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Integrated Riverside Development Along Adyar River, Chennai

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ABSTRACT

Integrated Riverside Development (IRD) is a planning approach that aims to achieve sustainable development of urban areas located along riverbanks. To implement this IRD with controlled regulations, the study is focused on developing a comprehensive riverside development and river zoning regulatory framework that integrates all five main elements, with particular emphasis on economic, ecological, and social factors, in order to reduce encroachment and pollution in the study area. The objectives of the study include analyzing the current land use, recreational parks, encroachments, pollution levels, sewage disposal patterns, and solid waste dumping zones in the study area, as well as studying the socio-economic and eco-environmental aspects of the area. Additionally, identifying and analyzing the major threats to the river and developing a river zoning regulatory framework using the land use matrix technique is also included in the study objectives. The study area (Adyar River) was chosen based on social, ecological, and economic factors, and data was collected through surveys and from government offices. Using the land use matrix method, proposals for riverside development were made, and the zones were classified into development-prohibited, development-restricted, and development-optimized zones. The zones were classified based on the calculated values of Eco sensitivity for each of the three zones. Proposals were then given based on these classified zones, and the levels of development potential were determined. The proposed zoning regulatory framework is expected to have a significant impact in reducing further encroachments and improving connectivity between the city and the river. By considering socio-economic, ecological, and environmental aspects, the study recommends appropriate zoning regulations for riverfront developments that promote sustainable growth.

INTRODUCTION

Rivers have long been a human settlement's lifeline. Humans originally plowed the very first lines along the rivers, creating the groundwork for the development of cities (Barve & Sen 2011). Rivers were important elements of the social fabric and have rapidly changed due to shifts in their usage, urbanization pressures, and the declining health of river systems. Then came the era of environmental protection and the rebirth of rivers through a much more comprehensive instrument: river rejuvenation and urban riverfront development to focus on all the physical, social, cultural, and heritage dimensions of the river that fills urban settlements once more. The challenge in recent years has been integrating waterways with urban areas (Barve & Sen 2011). Riverfront development is a way to integrate the river into the growth of the urban fabric that is environmentally favorable. Rivers are being rediscovered in cities all around the world with the idea of integrated riverside development (IRD), which encompasses physical, social, economic, ecological, and management aspects (Vriddhi 2017). Integrated riverside development (IRD) is a planning approach that focuses on the sustainable development of urban areas located along riverbanks (Gharge 2016). The aim of IRD is to improve the overall quality of life for residents, as well as to protect and enhance the natural environment of the river and its surroundings. Integrated riverside development (IRD) can be implemented with zoning regulations to ensure sustainable development and meet the needs of the local community. Zoning regulations can help create mixed-use zones, set height, and setback requirements, preserve green spaces, and promote sustainability. They play a critical role in the success of IRD projects by ensuring that the development is in line with the overall goals of the project.

It has been determined that according to the literature review and case study, there are safety concerns (Darshini & Lathia 2019), weak regulations for riverside construction, environmental problems like channelization, declining water quality, elimination of riparian vegetation, etc. and flooding problems (Bhavna & Vimwala 2015) These aforementioned problems will be addressed by integrating 3 factors of riverfront's economic, social, and ecological components (Xuejun Duan 2021). The research gap identified from the literature review and case studies was the lack of zoning restrictions for riverfront planning in both national and international contexts. This gap presents significant challenges in achieving sustainable riverfront development. Therefore, the research aims to address these difficulties by taking into account the parameters identified from the literature review and case studies.

