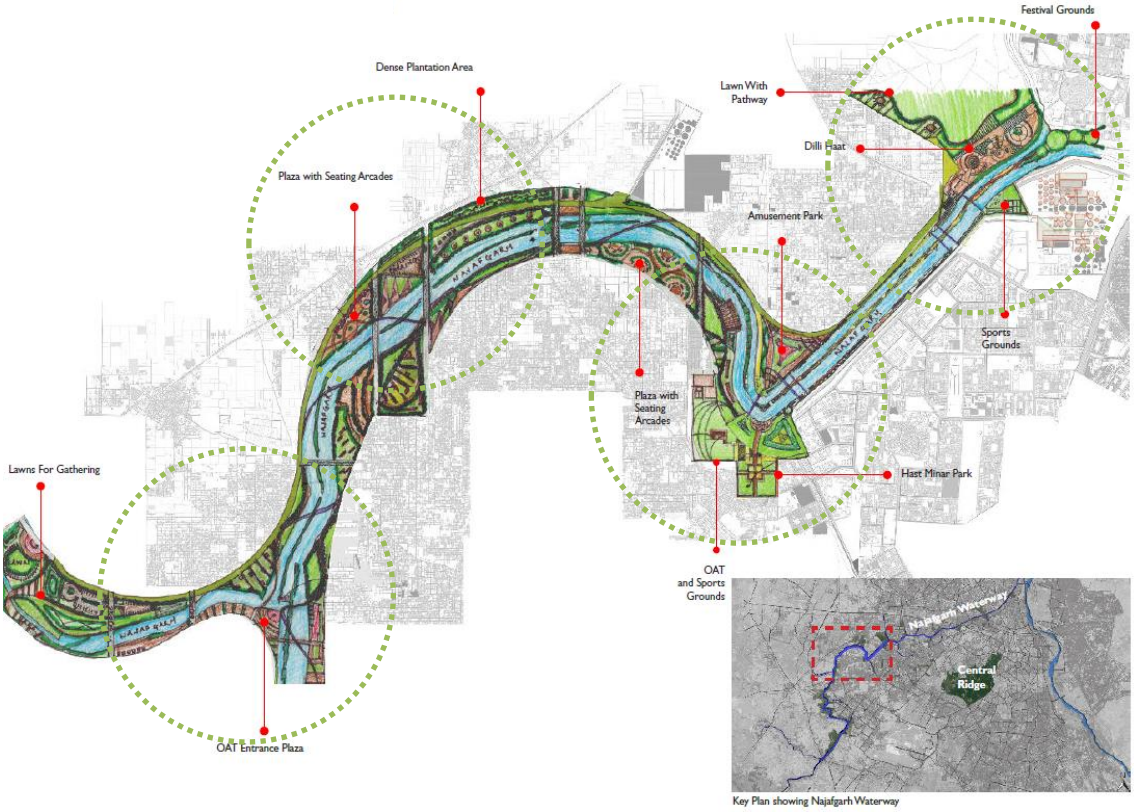


Figure 19: Sketch showing proposed activities and activity nodes along Najafgarh waterway (Rewal, Khanna, Mall, & Diptivilasa, 2015).

Planning and design:

- Rejuvenating the edges by activating the edges with entrance plaza and lighting.
- Activating the nodes by incorporating many activities like kiosk, restaurants, Delhi haat, etc.
- Pedestrian bridges connecting both sides of the waterway
- Retaining and enhancing the existing biodiversity by developing wetland area using bio-intensive beds.
- Planting native trees to revive the biodiversity and stabilise bank.
- Urban agriculture in the neighbourhood bringing healthy and sustainable food access to the people.
- Creating stepped edges by cut and fill method to prevent/ control flooding.

Expected Project Outcomes:

- **Environmental**
  - Biodiversity parks: Designated biodiversity zones for the preservation of the natural biodiversity.
  - Controlled flooding: water is welcomed through engineered landform and provides opportunities for programs and refuge for wild species.
  - Urban agriculture: Opportunity for weaker sections to be involved in urban agriculture bringing in healthy and sustainable food for the community.

- Energy efficiency: Water harvesting and solar energy can be used as sources of power as they are natural energy resources.

- **Social**
  - Culture and history: Through design, the site's cultural and ecological heritage are portrayed, having the potential to raise public awareness of the waterway.
  - Heritage: retaining and remembering the memory of culture and heritage of the nearby areas.
  - Environmental awareness: Raising awareness amongst the community for protection of water bodies.
- **Economic**
  - Site develops into a neighbourhood that generates employment opportunities: a commercial area where people may go for shopping, playing and relaxing.

2.6 Learnings from case studies

Table 1. List of reviewed case studies

Case study	Objectives	Approach
Cheonggyecheon Stream Restoration, Seoul, **South Korea**	To restore environmental, historic and improve the quality of life around the stream.	The elevated highway along the stream was demolished to shift from an auto-centric development-oriented landscape to one valuing the people's quality of life by participatory approach and clearly defining long-term vision, short-term action plans and implementing agency.
Houtan Park, Shanghai, **China**	To build a sustainable Expo that can handle a huge influx of tourists and transforming it into a long-term public waterfront park after the Expo.	A comprehensive restorative design strategy is used to treat contaminated river water and restore the deteriorated waterfront in a visually appealing manner.
Gorla Maggiore water park, Lombardy, **Italy**	To treat CSO (combined sewer overflows) in a sustainable manner and transform public space.	Nature-based Solution- Treatment wetlands used to treat CSO, mitigate flood and to increase biodiversity.
Najafgarh Waterway Revitalisation, Delhi, **India**	To rejuvenate the degrading riverine ecosystem and create places for public interaction and provide uninterrupted pedestrian network.	Activating the edges by incorporating many activities helped in educating people of culture and history of Yamuna as well as restore biodiversity.

Following are the catalysts for creating public space

- A strong local leadership to encourage the importance of public spaces and having the ability to go through with the vision.
- A strong vision, desire and willingness to change is key to successful placemaking
- Participatory designing with the community, local government authority and NGOs
- Identifying the opportunities or the urban voids which lack any activities and infusing them with life and character.
- On successful integration of public realm and natural ecosystem, the urban voids reap many socio-economic benefits.

3. Study Area

3.1 About Bhubaneswar

The site chosen for the thesis is Bhubaneswar. The tier 2 city is often illustrated as the **Ekamra Khetra or the City of Temples**. One of the earliest planned towns in India is Bhubaneswar, which was planned by Otto Königsberger in 1946. The city has expanded further towards the south-west because of reserve woods in the north-western part and flood plains in the eastern part. Kalinga architecture is evident in the entire city. The most popular tourist spots in Odisha are the Swarna Tribhuja or Golden Triangle, which constitutes of Bhubaneswar, Konark, and Puri.

The population of Bhubaneswar in 2022 is 1,226,033, with 2.65% increase from 2021 (Bhubaneswar Population 2022, 2022). The population density is about 76 PPH which is lower than average density of large cities (125- 175 PPH). With rapid urbanization and urban densification, Bhubaneswar has seen a rise to the urban voids, with some of them having the opportunity to be transformed into public spaces by infusing activities.

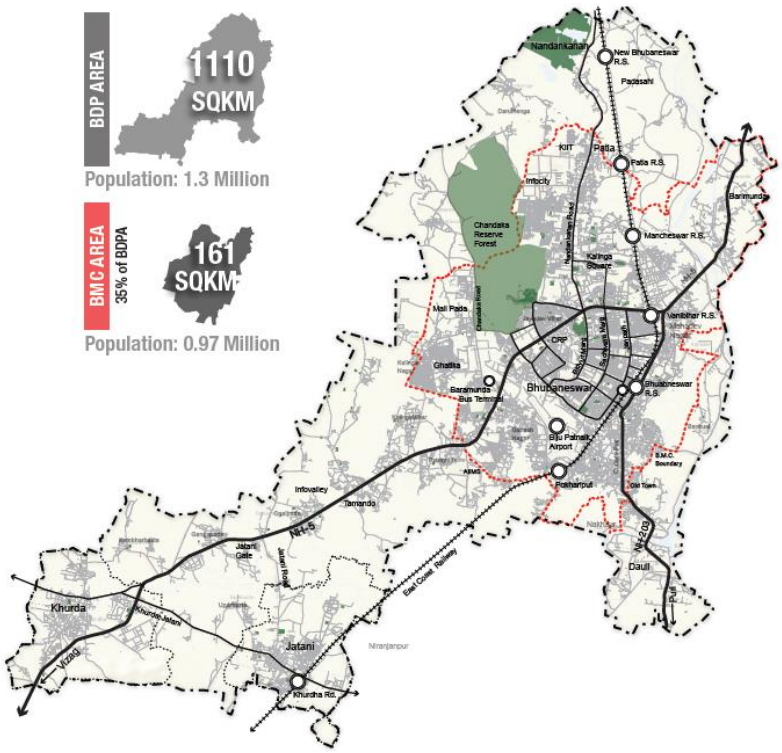


Figure 20: Bhubaneswar Development Plan and Bhubaneswar Municipal Corporation planning boundaries (Bhubaneswar Smart City Proposal, 2015)

3.2 Brief history

Bhubaneswar's history can be divided into two phases: Ancient Bhubaneswar and Modern Bhubaneswar. The ancient city has a rich history dating back over 3000 years (1st and 2nd century) to the Kalinga empire, while the modern city was established in 1948. The old city was of great significance prior to the emergence of the modern city. This is evident from the numerous historical monuments located in and around the city. The city was first mentioned during the

Kalinga war and has several Jain and Buddhist temples that were built during the Ashokan rule, indicating its importance during different periods.

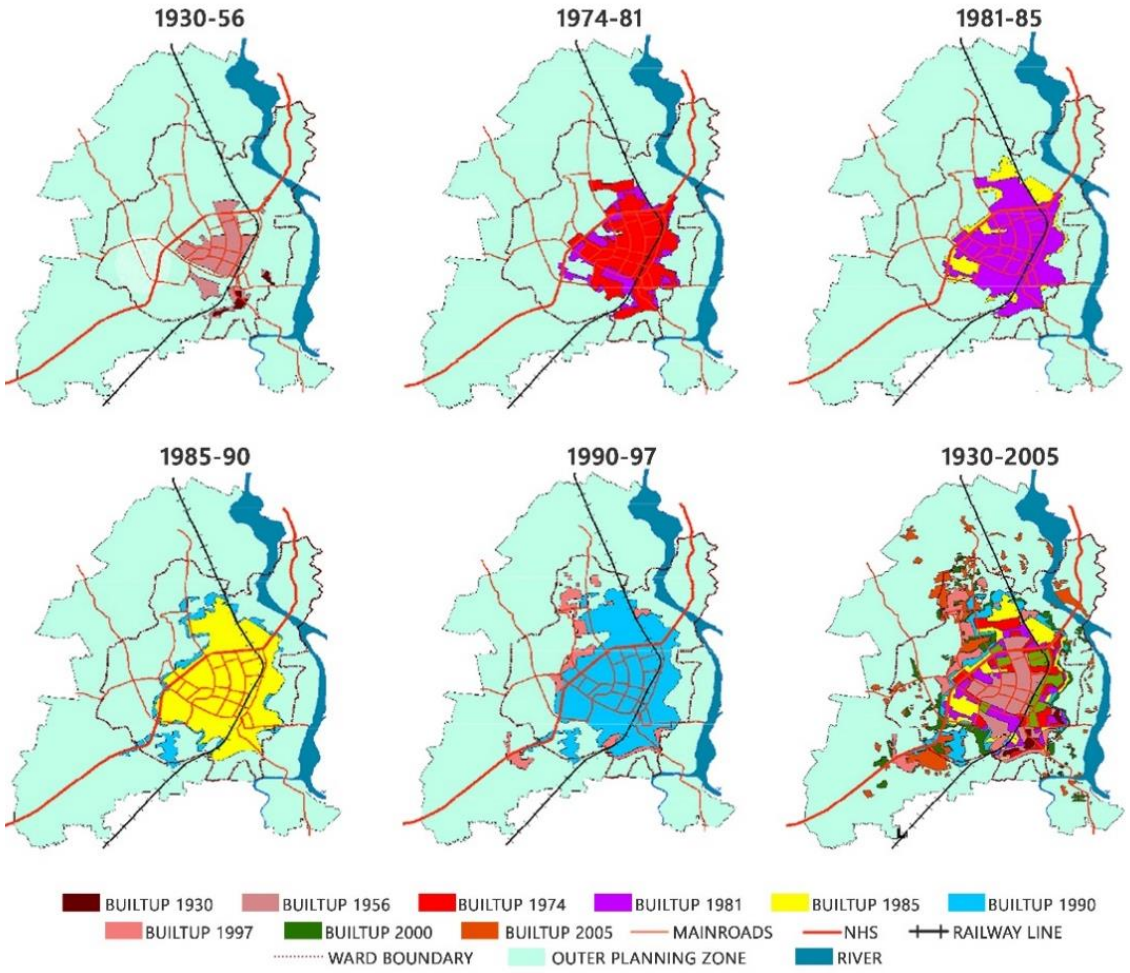


Figure 21. Bhubaneswar urban sprawl from 1930-2005 (Mishra, Mishra, & Subudhi, 2018)

From the 7th to the 11th centuries, the city continued to demonstrate its historical significance as several empires constructed Hindu temples dedicated to various deities. Although Cuttack was named Odisha's capital in 1936, due to its vulnerability to floods, it was no longer deemed suitable for the title in 1947. As a result, Bhubaneswar was awarded the capital status, a title it continues to hold today. In 1946, the German architect Otto Königsberger designed the modern city, which was one of the earliest planned cities in modern India, alongside Jamshedpur and Chandigarh.

3.3 Civic and planning organisations

Bhubaneswar is home to several key state and civic administration bodies. Bhubaneswar's urban local body, the Bhubaneswar Municipal Corporation (BMC), governs the city and covers an extensive area of 162.5 square kilometers, including 67 wards and 51 revenue villages. Founded in 1994, the BMC serves as the city's apex body and is primarily responsible for providing services that enhance residents' quality of life. Every five years, a councilor is elected for each of these wards. The mayor issues directives that the BMC carries out, and the Commissioner leads the

executive wing of the BMC. BMC oversees water supply, drainage and sewerage, sanitation, solid waste management, street lighting, and building regulation.

The Bhubaneswar Development Authority (BDA) is the primary planning authority for Bhubaneswar, established in 1983 under the Odisha Development Authorities (ODA) Act of 1982. BDA is responsible for managing the planning and development of infrastructure, providing development-related sites and services, and addressing the housing needs of the citizens (Know Bhubaneswar, 2018)

3.3.1 Organisation Structure

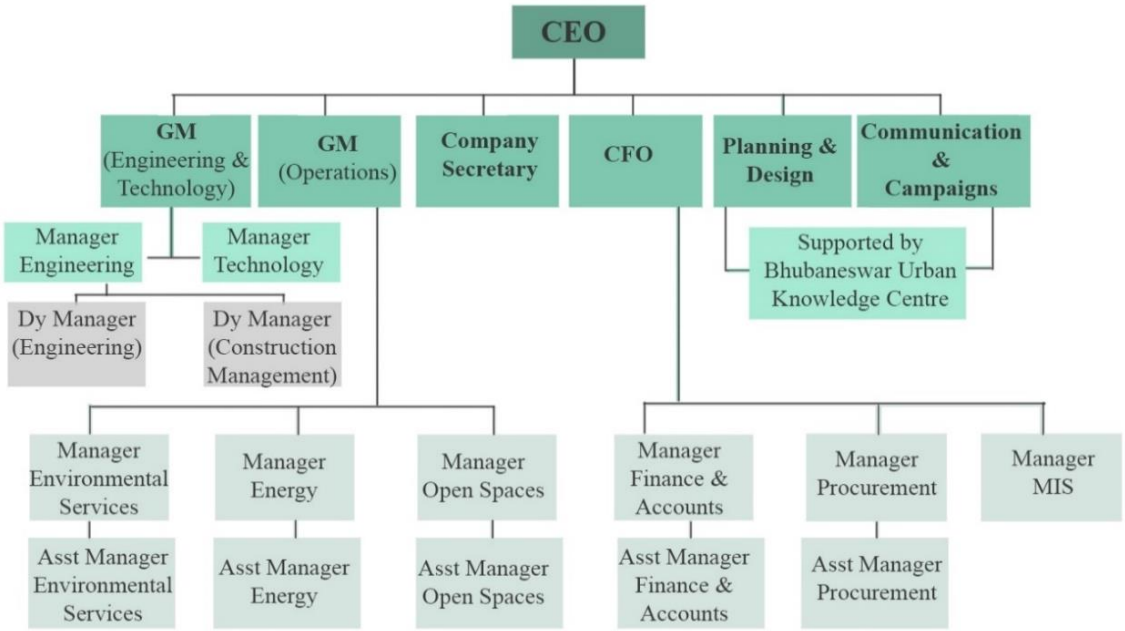


Figure 22. Organisational structure of BSCL

The **Bhubaneswar Smart City Limited** is a Special Purpose Vehicle (SPV) under the Smart City Mission programme. It collaborates with technology vendors, builders

and financers for the lake zone development along the drain no. X. There are various sections such as engineering and technology, administration, operations, planning and design, communications and campaigns under which planning and execution is done.

3.4 Demography profile

Bhubaneswar is a city with a diverse demographic profile, comprising individuals from various ethnic and linguistic backgrounds. As per the 2011 Census of India, the city had a population of 881,988 with a sex ratio of 899 females per 1000 males. Moreover, Bhubaneswar boasts a literacy rate of 93.63%, which is higher than the national average.

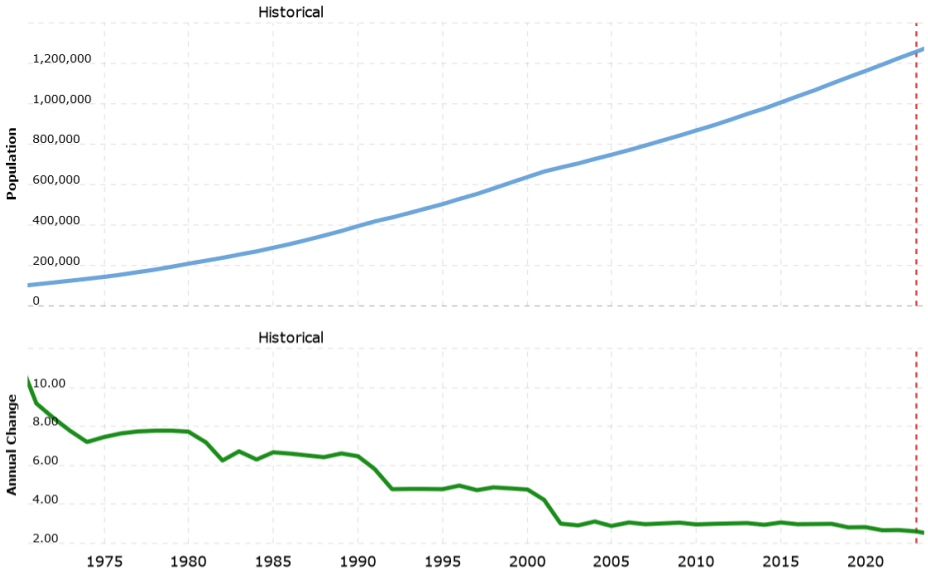


Figure 23. Chart showing population size and rate of increase for Bhubaneswar

The city's predominant religion is Hinduism, although there is also a substantial minority of Muslims and Christians. Odia is the official language of Bhubaneswar, but many people in the city also speak Hindi, English, and other regional languages.

Bhubaneswar is home to several prestigious educational institutions such as IIT Bhubaneswar, NISER, and AIIMS Bhubaneswar, which attract a significant student population. This has contributed to Bhubaneswar's reputation as an educational hub in eastern India.

3.5 Transport and connectivity

Bhubaneswar has a road network spanning over an area of 1960 sq.km, which provides direct connectivity to Kolkata and Ranchi in the North, and Visakhapatnam, Hyderabad, and Vijaywada in the South. In addition, Bhubaneswar has road connections to all major cities within the state.

It is home to the headquarters of the Odisha State Road Transport Corporation (OSRTC), and offers a variety of bus services ranging from state-run to private operators. Bhubaneswar has direct road links to neighbouring states like Andhra Pradesh, Jharkhand, and West Bengal, with NH-5 providing good connectivity.

Apart from roadways, Bhubaneswar is also well-connected through railways and airports.

Figure 24. Road network of Bhubaneswar (CDP,2030)

The East Coast Railway has its headquarters located here, with five railway stations within the city limits - Mancheswar, Vani Vihar, Patia Halt, Bhubaneswar Station, and Lingaraj Temple

Road. The Biju Patnaik Airport, located just 3 kilometres away from the city, has been upgraded to an international airport and connects to destinations in the Middle East and Southeast Asia.

3.6 Tourism

Odisha's tourism industry is closely linked to Bhubaneswar, which boasts a variety of attractions that draw millions of visitors each year from both within and outside the country. These include prominent landmarks such as the Old town, Lingaraja temple, Bindu Sarovar, Khandagiri and Udaygiri, Dhauli Giri, Nandankanan zoo, Mukteshwar temple, and Odisha state museum, among others. Each site has its own unique features and fascinating history, providing an enriching experience for tourists. Moreover, these landmarks are an integral part of Bhubaneswar and Odisha's culture and heritage. As one of the most peaceful and eco-friendly cities, Bhubaneswar is particularly attractive to tourists.

Figure 25. Major tourist attractions in Bhubaneswar
From top left- Lingaraj Temple, Khandagiri Caves, Nandankanan Zoological Garden, Ram Mandir, Dhauli Giri, Dhauli Giri- Buddha statue, Raja Rani Temple, Mukteshwara Temple, Udaygiri Caves

3.7 Natural drains of Bhubaneswar

The Gangua nallah is a stream that originates from the western upland region of Bhubaneswar in the Chandaka Reserve Forest area. It flows between ayacuts of Daya West branch canal and Lingipur distributary from NW to SE outskirts of Bhubaneswar. The total length of Gangua nallah from its source to its confluence point is approximately 45 kilometres, with a polluted stretch covering about 32 kilometres after it starts receiving wastewater from the city.

The city of Bhubaneswar lacks an organized sewage treatment system, and its untreated sewage is discharged through ten stormwater drains that carry wastewater and empty into Gangua nallah at different locations. As a result, the stream is polluted by the discharge of municipal wastewater from the city through several stormwater drains. However, the city's natural gradient from west to east provides a natural advantage for drainage, and the wastewater of the city flows through these stormwater drains.

Table 2: The major drains flowing in Bhubaneswar and draining to Daya (Joshi & Mishra, 2017)

Sl no.	Drain name	Starting from	Outfall Point	River	Length	Catchment	Discharge
					Km	Ha.	MLD
1	Gangua nallah	Chandka Forest	Daya R.	Daya	37.18	10343	107.25
2	Patia & Damana	Patia forest	Daya west canal	Kuakhai	4.32	1693	17
3	Mancheswar	Sainik School	Gangua	Daya	1.13	144	1.55
4	OAP area	Vani Vihar	Gangua	Daya	2.42	331	3.55
5	Barana	Vani Vihar	Gangua	Daya	5.63	1367	16.4
6	Jharpada	Old Rly station	Gangua	Daya	3.13	366	4.45
7	Baragarh	Baragarh area	Gangua	Daya	2.16	289	3.45
8	Gosagareswar	Old Bhubaneswar	Gangua	Daya	4.34	946	5.45
9	Airport area	Baramunda	Gangua	Daya	4.33	1299	14.3
10	Ghatikia	Aiginia	Gangua	Daya	4.24	1255	28.8
11	Nicco park	CRP Area	Gangua	Daya	5.48	1028	12.3

4. Data Inventory

Both **primary and secondary** surveys are carried out to understand the potentials, problems and opportunities of the study area through various parameters and variables. These parameters include physical determinants such as land use, accessibility, land ownership, water quality and socio-cultural determinants such as demography, economic condition, capacity building and institutional guidelines.

4.1 Survey Framework

The surveys carried out for the study can be broadly classified as shown in the figure below.

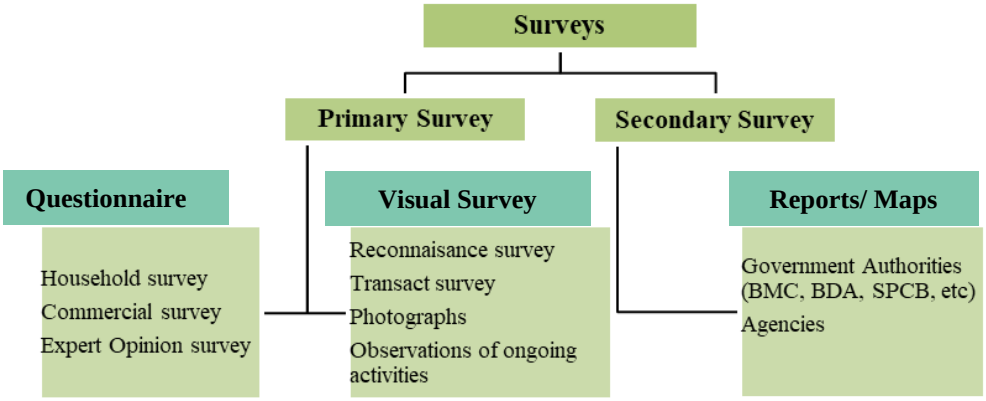


Figure 26. Survey Framework

4.2 Survey Procedure

4.2.1 Selecting geographical voids

- Preparation of drainage map using ArcGIS and delineation of catchment areas of the natural drains of Bhubaneswar
- Selecting geographical voids based on the natural drain from the drainage map
- Shortlisting voids based on the analysis of drainage maps and parameters identified
- Reconnaissance survey of the natural drain and its surrounding areas to further delineate action areas.
- User perception surveys and expert opinion surveys carried out for the selected action areas.

In order to select the geographical urban voids, criteria were created to see if the area would fulfill a minimal norm for potentially becoming a public space. The criteria were based somewhat on the (Characteristics and Guidelines of Great Public Spaces, 2014), and the "Project for Public Spaces' What Makes a Successful Place?'". The criteria for selecting the geographical voids (Patel & Gandhi, 2022):

a. **Size**: A minimum of 40 sqm must be accessible, which will easily accommodate at least 10 people.
b. **Visibility**: must be noticeable and raise awareness; and should not be hidden and visible public realm.

c. **Function**: The space's principal use might be altered without harming the environment in order to benefit the neighbourhood.
d. **Accessibility**: it must be accessible by roads or public spaces and not be hindered by any physical or social barriers.
e. **Safety**: It has to be regarded as a secure area for interaction and gathering by the general public. Additionally, areas with steep slopes that would be challenging for the general people to manoeuvre were removed.

4.2.2 Likert Scale Analysis

Place performance evaluation is carried out on the selected action areas of the geographical voids within the city. This is carried out with 7-point ordinal Likert scale to understand the citizens' response to the various attributes of placemaking. The attributes are selected on the basis of 4 parameters of placemaking (What is Placemaking?, 2007), which are comfort and image, access and linkages, uses and activities, and sociability. Rating the voids would help in identifying the current status of the voids and determining how these voids were functioning or interacting with the city fabric.

The places were ranked from 1 to 7 according to the given characteristics based on existing condition. (Where 1= Very Poor, 2= Poor, 3= Somewhat Poor, 4=Neutral, 5=Somewhat Good, 6= Good, 7= Very Good)

Table 3. Likert scale for rating of the geographical urban voids

Attributes							
Comfort & Image	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Overall attractiveness							
Feeling of safety							
Cleanliness/ Maintenance							
Comfort of places to sit							
Green							
Access & linkages	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Visibility from a distance							
Ease in walking to the place							
Transit access							
Clarity of info/ signage							
Uses & Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mix of stores/services							
Frequency of events/activities							
Overall busy-ness of area							
Economic vitality							
Sociability	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Number of people in groups							
Evidence of volunteerism							
Sense of pride & ownership							
Presence of children & seniors							

4.3 Primary Data Collection

Accessibility, assessment of existing natural drains and their voids are conducted as part of reconnaissance survey. Household survey to understand the demographic profile and people's perception survey about existing urban voids and their placemaking, commercial and expert opinion surveys are conducted through structured questionnaire **(Refer Annexure for sample survey formats)**. Expert opinion surveys will also help to identify the action areas around the natural drains in the city.

Reconnaissance survey is carried out to understand condition of the existing natural drain and the voids around it, accessibility, road width, land use, ownership, perception of people.

Table 4. Table showing type and relevance of survey

Sl	Type of Survey	Relevance of Data	Samples & Location
1	**Household Survey**	-Demography, Socio-economic status -Travel characteristics, -Recreation, Purpose of recreation -Willingness to pay, - Ranking of major attractions -Potential areas for waterfront development -Preferred activities/ facilities around the voids	**200 Samples** Collected (Influence zone of drain no. X)
2	**People's Perception**	-Place performance evaluation	
3	**Expert Opinion**	-Identifying voids of natural drains for action area -Current status of voids and need for revitalization, -Financing of projects, -Proposals for drain revitalization, -Main issues faced by the natural drains & their voids - Reasons for current situation (Authorities/ policies/ financial/ capacity building) -Potential areas for development along natural drain -Type of land use suited for the voids around drains -Preferred activities/ facilities around the urban voids -Factors affecting flood vulnerability	**9 Samples** (Planners, Professors, Forest, Environment and Climate Change Department, BMC, BDA, BSCL, SPCB officials)
4	**Commercial Survey**	-Ownership, -Size and type of business, -Average customers per day, -Need for revitalization of drain, -Aspirations for development, -Potential of the commercial establishment -Most preferred locations along the natural drain -Facilities expected to set up commercial establishments -Area requirements & monthly rental value	**50 Samples** Collected (Influence of Nicco Park Drain)
5	**Visual survey**	-Activities in the voids around the natural drain -Present condition of the voids -Polluting areas -Condition of existing infrastructure -Major issues	**Transact walk** **Photographs** **Observations**

4.3.1 Sample size calculation

The sample size is calculated using Cochran's sample size formula,

$$n_0 = \frac{Z^2 pq}{e^2}$$

Where e = Margin of error, p = population proportion.

As per census 2011, the population of zone of influence of the drain no. X is 99,015 which has been used for calculating the sample size. Sample size of 208 has been selected for the study.

Table 5. Cochran's sample size calculation

Population size	Confidence Level	Margin of Error	Population proportion	Sample Size
99,015	99%	5%	50%	666
99,015	90%	5%	50%	273
99,015	**85%**	**5%**	**50%**	**208**

4.4 Secondary Data Collection

Government departments and data collected from other sources for secondary data collection. All the secondary data collected from various sources are summarized in the following table.

