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Original Article

Urban Resilience in India: A Context Specific Definition and Parameter Framework for Strategic Planning in Kochi

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Abstract *- Resilient buildings are becoming increasingly important in sustainable urban planning due to climate change and human activities. Urban resilience has emerged as a critical paradigm in contemporary urban planning. This research examines the concept of resilience in relation to Kochi, a city in Kerala, India. Kochi faces escalating risk due to climate change and rapid urbanization. A mixed-methods approach has shown that resilience encompasses several dimensions, including physical, societal, and social aspects. The current studies include field surveys and setting up discussions with experts as a part of the process. The research examines a specific concept of resilience within the context of Kochi, concentrating on the capacity of the city's constructed and natural systems to endure, adapt, and reorganize in response to climate-induced changes while continuing to provide important services. Elevation, slope, drainage patterns, land use, and rainfall are some of the most critical elements that determine resilience. It relies on the current state of affairs and any problems in the region. The analytical framework focuses on physical and environmental factors, and institutional factors are discussed qualitatively for planning integration. The findings demonstrate a strong association between low-lying areas, drainage, and reoccuring flood exposure. The study will assist city planners, policymakers, and individuals who establish adaptive strategies related to climate change for the coastal communities.*

Keywords *- Resilience, Resilient city, Coastal inundation, Precipitation, Sea level rise.*

1. Introduction

As cities around the world deal with climate change, environmental damage, and economic problems, the idea of urban resilience has become an important part of planning at the regional and local levels. Urban resilience is the ability of a city to handle shocks, adjust to new situations, and change when current systems are no longer working [1, 2]. Resilience focuses on learning, adaptation, and systemic change over the long term, rather than just recovery, which is what more traditional methods of disaster risk reduction do [3]. The urbanisation of India underscores the importance of resilience-oriented planning. Over 35% of India's population currently resides in urban areas, with projections indicating that this number will exceed 600 million by 2050, thereby exerting significant pressure on land, infrastructure, water resources, and governance systems [4, 5]. Climate change is causing more floods, heat waves, shoreline erosion, and heavy rain in Indian cities. This is causing big economic losses and social unrest [6, 7]. Current forecasts indicate that without integrated resilience measures in India's urban planning frameworks, climate-related damages in the country's cities will increase significantly. Coastal cities are especially at risk in this national picture. Kochi is a major port city on India's southern coast that is dealing with problems related to the environment, weather, and urbanisation. Because it is low-lying, has reclaimed wetlands, and has a complicated network of backwaters, canals, and estuaries, Kochi is at risk of pluvial floods, tidal inundation, sea-level rise, and urban heat stress [9, 10]. Rising land surface temperatures cause energy use and public health problems. Studies show that a large part of Kochi's population lives in areas that are likely to flood [11, 12]. Recent studies on climate sensitivity [13, 14] show that about one-third of Kochi's urban population is very stressed by the heat. The city's ability to drain naturally has also been hurt by the growth of impervious surfaces. Also, tidal flooding events in the Vembanad backwater system have become more common and stronger, which could threaten homes, transportation infrastructure, and jobs for a long time. Given these findings, it is imperative to move away from generalised resilience indices formulated for Global North contexts, necessitating the development of resilience frameworks that consider regional geomorphology, socioeconomic disparities,

and ecological services. There is still a research gap between theoretical resilience frameworks and the practical frameworks that can be directly used in cities, even though national and international groups are more supportive of urban resilience as a policy goal [16]. While the global frameworks focus on integration of the current models, they predominantly emphasise overarching dimensions such as infrastructure resilience, governance efficacy, and social capital, lacking context-specific indicators that reflect localised hazard exposure, informal settlements, institutional fragmentation, and ecological interdependencies prevalent in Indian cities [17]. Strategic planning tools [18] show that when master plans, land-use zoning, and infrastructure expenditures are developed, difficulties with resilience are not taken into consideration. Recent studies have shown the significance of planning for resilience grounded in location and data. Researchers may accomplish this with the use of technologies like climatic predictions, geographical analysis, social risk maps, and joint governance [19, 20]. New initiatives in Kochi employ blue-green infrastructure, community-led adaptation, and nature-based solutions. These projects illustrate that even minor things can make a place better. For these initiatives to operate, there is a need to use current world data and different institutions working together [21]. The major goal of this research is to provide Kochi's strategic urban planning with a model and ideas for making cities more resilient that may be implemented in other coastal cities in India. The project seeks to reconcile the disparity between theoretical notions of resilience and practical planning instruments by integrating contemporary empirical data, planning literature, and resilience theory. The proposed framework can help planners and policymakers systematically evaluate risks, prioritise solutions, and incorporate resilience into long-term urban development plans [22].