The aim is to develop a comprehensive regulatory framework for riverside development and river zoning to reduce encroachment and pollution in the study area. To achieve this goal, several objectives were framed. Firstly, the current land use, proportion of recreational parks, encroachments, pollution levels, sewage disposal patterns, and solid waste dumping zones in the study area were analyzed to determine the river regulation zoning. Secondly, the socio-economic and eco-environmental aspects of the study area were studied. Thirdly, the major threats to the river were identified and analyzed. Finally, a river zoning regulatory framework was developed using the land use matrix technique. The zoning regulatory framework will have a significant impact on reducing further encroachments, and it will facilitate better connectivity between the city and the river. By considering socio-economic, ecological, and environmental aspects, the study can recommend appropriate zoning regulations for riverfront developments that promote sustainable growth. This will help to create a balance between the developmental needs of the city and the conservation of the river for future generations. The integrated development of riversides involves various factors such as social, economic, environmental, and infrastructural aspects. However, due to the time constraints and the specific aim of the study, the research is limited to analyzing the socio-economic and eco-environmental factors only.

MATERIALS AND METHODS

The site for this study was selected based on three main factors: social, ecological, and economic. In the secondary data collection stage, a reconnaissance survey was conducted, and a base map was prepared and identified the parameters for the socioeconomic and ecological factors. The primary

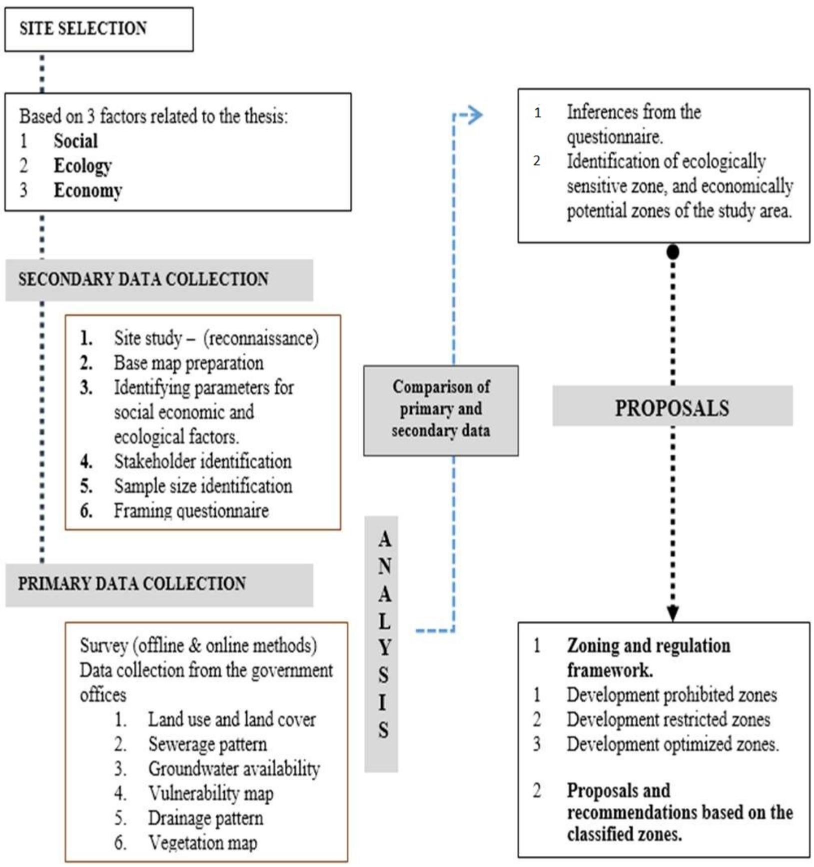

Fig. 1: Methodology flow chart.

data collection was conducted through surveys, both online and offline methods, and data was collected from government offices. Both primary and secondary data were then compared and analyzed to draw inferences. The proposals for riverfront development were made using the land use matrix method (Barve & Sen 2011), and the zones were classified into development-prohibited, development-restricted, and development-optimized zones (Xuejun Duan 2021). This zoning framework has the potential to reduce further encroachments along the river and to better connect the city and the river, thus contributing to the sustainable development of the area (Fig. 1).