Table 6. Table showing relevance of survey

Sl No.	Reports/ Documents/ Maps	Relevance of Data	Source
1	**Comprehensive Development Plan** 2030	- Proposed Land Use -Zoning regulations -Road hierarchy	BDA
2	**City Level information**- Ward map, Land use land cover, Land ownership	-Present land use activities in the voids along natural drains -Ownership details of each parcel of land	BMC
3	**Hydrology & drainage map**	-Understanding the hydrological regime	BMC
4	**Water quality data**	-Water quality- levels of BOD, COD, TSS & coliform	SPCB
5	**Contour map**	-Understanding the natural slope	BMC
6	**Physical Infrastructure** - sewerage layout, community and public toilets	-Sewage discharge and outfall points -Current scenario of availability of toilets	WATCO
7	**Recognized slums**	-Encroachment of informal settlements in the voids of natural drains	BMC Housing Dept.
8	**Progress report on initiatives** for natural drains	-Overall idea of ongoing works and their status, financing of the projects	BSCL, CITIIS
10	**Recreation areas** around Nicco Park drain	-Understanding current scenario of recreation areas	BDA
11	**Biodiversity and ecology**	-Native species of vegetation	FE & CC

5. Analysis

The analysis has been carried out as per the framework illustrated in the figure.

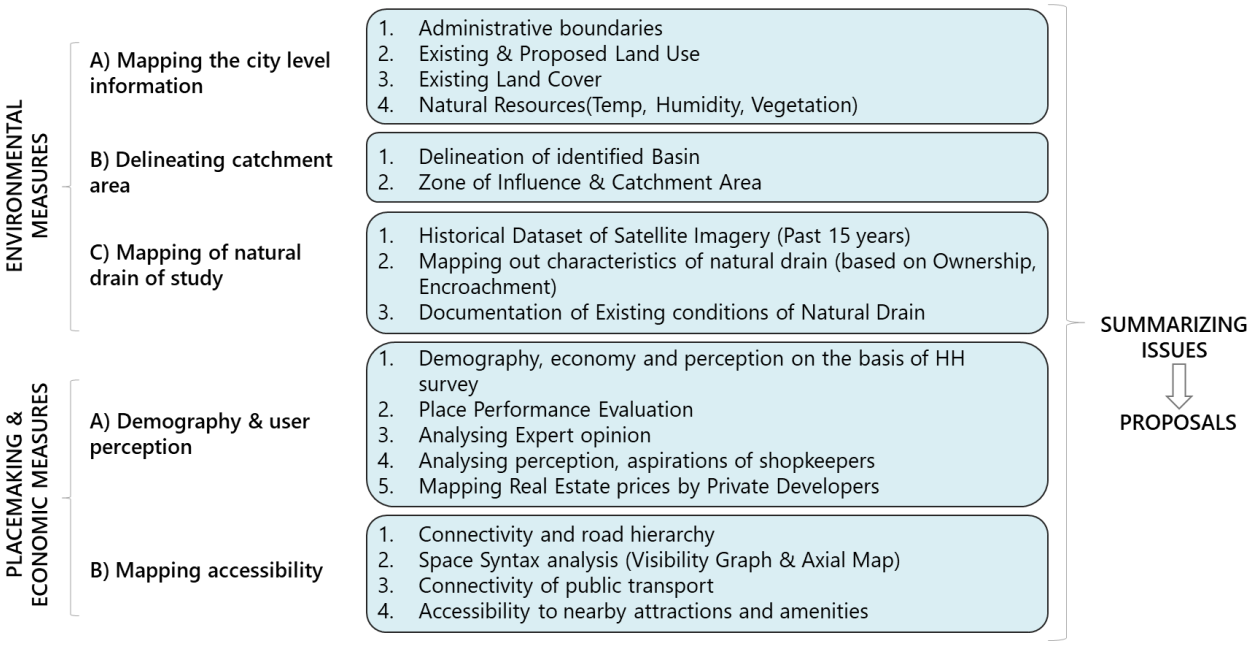


Figure 27. Analysis Framework

5.1 Action Area Delineation

There are 10 natural drains in Bhubaneswar, flowing into Gangua Nala. The natural drains were ranked on the basis of **parameters identified in the literature study- size, visibility from public realm, function, accessibility, safety** as per **reconnaissance survey and Landsat imagery, experts' preference** of transforming voids into public place was also identified. Opinions of 5 experts were considered and the final results were tabulated as following table.

Table 7. 5-point Likert scale analysis

Drain	Drain Name	Length (km)	Size	Visibility	Function	Accessibility	Safety
Drain I	Patia & Damana	4.32					
Drain II	Mancheswar	1.13					
Drain III	OAP area	2.42					
Drain IV	Barana	5.63					
Drain V	Jharpada	3.13					
Drain VI	Baragarh Drain	2.16					
Drain VII	Gosagareswar	4.34					
Drain VIII	Airport area	4.33					
Drain IX	Ghatikia	4.24					
Drain X	Nicco park	5.48					

Poor Somewhat Poor Neutral Somewhat good Good

Based on the above variables, **5-point Likert scale analysis** was carried out ranging from poor to good and was colour coded as shown in the table. **Drain no X or the Nicco Park drain** had the best score in Likert scale analysis and was selected for the study. Drain no. X has a length of 5.48km and action area was selected which was a part of the drain.

The action area is approximately **3.5 kilometres long stretch of Drain no. X**. The selected area stretches from old Nayapalli, Unit 9 and terminates at Saheed Nagar railway line.

Figure 28. Map showing action area highlighted and key map of Bhubaneswar showing drain no. X

The action area of drain no. X is divided into three zones 1-3 from West to East, which are separated by arterial roads – Jawaharlal Nehru Marg and Janpath. Zone 1 lies in Madhusudhan Nagar and is bounded by Bidyut Marg and Jawaharlal Nehru Marg. Zone 2 lies in Unit-IX area and is bounded by Jawaharlal Nehru Marg and Janpath. Zone 3 lies in the Bhubaneswar Town Center district and lies in Saheed Nagar and Satya Nagar area.

The action area zones are also the three lake zones defined by Bhubaneswar Smart City Limited and Bhubaneswar Municipal Corporation for revitalisation of lakes where lake zone 3 is also referred to as lake neutral.

5.2 Mapping the city level information

The layers of city information are mapped which includes administrative boundaries, existing and proposed land use, natural resources, infrastructure and economic base of the site.

5.2.1 Administrative boundaries

Table 8. Bhubaneswar statistics (Comprehensive Development Plan Projections/ Provisional Census,2011)

Jurisdiction Boundaries	BMC, BDA
BMC Area	135 Sq.km.
Population (BMC – 2011)	8,38,837**
Decadal growth rate	29.4%
Population density (BMC-2011)	62 pph

BDA Area	419.10 Sq.km. BDPA is divided in four administrative units, BMC, Khurdha, Jatni and BDA rural.
AUDA Area	15,72,000*
Population Density (BDA)	37.5 pph

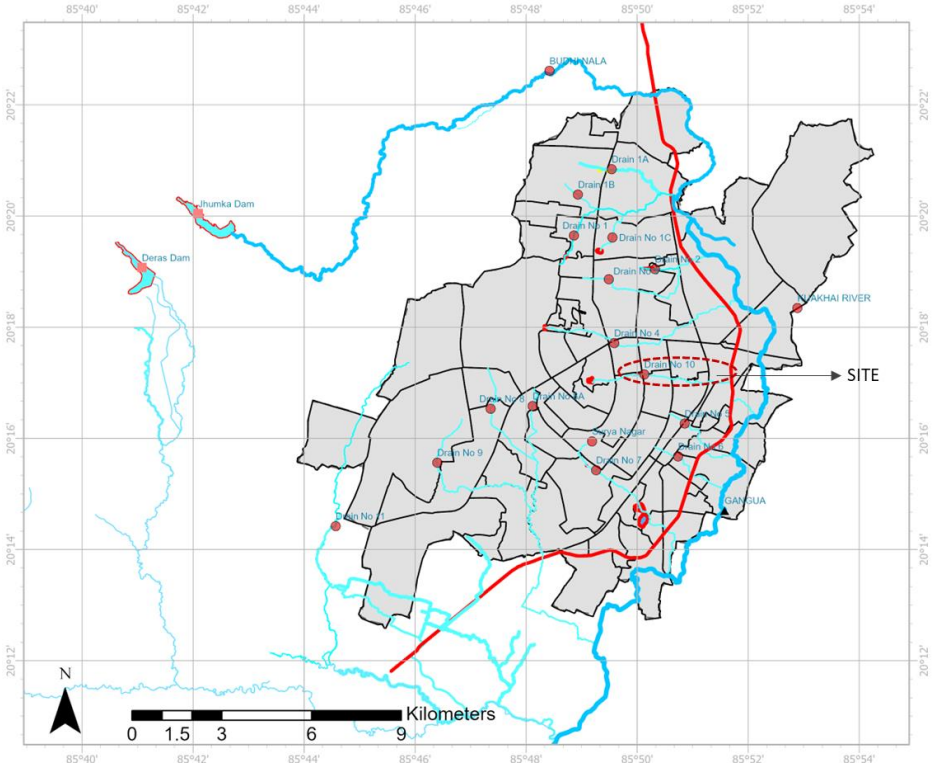


Figure 29. Administrative Boundaries and Site

The study area drain no X lies in wards 28-30 and 34-36 encompassing Madhusudhan Nagar, Unit-9, Saheed Nagar and Satya Nagar.

5.2.1 Population Statistics

Table 9. Ward wise population (Smart City Bhubaneswar (Bhubaneswar one, n.d.)

Ward No.	Area (sq km.)	Household	Total Population			Population - Children (0-14 yrs.)
			Total	Male	Female	
28	0.456063	2704	12230	6386	5844	1025
29	0.477211	2796	11518	6115	5403	1198
30	0.404762	2850	12220	6348	5872	441
34	0.551555	3375	13013	6854	6159	1108
35	0.43703	3422	14130	7436	6694	1392
36	0.233084	2744	11509	6058	5451	1783
37	0.425838	2831	11679	6079	5600	737
39	0.512167	3148	12716	6734	5982	587

Figure 30. Wards in the zone of influence of drain no X.

A total of 99,015 live in the wards in the influence zone of drain no. X. In 2011, average household size of Bhubaneswar was 4.36. Between 1991 and 2011, average household size declined from 5.28 to 4.36.

5.2.2 Land Use and Land Cover

Figure 31. Existing land use map

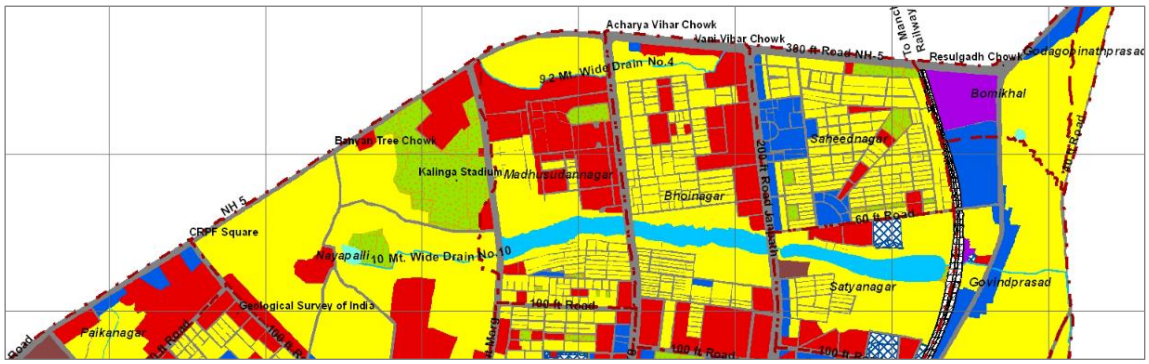


Figure 32. Proposed land use map of action area CDP 2030

As per CDP 2030 (land use below), the Drain no. X has been proposed to be widened and the residential character of the surrounding land use to be retained. Under this scheme, the encroached dwellers are to be resettled.

The existing land use map of drain no X and its zone of influence shows that the urban void of the drain has predominantly recreational or vegetation/ forest land use. The voids are currently neglected with no activities despite being recreation area.

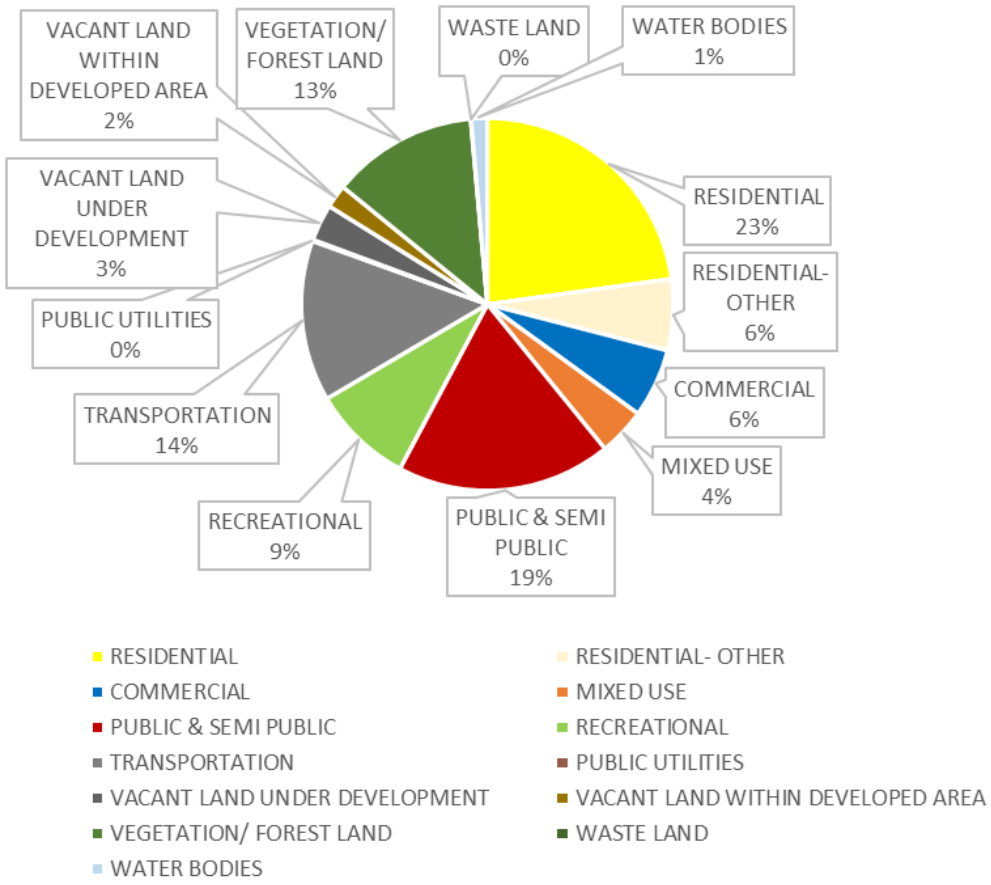


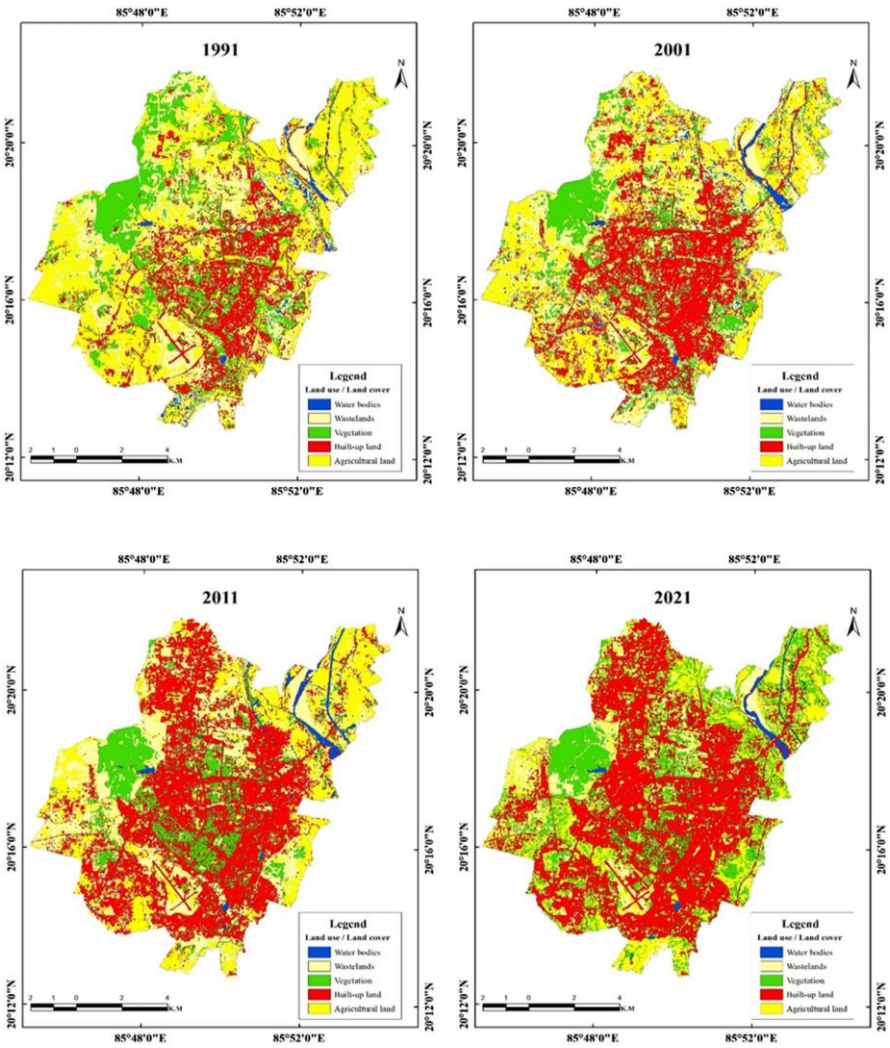
Figure 33. Land use percentages

The existing land use is predominant residential (23%) and public semi-public (19%) use constituting 42% of the total land use. Transportation constitutes a significant 14% and vegetation and forest land constitutes 12.7%. Informal settlements or slums constitute 6.2% which are mostly in the urban void of the natural drain. Recreational, commercial and mixed land use is also seen in the range of 4-6%.

Table 10. Land use percentages

Land use (L1)	Total Area (sq km)	Percentages
Residential	387785	22.8
Residential- other	105120	6.2
Commercial	101720	6
Mixed use	70204	4.1
Public & semi public	317438	18.7
Recreational	148937	8.8
Transportation	237271	14
Public utilities	2197	0.1
Vacant land under development	54054	3.2
Vacant land within developed area	34299	2
Vegetation/ forest land	215940	12.7
Waste land	698	0
Water bodies	23831	1.4

Land Cover



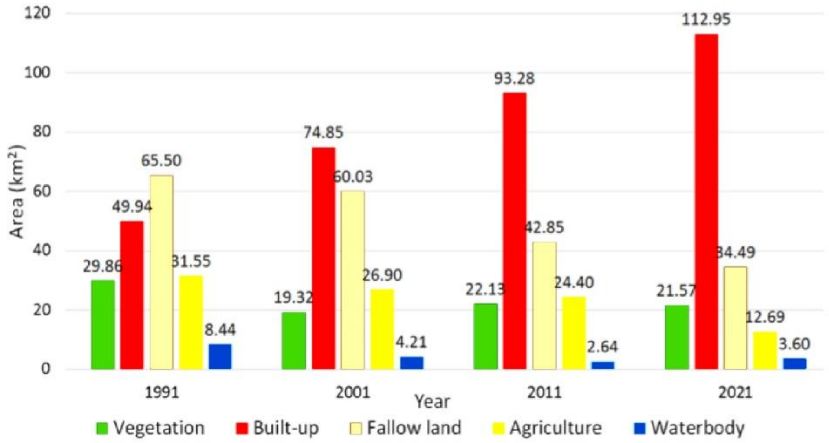


Figure 34. Land cover classification from 1991-2021 (Das, Jana, Mandal, & Sutradhar, 2021)

The landcover maps from past 20 years show that there is a significant increase in built up area around the natural drain no. 10. The built-up area of Bhubaneswar increased significantly from 49.94 sq km to 112.95 sq km, whereas the waterbody area decreased from 8.44 sq km. to 3.6 sq km. the developmental stress has contributed to the decline in areas of waterbody throughout the city.

5.2.3 Natural Resources

5.2.4 Climate

Bhubaneswar's climate is characterized as tropical, with high temperatures and humidity levels that persist year-round. The city undergoes a significant shift in precipitation between the summer and winter months, with most of the rainfall occurring between June and September during the monsoon season. Conversely, the winter period from December to February is relatively dry. On average, Bhubaneswar's temperature annually ranges around 26.6°C | 79.9°F, with the summer months occasionally seeing temperatures as high as 40°C | 104°F. Köppen and Geiger classify the region as Aw, indicating a **tropical savanna climate** that features dry winters. The city receives around 1628 mm | 64.1 inches of rainfall annually. Despite being located near the equator, the Bay of Bengal's proximity and the monsoon winds influence Bhubaneswar's weather, leading to indistinct summer seasons.

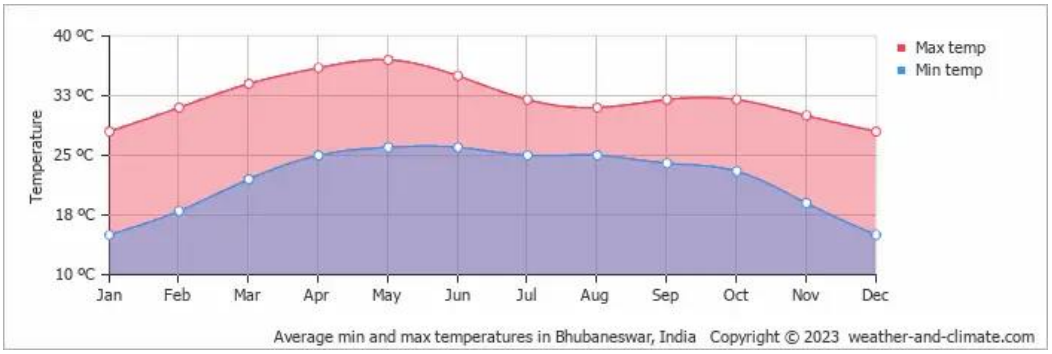


Figure 35. Average day and night temperature (Climate in Bhubaneswar (India), n.d.)

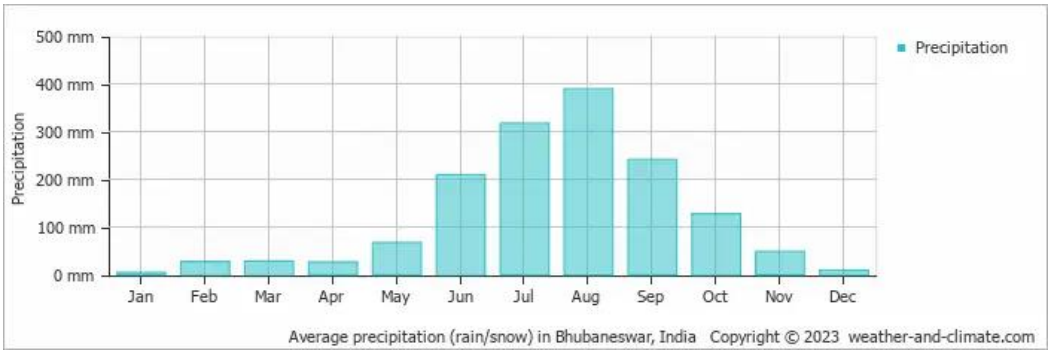


Figure 36. Monthly precipitation (Climate in Bhubaneswar (India), n.d.)

5.2.5 Normalized Difference Vegetation Index (NDVI)

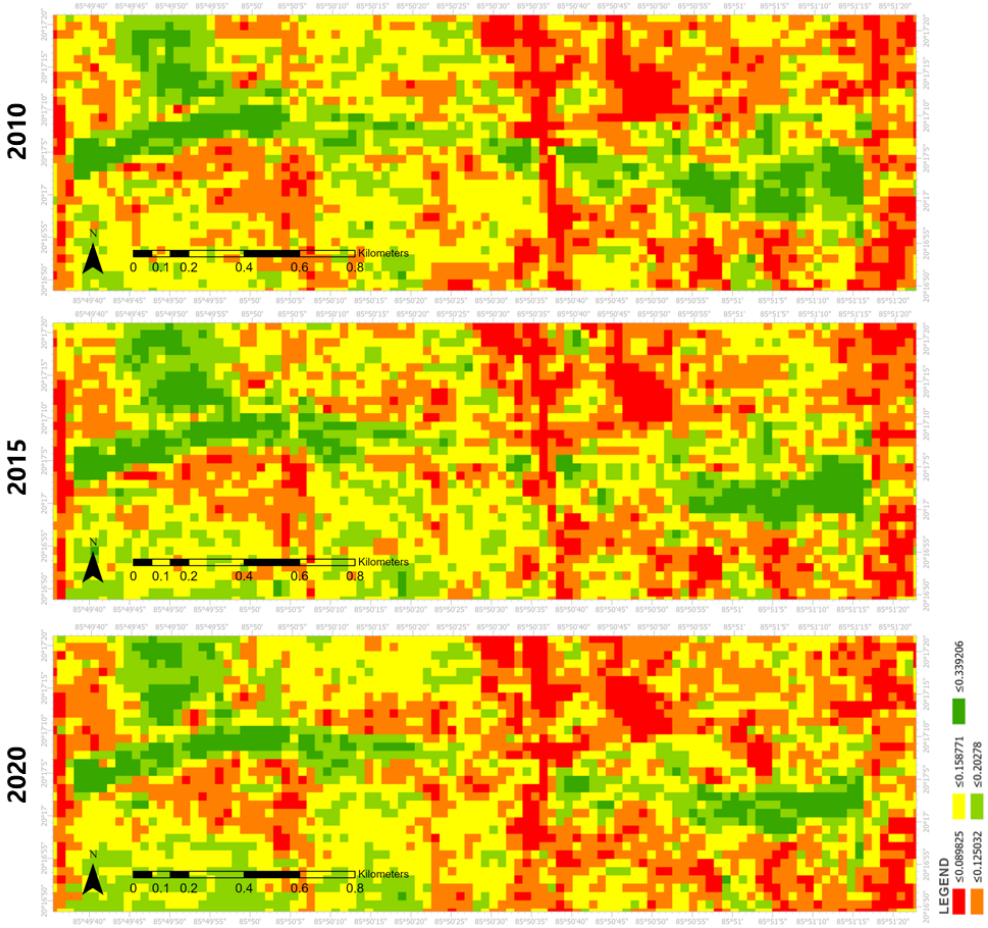


Figure 37. NDVI maps from 2010-2020

The NDVI maps are generated for 15 years in winter season (January) for the action area and its zone of influence. The NDVI maps shows the decreasing vegetation (values close to +1) in the site area. The NDVI values close to +1 shows a possibility of dense green leaves whereas, close to zero shows built up area.

5.2.6 Hydrogeomorphology

The hydrogeomorphology of Bhubaneswar is heavily influenced by its location in the Eastern Ghats Mountain range and its proximity to the Bay of Bengal. The city's terrain features **undulating hills, small streams, and several ponds and wetlands**. The **geology of the area is mainly composed of granites, gneisses, and schists**, which significantly impact groundwater quantity and quality. Bhubaneswar's hydrology is also affected by the Mahanadi River basin, Odisha's largest river system.

The city is situated in the upper regions of the Mahanadi basin, and its water supply comes from its tributaries, such as the Kuakhai, Daya, and Bhargavi rivers. Groundwater is the primary source of water supply in Bhubaneswar, mainly drawn from the deep aquifers in the region. Nevertheless, due to the swift urbanization and population growth, the demand for water resources has increased, leading to the overuse of groundwater and a decline in water quality.

The drain no X. which is a valley fill shows the hydro morphology of flood plains and pediment as per the above map. The drain no X flows into Gangua Nallah in the East by draining through the alluvial plains of Rasulgarh and other areas.

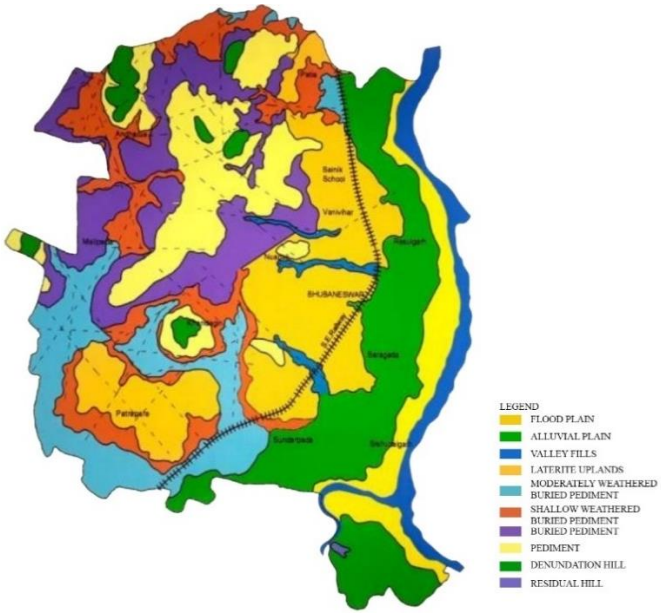


Figure 38. Hydro-geomorphological map of Bhubaneswar (CGWB, n.d.)

5.3 Delineating catchment area

The catchment area of the natural drain is delineated using by identifying and defining its boundaries. This process entails analysing the terrain and landscape. To accurately map and delineate the catchment area, various techniques, including remote sensing, GIS, and field surveys, are utilized.

Catchment area delineation is critical in water resource management and flood prediction because it aids in comprehending water flow, estimating water runoff volume, and evaluating the impacts of changes in land use and climate variability on water resources.

5.3.1 Delineation of identified Basin

The study area of drain no. X and its basin shows that the natural drain is a first order stream which joins the second order Gangua nala. Gangua nala discharges to Kuakhai river. The drainage

basin of Nicco Park is influenced by the topography and surrounding landscape, such as the land use patterns, soil characteristics, and slope of the terrain.