2. Methodology

The objective of this research is to delineate resilience for the coastal city of Kochi and to establish criteria for evaluating resilience in this context. The resilience components were examined through both descriptive and analytical approaches. Various forms of research were conducted:

- An extensive literature review to understand the concept of resilience.
- Primary study of Kochi city with the help of a field visit to identify the major issues of Kochi.
- Discussion with experts, local residents, and government authorities for the identification of parameters.

To identify the major issues of Kochi city in terms of Physical dimension, a detailed questionnaire was prepared as a structured questionnaire on the basis of previous studies done. The questionnaire has the following set of questions, predominantly closed-ended and perception-based:
How frequently does your area experience flooding? What are the Major Disasters you faced in Kochi? What do you think is the reason behind the disaster? Have you observed any change in the Coastline post-tsunami? How effective is the current drainage system during heavy rains? Are there flood-safe shelters or elevated buildings in your locality? Have you or your neighbours faced health issues after flooding events? Are you aware of any early warning systems or flood alerts used in your area?

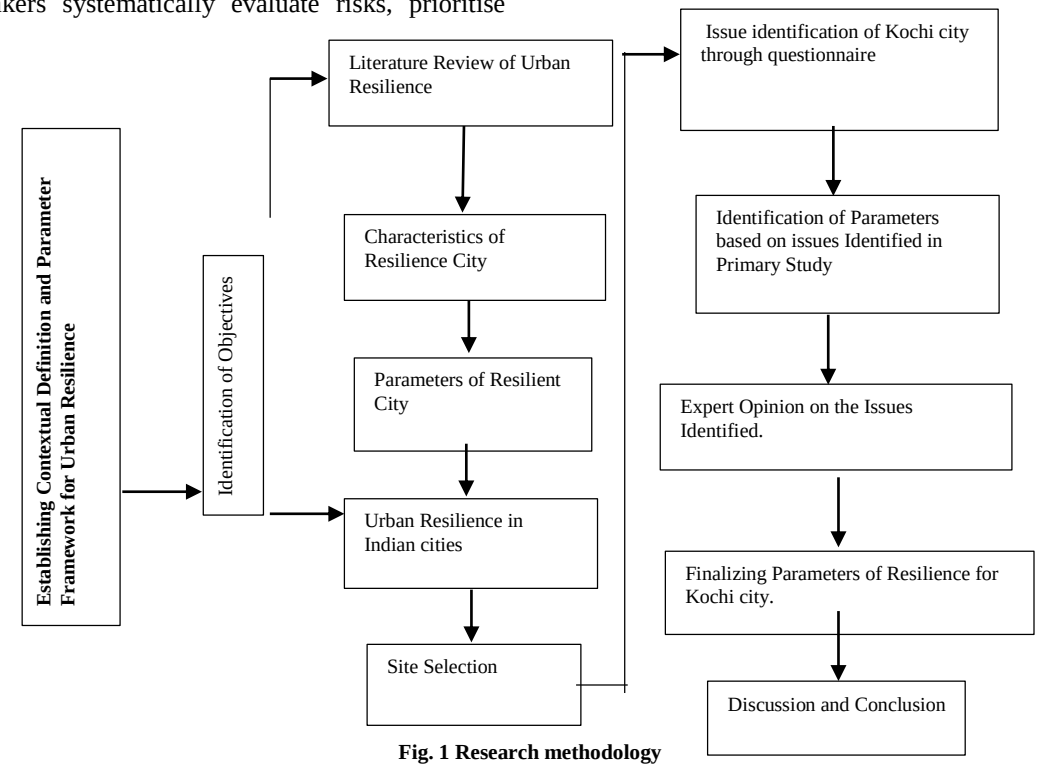


Fig. 1 Research methodology

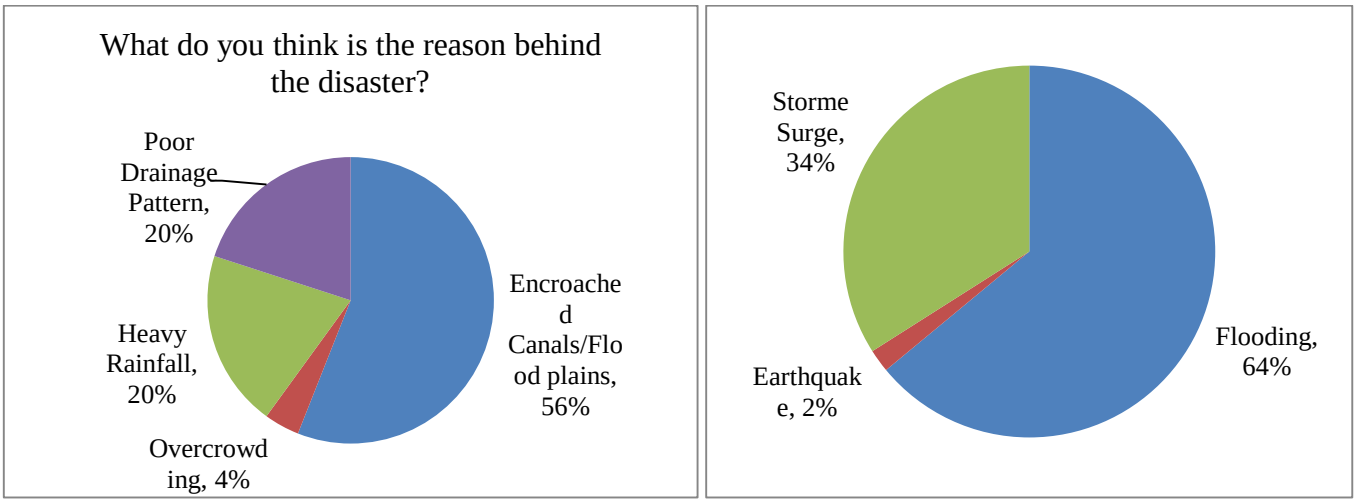


Fig. 2 Primary survey

Before the full poll, a sample pilot study by circulating the questionnaire was conducted. A structured questionnaire survey was administered to 100 residents across flood-prone zones to assess perceived vulnerability, drainage, and recurring hazard exposure. The sample consisted of one hundred people, consisting of male and female local residents from diverse locations (low-lying areas and high-elevation regions), with 40% aged between 18 and 30 years and 60% within the specified age range. This approach enabled capturing varied exposure levels to flood-related risks. Expert consultations were used to validate the identified parameters and improve reliability. A survey was made and sent to a wide range of community groups, working professionals, long-term residents, and college students to find out what the most important problems were. People could take the poll in person or online. According to 64% of those who answered, flooding, growing floodplains and canals, bad drainage systems, and coastal flooding are some of the biggest problems Kochi faces. The following issues were confirmed after long talks with government officials, subject experts, and specialists about the chosen resilience measures. Figure 1 presents the research methodology of the study. Figure 2 illustrates the results of the Primary survey.

2.1. Evolution and Conceptual Background of Resilience