Study Area

Chennai is a major city in southern India, located on the east coast of the country in the state of Tamil Nadu. The selected study area is the Adyar River, which is located in the city of Chennai, Tamil Nadu, India. Its latitude and longitude coordinates are approximately 13.0059° N, 80.2566° E. The Adyar River has great significance for the people of Chennai, as it is a major source of water for the city and also serves as a natural habitat for various aquatic species. The selected study area covers an area of 11.9 sq. km. It includes a 7.6 km stretch of the Adyar River, along with settlements situated within 500 m on either side of the river. The Adyar River is located in the southern part of Chennai, the capital city of the Indian state of Tamil Nadu. The river originates from the Chembarambakkam Lake in the west. It flows for approximately 42 km, and it is divided into two main stretches - the upstream stretch from Malaipattu to Guindy and the downstream stretch from Guindy to the estuary before emptying into the Bay of Bengal in the east. The soil type in the Adyar River basin is predominantly sandy and clayey. The climate of the Adyar River basin is tropical, with a hot and humid summer season and a mild winter season. The average annual rainfall in the Adyar River basin is approximately 1,300 mm. Adyar River has good connectivity to major roads and public transportation in Chennai.

As per the 2011 census, the study area has a total population of 3.5 lakhs. The study area is divided into wards for convenience to take survey and analysis. In each ward, 25 samples will have been taken, resulting in a total of 198 samples for the entire study area.

Analysis

Socio-economic analysis: The study area, including the Adyar and Kodambakkam zones, is characterized by various socio-economic factors, including occupation, education, income, and housing conditions. The Adyar zone has witnessed a high influx of Migrants due to the availability of employment opportunities and housing options. However, there is a disparity in the quality of housing between different areas, with the Thideer Nagar and Malligai Poonagar slums having a significant number of kutcha houses. The settlements along the riverbanks are primarily informal, with open defecation being common in the Adyar and Kodambakkam areas. Solid waste management is also a significant issue, with only a small fraction of waste being collected from doorsteps and the common disposal areas not being regularly cleaned. These factors highlight the need for efforts to improve housing conditions, provide services equitably, and develop effective solid waste management systems in the study area.

Eco-environmental analysis: Environmental and ecological aspects are crucial in the zoning of rivers to ensure sustainable use and conservation of the river ecosystem. River zoning regulations can minimize human activities that can negatively impact the river and its surroundings, thereby protecting the long-term health and well-being of both the river and the communities that depend on it. In the surveyed Adyar and Kodambakkam zones, the majority of the water supply comes from community water schemes, water boards, and bore wells. In contrast, surface water is relied on by those living along the river banks, especially in slums. The water quality of the Adyar River is extremely poor in all three zones, with the Adyar zone being the most severely impacted. Poor water quality has significant health impacts, including the spread of illnesses among those living in the surrounding areas. The Adyar zone is also highly affected by waterlogging and flooding incidents during the monsoon season and cyclones, causing severe damage to property and infrastructure, disrupting transportation and communication, and potentially leading to loss of life.

Threats and Suggestions

The Adyar River in Chennai, India, is facing severe environmental and ecological issues due to human activities. The river is polluted with domestic waste and plastic, indicating improper waste disposal by people living along the riverbanks. Urbanization and encroachments have significantly reduced the river's width, leading to sediment displacement, habitat loss for aquatic species, and an increased risk of flooding. Communities living near the Adyar River are concerned about the negative impacts of solid waste disposal and sewage on the river's health. They are urging the government to implement stricter waste disposal laws and build more sewage treatment plants. The direct discharge of urban wastewater, irregular solid waste dumps, and conversion of agricultural lands into commercial or residential plots due to urbanization are all contributing factors to the declining quality of river water.

Land Use Matrix Method

The Land Use Matrix Method is a commonly used approach in urban planning and land management to determine the best possible use of land within a certain area. In the context of the Adyar River, this method has been used to classify different zones along the river into development-prohibited, development-restricted, and development-optimized zones based on factors such as ecological sensitivity and economic development potential.