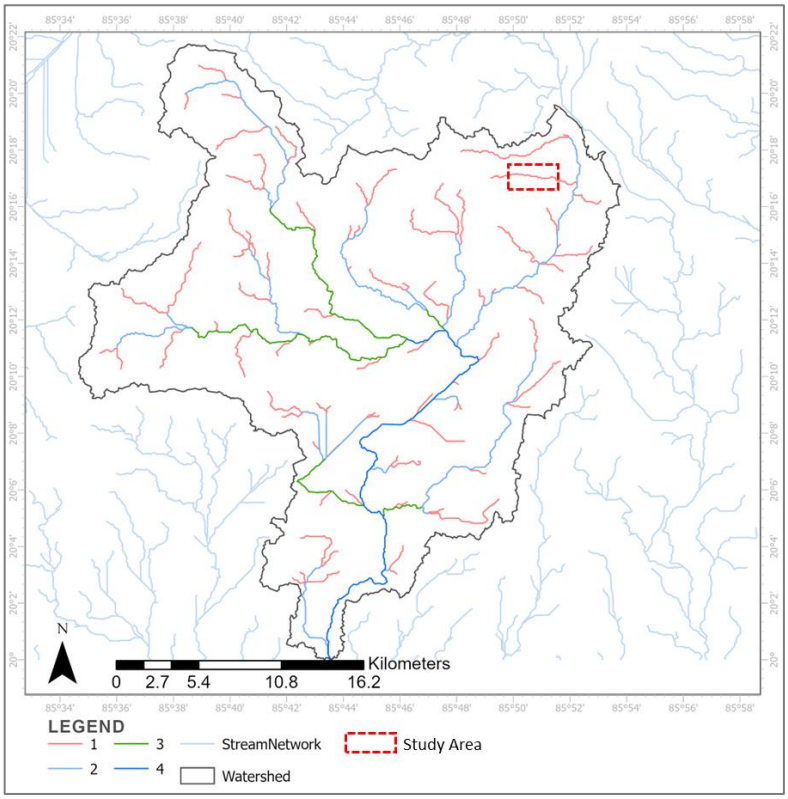


Figure 39. Drainage basin and stream order

5.3.2 Contour and Elevation profile

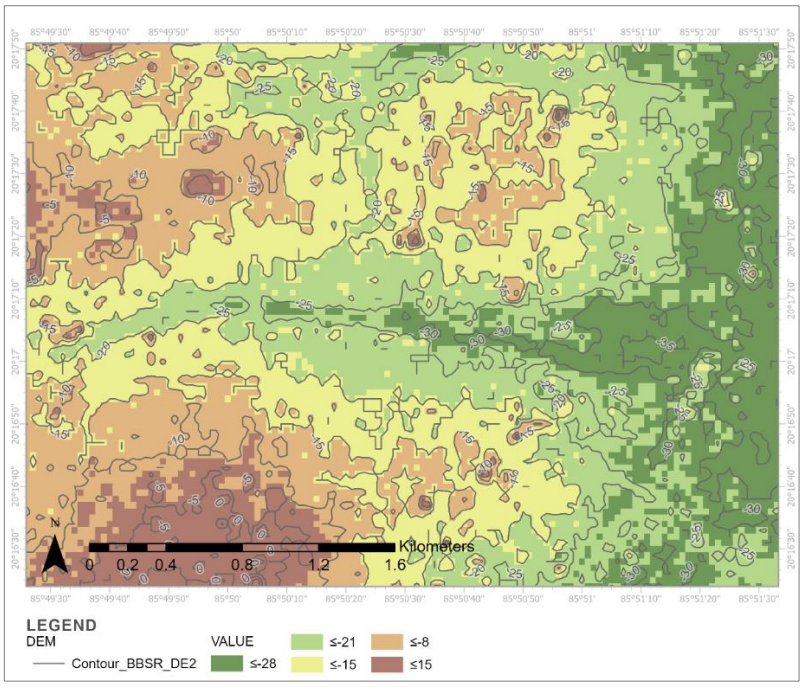


Figure 40. DEM & Contour of the drain no. X

Bhubaneswar is situated in the hilly terrain of the Eastern Ghats in the eastern part of India. Its topography is marked by undulating hills, plateaus, and valleys, and its elevation ranges from 45 meters (148 feet) to 110 meters (360 feet) above sea level. The highest point in the city is the Dhauli hill located in the southern part of the city. The contour map of the drain no. X is studied.

Figure 41. Contour profile

The city has a natural gradient from West to East and therefore has a natural advantage for drainage. The wastewater of the city flows through the storm water drains. The elevation profile of the action area shows about 12m difference from west to east, east being the lower gradient. The drain has **dry flow of 0.414 cubic metres per second** in dry or non-monsoon season.

5.4 Mapping of natural drain of study

5.4.1 Physical Vulnerability Mapping

Shannon's Entropy and Fuzzy TOPSIS

An expert opinion survey was conducted with experts from academia and the government in the form of semi-structured interviews to better understand the significance of the measures of physical vulnerability that were chosen. Experts were asked to give a score depending on how a particular criterion affected how vulnerable a particular site was. Five experts were chosen from various disciplines related to urban planning and governance and their given scores were tabulated and analysed using fuzzy TOPSIS. The experts had the following designations

i. Assistant Planner, Bhubaneswar Development Authority
ii. Additional Chief Environmental Engineer, SPCB (State Pollution Control Board)
iii. Chief Environment Scientist, Bhubaneswar Municipal Corporation
iv. Chief Engineer, Water Department, Bhubaneswar Municipal Corporation
v. General Manager, Project division- II, Water Corporation of Odisha

Table 11. Criteria for mapping physical vulnerability

Question	Score the following factors as per their contribution to increasing vulnerability of people during flood				
Criteria	**Infrastructure**	**Natural Terrain**		**Locational**	
	Presence of drain lines, pumping stations etc (flow length)	Spot elevation	Slope (hilly terrain)	Proximity to river/canal	Proximity to major traffic routes
Opinion score					

Table 12. Ranking of criteria from low to high vulnerability

Very Low =1	Low =2	Medium =3	High =4	Very High =5
Criteria has no effect on vulnerability	Criteria has minor effect on vulnerability	Criteria has considerable effect on vulnerability	Criteria has an indirect but strong effect on vulnerability	Criteria has a direct and strong effect on vulnerability

Fuzzy TOPSIS was used to determine which response had the best fit score. Weightages were calculated using Shannon's entropy approach to help with the selection.

5.4.2 Shannon's Entropy for determining weightages

5.4.3 Decision Matrix

Raw data is collected during the expert opinion survey which are conducted during primary interviews. Scores are assigned based on the expert opinion and are converted to a numerical scale for ease of calculation. A decision matrix that shows the performance of each alternative against each criterion is created. The decision matrix can be denoted by X, where Xij represents the performance of alternative i on criterion j.

Table 13. Raw data collected from respondents. Experts anonymised for minimising bias.

Expert	Flow Length	Spot elevation	Slope (hilly terrain)	Proximity to river/canal	Proximity to major traffic routes
A	3	4	2	5	4
B	1	2	2	4	3
C	2	1	1	5	2
D	1	3	2	4	3
E	2	3	1	5	2
Sum	9	13	8	23	14

5.4.4 Step 1 – Normalized Decision Matrix

Scores in the decision matrix are normalized by dividing each value in the matrix by the square root of the sum of squares of the values in the corresponding column.

$$pij = \frac{Xij}{\sum_{j=1}^{m} Xij} \quad ; j = 1,\ 2,\ \ldots,m \quad ; i = 1,\ 2,\ \ldots,n$$

Table 14. Normalised Matrix for finding Project Outcomes Pij

Expert	Flow Length	Spot elevation	Slope (hilly terrain)	Proximity to river/canal	Proximity to major traffic routes
A	0.33333333	0.30769231	0.25	0.2173913	0.28571429
B	0.11111111	0.15384615	0.25	0.17391304	0.21428571
C	0.22222222	0.07692308	0.125	0.2173913	0.14285714
D	0.11111111	0.23076923	0.25	0.17391304	0.21428571
E	0.22222222	0.23076923	0.125	0.2173913	0.14285714

5.4.5 Step -2 Computation of Entropy

Entropy refers to the amount of information contained in the data. Entropy is calculated using the following equation and is shown in the following table.

$$E_j = -k \sum_{i=1}^{m} [p_{ij}.\ln(p_{ij}j)] \;\; ; j = 1,2,..,n; \quad i = 1, \;\; 2, \;\; ,.,m.$$

In which ***k= 1/ln (m)*** which is a constant (normalizing) value.

Table 15. Computation of Entropy

Expert	Flow Length	Spot elevation	Slope (hilly terrain)	Proximity to river/canal	Proximity to major traffic routes
A	-0.36620	-0.36266	-0.34657	-0.33175	-0.35793
B	-0.24414	-0.28797	-0.34657	-0.30421	-0.33010
C	-0.33424	-0.19730	-0.25993	-0.33175	-0.27799
D	-0.24414	-0.33839	-0.34657	-0.30421	-0.33010
E	-0.33424	-0.33839	-0.25993	-0.33175	-0.27799
Sum	-1.52296	-1.52471	-1.55958	-1.60367	-1.57410
Eij= sum*(-k)	0.94627	0.94735	0.96902	0.99642	0.97804
Eij(approx. to 3 dec)	0.946	0.947	0.969	0.996	0.978
dj= 1-Eij	0.054	0.053	0.031	0.004	0.022
Sum of (1-Eij)	0.164				

5.4.6 Step -3 Computation of Weights

The weights of all the criteria are calculated on the basis of the following equation:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \;\; ,\forall j$$

In which, Dj = 1 – Ej

Table 16. Computation of Weights

Expert	Flow Length	Spot elevation	Slope (hilly terrain)	Proximity to river/canal	Proximity to major traffic routes
Wij	0.329	0.323	0.189	0.024	0.134
Sum Wij	1.000				
	Positive	**Positive**	**Positive**	**Negative**	**Positive**
	Presence=high score	Presence=high score	Presence=high score	Shorter distance/more canals= lower score	Shorter distance/more roads= higher score

5.4.7 Fuzzy TOPSIS for selecting ideal score

A fuzzy number is number of vague or imprecise value, and is often used when converting non-numerical scores to a numerical scale. It converts the scale to an overlapped numerical scale, and often mirrors the physical world better than single digit scores. Fuzzification is the conversion of a crisp set to a fuzzy set. In this case, fuzzification by triangulation is used to convert the scores within a range of 1-9 over five bands.

Table 17. Fuzzy scale used for analysis

Rank	Term	Fuzzy Number
1	Very Low	1,1,3
2	Low	1,3,5
3	Moderate	3,5,7
4	High	5,7,9
5	Very High	7,9,9

5.4.8 Fuzzified Matrix

The fuzzified numbers are entered in the score matrix generated previously.

Table 18. Scores are fuzzified as per given scale

Wij	0.329	0.323	0.189	0.024	0.134
A	3,5,7	5,7,9	1,3,5	7,9,9	5,7,9
B	1,1,3	1,3,5	1,3,5	5,7,9	3,5,7
C	1,3,5	1,1,3	1,1,3	7,9,9	1,3,5
D	1,1,3	3,5,7	1,3,5	5,7,9	3,5,7
E	1,3,5	3,5,7	1,1,3	7,9,9	1,3,5

5.4.9 Normalization of Fuzzified Matrix

The scores are then normalized as per the formulae given below for the benefit and cost criteria which was identified previously.

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \text{ and } c_j^* = \max_i\{c_{ij}\} \text{ (benefit criteria)}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \text{ and } a_j^- = \min_i\{a_{ij}\} \text{ (cost criteria)}$$

Table 19. Normalised matrix

Wij	0.329			0.323			0.189			0.024			0.134		
A	0.429	0.714	1.000	0.111	0.333	0.556	0.200	0.600	1.000	0.556	0.556	0.714	0.556	0.778	1.000
B	0.143	0.143	0.429	0.111	0.333	0.556	0.200	0.600	1.000	0.556	0.714	1.000	0.333	0.556	0.778
C	0.143	0.429	0.714	0.111	0.111	0.333	0.200	0.200	0.600	0.556	0.556	0.714	0.111	0.333	0.556
D	0.143	0.143	0.429	0.333	0.556	0.778	0.200	0.600	1.000	0.556	0.714	1.000	0.333	0.556	0.778
E	0.143	0.429	0.714	0.333	0.556	0.778	0.200	0.200	0.600	0.556	0.556	0.714	0.111	0.333	0.556

5.4.10 Weighted Normalized Matrix

The normalized matrix is multiplied by the weightages obtained by Shannon's entropy method in the previous stage.

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \cdots, \tilde{v}_n^*), \text{ where } \tilde{v}_j^* = \max_i\{v_{ij3}\}$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \cdots, \tilde{v}_n^-), \text{ where } \tilde{v}_j^- = \min_i\{v_{ij1}\}$$

Table 20. Weighted Normalised Matrix

Wij	0.329			0.323			0.189			0.024			0.134		
A	0.141	0.235	0.329	0.036	0.108	0.179	0.038	0.113	0.189	0.013	0.013	0.017	0.074	0.104	0.134
B	0.047	0.047	0.141	0.036	0.108	0.179	0.038	0.113	0.189	0.013	0.017	0.024	0.045	0.074	0.104
C	0.047	0.141	0.235	0.036	0.036	0.108	0.038	0.038	0.113	0.013	0.013	0.017	0.015	0.045	0.074
D	0.047	0.047	0.141	0.108	0.179	0.251	0.038	0.113	0.189	0.013	0.017	0.024	0.045	0.074	0.104
E	0.047	0.141	0.235	0.108	0.179	0.251	0.038	0.038	0.113	0.013	0.013	0.017	0.015	0.045	0.074
FPIS	0.177	0.294	0.412	0.108	0.179	0.251	0.038	0.113	0.189	0.017	0.022	0.031	0.093	0.131	0.168
FNIS	0.059	0.059	0.177	0.036	0.036	0.108	0.038	0.038	0.113	0.017	0.017	0.022	0.019	0.056	0.093

5.4.11 Computing distance to ideal Positive

The distance from the ideal positive is calculated using the following formula. Out of the 5 chosen criteria, 4 impact the score positively.

$$d(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]}$$

Table 21. Calculated distance to the Ideal Positive

	1	2	3	4	5	SUM (Di *)
A	0.062	0.072	0.000	0.010	0.027	0.171
B	0.225	0.072	0.000	0.005	0.057	0.358
C	0.155	0.124	0.062	0.010	0.086	0.437
D	0.225	0.000	0.000	0.005	0.057	0.287
E	0.155	0.000	0.062	0.010	0.086	0.312

5.4.12 Computing distance to ideal Negative

The distance from the ideal negative is calculated using the following formula. Out of the 5 chosen criteria, 1 impacts the score negatively.

$$d(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]}$$

Table 22. Calculated Distance to the Ideal Negative

	1	2	3	4	5	SUM (Di-)
A	0.143	0.059	0.062	0.004	0.049	0.316
B	0.023	0.059	0.062	0.002	0.019	0.165
C	0.059	0.000	0.000	0.004	0.013	0.076
D	0.035	0.124	0.062	0.066	0.019	0.306
E	0.059	0.124	0.000	0.004	0.013	0.200

5.4.13 Ranking of alternatives

The alternatives are ranked as per the distance from the ideal positive & negative scores.

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*}$$

Table 23. Distance of alternative to FPIS/FNIS

	Sum (Di *)	Sum (Di-)	Closeness	Rank
A	0.171	0.316	0.75	**1**
B	0.358	0.165	0.32	5
C	0.437	0.076	0.15	2
D	0.287	0.306	0.52	4
E	0.312	0.200	0.39	3

As can be seen, Respondent A's score ranks closest to 1 and is chosen as the final weighting score for further GIS analysis.

Rank	Attribute	Expert's score	Weightage
1	Proximity to river/ canal	5	**30**
2	Proximity to major traffic routes	4	**22.5**
3	Spot elevation	4	**22.5**
4	Flow Length	3	**15**
5	Slope (hilly terrain)	2	**10**

5.4.14 Vulnerability Map

The base maps of physical conditions are created on Arc-GIS using SRTM-DEM of the site. Spot elevation and slope are derived from DEM. River and canals are taken from the stream order maps derived on GIS. Watersheds and stream orders are derived using the Hydrology toolset in ArcGIS, to determine the catchment area of water bodies Traffic route data is taken from Open Street Maps. Vulnerability map is generated using Weighted Overlay function in ArcGIS.

The input maps are then reclassified into 5 classes of natural breaks and the weights are assigned in the weighted overlay tool in ArcGIS. Proximity to river/ canal was assigned weight of 30, whereas proximity to major traffic routes and spot elevation were assigned weights of 22.5, flow length was assigned weight 15 and slope or terrain was assigned 10.

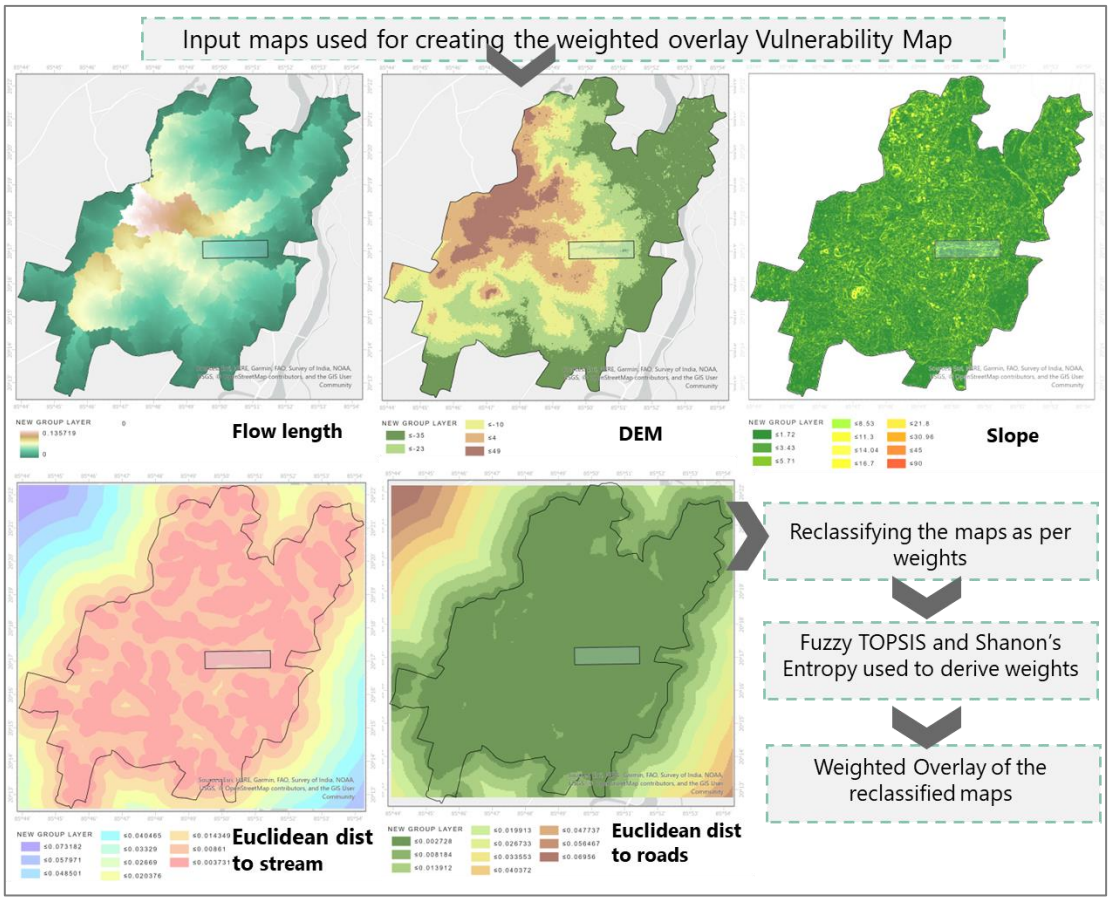


Figure 42. Input maps used for creating the weighted overlay Vulnerability Map

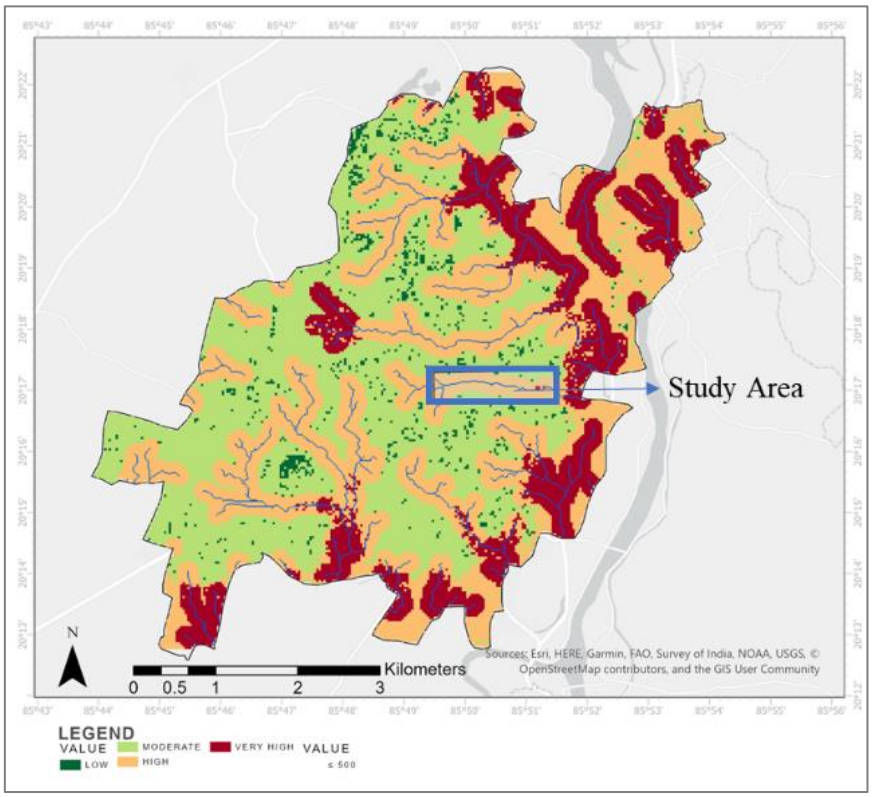


Figure 43. Physical Vulnerability Map

The physical vulnerability mapping shows that the site lies in highly vulnerable area and is subject to anthropogenic flooding during rainy season. The majority of the stormwater channels and drainage network in Bhubaneswar remain significantly filled with sediment and obstructed by waste material, including plastic debris. Also, encroachment by informal dwellers in these low-lying areas is a major concern.

5.4.15 Documentation of Existing Conditions

The existing conditions of the drain and its voids are documented by reconnaissance survey through photographs and interviews. The drain no. X has voids that are either recreational or in neglect. The current land use is also mapped.

Zone 1

This stretch lies in Madhusudhan Nagar and the primary recreational areas of this zone are Kalinga Stadium and Nicco Park (which is defunct). Nicco Park has seen a loss in footfall from the beginning of its inception.

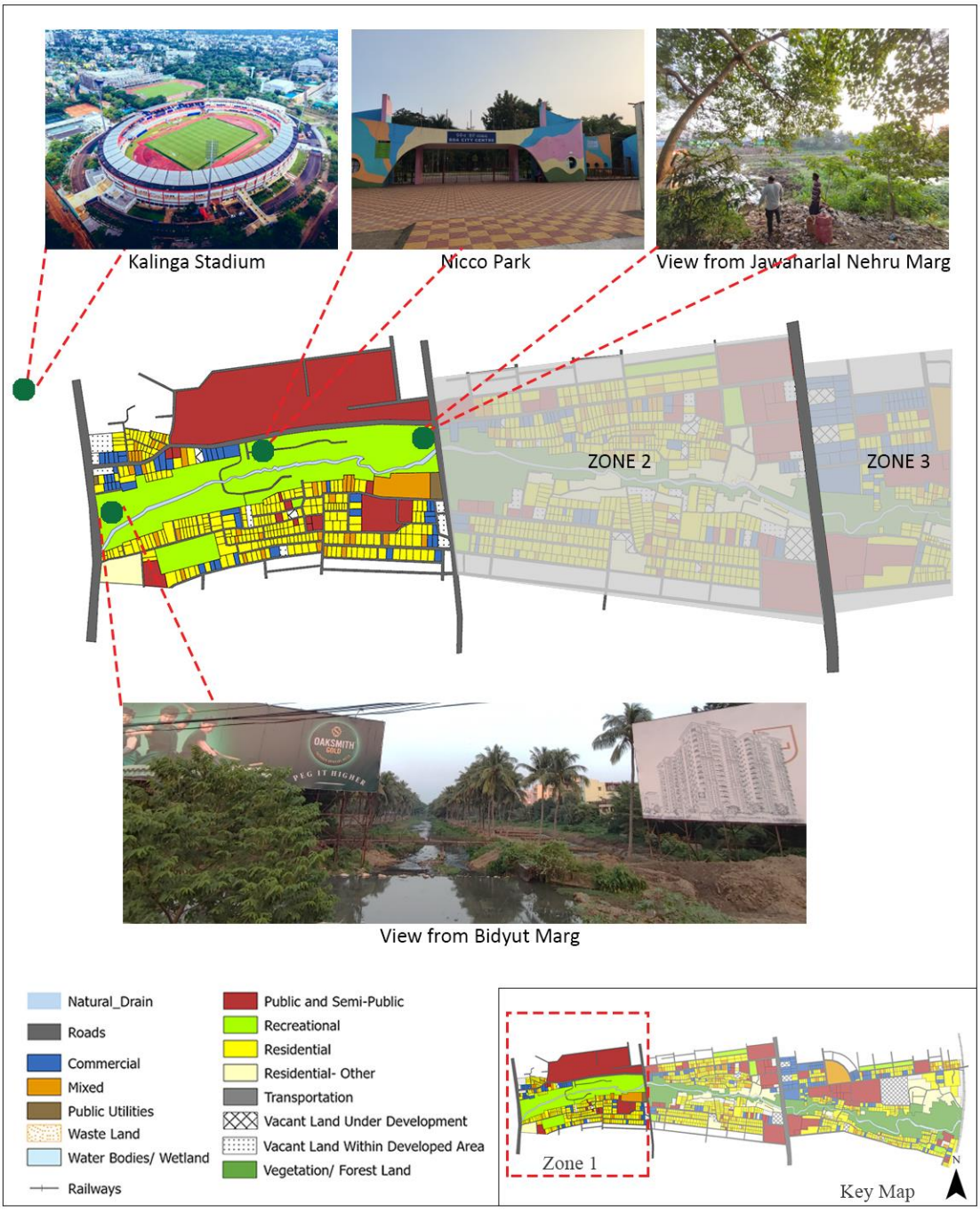


Figure 44. Zone 1 land use map and surrounding area with visuals

The primary reason is that the natural drain water is highly deteriorated from the **untreated domestic effluents** which resulted in foul smell. Currently, the drain discharge point has been changed to zone 3. This zone lies in neglect with dumping of solid waste and advertisement hoardings marring the view. This zone has the maximum potential for redevelopment and it also has no encroachments.

Zone 2

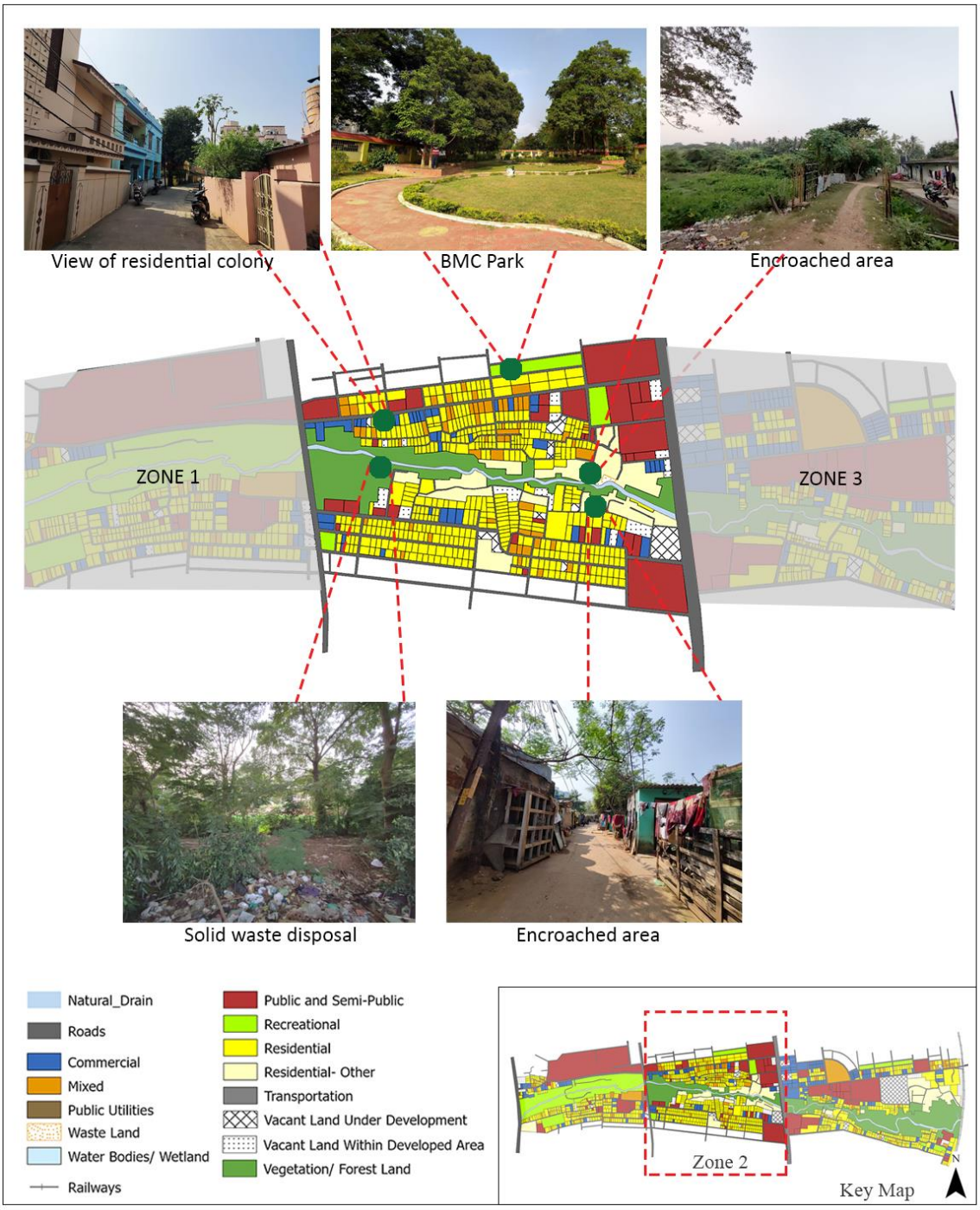


Figure 45. Zone 2 land use map and surrounding area with visuals

Zone 2 lies in unit-IX area has primarily residential area and the void is under-utilised with encroachments which significantly narrows the drain. Developmental stress oof residents has also contributed to the narrowing of the drain. Solid waste disposal can be seen at many places along the stretch. There are offices along the Janpath road and there is a park near zone 2.

Zone 3

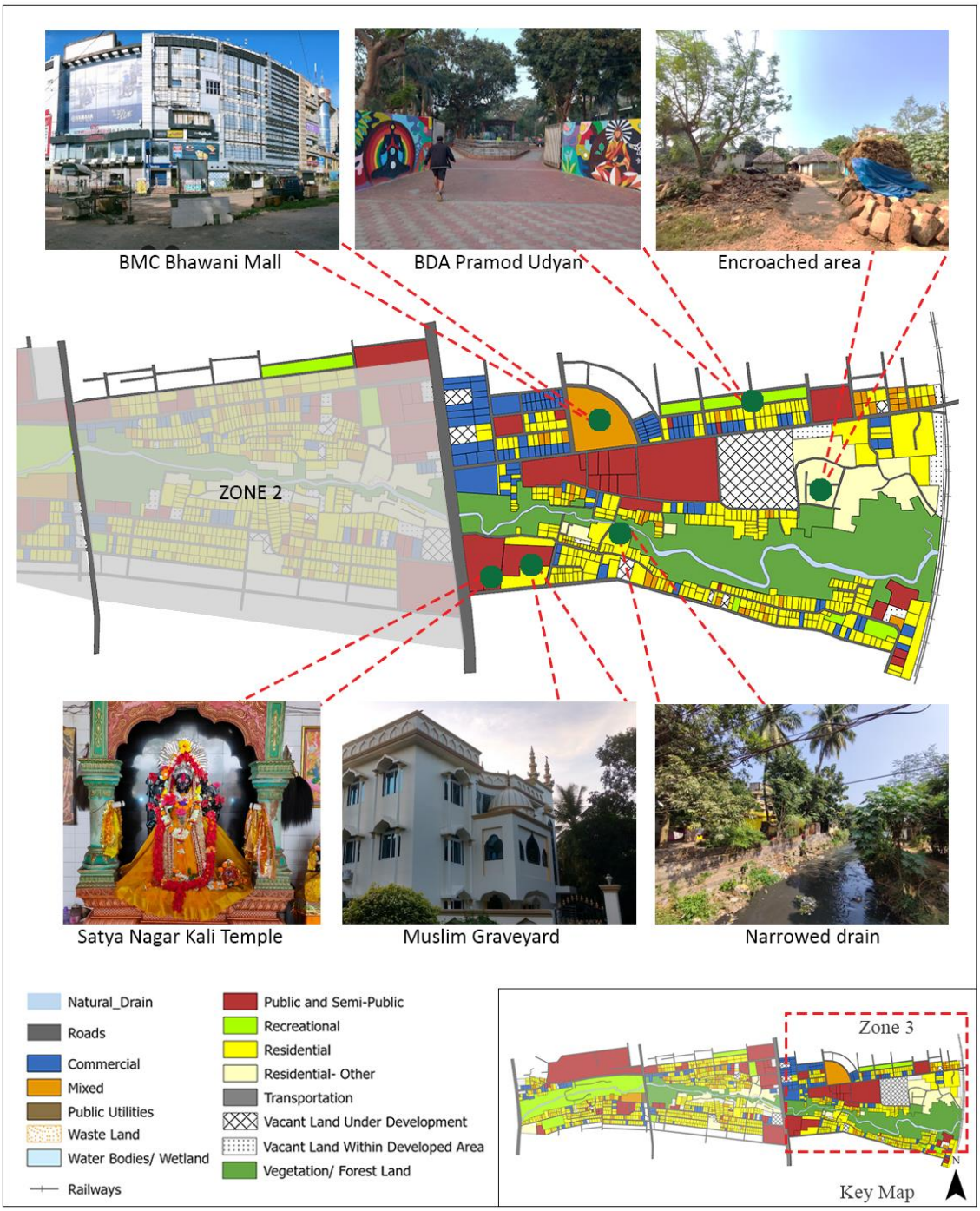


Figure 46. Zone 1 land use map and surrounding area with visuals

Zone 3 lies in Saheed Nagar and Satya Nagar area and has major recreational and religious areas such as Bhawani Mall, Kali temple and also Muslim graveyard. This zone has also seen developmental stress leading to narrowing down of the drain. The stretch widens considerably towards the east which is a low-lying area having scope for retention ponds.

5.4.16 Historical dataset of Satellite Imagery

The natural drain was mapped historically using satellite imagery to understand the impact of developmental stress on its voids. The mapping of imagery has been done from 2005- 2020, a period of 15 years.

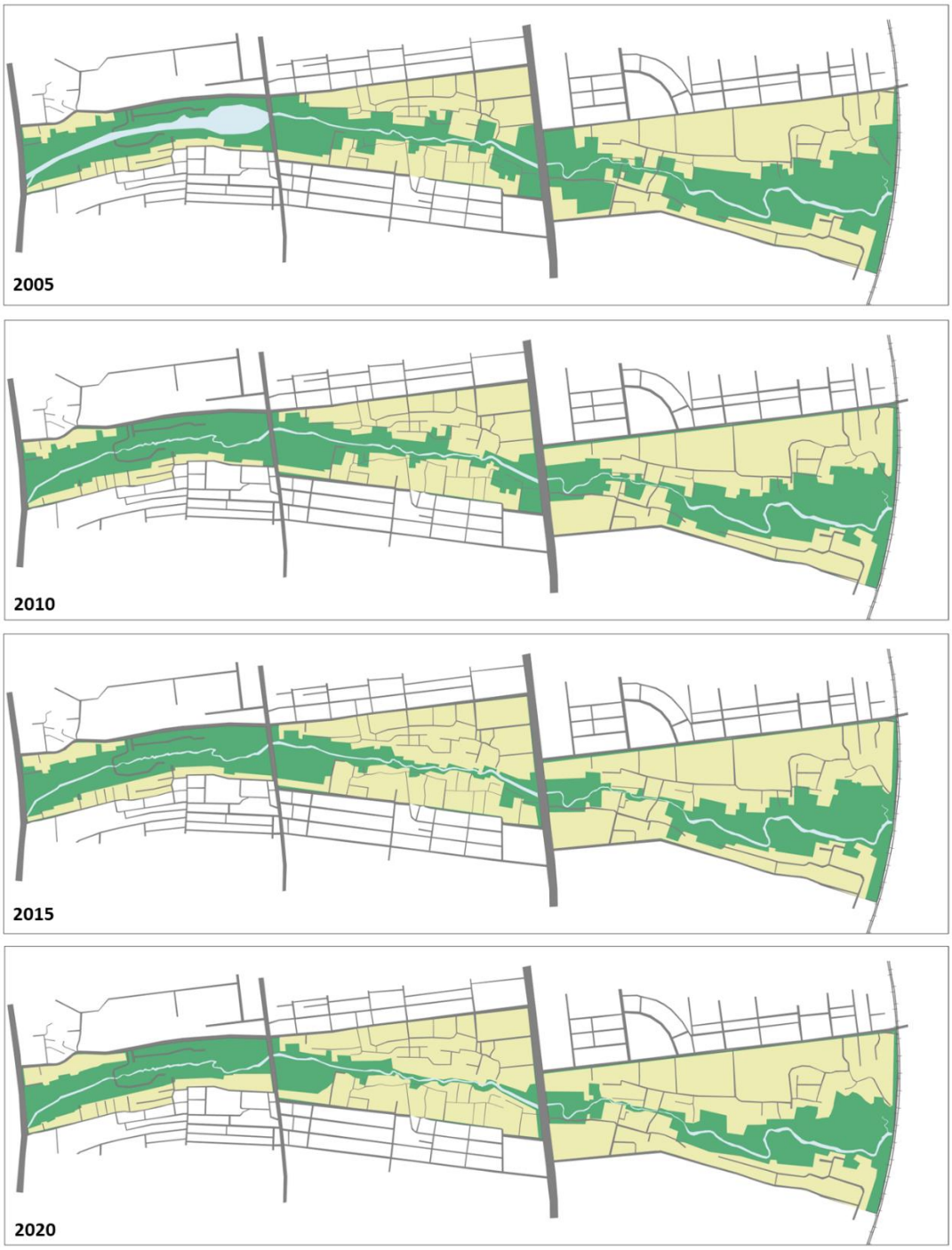


Figure 47. Site conditions in the year 2005, 2010, 2015 and 2020

The overall encroachment along the drain edge shows 6% increase in built up from year 2005 to 2020. The drain channel was wider in 2005 and under the developmental stress, encroachment and disposal of solid wastes, it has narrowed down significantly causing urban flood along the riparian zone.

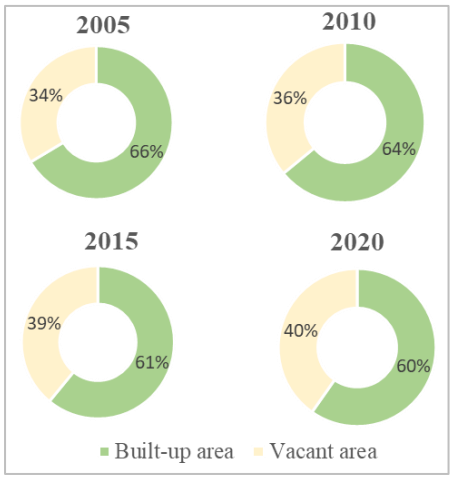


Figure 48. Percentage of built to vacant area near the drain no. X from year 2005-2020

5.4.17 Land Ownership

The land ownership data has been obtained from Bhubaneswar Municipal Corporation and it is categorised as Government, temple/ trustee and privately owned.

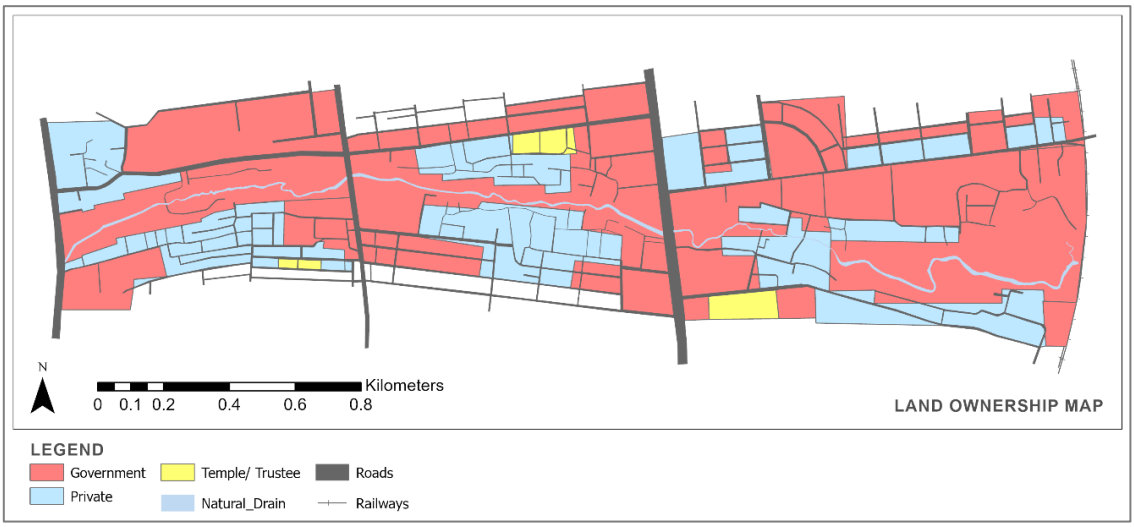


Figure 49. Land Ownership Map

68% of the land is owned by government, 30% by private landowners and 2% by temple/ trust. The primary areas are recreational, public semi-public as well as institutional.

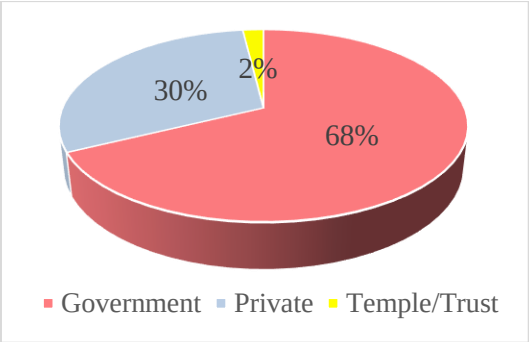


Figure 50. Land ownership percentages

5.4.18 Encroachments - Informal settlements

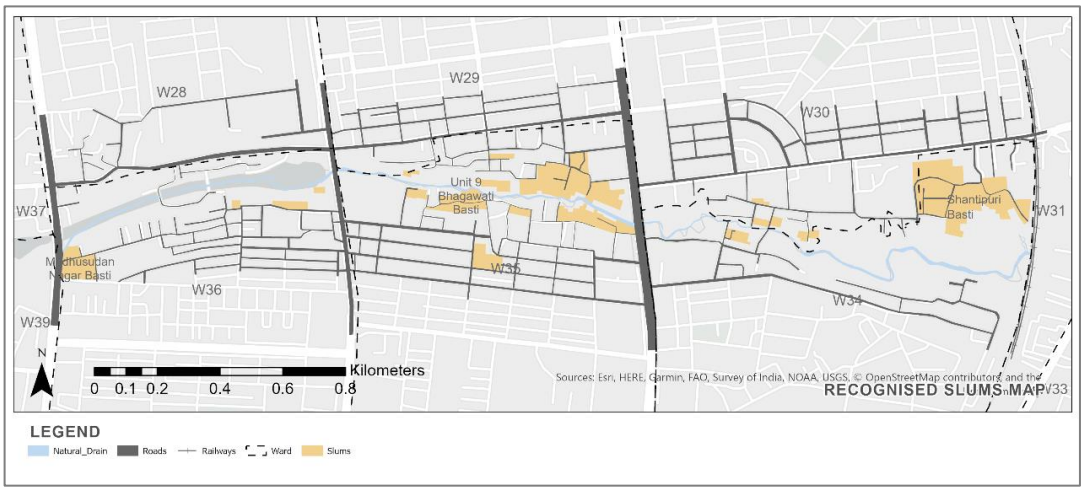


Figure 51. Recognised slums map

Table 24. Ward wise slum population and number of HHs (Slum Profile Data , 2008)

Slum Name	Ward No	No. of HHs	Total Population
Shantipuri Basti	34	116	417
Bhagabati Basti	35	112	424
Nicco Park Basti	36	58	203

Informal settlements have encroached upon the govt. owned land. Three major slums- Shantipuri slum, Bhagabati slum and Nicco Park slum with a population of 1044 people as per 2008 slum profile are currently residing there. The slums contribute to the narrowing of the drain. In zone 2, the slums have encroached upon the riparian zone affecting the biodiversity and hampering the ecosystem of the natural drain. Measures are being taken to relocate them under various government schemes.

5.4.19 Infrastructure

Bhubaneswar is estimated to receive a daily supply of 182 MLD of water, out of which 145.6 MLD is generated as sewage, constituting 80% of the supplied water. However, there is no integrated sewage treatment system in place. Currently, sewage is treated locally through various methods such as septic tanks, aerated lagoons, and oxidation ponds. The resulting effluent is then discharged into different natural Nallahs, which eventually flow into Gangua Nallah situated on the eastern side of Bhubaneswar. This Nallah eventually merges with the Daya River, which then flows into Chilka Lake after a distance of 15 km.

Table 25. STP status in Bhubaneswar (State Pollution Control Board, Bhubaneswar, 2022)

Location	Capacity of the plant in MLD	Physical Progress in %	Status of I&D or House sewer connections	Completion Timeline
Rokat,	48	90.98% completed	0 % (0/36000 Nos.)	STP: Dec. 2022; Sewer Network: Dec. 2022; House Sewer Connection: March, 2023
Meherpalli	56	Commissioned	47.50 % (35747 out of 75269)*	House Sewer connection- Dec.,2022
Basuaghai	28		65% (24462 out of 37634)*	
Kochilaput	43.5		43.07 % (25187 out of 58468)*	March, 2023
Paikarapur	8		100 % (10753 out of 10753)*	Completed
Total	183.5			
*Source- State Pollution Control Board, Bhubaneswar				

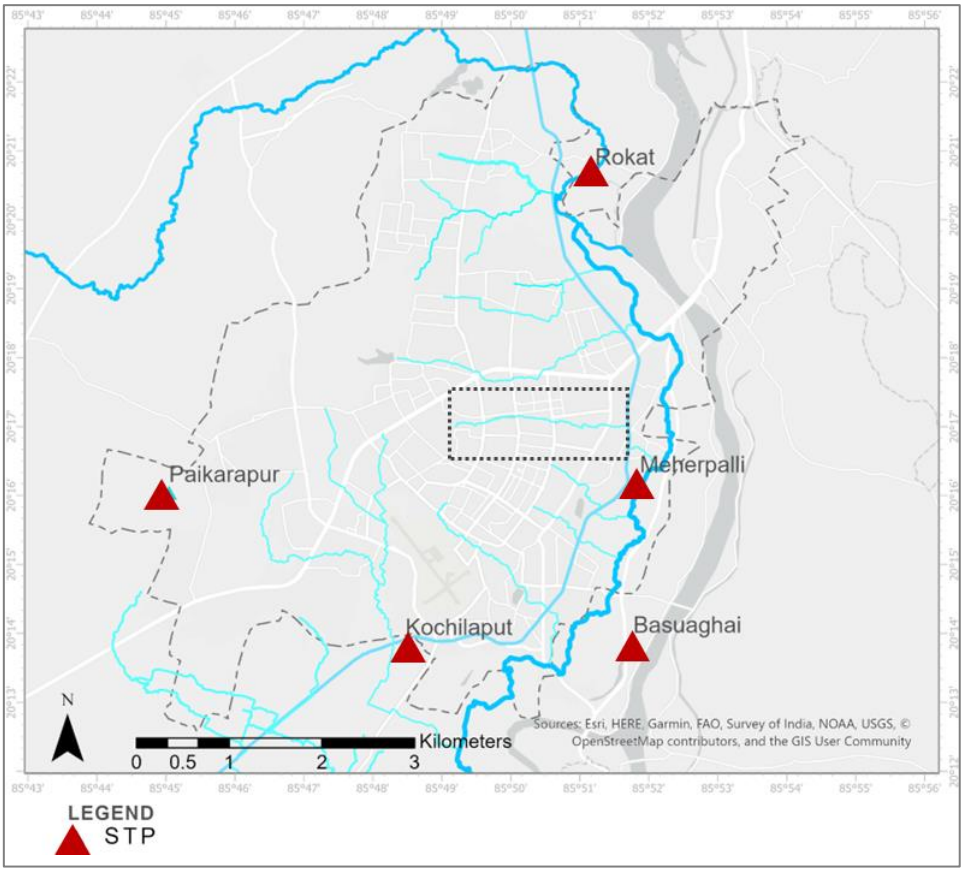


Figure 52. STP Locations

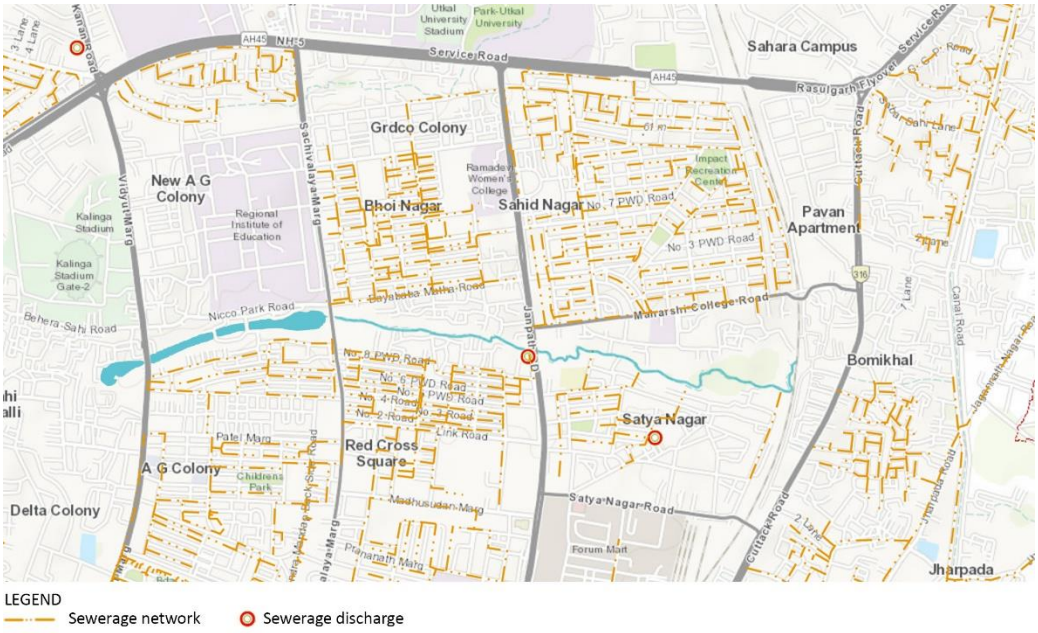


Figure 53. Sewerage network and sewerage discharge

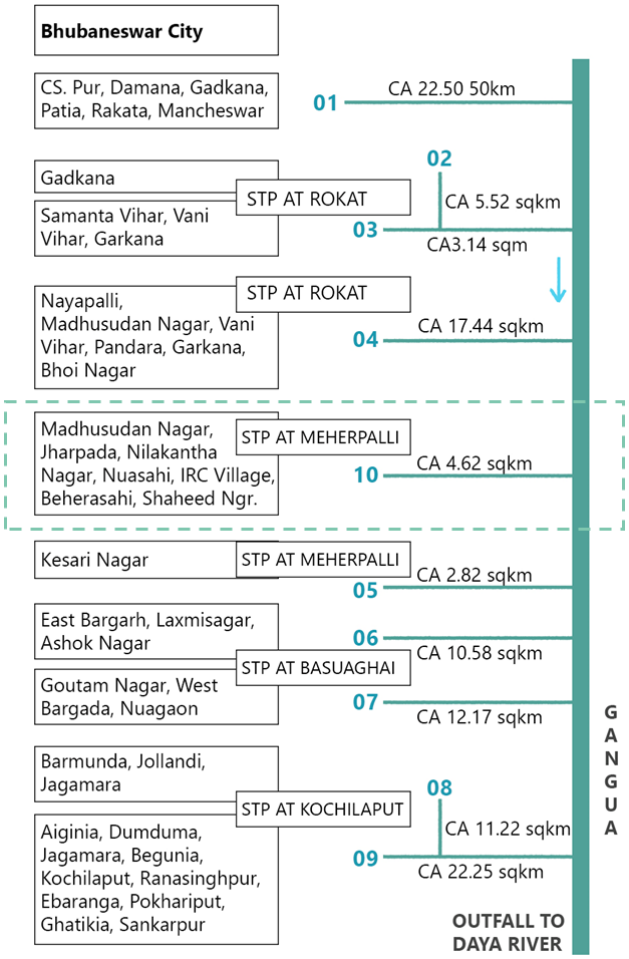


Figure 54. Major Bhubaneswar city drains shown schematically as they intersect with Gangua Nallah (Action plan for Priority -I Polluted River Stretch (Gangua Nalla) along Bhubaneswar, 2019)

The areas surrounding the drain no. X discharge their sewage into the drain. Most households dispose through private septic tanks but these tanks are not maintained and some are overloaded leading to open discharge. The discharge is directed through oxidation ponds into open drains, the ponds are currently overwhelmed with load. Slums also discharge directly into the natural drains. The sewerage discharge point is at the Janpath which is the beginning of zone 3.

5.4.20 Water quality

Water quality data has been obtained from State Pollution Control Board for the year 2022. Parameters such as pH, BOD, COD, TSS, total and faecal coliform have been measured for analysis.

Table 26. Water Quality of Drain no.X/ Nicco Park Drain (State Pollution Control Board, Bhubaneswar, 2022)

Parameters	**2017**	**2022**													**Standards/ Regulatory Limits***
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Avg**	
pH	**6.8**	-	-	-	-	7.6	6.8	6.1	6.9	7.2	7.1	6.9	7.1	**6.96**	6.5-9.0
Total Suspended Solids (TSS), mg/L		-	-	-	-	249	125	386	36	36	233	179	238	**185.25**	100
Biochemical Oxygen Demand (BOD), mg/L	**80**	205	160	100	83	90	100	148	57	58	63	90	75	**102.42**	30
Chemical Oxygen Demand(COD), mg/L	-	-	-	-	-	186	222	304	122	104	139	183	168	**178.5**	250
Total Coliform (TC), MPN/100 mL	-	>16000													-
Faecal Coliform (FC), MPN/100 mL	-	>160000													-

Following observations are made as per the table above

- Average TSS is higher than standard which makes the water turbid and doesn't allow plants/ algae to grow.
- Maximum BOD value in Nicco Park drain remained in the range 160-205 mg/l. This indicates significant contribution of untreated sewage, stormwater discharge, leafy debris, etc on the drain
- COD values ranged between 104-304 mg/l in the year 2022 and the average is within the regulatory range of 250 mg/L which indicates that the amount of organic materials that are biodegradable and non-biodegradable is within range.
- The annual range of Total and Faecal coliform bacteria during 2017 and 2022 were observed to be 160000 MPN/100 ml.

5.5 Demography & user perception surveys

Planning processes need to involves people in order to achieve successful implementation of projects. Peoples' opinion surveys are conducted which include **household and commercial surveys** to analyse how they perceive and react to the urban voids around the drain no. X. Place performance evaluation is also carried out on the voids around the drain since these voids were part of the public realm. The place performance evaluation would help us in determining how these voids were functioning in the public realm.

5.5.1 Objectives of Demography & user perception surveys

The primary objectives in conducting household and commercial surveys are as follows *(Refer annexure for survey sheet format)*

- **Place performance evaluation**
- **Socio-economic status**
- **Travel** characteristics
- **Preference and frequency** of recreation
- **Willingness to pay**
- Current status of voids and need for revitalization
- **Issues** faced for revitalisation of drains
- **Ownership** of land
- Size and type of business
- **Preferred activities/ facilities** for the development of voids around the drain
- **Aspirations** for development
- **Potential for commercial establishments**

5.5.2 Findings from Household Surveys

The Household Survey was carried out to collect comprehensive, diverse demographic data, as well as to identify issues and needs of residents living in the study area. The sample size for the HH survey is 200 respondents.

5.5.3 Demography

The household survey constituted about **54% of population is male and 46% population is female**. A significant **36% of population is MIG 2** and **EWS (<10,000 monthly income) and LIG constitute 35%** in total with some living in informal settlements.

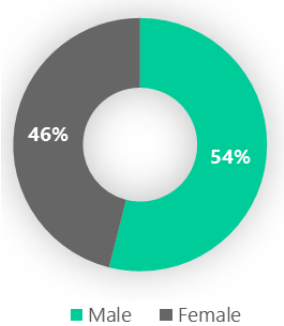


Figure 55. Sex ratio

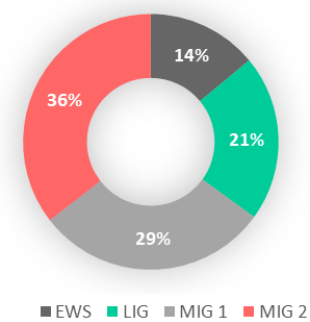


Figure 56. Income category

43% of the houses are row houses and 13% are squatter settlements/ slums which shows that informal settlements occupy many parts of the influence area of the drain. 40% are employees and 16% are involved in services, 18% are students.

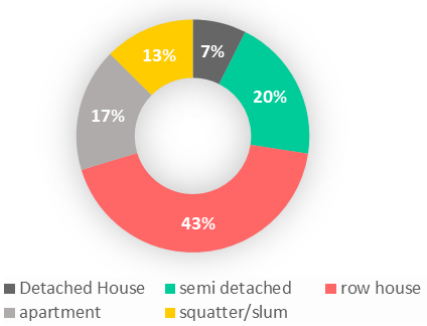


Figure 57. Housing Typology

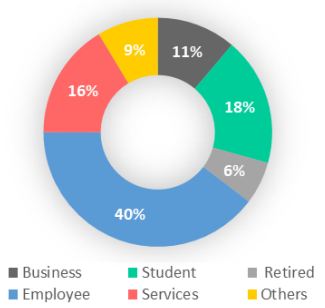


Figure 58. Employment

5.5.4 Physical Infrastructure

Most of the households **(83%) have private toilets whereas community toilets are common within EWS and few LIG groups** living in the informal settlements. Wastewater of 83% households are disposed through stormwater drain which is then directly discharged to the drain no X.

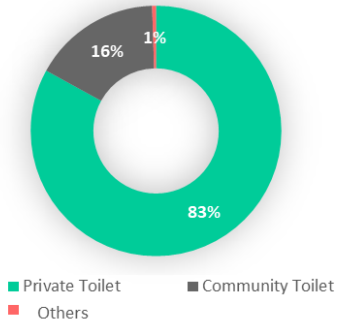


Figure 59. Availability & type of Toilets

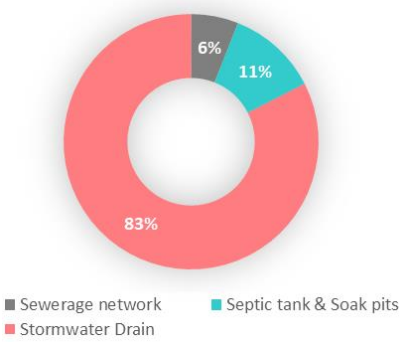


Figure 60. Type of wastewater disposal system

84% of households have Septic tanks and soak pits but many are in neglect or haven't been cleaned regularly resulting in open discharge of the sewage whereas 10% directly discharge into the natural drain. 60% households don't clean their septic tank regularly within 5 years.

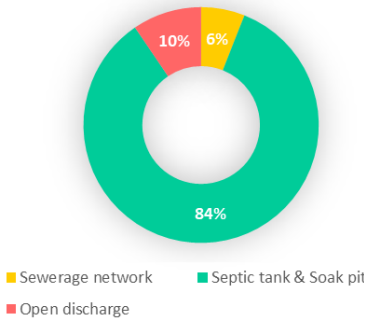


Figure 61. Type of sewage disposal system

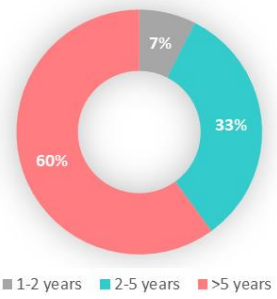


Figure 62. Frequency of cleaning septic tanks

These households discharge untreated sewage along with wastewater into the natural drain discharge point.

5.5.5 Recreation and Travel Characteristics

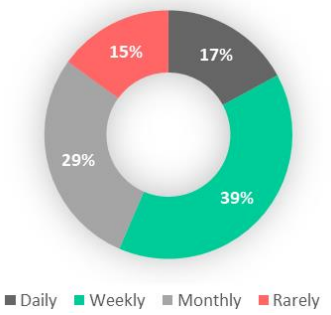


Figure 63. Frequency of trips to park

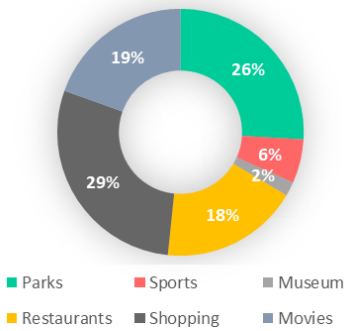


Figure 64. Preference to visit recreational spaces

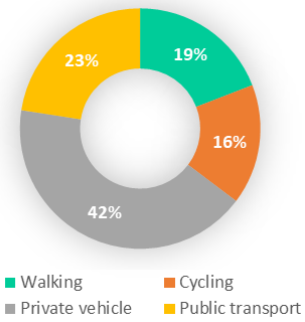


Figure 65. Travel Characteristics (mode)

39% visit parks weekly and 17% daily for jogging, etc. The **mode of transport preferred is private vehicle and a significant 23% use public transit** owing to well- connected Mo-Bus routes. 26% and 29% people prefer to visit parks and shopping malls respectively.

5.5.6 Willingness to pay

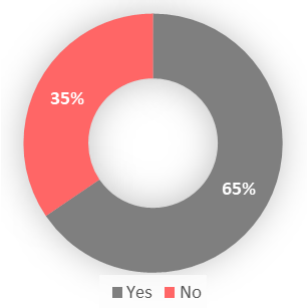


Figure 66. Willingness to pay

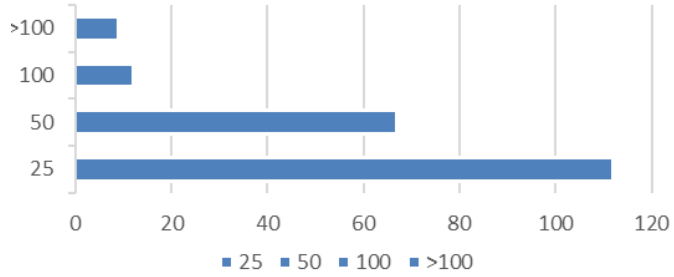


Figure 67. How much are you willing to pay for the entry?