The land use matrix method involved the identification of vacant lands within a 3 km radius on both sides of the study area. These vacant lands were then analyzed based on ecological and economic development potential factors (Gharge 2016). For ecologically sensitive zones, parameters such as proximity to nature reserve zones, flood plains, and CRZ zones were considered. On the other hand, the economic development potential zone was analyzed based on the waterway grade and transport conditions (Xuejun Duan 2021)

The assessment of ecological sensitivity represents the evaluation of the environmental vulnerabilities and ecological functions of nature reserve zones, flood plains, and coastal regulation zones. This assessment helps to ensure the preservation of the integrity, stability, and interconnectedness of these areas. Similarly, the economic development potential assessment represents the value of the riverside in terms of socio-economic development. This includes consideration of factors such as waterway grade and transport conditions to determine the suitability of the area for future development (Xuejun Duan 2021) (Fig. 2).

Assessment Method for Ecological Sensitivity in Land Use Matrix Method

Ecological sensitivity is assessed based on the proximity of the identified vacant lands to the selected parameters, such as nature reserve zones, flood plains, and CRZ zones. Compliance with national standards is also an essential consideration.

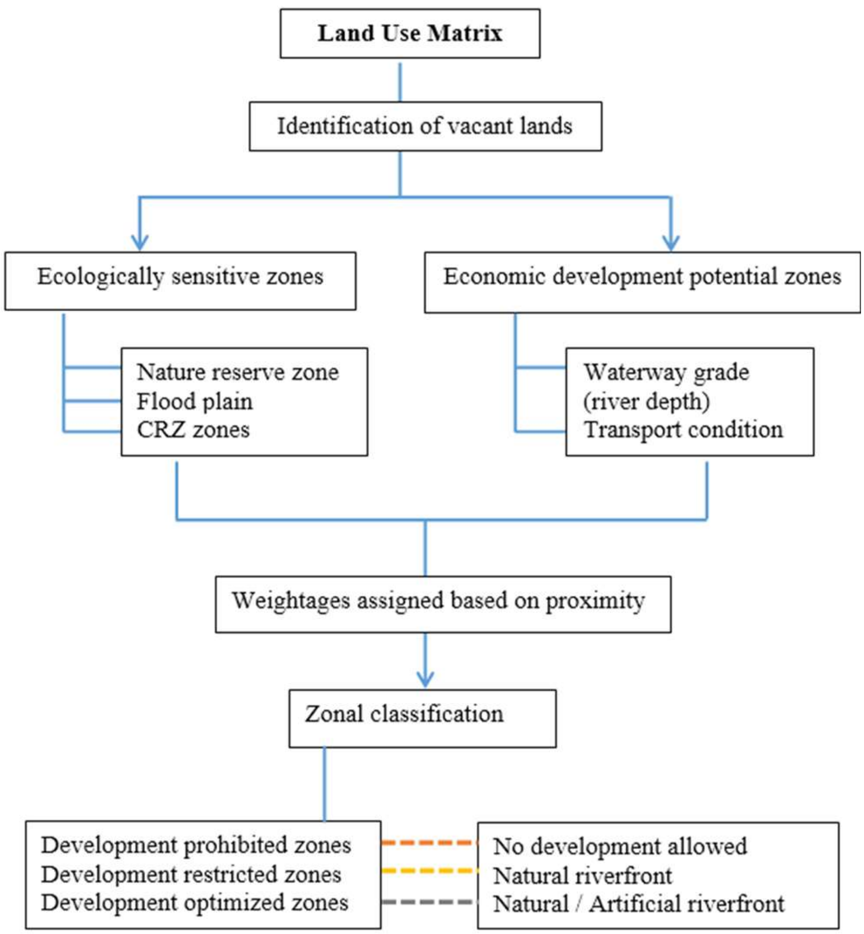

Fig. 2: Land use matrix methodology.

Table 1: Eco-sensitive zones assessment.

Proximity to nature reserve zones	proximity to floodplain zones	proximity to CRZ zones	Weightage
< 1km	< 500 m	< 100 m	1
1km to 3km	500 m to 1km	100 m to 500 m	2.5
>3 km	>1 km	>500m	5

The evaluation of vacant land in proximity to nature reserve zones, flood plains, and coastal regulation zones is critical in determining its potential for development. For nature reserve zones, a buffer of at least 1 km is recommended, with a weightage of 1 assigned to land within this distance, indicating low potential for development. A weightage of 2.5 is provided for distances between 1 km and 3 km, signifying minimal development potential. Land located beyond 3 km is assigned a weightage of 3, indicating higher potential for development. For flood plains, a minimum buffer zone of 500 m from the high flood plain is recommended. A weightage of 1 is assigned to land within this distance, with a weightage of 2.5 provided for distances between 500 m and 1 km and a weightage of 5 assigned for distances greater than 1 km. Regarding the proximity of vacant land to the CRZ zone, a buffer of 100 meters is recommended. A weightage of 1 is assigned for distances less than 100 meters, a weightage of 2.5 for distances between 100 meters to 500 meters, and a weightage of 5 for land located beyond 500 meters. These weights indicate the development potential of the land, with a higher weightage indicating a greater potential for development. (Table 1)

Assessment Method for Development Potentials

Development potentials of the study area are assessed with the two parameters: depth of the river and transport condition. To identify the river depth, the study area is divided into three zones, from TVK Bridge to Kotturpuram Bridge (zone1), Kotturpuram Bridge to Maraimalai Adigalar Bridge (zone 2), and Maraimalai Adigalar Bridge to Ekatuthangal Bridge(zone 3). The river depth was calculated and given a weightage as shown in the table. Proposals for public squares and recreational parks will be given in areas with lower river depth, while proposals for boating activities will be made in areas with higher river depth (Fig. 3).

Furthermore, to assess the transportation conditions and accessibility of the study area, the entire river stretch, which is 7.9 km in length, was divided into sections of 500 m radius, placed adjacently along the river. The weightage for each section was determined based on the availability of public transport modes within the 500 m radius. The weightage system evaluates the availability of public transport modes based on proximity, with a score of 5 if all three modes are available, 2.5 for two modes, and 1 for one mode (Table 2).

Table 2: Economic development potential assessment.

Distance interval	Waterway grade (depth of the river)	Transport conditions and accessibility based on the availability of public transport. (bus stops/ stands, railway stations, metro stations) if,	Weightage
500 m	< 5m	Single mode	1
	5m - 10 m	double mode	2.5
	> 10 m	Three modes	5

Zonal Classification

The zonal classification is done with the output values of the land use matrix as given in Fig. 2. It is further classified

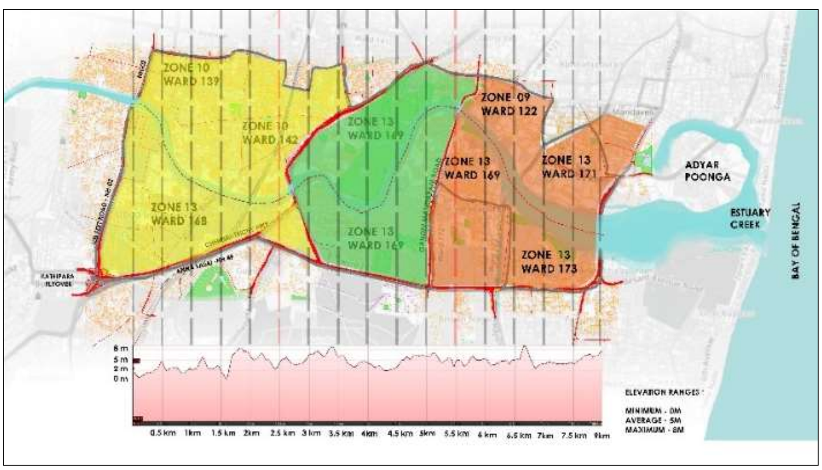

Fig. 3: Waterway grade mapping.

into 3 zones: development prohibited, development restricted zone, and development optimized zones calculated from the eco-sensitivity. With the output of development potential zone values, the proposals will be given (Table 3).