65% respondents are willing to pay entry fees of about 25-50. This shows a positive outlook to contribute for the development of the voids around natural drains.

5.5.6.1 Aspirations and perception

The major concern for 80% of people if parks are located around natural drain is **odour or smell**, whereas 40% are concerned about the **cleanliness**. **Lack of maintenance** is another cause of concern for the users.

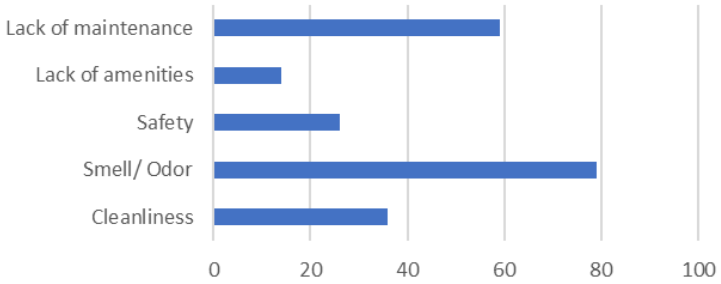


Figure 68. If parks are provided around the natural drain, what will be your major concern?

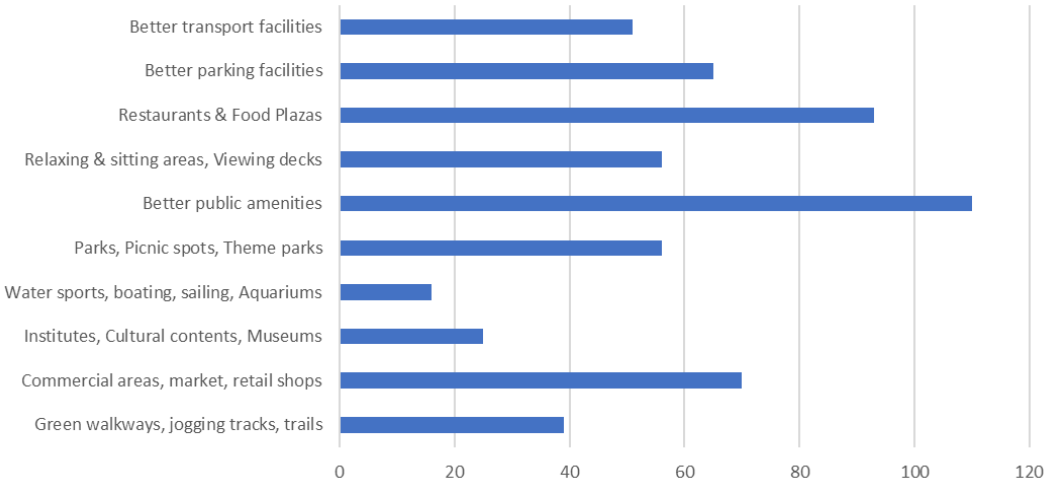


Figure 69. Preferred facilities for waterfront development

Most of the households preferred better **public amenities, restaurants and commercial areas** which will activate the voids around the drain no X. Very few of the households prefer museums and water sports. Better parking and transport facilities are also the preferred facilities for many.

5.5.7 Place Performance Evaluation

The places were rated from 1 to 7 according to the placemaking parameters based on existing condition.

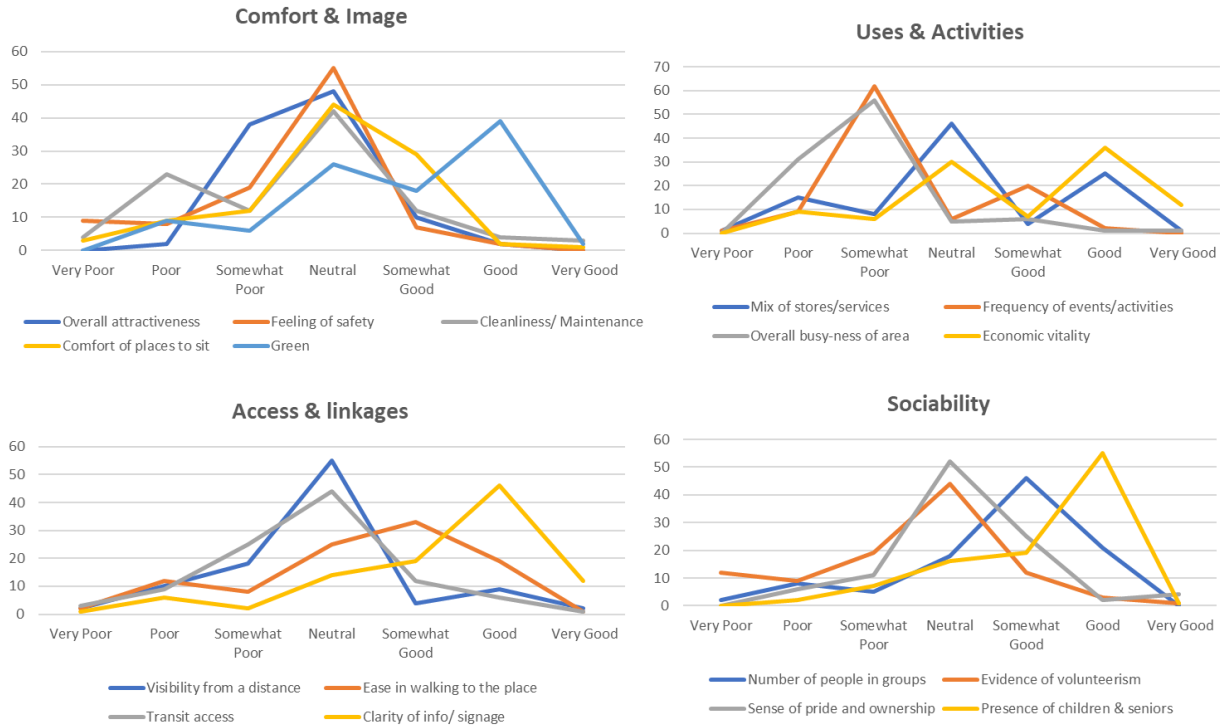


Figure 70. Place Performance Evaluation

- **Comfort & Image-** Most people are neutral about the comfort and about 39% rate the greenery good of the urban void.
- **Access & Linkages-** Around 44-55 people are neutral about visibility from a distance and transit access and 46 have rated the clarity of signage as very good.
- **Uses-** Around 56-62 people have rated activities and overall busyness as poor whereas 36 people are happy with the economic vitality.
- **Sociability-** 44-52 people are neutral about volunteerism and sense of pride. 50-60 people think that children and senior citizens also visit the areas of recreation near the natural drains.

5.5.8 Commercial Survey

Commercial survey of 40 shopkeepers was carried out to understand the economic profile and needs/ aspirations of the shopkeepers.

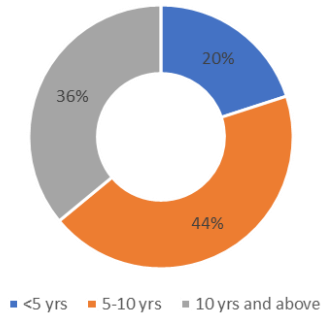


Figure 71. Age of shop

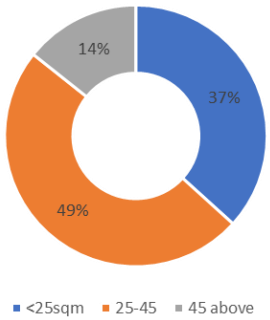


Figure 72. Area of shop

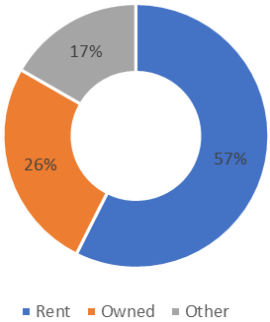


Figure 73. Ownership

A general trend **(44%) of new shops with age 5-10** years is observed along the site. About 49% shops are mid-sized with area 25-45 sqm

47% of the shops have monthly income ranging from 25,000-50,000 and **35% have income greater than 50,000 owing to the prime location** of the shops. 40% of the shops are selling grocery and 23% eatery or other items.

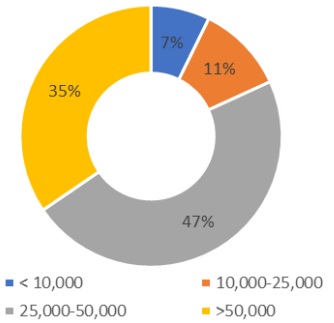


Figure 74. Monthly Income

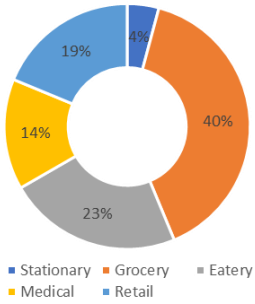


Figure 75. Type of commercial establishment

5.5.9 Aspirations and Perception

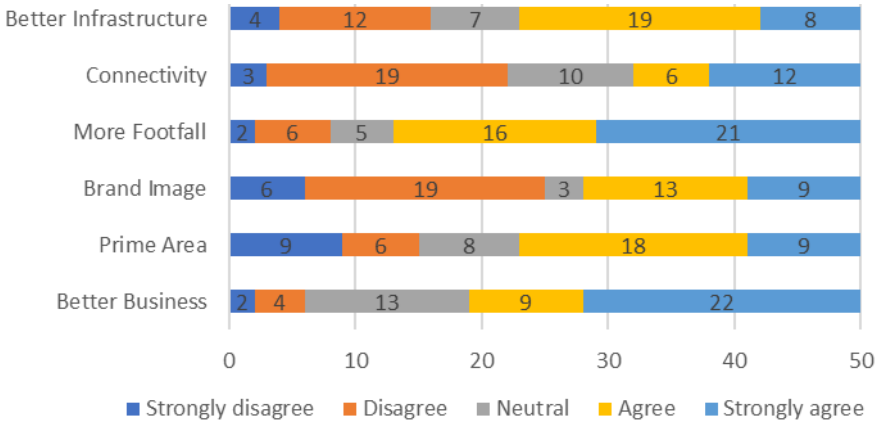


Figure 76. Factors influencing new establishment along the waterfront

About 38% of the shopkeepers agree that better infrastructure is important for new establishment along the waterfront and around 44% agreed that better business and footfall is necessary to increase their monthly income.

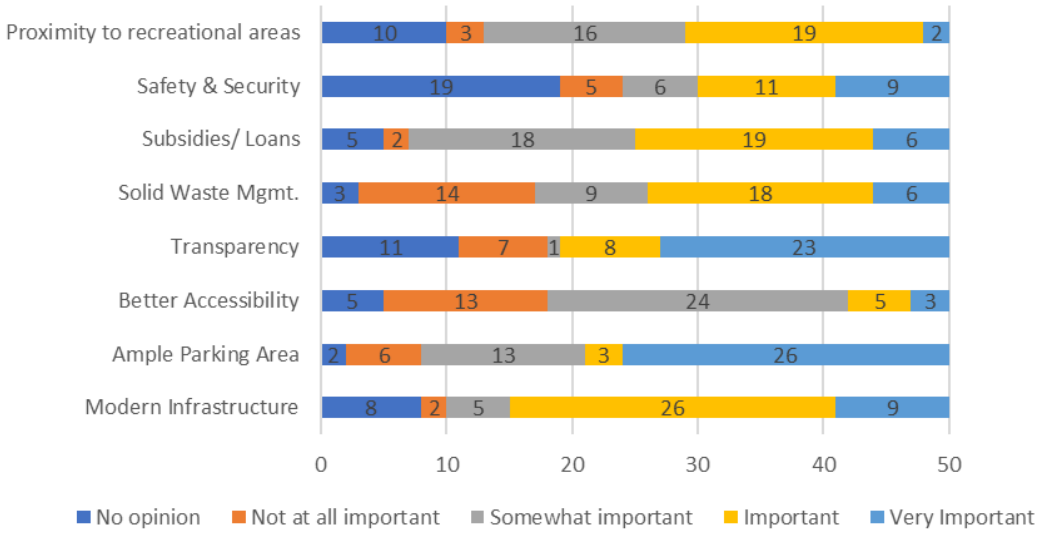


Figure 77. Facilities expected from authorities

The survey regarding the facilities expected from authorities showed that about 52% considered modern infrastructure and ample parking area to be an important factor and 46% wanted transparency in the process. 36-38% people considered loans/ subsidies and solid waste management to be an important factor. Overall, the shopkeepers wanted better facilities as well as economic assistance for new establishments.

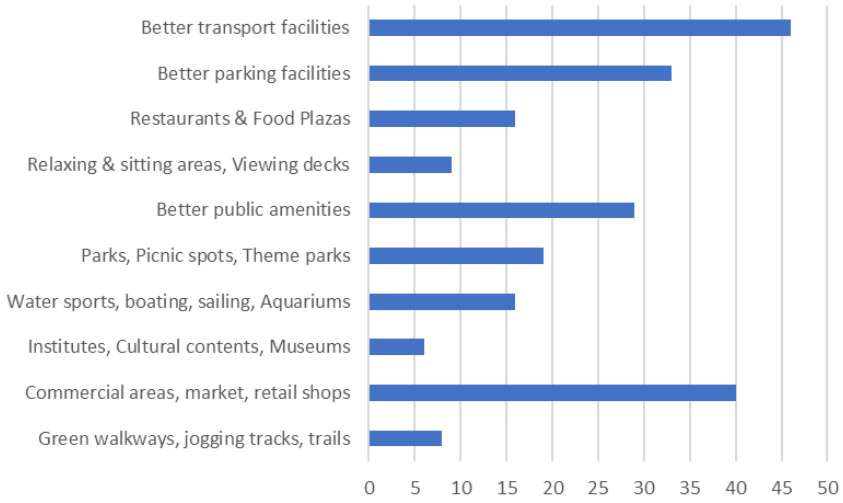


Figure 78. Preference of activities for waterfront development

The shopkeepers agree that **better infrastructure and prime location** will influence new establishments along or near the natural drain. More than 40 people strongly agree that more footfall and better business will help in new establishment.

5.5.10 Expert opinion Survey

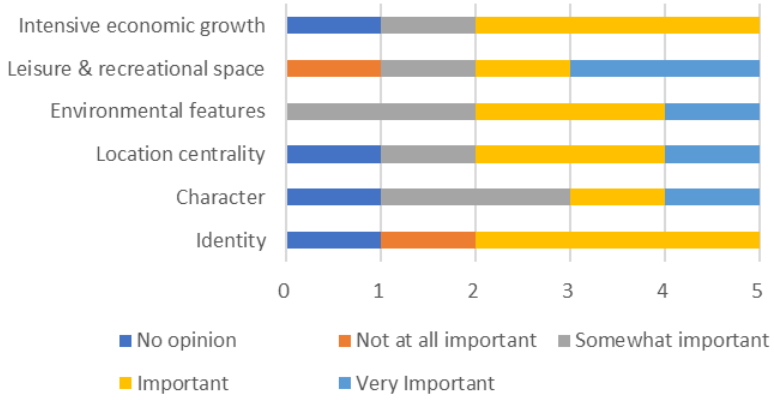


Figure 79. Importance of Drain no. X in the context of Bhubaneswar

Location centrality, identity, intensive economic growth and environmental features of the drain no. X are regarded as important factors in the context of the city of Bhubaneswar. **Leisure and recreation** is also very important as per the experts opinions.

Major issues and reasons for present conditions of the drain

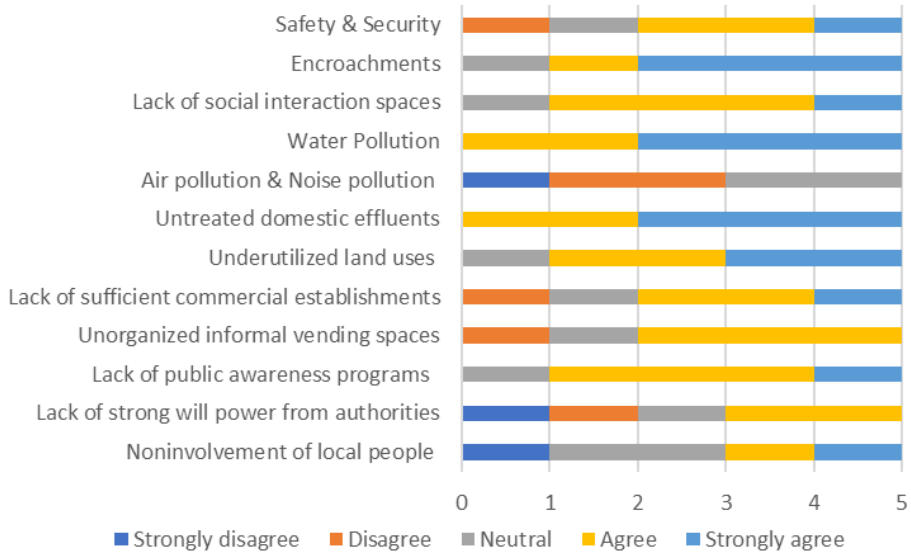


Figure 80. Major issues faced by Nicco Park stretch

Untreated domestic sewage, water pollution, informal vending areas, and encroachments by informal settlements are some of the major problems faced by the drain no. X. there is also lack of strong will power from authorities regarding the planning of urban voids.

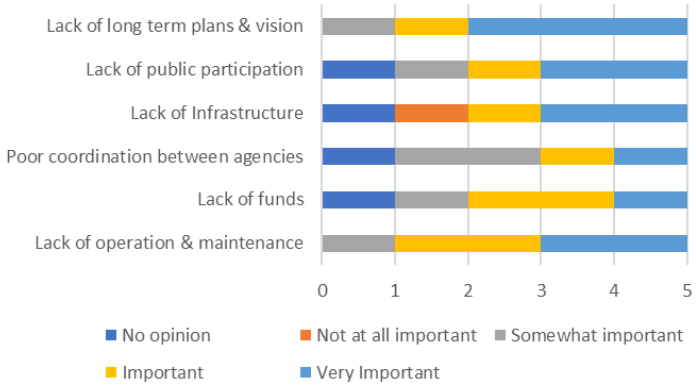


Figure 81. Reasons for the present situation of the drain

Absence of long- term plans, operation and maintenance programs, lack of public participation and infrastructure are major reasons for the current situation of the natural drain and its voids.

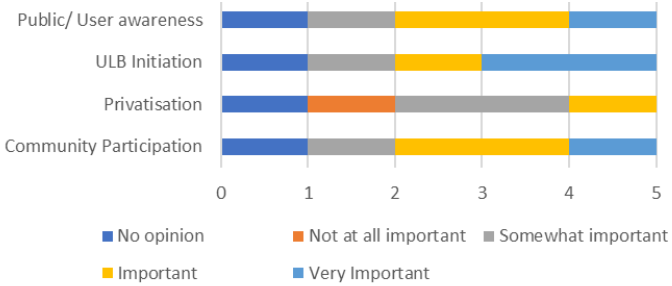


Figure 82. Suggestions for better maintenance of voids around the drain

ULB initiation, user awareness and community participation are important for better maintenance of the urban voids around the drain no. X. Privatisation is considered somewhat important by 40% of the experts.

Suitable land use and preferred activities

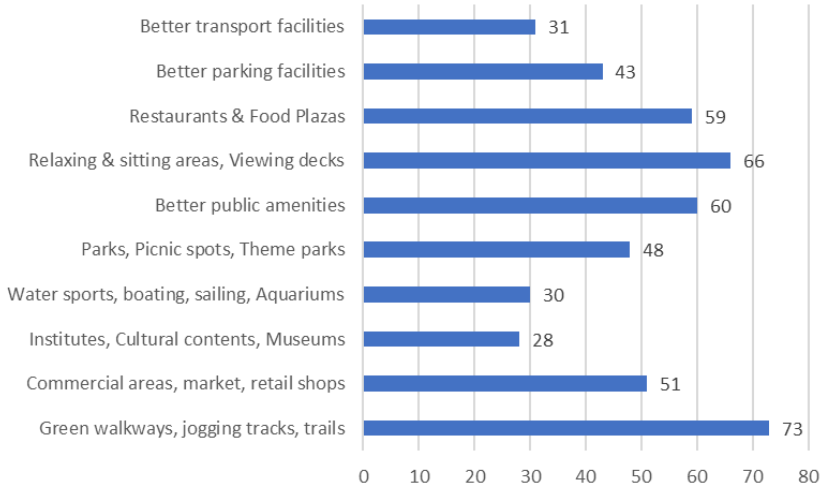


Figure 83. Preference of activities for waterfront development

Located in the prime area of Bhubaneswar, there is a lot of scope for the development of drain no. X and its voids. **Public amenities, commercial areas, green walkways and jogging tracks, relaxing areas** are preferred for waterfront development along the natural drain. restaurants, food plazas and better parking facilities are also necessary for better waterfront development.

5.1 Mapping Accessibility

5.1.1 Connectivity and Road Hierarchy

The natural drain and its voids are well connected by arterial roads and local roads. Three major arterial 4-lane roads pass through and divide the natural drain into 3 zones. These major roads are Bidyut Marg, Pandit Jawaharlal Nehru Marg and Janpath which connect to Jayadev Vihar, Acharya Vihar and Vani Vihar respectively. Zone 3 is bounded by railway line on the Eastern edge.

Public transport Mo-Bus routes are well connected in Madhusudhan Nagar and Unit-9 whereas Satya Nagar and Saheed Naga area are not well connected. The Janpath road dividing zone 2 and 3 has as many as 11 bus routes showing that it is very well-connected to the other parts of the city. The arterial 4- lane roads have public buses plying through them.

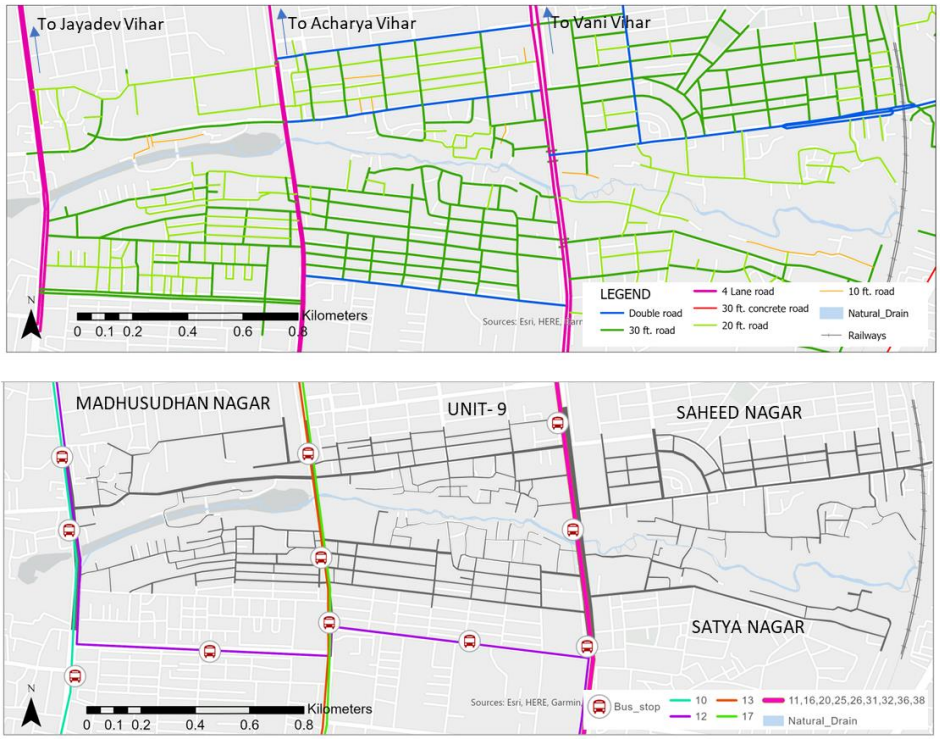


Figure 84. Map showing road hierarchy and public transit (Mobus) routes

5.1.2 Amenities and Attractions

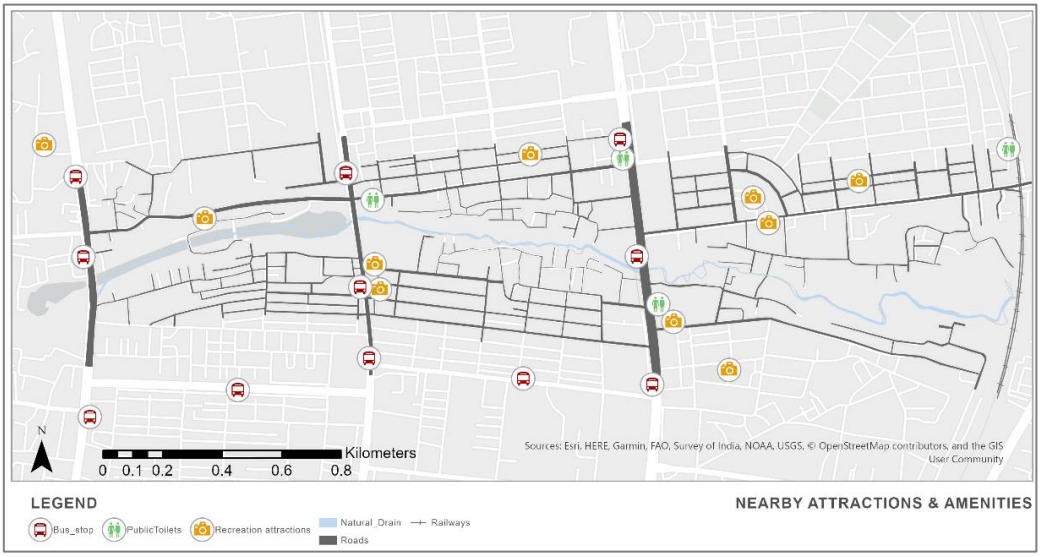


Figure 85. Nearby amenities and attractions

Many recreational areas are there near the drain no. X ranging from parks and stadium to shopping complexes. Many administrative headquarters are also located along this stretch. Public toilets ae available in zone 2 and zone 3 but not in zone 1. Religious spaces such as temples, Christian and Muslim graveyards are also in the vicinity of the study area.

5.1.3 Space Syntax analysis

As per (Batty, 2009), "Space syntax is a descriptive technique for working out the **relative accessibility or nearness of a set of spaces**, often defined as streets, to one another." This makes it possible to compare how close they are to each space's or street's linked movement. **Space syntax analysis is done using the software DepthmapX**.

5.1.4 Visibility Graph Analysis

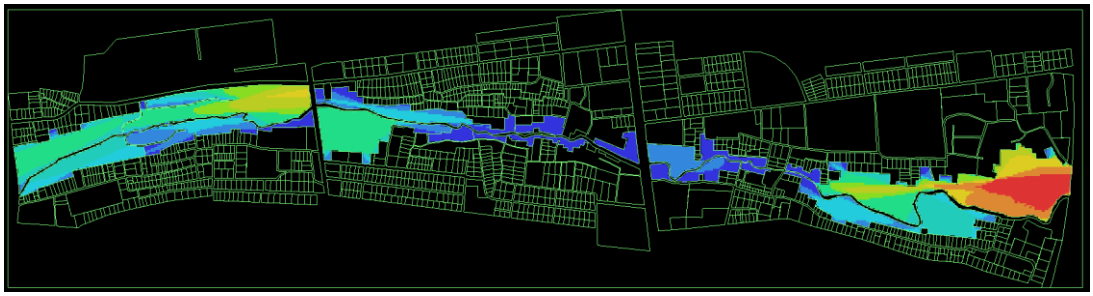


Figure 86. Visibility graph analysis showing connectivity to various parts of the void

The default attribute shown is the number of connections for each location –connectivity. The range runs from blue (for low) through green and yellow to red (many visible locations). The zone 3 has wider open space and is more connected visually which is indicated in the map above as red, whereas other two zones have reduced connectivity where the stretches are narrow.

5.1.5 Axial Map Analysis

Axial maps help to visualize the connections between various elements of the built environment in a city, including but not limited to buildings, streets, parks, and landmarks. For this study it will help to understand the connection between natural drain with the connecting roads.

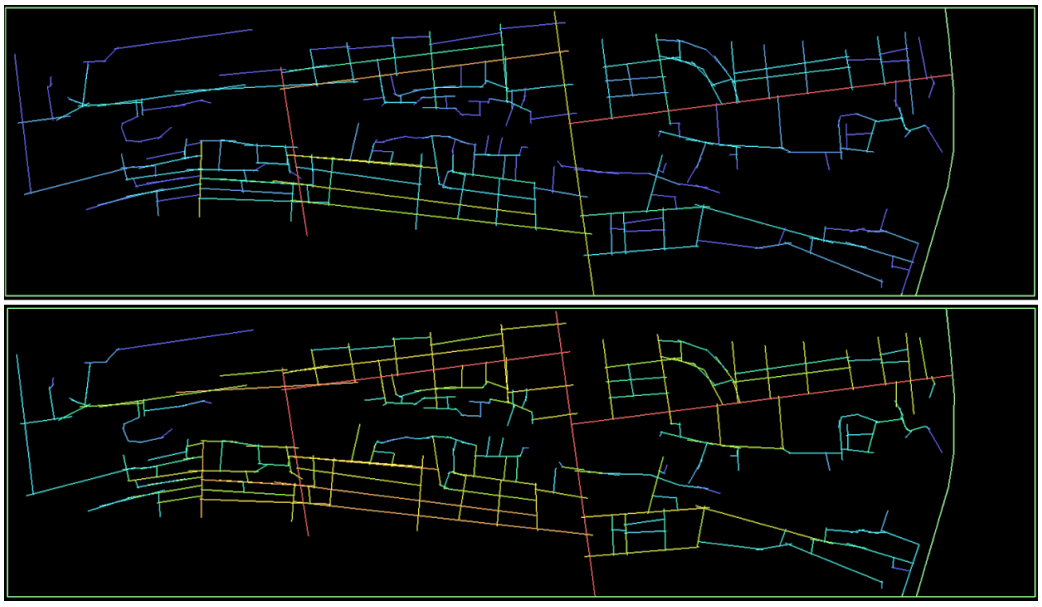


Figure 87. a) Connectivity graph, b) Integration graph

Connectivity graph shows how well the streets are interconnected. Well interlinked streets with high degree of connection- darker/redder which are more active. The arterial roads are well connected with other streets and are shown in red or yellow, whereas the local street with low level of interconnection is shown in blue.

Integration graph with global and local integration (n,3) shows the level at which a node is integrated or segregated to the whole system- no. of turns and ease of accessibility. Red shows higher integration which is seen in the arterial roads encompassing the natural drain.