RESULTS AND DISCUSSION

The zones were classified based on the calculated values of Eco sensitivity for each of the three zones (Table 4). This classification revealed that Zone 1 should be designated as a development-prohibited zone, while Zone 2 is development-optimized, and Zone 3 is development-restricted. Proposals were then given based on these classified zones, and the levels of development potential were determined with the waterway grade and transport condition parameters (Tables 5 & 6). It was found that Zone 1 has a lower potential for development, while Zone 2 has medium potential, and Zone 3 has a higher potential for future development (Table 7).

Table 3: Zonal classification.

Zone	Eco Sensitivity Level	Development Potential Level	Proposal
Development prohibited zones	High	Any level	No development allowed
Development restricted zones	Low/ Medium	High/ Medium	Natural riverfront
Development optimized zones	Low	High	Artificial riverfront
	Low	Low/ Medium	Natural riverfront

Based on the zoning plan (Table 3*)*, it was determined that no developments should be allowed in Zone 1, which is designated as a development-prohibited zone. For Zones 2 and 3, the recommendation is to preserve the natural riverfront, considering both the ecological sensitivity and development potential of the areas (Table 8).

Table 4: Eco-sensitive zone matrix results.

ECOLOGICALLY SENSITIVE ZONES (Based on proximity)									
Zone	Vacant Land	Nature reserve zones -Guindy National Park (Kms)	Weightage	Floodplain (m)	weightage	CRZ zones (m)	weightage	Added weightage	Eco sensitivity level
z1	v1	1.69	2.5	177	1	200	2.5	6	23
z1	v2	1.52	2.5	100	1	19	1	4.5	
z1	v3	1.5	2.5	160	1	70	1	4.5	
z1	v15	2.08	2.5	200	1	160	2.5	6	
z1	v17	2.45	2.5	920	2.5	400	2.5	7.5	
z1	v11	5	5	3235	5	2400	5	15	
z1	v26	0.15	1	1990	5	1200	5	11	
z1	v27	0.15	1	2000	5	1200	5	11	
z1	v28	4.9	3	3150	5	2900	5	13	
z1	v29	4.63	3	2300	5	2300	5	13	
z2	v12	2.45	2.5	320	1	320	2.5	6	6.4
z2	v21	0.75	1	450	1	1645	5	7	
z2	v22	1.45	2.5	10	1	200	2.5	6	
z3	v4	2.16	2.5	563	2.5	3430	5	10	9.75
z3	v5	1.89	2.5	209	1	3300	5	8.5	
z3	v6	1.66	2.5	1006	5	3890	5	12.5	
z3	v7	1.75	2.5	1540	5	3984	5	12.5	
z3	v8	1	2.5	923	2.5	3460	5	10	
z3	v9	1.45	2.5	40	1	2752	5	8.5	
z3	v10	0.9	1	40	1	2442	5	7	
z3	v13	3	2.5	115	1	3160	5	8.5	
z3	v14	1.78	2.5	240	1	3085	5	8.5	
z3	v18	2.21	2.5	15	1	2787	5	8.5	
z3	v19	1.5	2.5	20	1	2665	5	8.5	
z3	v20	1.9	2.5	10	1	2690	5	8.5	
z3	v16	0.3	1	609	2.5	1912	5	8.5	
z3	v23	1.17	2.5	3057	5	4600	5	12.5	
z3	v24	1.13	2.5	2350	5	4036	5	12.5	
z3	v25	0.8	1	2516	5	4090	5	11	

Table 5: Economic development - Waterway grade results.

ECONOMIC DEVELOPMENT POTENTIAL - WATERWAY GRADE				
Zone	Distance interval	River depth points	Average for weightage values	River depth average
zone 1	0 - 0.5 km	2m + 2m + 5m	8	6.5
	0.5 km - 1 km	2m + 2m + 2m	3	
	1 km - 1.5 km	5m + 2m + 2m	7	
	1.5 km -2 km	2m + 5m + 8m	8.5	
	2 km -2.5 km	5m + 5m + 2m	6	
zone 2	2.5 km - 3 km	5m + 5m + 5m	7.5	6.9
	3 km - 3.5 km	6m + 6m + 8m	10	
	3.5 km -4 km	5m + 2m + 5m	6.5	
	4 km - 4.5 km	2m + 2m + 2m	3	
	4.5 km - 5 km	5m + 5m + 5m	7.5	
zone 3	5 km - 5.5 km	5m + 5m + 6m	7.5	7.7
	5.5 km - 6 km	5m + 5m + 5m	7.5	
	6 km - 6.5 km	5m + 4m + 5m	6	
	6.5 km - 7 km	5m + 8m + 5m	10	
	7 km - 7.5 km	4m + 4m + 4m	7.5	
	7.5 km - 8 km	5m + 6m + 6m	7.5	

Table 6: Economic development - transport accessibility condition.

ECONOMIC DEVELOPMENT POTENTIAL - TRANSPORT AND ACCESSIBILITY CONDITION					
Distance Interval (500 m Radius (r) from the River)	Bus Station	Railway Station	Metro Station	Weightage (Based on the availability of No. of Modes)	Development Potential Level
r0	1	0	0	1	1.5
r1	1	2	0	2.5	
r2	3	0	0	1	
r3	1	0	0	1	1.75
r4	3	0	1	2.5	
r5	2	0	0	1	1
r6	3	0	0	1	

Table 7: Development potential level.

ECONOMIC DEVELOPMENT POTENTIAL			
Zone	Waterway grade average	Transport and accessibility conditions average	Development potential level
zone 1	6.5	1.5	8
zone 2	6.9	1.75	8.65
zone 3	7.7	1	8.7

Table 8: Zoning classification and proposals.

Zone	Eco sensitivity level	Weightage	Zones classified based on Eco eco-sensitivity	Development potential level	Weightage	Proposal
Development prohibited zones	High	23	ZONE 1	Any level	8	No development allowed
Development restricted zones	Low/ Medium	9.75	ZONE 3	High/ Medium	8.7	Natural riverfront
Development optimized zones	Low	6.4	ZONE 2	High	Nil	Artificial riverfront
	Low			Low/ Medium	8.65	Natural riverfront