5.2 Issues Identified

The primary issues were identified as per analysis and are as shown in the table below. The major issues are related to ownership, administrative negligence and environmental issues, lck of safety and imageability of the site and state of physical infrastructure**.**

Table 27. Issues identified after analysis

	Issues
Ownership	Encroachment by informal dwellers
Administrative	Poor land use management,
	Ineffective decision-making, and lack of coordination between decision-makers and urban planners
Environment	Urban flood during rainy season, narrowing riparian zone due to the encroaching-built forms, channelizing by creating canals, deposit of silt & waste disposal.
	Foul smell owing to discharge of untreated sewage
Physical Infrastructure	Disposal of untreated sewage
	Solid waste disposal near fringes of the drain
	Electrical cables hanging loosely creating menace during cyclones and also affecting the imageability
Imageability	Illegal hoardings
Safety	Lack of illumination at night
	Lack of safety in many parts owing to illumination, lack of public activities

Figure 88. Issues identified at various parts of site a) hoardings in zone 1, b) narrowed drain due to development along and c) encroached area in zone 3, d) dumping of solid waste in zone 2

5.3 SWOT Analysis

Strengths

- The drain no. X lies partly in Bhubaneswar Town Centre District, which is the central part of the city.
- Access to public transport and intermediate public transport.
- Availability of vacant land in the voids allowing creation of seamless public spaces.
- Imageability of the site along many parts of the stretch.
- Major recreational area such as Bhawani mall and many parks near the natural drain.
- High land value because of prime location in the city.
- Commercial areas along the Janpath and near the site.
- Administrative headquarters of different departments are located.

Weaknesses

- Urban flood during rainy season in low lying areas near the natural drain.
- Foul smell of natural drain due to discharge of untreated sewer.
- Incompatible land uses along the voids of natural drain.
- Lack of public amenities and street furniture.
- Slum pockets near the drain spoiling the image of the voids.
- Lack of 24/7 activities.
- Rail line acting as a physical barrier in zone 3.
- Lack of physical access to the natural drain from surrounding areas.

Opportunities

- The visual connect of the voids to the surroundings provides opportunities for better connect with people.
- Avenue for temporal activities, cultural events, celebrations and exhibitions.
- Establishment of leisure spaces along both sides of the drain.
- Opportunities for land-water interface in public outdoor recreation.
- Physical linkage with the voids around the drain.
- Provision of organised spaces for informal markets and hawkers.
- Creating awareness and community participation can help in reviving the degraded ecosystem.
- Potential for more institutional buildings and other interdependent activites.
- Rethinking the issue of encroachment as well as encouraging other land owners to submit parcels of land for widening of drain.

Threats

- The urban voids around the drain is encroached upon by informal dwellers at multiple locations.
- Indiscriminate solid waste disposal along the voids of the natural drain has hampered the experience of the space.
- Discharge of untreated sewage poses threats to the cleaning capacity of the natural drain.
- Siltation from the drains.

6. Proposals

The proposals range from restoring both the upland and wetland ecosystem by treating wastewater discharged into the natural drain as well as creating a public realm which will create awareness and improve the biophilic connect of the people with nature.

Figure 89. Proposals framework

The proposals will include policy level interventions in which framework will be created for creating public spaces around urban voids along the natural drains of the city. Planning level interventions will be focused on the action area of drain no X in which holistic proposals for the three zones of the drain will be given.

6.1 Concept

Understanding the **interlinked fabric of urban ecosystem with natural ecosystem and restoring the natural ecosystem by connecting it with socio cultural activities and placemaking** as shown in figure below. The tangible aspects of society such as livelihood, recreation, awareness as well as intangible aspects of well-being (both physical and psychological) will be addressed through interaction with natural ecosystem which will, in turn help in creating collective memory for the citizens. Thus, rejuvenation of the natural drains will also help in rejuvenation of the communities.

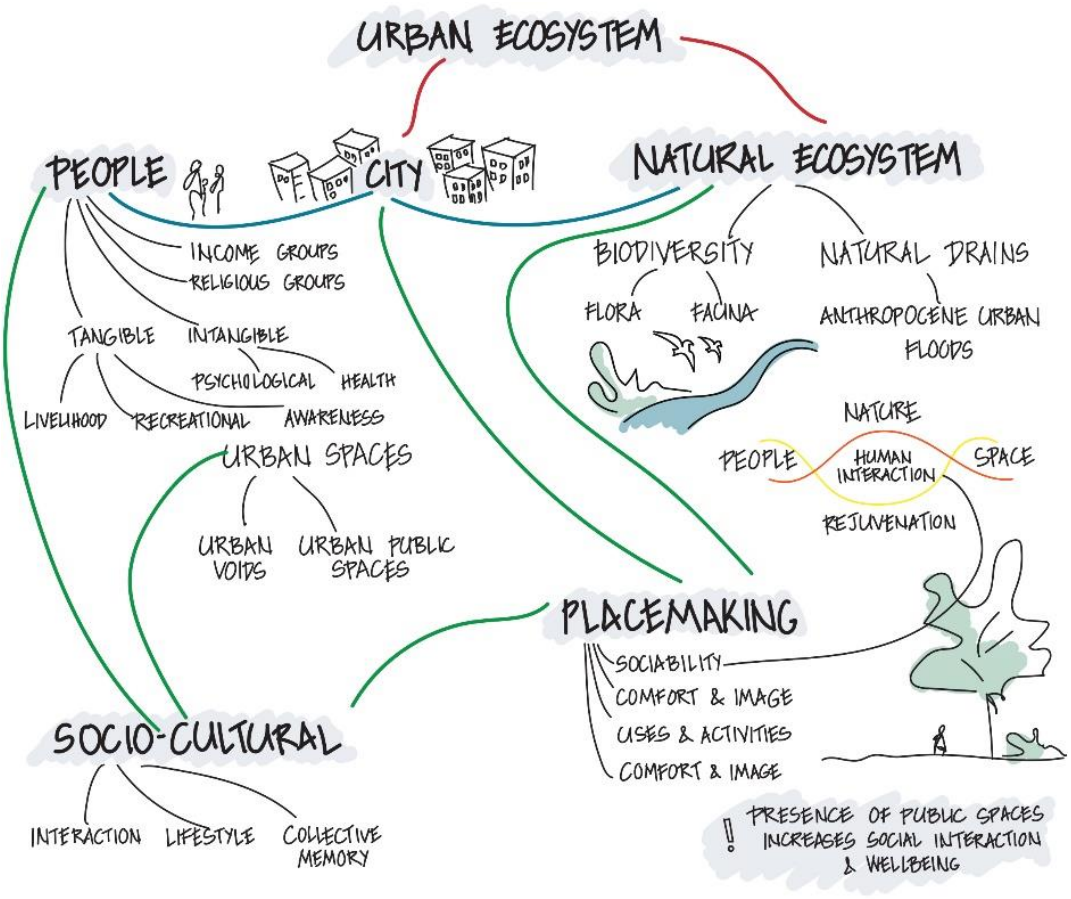


Figure 90. Interlinked fabric of urban ecosystem (Source- Author)

6.2 Planning Level Interventions

The objective of these interventions is to foster sustainability, enhance liveability, and promote economic development through placemaking which will be specifically for the action area of drain no. X.

6.2.1 Channel Improvisation & Flood Control

Channel improvisation and flood control is necessary to restore and improve the ecosystem of the natural drain. This would involve desilting and desludging, weeding and creating embankments.

Desilting- It involves removing accumulated silt, sand, and other debris from the natural drain. The presence of silt and sediment diminishes the depth and capacity of these water bodies, causing ecological and other related problems. Dredging equipment such as backhoes, suction pumps, or draglines are used for desilting.

Desludging- It is the process of extracting solid waste and sludge from wastewater discharged into the drain. Sludge is the semi-solid waste left behind after wastewater treatment, following the

separation of liquid components. Vacuum trucks are used for desludging, which remove the sludge and transport it to a treatment or disposal facility.

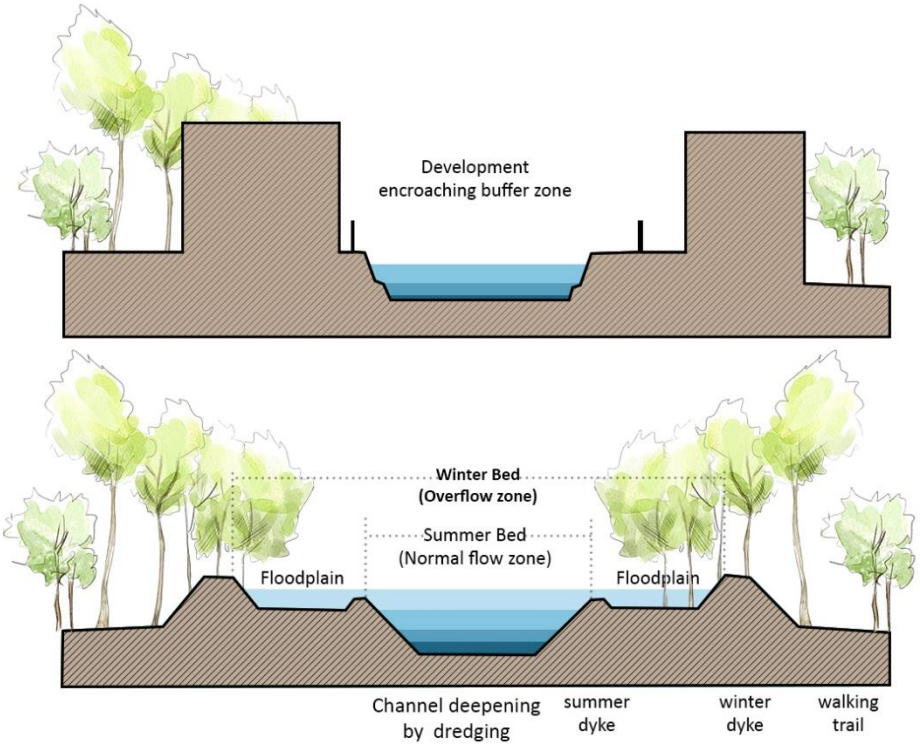


Figure 91. Existing section vs proposed two stage-channel (Source- Author)

Two-stage channel (TSC) design- It is inspired by nature that incorporates floodplains along the main channel. It involves creating winter dykes or floodplain which will prevent floods during rainy season. The primary goal of the TSC design approach is to enhance **the efficiency and sustainability of water flow management**.

By directing most of the runoff through the first stage channel, the design can **minimize erosion, prevent flooding, and encourage infiltration and groundwater recharge.**

The second stage channel acts as a backup channel to mitigate flooding risk by carrying any excess runoff. Cut and fill method is used for creating the dykes and gabion wall is used to protect the banks of the natural drain.

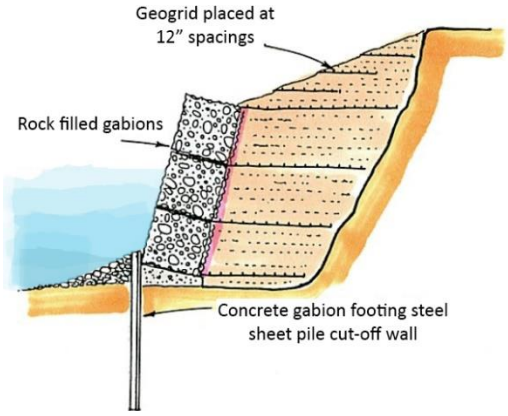


Figure 92. Gabion wall schematic

Restoring the drainage as per historical flow and widening the channels will prevent urban flooding in the vulnerable areas as well as reduce the development pressure on the stream.

6.2.2 Nature Based Solutions

6.2.3 Scientific Wetland with Active Biodigester (SWAB)

The SWAB technique is used to rejuvenate and treat wastewater in zone 3 where the sewage is discharged. This system incorporates both physio-chemical and biological components- a sedimentation tank furnished with a biodigester and a constructed wetland system.

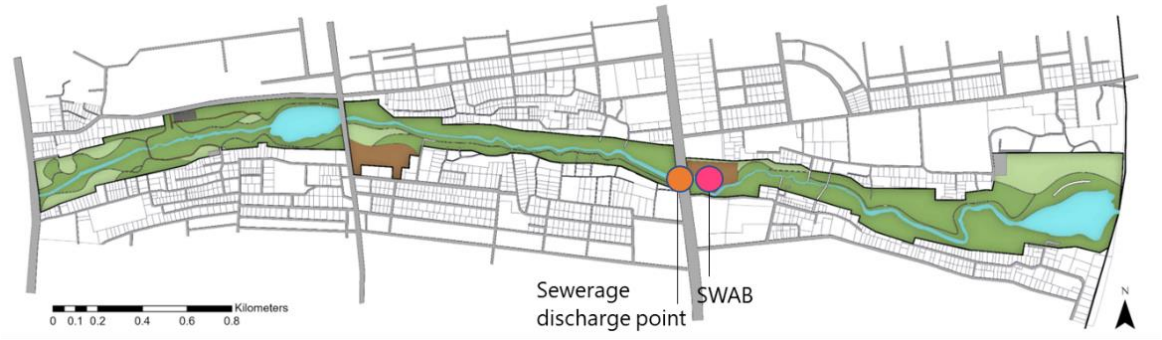


Figure 93. Key map showing SWAB technique in zone 3

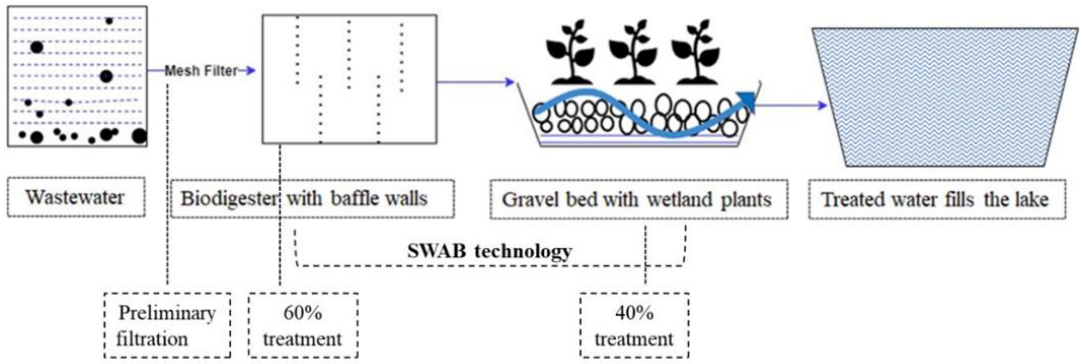


Figure 94. Schematic showing SWAB technology (Shrivastava & T.C)

The 12.3MLD sewage discharge is **filtered through mesh filters** and sent to **biodigester where it is 60% treated**. The fine solids that were not trapped by the mesh filters are treated. The water remains still in this section, allowing particles to settle and the fine faecal matter, crushed organic solids, small stones, and sand to form sludge. The organic part of the sludge is decomposed by bacteria, while the inorganic portion may require cleaning every six months or as needed.

In the second stage, the partially treated water flows into the **artificially constructed wetland**, passing through a 2.5 m deep gravel bed that contains hormonally treated wetland plants. The water moves in a **zig-zag pattern to enhance retention in the wetland and prevent flooding**. The gravel bed filters out any unfiltered solids from the biodigester through physical sieving, which are later consumed by the microbes present in the biofilm on the gravel bed. Chemical reactions in the filtration process aid in the **removal of nitrates, ammonia, phosphates, heavy metals, pesticides,** and other substances. Post treatment it is released to the drainage channel.

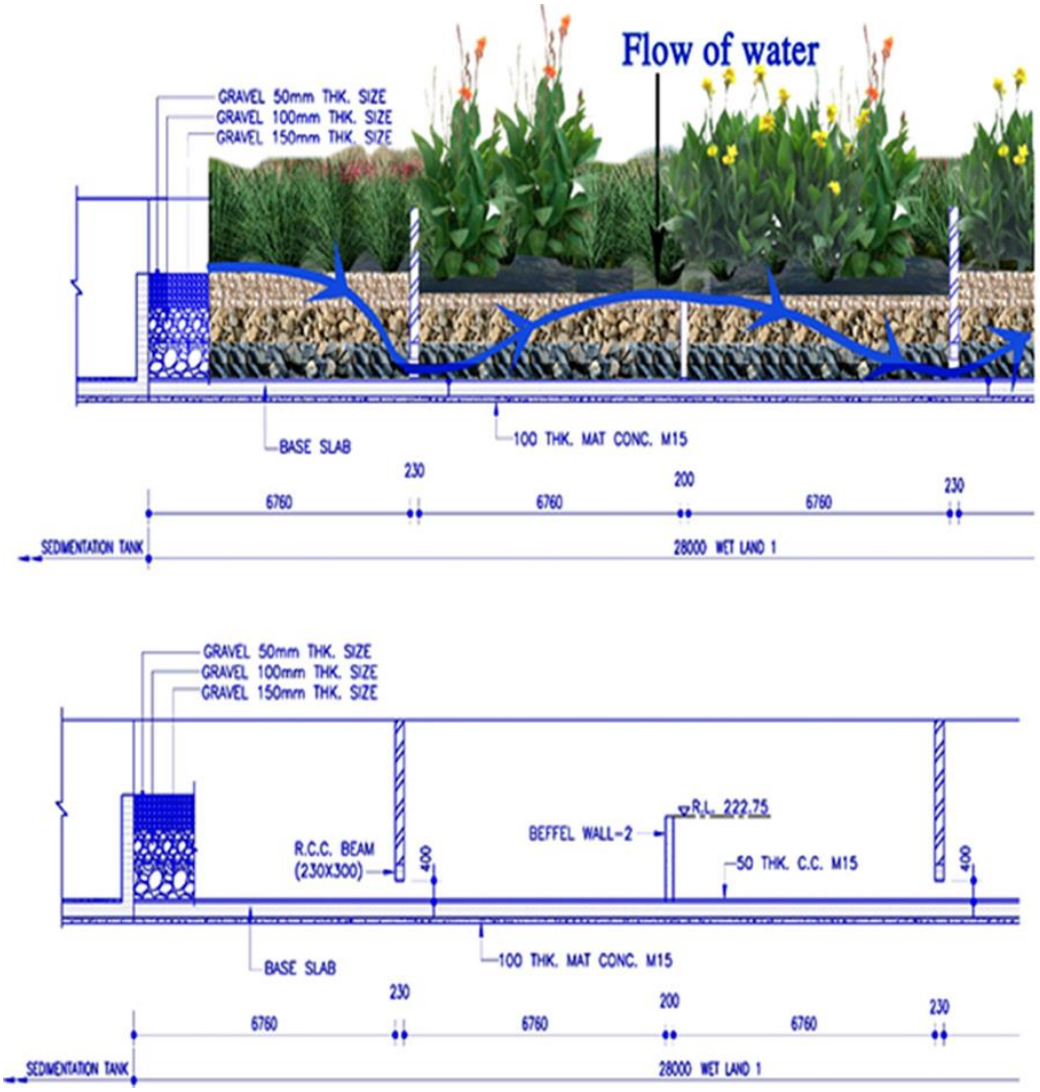


Figure 95. Conceptual mechanism of constructed wetlands in the SWAB technique (Shrivastava & T.C)

Plant species- The efficiency of nutrient and heavy metal removal can be improved by using hormonally treated wetland plants such as **Canna, Typha, Phragmites, Ipomea, Alternanthra, Polianthus tuberosa.**

Salient features of the SWAB technology:

- Cost-effective
- High efficiency
- Easy Maintenance & no skilled labor required
- Negligible operation and maintenance expenses
- Smaller footprint
- Facilitates recycle and reuse of water
- No foul odour and mosquito infestation
- Low energy consumption required for operations
- Aesthetic appeal

Figure 96. Scientific Wetland with Active Biodigester at Ghogha and Sannoth Lake (Delhi) (Shrivastava & T.C)

Area requirements

Table 28. Comparison of wetland techniques for wastewater treatment (Shrivastava & T.C)

Requirement for 1 MLD with 250 to 20 mg-BOD/L	**DEWATS**	**Phytorid**	**SWAB**
Footprint (m2)	4000-5000	~2000	~600
Gravel bed depth (m)	1-1.5	2-2.5	2.5–3
Carbon removal	Oxidized to carbon dioxide	Converted to methane in the absence of oxygen	Converted to methane which is oxidized to carbon dioxide through biological processes

From the table above it can be seen that SWAB The area required for SWAB technique is 600 sqm for 1 MLD. For the study area, in order to treat **12.3 MLD water, the total area required is 5535 sqm**.

Finance

The basic capital cost includes cost of **land, site investigation, labor for earthworks and construction, construction and other materials, and media and vegetation,** etc.

The total wastewater to be treated is **12.3 MLD** and the cost of treatment is as shown in the table below. The total cost of construction is **18.45 Cr and operation cost annually is 4.92 lakhs.** The unit cost has been established from SWAB technique in the Rajkori lake, Delhi.

Table 29. Construction and operation cost

	Cost Per MLD	**Cost for 12.3 MLD**
Construction cost (Lakh)	150	**1845 (18.45 Cr)**
Operation cost (Lakh)	0.4	**4.92**

6.2.4 Floating Wetlands

The floating wetlands have **plant, soil and root interactions similar to a natural wetland** and provide homes to beneficial water-cleaning microorganisms. They reduce nitrogen and phosphorous levels in water body. Floating wetlands are proposed in zone 1 and 2 as the amount of pollution is low.

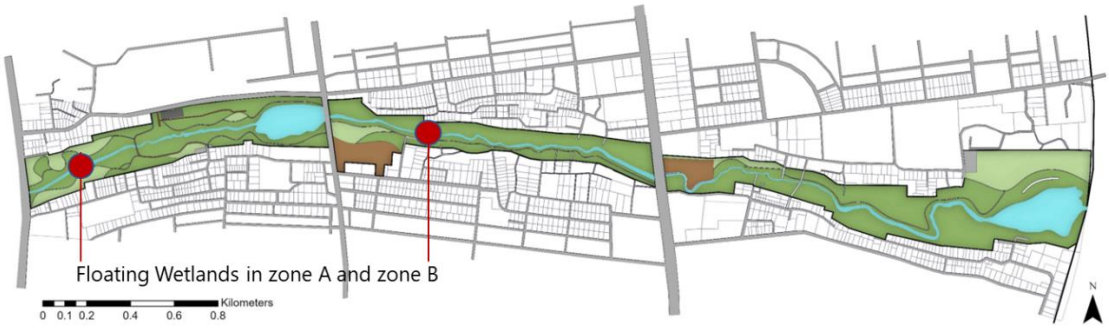


Figure 97. Key map showing floating wetlands in zone 1 and 2

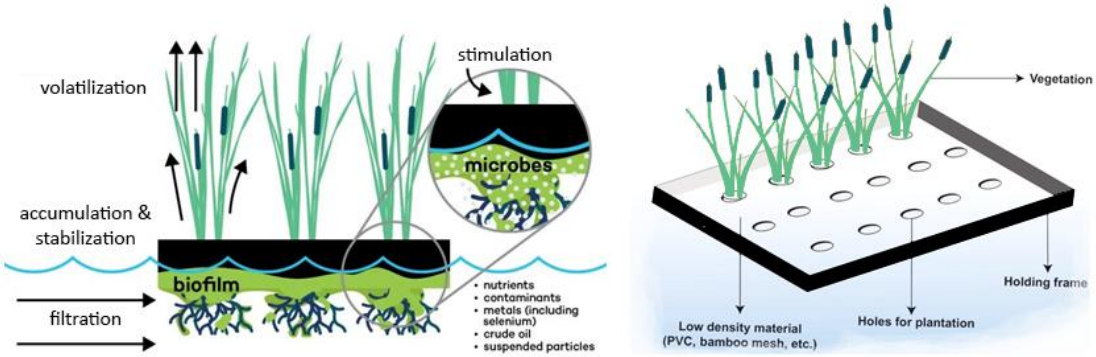


Figure 98. Floating wetland (Floating treatment wetlands, 2023)

It comprises of a **floating platform that holds various types of wetland plants and their roots**. These plants can assimilate excessive nutrients, enhance water quality, and offer a conducive habitat for aquatic life. The vegetation on a floating wetland minimizes wave action and erosion, while also providing aesthetic value.

In order to prevent roots from connecting to benthic substrate or macrophyte vegetation being submerged, the **floating mat's anchoring should allow it to rise and fall** with changing water levels.

Plant species

Figure 99. a) Floating wetland, b) Canna Indica, c) Cyperus papyrus

Native plants such as P. australis, T. latifolia, P. hydropiper, A. sessilis, C. esculenta, P. stratoites help in treating BOD, TSS, phosphate-phosphorus and ammonium-nitrogen. Common reed (Phragmites australis) treats BOD, COD and ammonia (Bajpai & Jethwa, 2016).

Finance

Floating wetlands of screen Size: 1.2m X 1.2m X 0.25m are used in the site and the total number of such screens used are 60 in phase 1 of the project- 30 in each zone. The cost of each such screen is 30,000 rupees, so **the total cost is 9 lakh rupees.**

6.2.5 Riparian zone

The riparian zone is the urban void surrounding the natural drain. To restore the natural habitat, **fish shelters and wetland plantations** are implemented along the drainage channel.

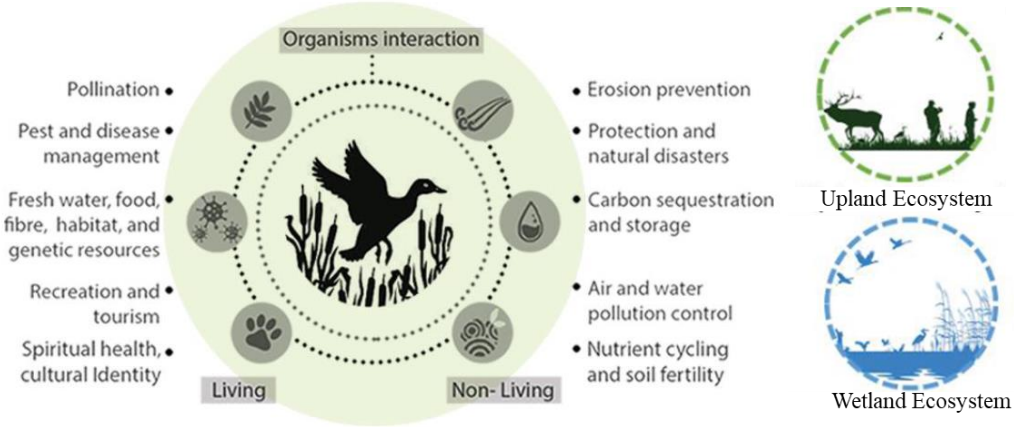


Figure 100. a) Ecosystem building parameters and b) ecosystems created (Rewal, Khanna, Mall, & Diptivilasa, 2015)

A **two-year planting trial** is carried out in the design stage to identify suitable species tolerant to the nutrient content of the nullah flow. It will be **followed by a full-scale implementation** during the construction process. The proposed interventions will improve both wetland ecosystems and upland ecosystems and replicate multiple ecosystems from bottom to top tier.

Ecosystem is restored by desilting the riparian zone and stabilising it with afforestation of native species. Mounds are also proposed in the two lakes in zone 1 and zone 3 which will attract birds and further improve the biodiversity.

Figure 101. Reference of lake mound

6.2.6 Placemaking

The transformation of voids into public space involves proposing many activities and attractions which will attract the public. The activities range **from recreational, economic to socio-cultural and educational**. This will help to achieve the objective of restoring the natural drain and its voids as well as raise awareness about the possibility of integrating voids into urban fabric. The phasing is further detailed out in the development, management and finance section.

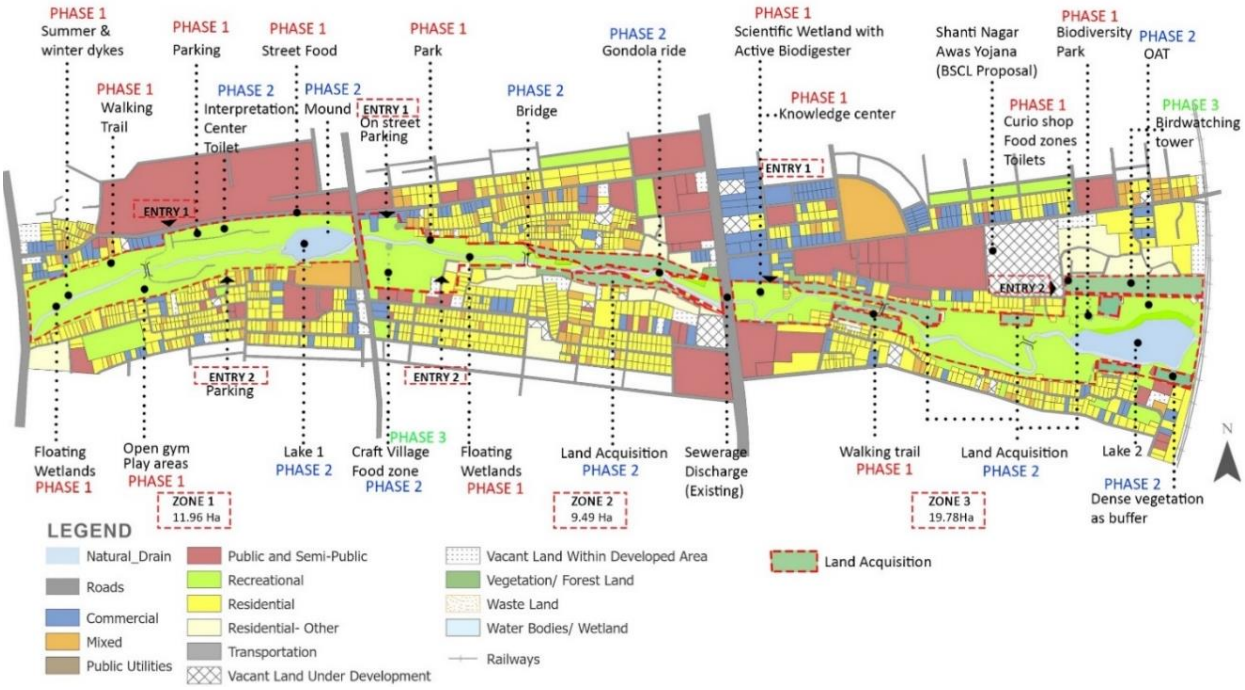


Figure 102. Conceptual plan of proposed interventions along with their phasing

Area requirements

Table 30. Area requirements

Intervention	Zone	Measure	Units
Retention pond/ lake	Zone 1	20700	sqm
	Zone 3	13765	sqm
Channel deepening & dykes	Zone 1	780	m
	Zone 2	1017	m
	Zone 3	1259	m
SWAB	Zone 3	5535	sqm
Mound in pond	Zone 1	320	sqm
	Zone 3	496	sqm
Interpretation centre	Zone 1	1400	sqm
Curio shop and food zone	Zone 3	500	sqm
Crafts village	Zone 2	15000	sqm

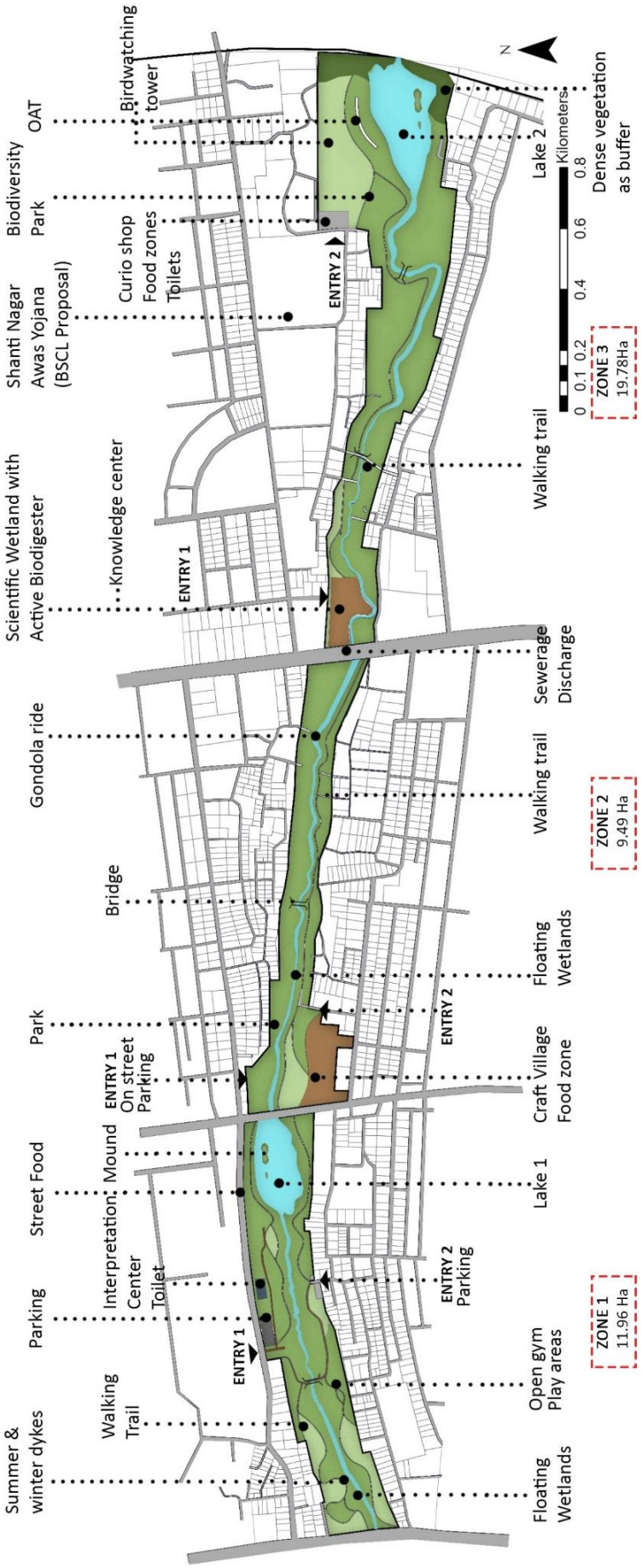


Figure 103. Proposed interventions in the three zones

6.2.7 Zone 1 Interventions

Zone 1 has educational, recreational and commercial areas for increasing footfall as well as measures are taken to restore the natural ecosystem. It has an area of about **12 Ha.**

- Recreational areas- **Walking trail, open gym, play areas, street food**.
- Educational areas- **Interpretation centre** in order to know about the biodiversity and importance of natural drain in the city
- Drain rejuvenation is done by channel widening, summer and winter dykes, and water treatment is done by floating wetlands.
- **Retention pond or lake** is provided at the eastern area where the gradient is low and mound is provided in the lake for improving the biodiversity of the lake.

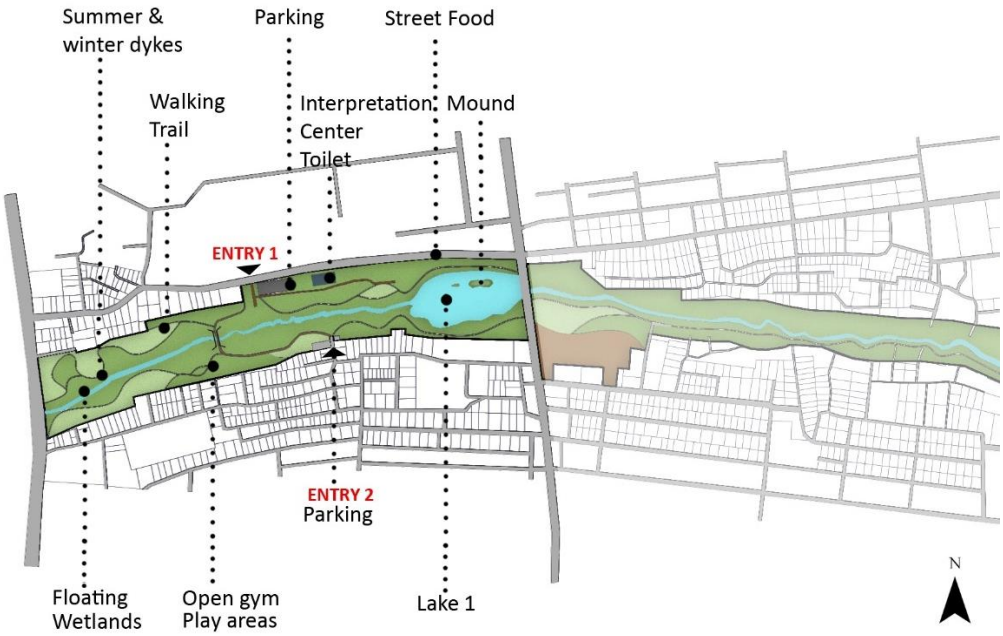


Figure 104. Zone 1 interventions

6.2.8 Zone 2 Interventions

Zone 2 has primarily recreational and commercial areas. It is linear and the narrowest zone and has an area of about **9.5 Ha.**

- Craft village and food court is proposed in zone to promote local handicrafts and food.
- **Walking trail** is provided along the natural drain providing scenic view of the green and natural drain. A bridge connecting both edges of the drain is provided and an underpass connect is proposed which connects with zone 3.
- **Gondola ride** is provided for recreation in this zone.

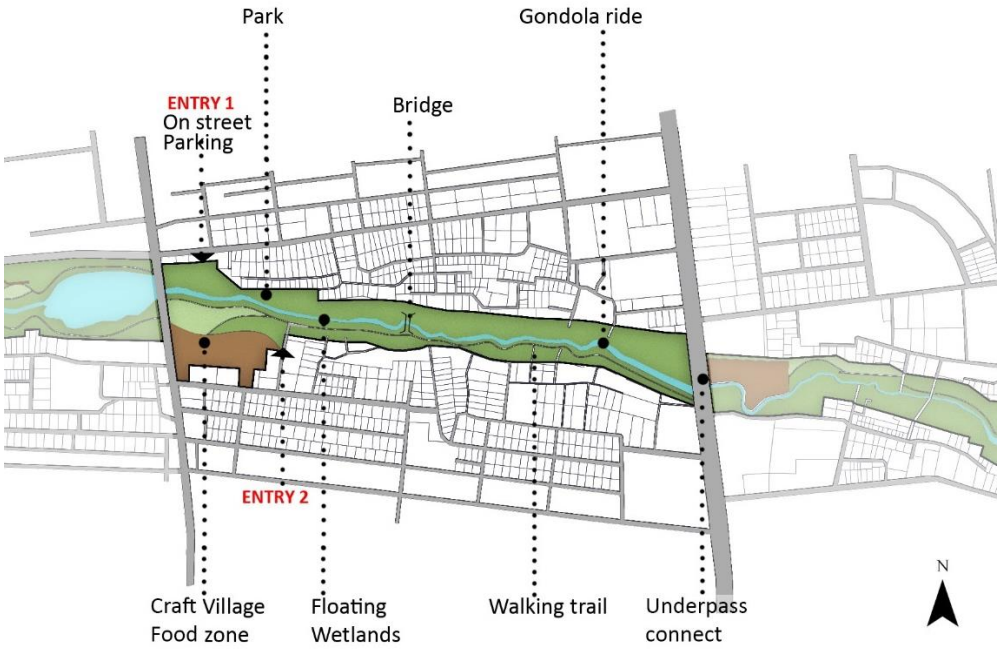


Figure 105. Zone 2 interventions

- **Floating wetlands** are proposed for water treatment in this zone which also attracts birds and other species and enriches the biodiversity of the area.

6.2.9 Zone 3 Interventions

Zone 3 educational, recreational and commercial areas. It is the zone with most potential and has an area of about **19.8 Ha**.

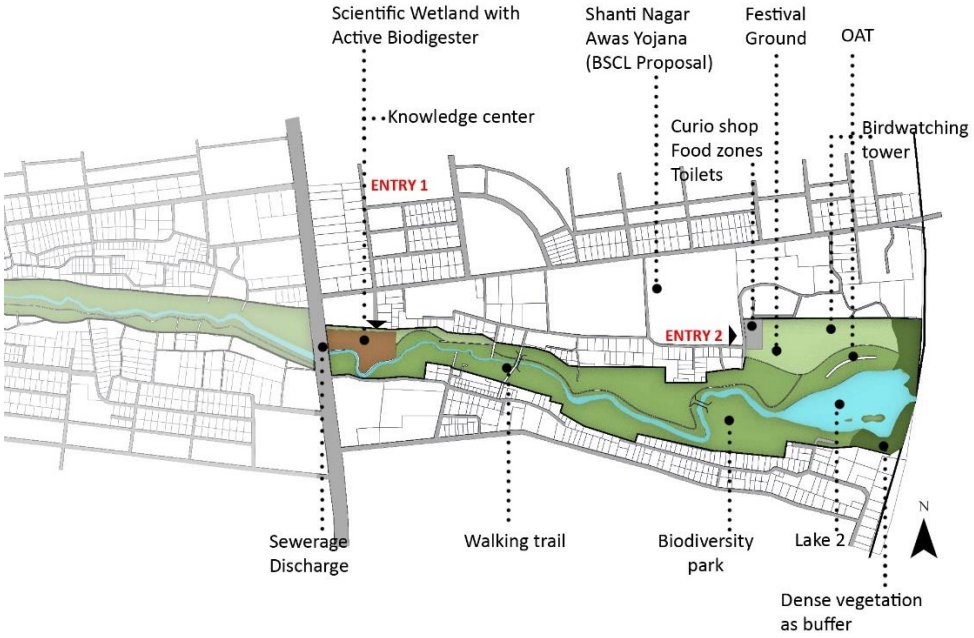


Figure 106. Zone 3 interventions

- **Biodiversity-park and knowledge centre** is the highlight of this zone. The knowledge centre is an on-site experience and education of the **SWAB technique of water treatment.**
- **Retention pond** is provided at the eastern edge and mound is proposed for improving the biodiversity.
- **Festival ground** is proposed for small scale cultural events and **OAT** is provided near the lake for relaxation.
- **Curio shop and food zone** is proposed near the second entrance.
- **Walking trails and seating areas** are provided throughout the park to encourage walking, jogging and active recreation. A bridge connecting both edges of the drain is provided and an underpass connect is proposed which connects with zone 2.
- **Dense vegetation** has been proposed along the eastern edge which serves as buffer from the railway line.

6.2.10 Circulation

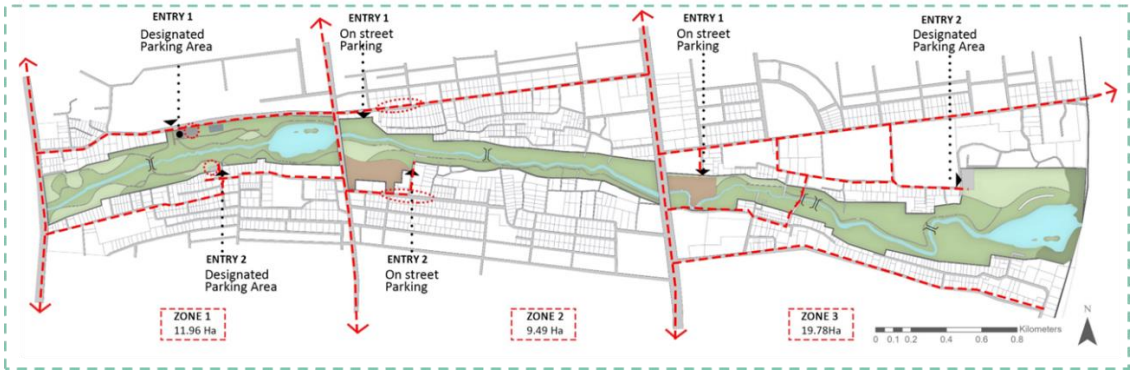


Figure 107. Vehicular Circulation

Each of the zones have two entries. Zone 1 has entries on the north and south banks of the natural drain and has designated parking area. Zone 2 also has entries on both sides but due to its narrow width, on-street parking has been proposed. Zone 3 has two entries on the northern side and has on-street and designated parking area.

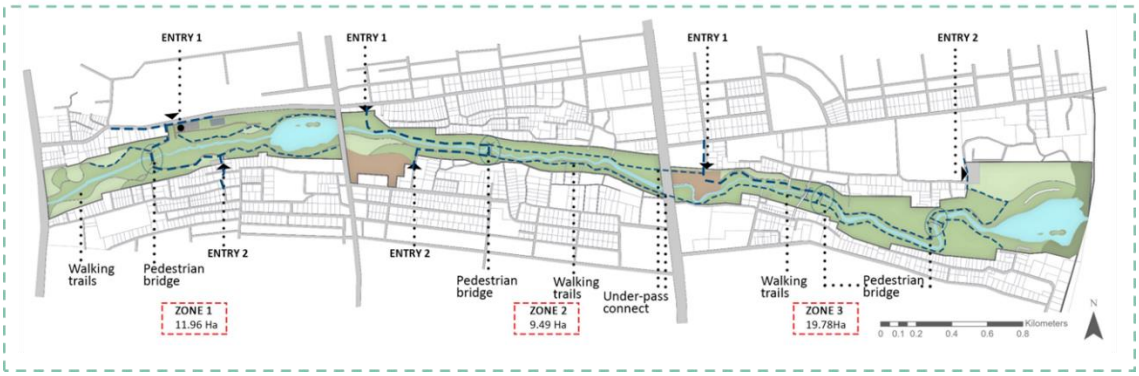


Figure 108. Pedestrian Circulation

Pedestrian walkways are provided along the natural drain and meandering walking tracks are also provided in zone 1 and 3. Bridges are provided for crossing the natural drain and zone 2 and 3 are also connected by underpass connect.

Figure 109. Schematic sketch of underpass connect (MTD, 2023)

6.2.11 Land Acquisition

As per MoHUA- River Centric Urban Planning (RCUP) guidelines, **buffer of 35m** is to be provided along secondary drains to repair and protect the riparian zone of the natural drain.

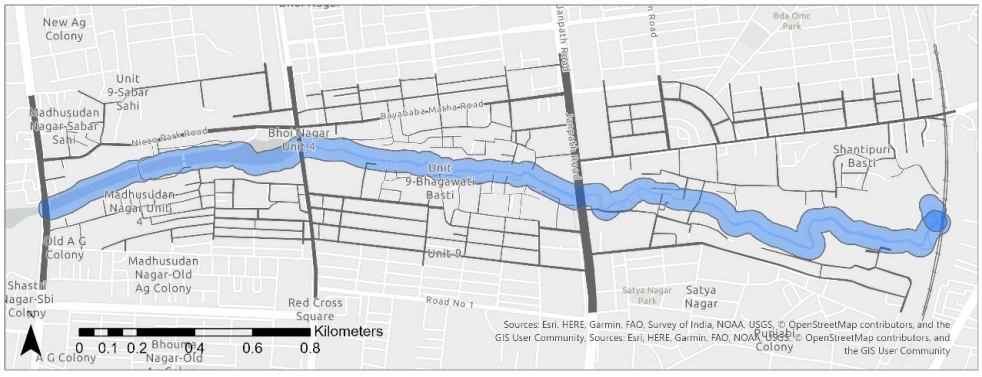


Figure 110. 35m buffer around the drain, **Figure 111**. Proposed land acquisition and resettlement location

Proposal is to **acquire and relocate part of the informal settlements** in the **Shanti Nagar Jan Awas Yojana** and to provide incentive/ plots in other areas to the private landowners.

Table 31. Land acquisition in the 3 zones with area

Land Acquisition			
Ownership	**Zone**	**Type**	**Area (sqm)**
Government	Zone 2 south bank	Slum	8760
Private		Plotted	2313
Government		Vacant land	786
Government	Zone 2 north bank	Slum	9500
Government		Waste land	698
Government		Vacant land	311
Private	Zone 3 north bank	Plotted	6009
Government		Slum	1150
Government		Vacant land	360
Private		Plotted	2503

6.2.12 Tourist Circuit

Designing a tourist circuit in Bhubaneswar that covers a long stretch and includes all the essential elements such as **heritage, recreational, religious, and commercial bustling spots** is quite a challenging task. The proposed circuit is a mixed trail that aims to cater to all aspects of a tourist's needs. The route starts with the **Nandankanan Zoological Park,** which would take some time to explore, and then proceeds to the next destination - the **Dhauli Shanti Stupa heritage site** located on the Puri Road. This Buddhist stupa is situated in eastern Odisha and has historical significance. The next stop is the **Lingaraj Temple**, a popular religious site where visitors seek blessings. After that, tourists can head to the **three zones of drain no. X** or the Nicco Park area,

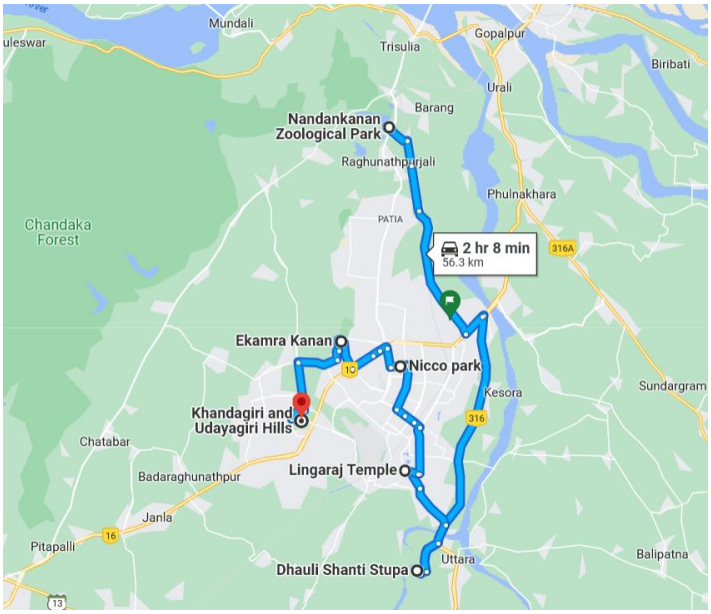


Figure 112. Proposed tourist circuit

which is located in a central landmark and has been recreated to enhance the city's image. The next destination is Ekamra Kanan, followed by the final stop, Khandagiri, and Udaygiri Hills.

The proposed circuit will take around 120 minutes or 2 hours for travel and additional time for visiting and experiencing the places. The mode of transport available are public transport such as local buses, IPT such as autorickshaw or cabs, private vehicles.

6.2.13 Sustainable Development Goals

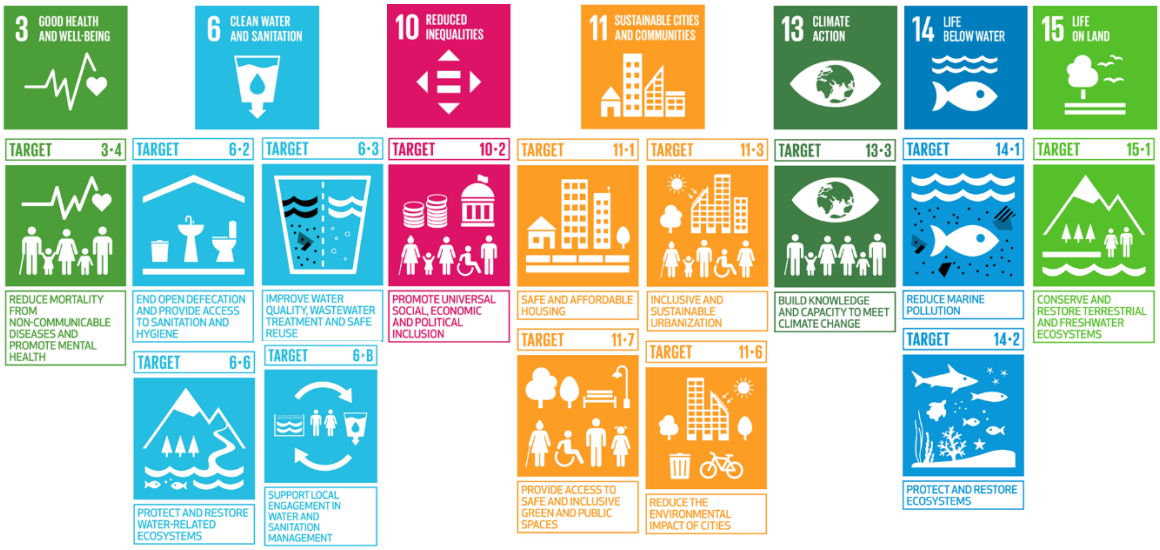


Figure 113. SDG goals achieved (The 17 Goals, 2016)

The following SDGs are achieved after interventions.

- **SDG 3** is achieved because the parks encourage walking, cycling, jogging and open gym encourages people to exercise and stay healthy. Enabling physical activities and creation of opportunities for recreation and relaxation ensures well-being.
- **SDG 6** is achieved as water quality is improved due to wetland treatment and flood is also prevented.
- **SDG 10** is due to environmental education and raising awareness about nature-based solutions. Also, social and economic inclusion is encouraged by providing vending areas, universal design.
- **SDG 11** aims to creating sustainable communities which is possible by providing adequate opportunities for the informal settlement as well as improving their quality of life. The parks along the voids provide safe and inclusive space for recreation.
- **SDG 13** refers to climate action which is achieved through water treatment and restoring upland and wetland ecosystem, educating communities about environment.
- **SDG 14** ensures conserving and sustainably using water bodies. This thesis achieves by protecting ecosystems under water, reducing pollution.
- **SDG 15** includes restoring and conserving habitats and biodiversity, managing green spaces, and ensuring environmental quality through effective waste management.

6.3 Policy Level Interventions

6.3.1 Waterbody management Guidelines

To ensure the long-term sustainability of water resources, protect aquatic ecosystems, and maintain water quality for human use, effective management of waterbodies is crucial. The following guidelines can be used for effective waterbody management:

1. Riparian Buffer Zone Policy for Managing natural drains- boundary mapping and delineation, protecting from encroachment, solid waste disposal, non-naturalized meandering, invasion by foreign species.
2. Regular water quality monitoring to track changes and accordingly guide management decisions.
3. Control point source and non-point source pollution by regulating and monitoring the effluent discharged into natural drain.
4. Zero tolerance policy for combined sewer overflow (CSO).
5. Zero tolerance policy for construction and demolition (C&D) waste disposal along the riparian buffer as well as in the natural drain.
6. Natural drains bank treatment specifications outlining the necessary slope, flood prevention dykes, materials for embankment.
7. Managing aquatic vegetation and controlling invasive species that disrupt the ecological balance of waterbody and harm the native species.
8. No construction zone within the width of 35 meter of the stream/ Drainage Channel
9. Land Acquisition Policy incentivizing private landowners to submit land parcels within the riparian zone, and reclaiming encroached land with resettlement
10. Building bye laws for buffer zones specifying height, FAR and setbacks for areas near the riparian buffer zones.

6.3.2 Placemaking Guidelines

Placemaking refers to the process of creating vibrant, liveable public spaces that reflect the local community's values and character. Placemaking can be used in urban voids and create successful public space. To achieve this, following are the guidelines:

1. **Identifying the community's needs**: Begin with understanding the needs and wants of the community. This includes recognizing where people gather or feel a lack of community, as well as the types of activities that suit the area.
2. **Involving the community**: Collaborate with the community throughout the placemaking process. This involves engaging with local residents, businesses, and community organizations to identify community requirements and come up with ideas for building lively public spaces.
3. **Creating a sense of place**: Build public areas that showcase the unique character and values of the community. This can entail designing public spaces that have cultural or historical significance and integrating local art and materials.

4. **Designing for accessibility**: Ensure that public spaces are accessible to people of all ages and abilities by providing amenities such as accessible seating, ramps, and sidewalks.
5. **Encouraging active mobility**: Encourage walking, biking, and public transportation use by creating public spaces that support these activities. This can involve providing bike lanes, pedestrian crossings, and public transportation stops that are safe and easy to use.
6. **Providing amenities**: Make public spaces more inviting by providing amenities such as seating, shade, water features, and public art installations.
7. **Triangulate**: Activate public spaces through programming and events that draw people to the area. This can include organizing music performances, food markets, and cultural festivals.
8. **Experimenting the Lighter, Quicker, Cheaper (LQC) approach**: Designing elements such as signages, seating area, vending area, public art, murals and painting of walkways are some examples of revitalising urban voids.

These guidelines are loosely based on placemaking by project for public spaces. By following these guidelines, placemaking can help create public spaces that are dynamic, comfortable, and accurately reflect the character and values of the local community. It can also encourage community engagement and social interaction.

6.3.3 Urban Design Guidelines

1. **Material specifications** for public spaces- locally available materials such as laterite stone and eco-friendly materials such as permeable pavement for pedestrian paths.
2. **Street furniture** such as benches, trash bins, signages should be provided.
3. **Benches**- Seating design to be uniform throughout the public spaces. It is advisable to have seats or benches located at the building or street edge of the sidewalk, and with provision for shade.
4. **Parking** – Bioswale is to be introduced to ensure increased groundwater percolation.

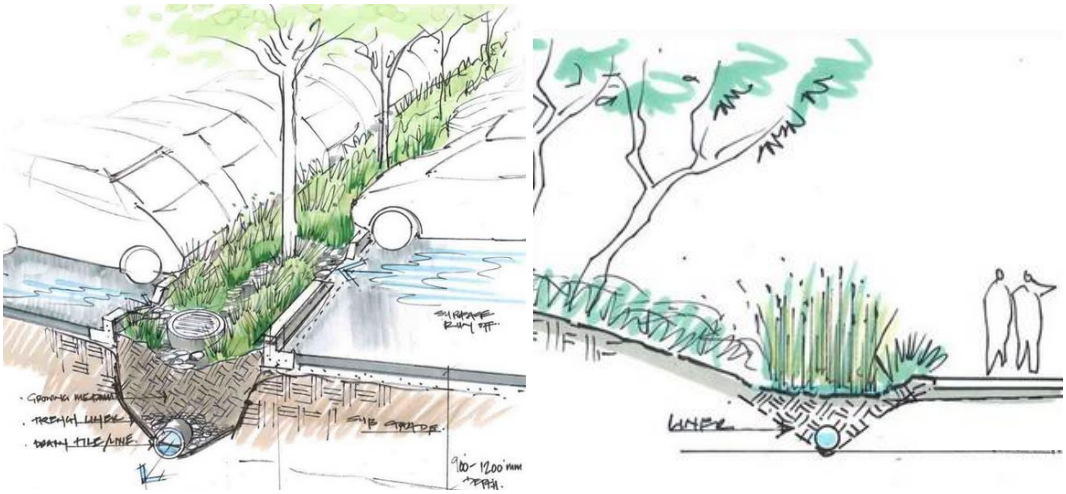
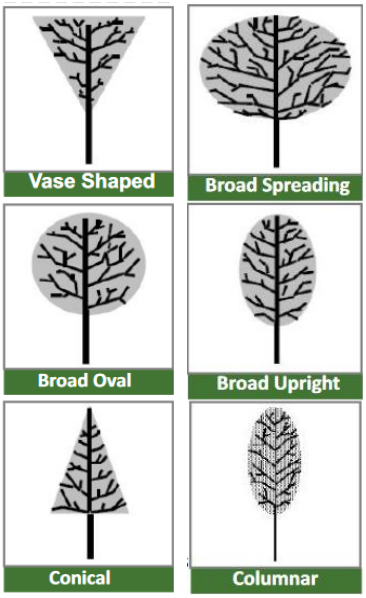


Figure 114. Bioswale in parking and in pedestrian walkways (MTD, 2023)

5. **Trash bins**- They should be designed to take up no more than 2 square meters of space and placed 200 meters apart. Separate bins for wet waste and recyclable waste should be provided.
6. **Signages**- They should have uniform design and pattern. Signages should highlight the heritage and culture of Bhubaneswar.
7. **Advertisements**- To avoid obstructing pedestrians, vehicles, and signage, advertisement boards should be positioned in a way that does not create physical or visual blockages. The advertisement boards should not harm the overall aesthetic or beauty of the city.
8. **Street lights**- It should be ensured that both the vehicle carriageway and pedestrian/ cycle tracks are sufficiently illuminated. Street lighting placement needs to be coordinated with other street features including trees, signage, and hoardings. Solar powered LED lights should be used for energy saving.
9. **Plantation**- Native plants and trees for landscaping to improve the biodiversity of the urban area. It is recommended to avoid planting certain types of trees such as Eucalyptus, Australian Acacia, Lantana, Lucena, and Mast Tree (False Ashoka). To protect the trees, it is suggested to provide tree grates and tree guards.



Type of Tree	Location on street	Size of Tree guard (M)
Columnar, Conical	Shoulder	0.6 X 0.6
Columnar, Conical, Vase shaped	MUZ	0.6 X 0.6
Columnar, Conical, Vase, broad upright	Parking/Shoulder/MUZ	0.6 X 0.6
Broad Upright, Broad Oval	Parking/Shoulder/MUZ	0.75 X 0.75
Broad Upright, Broad Oval, Broad spreading	Multi-Utility Zone/Parking / Shoulder	0.75 X 0.75, 1x1,1.5x1.5,2x2

Figure 115. Schematic representation of tree typology (Inamdar, Deshpande, & Mahajan, 2016)

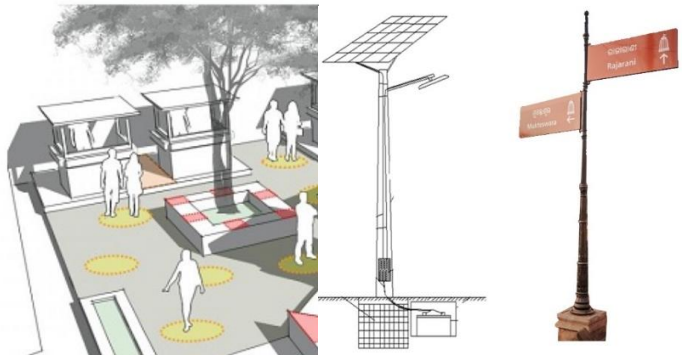


Figure 116. a) vending zone b) street light c) typical signages.