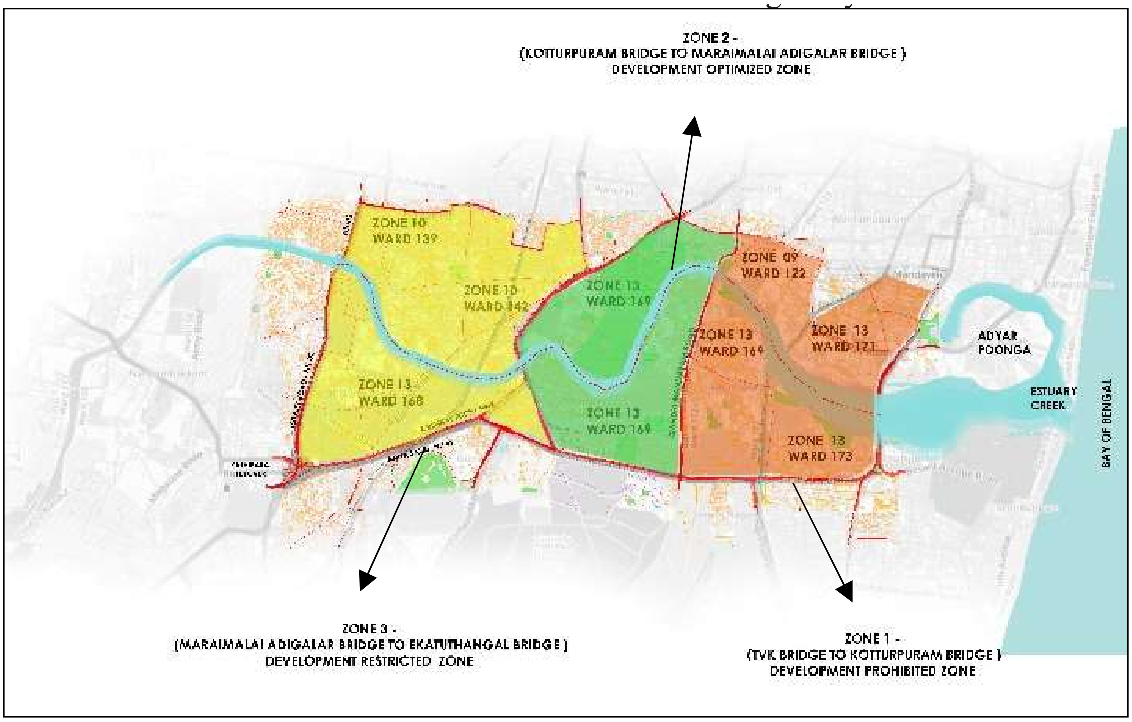

Fig. 4: Zone classification.

The classified zones and the proposal have been mapped and are displayed in Fig. 4. The development prohibited zone is depicted in orange, the development optimized zone is shown in green, and the development restricted zone is indicated in yellow. This approach aims to protect the environment while also promoting development in suitable locations.

CONCLUSION

The zones were classified based on the calculated values of Eco sensitivity for each of the three zones. The output value of Eco sensitivity shows that Zone 1 (TVK Bridge to Kotturpuram Bridge) has a higher level of Eco sensitivity. In contrast, Zone 2 (Kotturpuram Bridge to Maraimalai Adigalar Bridge) has a lower Eco-sensitivity value. Zone 3 (Maraimalai angular Bridge to Ekatuthangal Bridge) has a medium Eco sensitivity level with values of 23, 9.75, and 6.4, respectively. Based on the Eco sensitivity level, Zone 1 is classified as a development-prohibited zone, Zone 2 comes under development-optimized zones, and Zone 3 comes under development-restricted zones.

Further, with the output values of development potential, proposals were given. The results of the development potential show that Zone 1 has a low potential with a value of 8, Zone 2 has a low potential with a value of 8.65, and Zone 3 has a medium potential level with a value of 8.7. Thus, the zonal classification suggests that no further developments should be allowed in Zone 1, and in Zones 2 and 3, developments should be based on the natural riverfronts.

In prohibited zones (zone 1), Hospitals, nursing homes, and housing likely to have occupants who may not be sufficiently mobile to avoid injury or death during a flood, Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for flood response activities before, during, and after the flood, STP /WTP/Power plant and stations: bus depot were not allowed to construct. In development-optimized zones (zone 2), developments like Open-air theatres, indoor recreational uses, dwellings, waterfront tourism development projects, Co- cooperative markets, public toilets, libraries, and more than G+1 buildings were allowed to be constructed in this zone. In the restricted zone (zone 3), Parks /gardens/ playgrounds, sports facilities, Burial crematoria, and ground and only up to G +1 buildings only allowed to be constructed in this zone.

The recommendations and proposals were based on the classified zones. Several recommendations can be implemented to address the challenges faced by the Adyar River. These include increasing the capacity of the existing sewerage system and constructing new Sewage Treatment Plants (STPs) to ensure proper treatment of sewage, relocating slum areas that are prone to flood danger to safer areas, enforcing Development Control Regulations (DCR) for any new development along the riverfront, implementing proper regulations for solid waste management, and undertaking regular cleaning and maintenance of the river by a separate river maintenance team. These recommendations can help maintain the water quality of the river, reduce pollution, prevent further Encroachments, and improve the overall quality of life of the residents.

By implementing the above recommendations, the river's ecological and social values can be restored. The findings of this study will be useful for policymakers and urban planners in formulating and implementing effective zoning regulations for the future growth of riverside areas. Integrated development of riversides involves a range of factors, including social, economic, environmental, infrastructural, physical, and management aspects. However, due to time constraints and the study's specific aim, the research analyzed only the socio-economic and eco-environmental factors. By including both physical and management parameters, the project can achieve a more comprehensive and holistic approach towards riverside development, leading to better outcomes in terms of economic, environmental, and social benefits.

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