6.4 Summary of Proposals

Table 32. Summary of Proposals

Measures	Phase	Structural/ Non structural	Green/ Grey	Co- benefits
Scientific Wetland with Active Biodigester & Floating Wetlands	Phase 1	Structural	Green & Grey	• Natural value • Biodiversity
Floodplain widening/Restoration	Phase 1	Structural	Green	• Natural value • Aesthetic value • Decreased bed degradation
Channel deepening and Dredging	Phase 1	Structural	Grey	• Potential flexibility • Increased conveyance capacity
Summer and winter dikes	Phase 1	Structural	Grey	• Fertile sediment deposition
Retention ponds / lake	Phase 2	Structural	Depending on execution	• Natural value • Recreational value • Decreases urban heat effect • Water storage
Biodiversity Park	Phase 1	Non structural	Green	• Natural value • Recreational value • Economic value
Birdwatching tower	Phase 2	Structural	Green	• Educational value • Recreational value • Economic value
Solid waste management	Phase 1	Non structural	Green	• Natural value • Recreational value
Land acquisition within 35m riparian zone	Phase 2	Non structural	Green	• Natural value • Aesthetic value • Decreased bed degradation
Relocation of Communities	Phase 2	Non structural – Policy level	Grey	• Natural value • Recreational value
Interpretation Center	Phase 2	Structural	Grey	• Public awareness • Economic value • Socio-cultural value
Parking	Phase 2	Structural	Green	• Natural value
Food street (kiosks)	Phase 1	Structural	Grey	• Economic value
Craft Village	Phase 3	Structural	Green	• Recreational value • Economic value • Socio-cultural value
Community awareness, birdwatching	Phase 1	Non structural	Green	• Educational value • Socio-cultural value

7. Development, Management and Finance

Effective and careful planning must be complemented by proper execution for success. Factors such as **administrative structure, financial policies, political environment, citizen engagement**, and unforeseen circumstances all play a role in this process. The proposed project aims to enhance facilities, optimize the use of underutilized urban voids around the natural drains, develop vacant lands, and provide modern amenities.

The project requires a **collaborative effort between the public and private sectors** in order to overcome technical and financial difficulties. The public sector will oversee administration, legal measures, and management, while the private sector will execute the project with financial support.

7.1 Capacity Building Strategies

The Bhubaneswar Smart City Limited is a Special Purpose Vehicle (SPV) under the Smart City Mission programme. It will collaborate with technology vendors, builders and financers for the lake zone development along the drain no. X. In order to strengthen the organisation structure of BSCL, there will be a high-level steering committee. There will be a clear division of work between the various departments that is engineering and administration, planning and design, finance and others. The outsourcing of technical skills must be clearly defined.

7.2 Mobilisation of Fiscal Resources

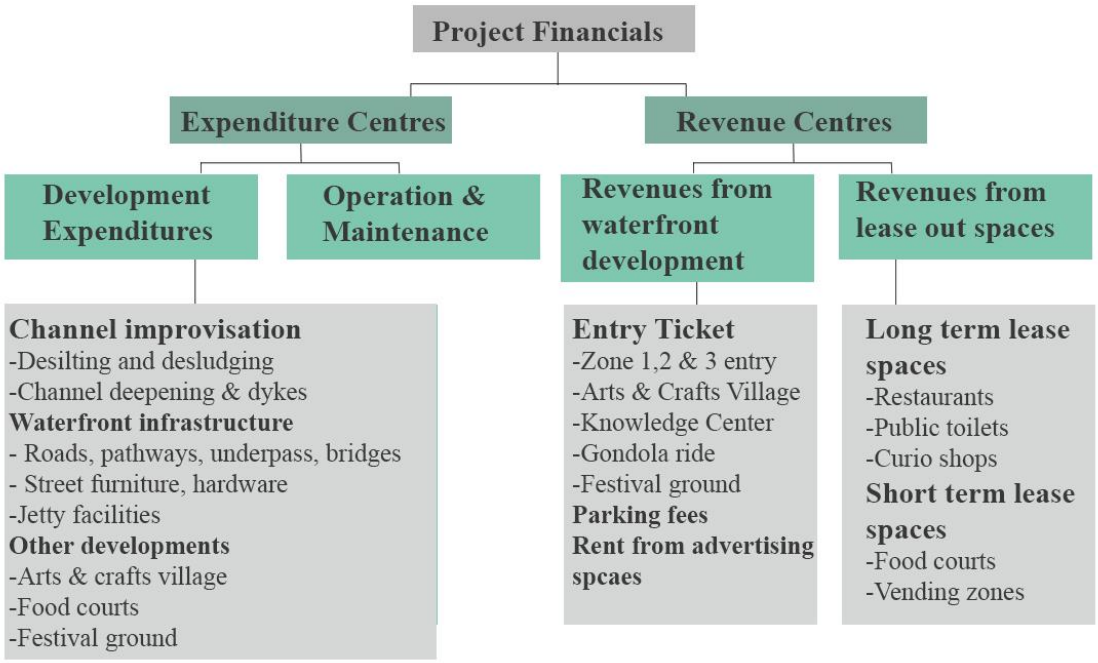


Figure 117. Project financials

For deployment of financial resources, the two major heads- **Expenditure & Revenue heads** details are worked out as follows for the drain no. X urban void development. The expenditure head includes both development as well as operation and maintenance of the proposed intervention. Revenue head explores the various sources of revenue generation from the development of urban voids as well as from the lease out spaces which add to the total income for the authorities.

Further the possible financial resources for implementation of each component of the project is detailed out as follows

Table 33. Component wise financing sources

Components	Financing source
Solid waste management	Bhubaneswar Municipal Corporation
Restoration of drain • Channel deepening • Flood control	**Central govt. schemes-** National Plan for Conservation of Aquatic Ecosystems (NPCA) Green Climate Fund by NABARD Loans from international agencies- • **Bilateral agencies & Multilateral agencies**
Waterfront Infrastructure devp. • Roads • Walkways/ cycle tracks • Street furniture and amenities	Bhubaneswar Smart City Limited Bhubaneswar Municipal Corporation Floating Municipal Bonds
Green areas • Botanical garden • Wetland	Public Private Partnership (PPP) Lease areas for a time frame
Public Amenities • Parking (off street) • Public Toilets	Public Private Partnership (PPP)- Build Operate Transfer Urban design guidelines governing type of construction and materials used.
Crafts village	Turnkey project- Design and Build
Temporary structures • Food courts • Vending zones	Short term lease (5-10 years) Urban design guidelines governing type of construction and materials used.

7.3 Phase wise project planning

The drain no. X waterfront development will be **executed in the following three phases of five year each**. These phases are formulated according to **the priority of development works, dependency, time and mobilisation of funds.**

7.3.1 Phase I (2023-28) Project Planning

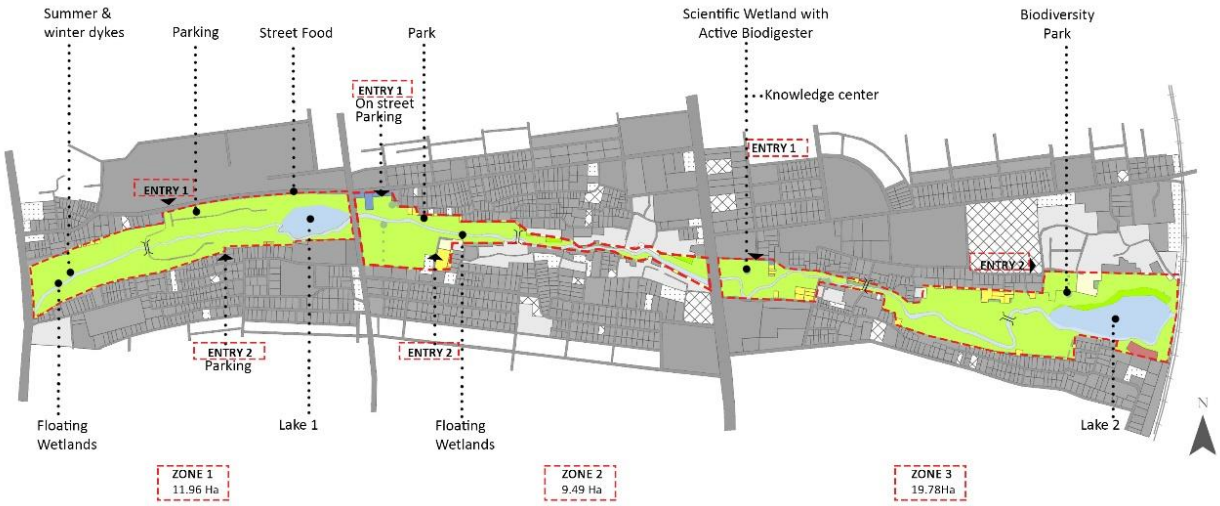


Figure 118. Proposed Phase I developments

First phase deals with addressing **major issues before taking up development activities.** These include improving the natural drain environs and its void or riparian zone by channel widening and deepening, desilting and desludging, introducing recreational areas, enhancement of existing facilities, etc. The SWAB treatment and floating wetlands are also implemented in this phase.

7.3.2 Phase II (2029-33) Project Planning

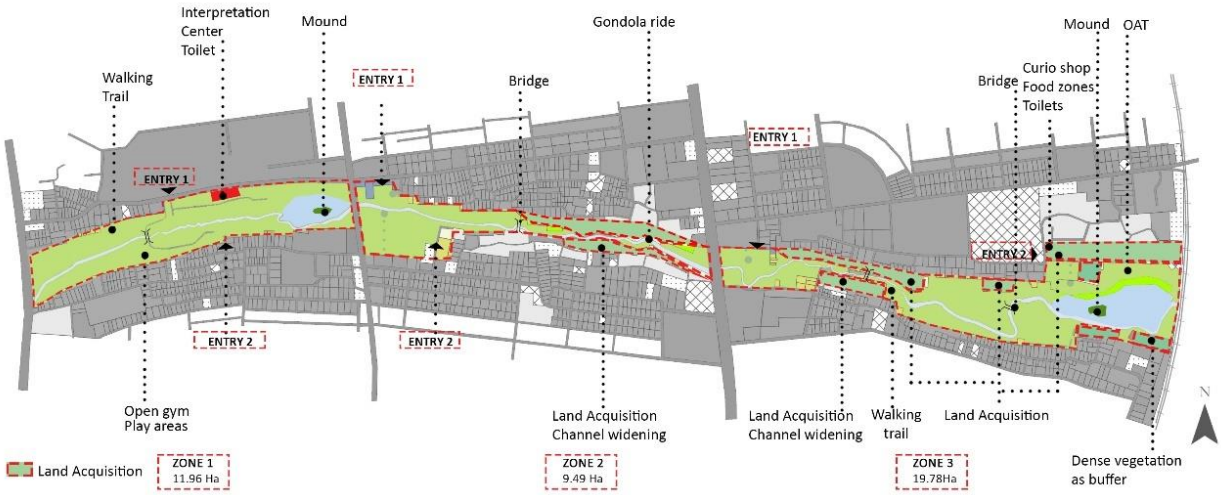


Figure 119. Proposed Phase II developments

Second phase involves **shoreline development works and improving accessibility** within the voids such as pedestrian trails, pedestrian bridges, recreation ghats, jetty for gondola ride as well as interpretation centre, curio shop. **Land acquisition** and resettlement, and **channel widening in those constricted areas** will also be carried out in this phase.

7.3.1 Phase II (2029-33) Project Planning

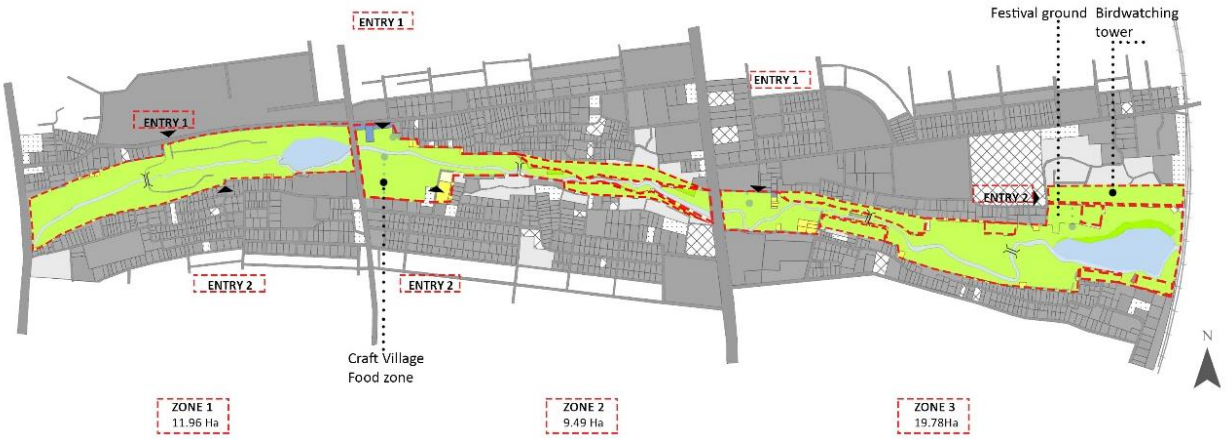


Figure 120. Proposed Phase III developments

Final phase will take up **proposed new developments / facilities on vacant land parcels** such as arts and crafts village, food plazas, festival ground, birdwatching tower and other lease out spaces for development.

8. Conclusion & Way Forward

Urban voids are the underutilised or neglected parts of the city. This study specifically aims at the urban voids around the natural drains which now carry the load of anthropogenic activities. The natural drains are highly polluted due to solid waste disposal and discharge of untreated sewage. River centric city planning can be the key to reintegrate the neglected drains of the city. This thesis aimed at identifying the issues faced by natural drains and their voids and formulating proposals to tackle them.

Nature based solutions help in restoring the natural drains in a sustainable manner. They help in treating wastewater, flood control and also creating awareness about the natural ecosystem present in our city. These solutions are sustainable alternatives to mechanical ones and are more cost effective. They can restore both the wetland and upland ecosystem around the drains. People play an important role in successfully rejuvenating the natural drains and their voids. Prevention begins at home and it is in the hands of people to become aware and keep the natural drains and their voids clean by not discharging untreated sewage or solid waste in the riparian zone.

Policy level interventions play a major role in creating river sensitive cities which have sustainably integrated the rivers and natural drains into their fabric. Defining implementing agencies and clear delegation of roles is vital to ensure successful restoration of drains and their riparian zones. Piecemeal measures or one size fits all measures would not help in rejuvenation of natural drains. Activating the edges by incorporating placemaking strategies along with nature-based solutions has been explored in this thesis.

Bibliography

(n.d.). Retrieved from bhubaneswar one: https://cms.bhubaneswarone.in/uploadDocuments/content/WARD_WISE_Household_POPULATION_3.pdf

Action plan for Priority -I Polluted River Stretch (Gangua Nalla) along Bhubaneswar. (2019). Retrieved from River Rejuvenation Committee : https://www.rrcodisha.org/action-plan-for-daya-and-gangua-along-bhubaneswar/

Batty, M. (2009). Cities as Complex Systems: Scaling, Interaction, Networks, Dynamics and Urban Morphologies. *Encyclopedia of Complexity and Systems Science*.

Batty, M. (2022). Integrating space syntax with spatial interaction. *Urban Informatics*.

Bhubaneswar Population 2022. (2022). Retrieved from World Population Review: https://worldpopulationreview.com/world-cities/bhubaneswar-population

Bhubaneswar Smart City Proposal. (2015). Bhubaneswar: Bhubaneswar Municiapl Corporation.

Calvino, I. (1978). *Invisible Cities.* New York: Harcourt Brace & Company.

Case Study: Cheonggyecheon; Seoul, Korea. (2022). Retrieved from Global Designing Cities Initiative: https://globaldesigningcities.org/publication/global-street-design-guide/streets/special-conditions/elevated-structure-removal/case-study-cheonggyecheon-seoul-korea/

Characteristics and Guidelines of Great Public Spaces. (2014). Retrieved from American Planning Association: https://ddd.uab.cat/pub/disturbis/disturbis_a2011n10/disturbis_a2011n10a4/characteristics.htm

Cheonggyecheon Stream Restoration Project. (2022, Sept). Retrieved from Landscape Performance Series: https://www.landscapeperformance.org/case-study-briefs/cheonggyecheon-stream-restoration#/lessons-learned

Climate in Bhubaneswar (India). (n.d.). Retrieved from Weather and Climate: https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-fahrenheit,Bhubaneswar,India

Cross, K., Tondera, K., Rizzo, A., & Andrews, L. (2021). *Nature-Based Solutions for Wastewater Treatment - A series of factsheets and case studies.* London: IWA Publishing.

Hashem, O. M., Wahba, S. M.-E., & Nasr-Eldin, T. I. (2022). Urban voids: identifying and optimizing urban voids potential as a revitalization source in enhancing developing countries' city income. *Journal of Engineering and Applied Science*.

Hassan, I., Chowdhury, S., & Prihartato, P. (2021). Wastewater Treatment Using ConstructedWetland: Current. *MDPI*.

Improving Mobility, Improving Resilience Shanghai Houtan Park: Landscape as a Living System. (2015). ADB Headquarters.

Inamdar, P., Deshpande, P., & Mahajan, A. (2016). Urban Street Design Guidelines, Pune. *ITDP*.

Joshi, A., & Mishra, S. P. (2017). Anthropocene effects on the river daya and the lagoon chilika by the effluents of bhubaneswar city india: a physico-chemical study. *International Journal of Advanced Research*.

Kasarabada, D. (2020). Urban Leftovers: Identifying and Harnessing their potential for the Agenda 2030 in Malmö. Malmo University.

Katkar, H. (2021). Infrastructural Urban Voids as an Instrument for Homogenous Urban Fabric Case of Kharghar. *Civil Engineering and Urban Planning: An International Journal (CiVEJ) Vol.8*.

Khalid, N. S. (2020). Exploring the Prescriptive and Descriptive Lost Space in the Setting of Urban Fabrics of Kuala Lumpur.

Know Bhubaneswar. (2018). Retrieved from Smart City Bhubaneswar: https://www.smartcitybhubaneswar.gov.in/know-bhubaneswar

Mishra, M., Mishra, K. K., & Subudhi, A. P. (2018). Urban Sprawl Mapping And Land Use Change Analysis Using Remote Sensing And Gis. *Geospatial World Forum.* Hyderabad.

Nipesh. (2012, May 7). *Urban Voids & Shared Spaces*. Retrieved from https://nipppo.wordpress.com/2012/05/07/urban-voids/

Omar, N. A., & Saeed, E. H. (2019). Urban Voids as Potential Resources for the City Development. *Journal of Engineering Sciences*, 585-600.

Patel, R. G., & Gandhi, G. H. (2022). Assessment of Urban void space – A case of the west zone, Surat city. *International Research Journal of Engineering and Technology (IRJET)*.

Pluta, A. (2017). Urban Void as a Potential of Tthe Contemporary City Development.

Rewal, R., Khanna, S., Mall, E. P., & Diptivilasa, D. (2015). *Rejuvenation of Najafgarh Waterway.* Delhi: Delhi Urban Art Commission.

Reynaud, A., Lanzanova, D., Liquete, C., & Grizzetti, B. (2017). Going green? Ex-post valuation of a multipurpose water infrastructure in Northern Italy. *Elsevier*.

Seoul Urban Renewal: Cheonggyecheon Stream Restoration. (2022). Retrieved from Urban Sustainability Exchange: https://use.metropolis.org/case-studies/seoul-urban-renewal-cheonggyecheon-stream-restoration#casestudydetail

Shanghai Houtan Park. (2022, September). Retrieved from Landscape performance series: https://www.landscapeperformance.org/case-study-briefs/shanghai-houtan-park

Slum Profile Data . (2008). *Exact Enumeration Block of Census Data*.

South Korea: Restoration of the Cheonggyecheon River in Downtown Seoul. (2022). Retrieved from Societal for Ecological Restoration: https://www.ser-rrc.org/project/south-korea-restoration-of-the-cheonggyecheon-river-in-downtown-seoul/

State Pollution Control Board, Bhubaneswar. (2022).

Swain, D., Roberts, G. J., Tripathy, S., Dash, J., Krishna, L., & Vinoj, V. (2017). Impact of Rapid Urbanization on the City of Bhubaneswar, India. *Proceedings of the National Academy of Sciences, India*.

The World Bank. (2020, Apr). Retrieved from https://www.worldbank.org/en/topic/urbandevelopment

Trancik, R. (1990). *Finding Lost Space.* New York: VAN NOSTRAND REINHOLD COMPANY.

Trancik, R. (1990). *Finding Lost Space- Theories of Urban Design.* New York: Van Nostrand Reinhold Company.

UN-Habitat- Training Module Public Space. (2018). Nairobi: UN-Habitat.

Urban Wetland/Water Bodies Management Guidelines - A Toolkit For Local Stakeholders. (2021).

Vakarelov , Y., & Fracasso, S. (2015). Urban Voids Unpacked. Aalborg University.

What is Placemaking? (2007). Retrieved from Project for Public Spaces: https://www.pps.org/article/what-is-placemaking

Yu, K. (2010). Shanghai 2010 Expo Houtan Park- Landscape as a Living System. *A Centre for Urban Greenery and Ecology Publication*.

Appendices

NEIGHBOURHOOD LEVEL HOUSEHOLD SURVEY | 2022

Conducted by Monali Biswal, Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur	

Demography						
Name Respondent						
Address						
No of family members	Male			Female		
Type of Ownership	Owned		Rented	Informal		Others
Monthly HH income from all sources	<10k	10k-25k	25k-50k	50k-1lakh	1lakh-1.5lakh	>1.5 lakh

Recreation survey				
Do you or your family members use any park?	Yes		No	
How often do you or your family members use the park?	Daily		Weekly	
	Monthly		Rarely	
Rank the preference of recreation from 1-10 (1=Most preferred, 10= Least Preferred)				
Parks	Restaurants			
Sports	Shopping			
Museums	Movies			
Rank the preference of activities for waterfront development along Nicco Park drain in near future. (1=Most preferred, 10= Least Preferred)				
Green walkways, jogging tracks, trails	Better public amenities			
Commercial areas, market, retail shops	Relaxing & sitting areas, Viewing decks			
Institutes, Cultural contents, Museums	Restaurants & Food Plazas			
Water sports, boating, sailing, Aquariums	Better parking facilities			
Parks, Picnic spots, Theme parks	Better transport facilities			
Rank the activities you would prefer in the park from 1-10 (1=Most preferred, 10= Least Preferred)				
Enjoy Nature	Attend Special Events			
Walking/ jogging	Spending time with Family & Friends			
Exercise	Socializing with people			
If the entry of the parks is through ticketing, would you support?	Yes		No	
How much are you willing to pay for the entry?	Rs.10	Rs.20	Rs.30	Rs.40

What would help to maintain parks better?			
Community Participation	Availability of funds	Local municipality help	Public/ User awareness
If the parks are linked through pedestrian corridors with trees, would you prefer walking/ cycling to these parks for recreation? (Yes/No)			
If parks are provided around the natural drain, what will be your major concern?			
Cleanliness	Smell/ Odor	Safety	Others (specify)

Travel Characteristics				
Purpose	**Destination Location**	**Frequency**	**Mode**	**Distance (mins)**
Work				
Recreation				
Shopping				

Walk = **W**, Cycle = **C**, Scooter/ Motorbike = **B**, Self-Own Car = **S**, Rickshaw = **R**, Auto=**A,** Tempo= **T**, Institutional Transport = **I**, Public Bus = **P**, Taxi = **X**, Other = **O, Frequency: D**=Daily, **A**=Alternate days, **E**=Weekends, **W**= Weekly, **M**= Monthly, **H**= Holiday

Physical Infrastructure		
What is the type of toilet used by the family member?	Private Toilet	Community Toilet
	Community Toilet	Others (Pls specify)
What is the type of wastewater disposal system present if you have private toilets?		
Sewerage network	Septic tank & Soak pits	
Stormwater Drain	Others (pls specify)	
What is the type of sewage disposal system present if you have private toilets?		
Sewerage network	Septic tank & Soak pits	
Stormwater Drain	Others (pls specify)	
What is the frequency of cleaning septic tanks if you answered septic tanks and soak pits in the previous question?		
1-2 years	2-5 years	>5 years

Place performance evaluation							
Rate the places from 1 to 7 according to the given characteristics based on existing condition. (Where 1= Very Poor, 2= Poor, 3= Somewhat Poor, 4=Neutral, 5=Somewhat Good, 6= Good, 7= Very Good)							
Comfort & Image	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Overall attractiveness							
Feeling of safety							
Cleanliness/ Maintenance							
Comfort of places to sit							
Green							
Access & linkages	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Visibility from a distance							
Ease in walking to the place							
Transit access							

Clarity of info/ signage							
Uses & Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mix of stores/services							
Frequency of events/activities							
Overall busy-ness of area							
Economic vitality							
Sociability	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Number of people in groups							
Evidence of volunteerism							
Sense of pride & ownership							
Presence of children & seniors							

Special Remarks/ Opinion (if any):

_____

Date: _____ **Thank you for your kind cooperation!**

COMMERCIAL SURVEY | 2022

Conducted by Monali Biswal,
Department of Architecture and Regional Planning,
Indian Institute of Technology Kharagpur

Area of the shop		Age of shop
Name and location of the shop		
Formal or informal		Formal =1, Informal=2
Which zone is it located in?		Residential =1, commercial =2, others=3
Separate unit or part of a residence		Separate =1, Within the residential Unit=2
What are the **types of goods** handled?		
Ownership pattern		Rent=1 owned=2 other=3
Total sale per day		
Capital source		own=1, bank=2, loan from others=3
Catering radius		0 to 1 km=1, 1 to 3 km=2, 3 to 5 km=3, 5 and above=4
Monthly Turnover		
Total customers per day		Total footfall per day
No. of employees		
Electricity and other charges		
Parking facility		On-street=1, off-street=2, others=3
Total Annual Investment		

Factors influencing new establishment along the waterfront. Rank from 1-5 (1=Strongly disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree)

Better Business	More Footfall
Prime Area	Connectivity
Brand Image	Better Infrastructure

Area Requirement

<500 sft.	1001-2000 sft.
500-1000 sft.	>2000 sft.

Facilities expected from authorities. Rank from 1-5 (1=No opinion, 2=Not at all important, 3=Somewhat important, 4=Important, 5=Very Important)

Better Business	More Footfall
Prime Area	Connectivity
Brand Image	Better Infrastructure

Rank the preference of activities for waterfront development along Nicco Park drain in near future. (1=Most preferred, 10= Least Preferred)

Green walkways, jogging tracks, trails	Better public amenities
Commercial areas, market, retail shops	Relaxing & sitting areas, Viewing decks
Institutes, Cultural contents, Museums	Restaurants & Food Plazas
Water sports, boating, sailing, Aquariums	Better parking facilities
Parks, Picnic spots, Theme parks	Better transport facilities

Special Remarks/ opinions (if any): _____

Date: _____ **Thank you for your kind cooperation!**

EXPERT OPINION SURVEY | 2022

Conducted by Monali Biswal,
Department of Architecture and Regional Planning,
Indian Institute of Technology Kharagpur

(The data and other valuable inputs will be used for academic purpose only)

Name Respondent	
Designation	
Name of the Organization	

Place performance evaluation							
Rate the places from 1 to 7 according to the given characteristics based on existing condition. (Where 1= Very Poor, 2= Poor, 3= Somewhat Poor, 4=Neutral, 5=Somewhat Good, 6= Good, 7= Very Good)							
Comfort & Image	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Overall attractiveness							
Feeling of safety							
Cleanliness/ Maintenance							
Comfort of places to sit							
Green							
Access & linkages	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Visibility from a distance							
Ease in walking to the place							
Transit access							
Clarity of info/ signage							
Uses & Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mix of stores/services							
Frequency of events/activities							
Overall busy-ness of area							
Economic vitality							
Sociability	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Number of people in groups							
Evidence of volunteerism							
Sense of pride & ownership							
Presence of children & seniors							

Score the following factors as per their contribution to increasing vulnerability of people during flood (Rank from 1-5 where 1=less contribution, 5= most contribution)

Infrastructure	**Natural Terrain**		**Locational**	
Presence of drain lines, pumping stations etc (flow length)	Spot elevation	Slope (hilly terrain)	Proximity to river/canal	Proximity to major traffic routes

Perception survey			
Rank the Importance/ Scope of Nicco Park stretch? From 1-5 (1=No opinion, 2=Not at all important, 3=Somewhat important, 4=Important, 5=Very Important)			
Identity		Environmental features	
Character		Leisure & recreational space	
Location centrality		Intensive economic growth	
Rank the Major issues faced by Nicco Park drain stretch? From 1-5 (1=No opinion, 2=Not at all important, 3=Somewhat important, 4=Important, 5=Very Important)			
Lack of operation & maintenance		Lack of Infrastructure	
Lack of funds		Lack of public participation	
Poor coordination between agencies		Lack of long-term plans & vision	
Which model do you suggest for better development & management of open spaces?			
BOOT (Build-own-operate- transfer)	BOO (Build-own-operate)	BOT (Build-operate-transfer)	BLT (Build-lease-transfer)
What do you suggest for better maintenance of open spaces?			
Community Participation	Privatisation	ULB Initiation	Public/ User awareness
If the parks are linked through pedestrian corridors with trees, would you prefer walking/ cycling to these parks for recreation? Yes / No			
If parks are provided around the natural drain, what will be your major concern?			
Cleanliness	Smell/ Odour	Safety	Others (specify)
Rank the preference of activities for waterfront development along Nicco Park drain in near future. (1=Most preferred, 10= Least Preferred)			
Green walkways, jogging tracks, trails		Better public amenities	
Commercial areas, market, retail shops		Relaxing & sitting areas, Viewing decks	
Institutes, Cultural contents, Museums		Restaurants & Food Plazas	
Water sports, boating, sailing, Aquariums		Better parking facilities	
Parks, Picnic spots, Theme parks		Better transport facilities	

Special Remarks/ Opinion (if any):

_____

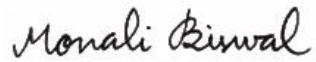
Date: _____ **Thank you for your kind cooperation!**

CERTIFICATE OF COMPLETION

This is to certify that this thesis project titled "**Unpacking the catalyzing potential of geographical urban voids around the natural drains in the fabric of Bhubaneswar**" was carried out by **Monali Biswal**, a student of **Masters in City Planning**, at **IIT Kharagpur**. The research for this project was undertaken under the guidance of the afore-mentioned institute and completed during the period of **3rd August 2021** to **23rd June 2023**.

This project was shortlisted under the *Sponsored Thesis Project Competition on "RE-IMAGINING URBAN RIVERS" (Season- 3)* hosted by the National Institute of Urban Affairs (NIUA) and the National Mission for Clean Ganga (NMCG).

This report has been submitted by the student as a final deliverable under the competition. All parts of this research can used by any of the undersigning parties.

1. **Student**
   - Name - Monali Biswal
   - Signature - 

2. **Institute**
   - Name - IIT Kharagpur
   - Department - Dept. of Architecture & Regional Planning
   - Authorized Representative - Prof. Haimanti Banerji
   - Signature - 

3. **Sponsors**
   - Name - National Institute of Urban Affairs
   - Authorized Representative - Hitesh Vaidya, Director
   - Signature -

   - Name - National Mission for Clean Ganga
   - Authorized Representative - G Asok Kumar, Director General
   - Signature -