"Resilience" has become an important idea in many fields in the last few years, such as ecology, urban planning, engineering, psychology, and disaster management. The Latin verb "resilire," which means "to recoil" or "to rebound," is the actual word that comes from. The phrase has been used in technical contexts since the 17th century, when Thomas Tredgold used it to talk about how materials can bounce back after being changed. Resilience was a big part of ecological research in the 1960s and 1970s. Holling characterised system resilience as "the capacity of a system to absorb disturbance and reorganise during change to maintain its fundamental function, structure, identity, and feedback mechanisms" [23]. This ecological perspective was predicated on the concept of stability via equilibrium, but also considering nonlinearity, limits, and adaptation. A psychological word for being able to cope with terrible things is "being able to deal with bad things." The process is more significant than the standard that is created. Luthar characterized resilience as "a process encompassing positive adaptation within the context of significant adversity" [24], underscoring the importance of environment and growth. In the end, the concept of being powerful included social processes. This indicates that a group or community can handle and get through challenges that come up as the environment, politics, and society change. Adger's idea of "social resilience" is that a social system can keep running even when things go wrong [25]. The concept of resilience has become crucial. These days, cities have to deal with a variety of natural/man-made hazards, some of which are connected to each other. These dangers include climate change, unstable markets, and failing infrastructure. People, communities, schools, businesses, and systems in a city must be able to exist, change, and flourish even when things are hard for a long time or when something happens suddenly [26]. The Rockefeller Foundation's 100 Resilient Cities initiative dubbed this "urban resilience." Meerow et al. characterised urban resilience as "the capacity of urban systems to sustain or swiftly restore essential functions while adapting to change and reforming systems that hinder future resilience" [1], emphasising adaptation and transformation. Scholars in the fields of climate adaptation and disaster risk reduction have acknowledged resilience. The United Nations Office for Disaster Risk Reduction (UNDRR) says that resilience is the ability of a group, organisation, or community to resist, adapt to, and quickly recover from disasters [27]. The Intergovernmental Panel on Climate Change defines resilience as the ability of social, economic, and environmental systems to handle disasters while maintaining and being able to adapt and change. In engineering, resilience means mostly how well a system can handle and bounce back

from bad situations. Bruneau et al. characterised engineering resilience as the capacity to diminish the likelihood of failure, alleviate its consequences, and expedite recovery after disturbances. Income, education, housing quality, and livelihoods are all socioeconomic factors that have a big effect on how well someone can adapt. Current studies on urban resilience show that this is especially true in coastal areas, which are more likely to be affected by climate-related risks.

2.2. Exploring the Characteristics of Resilient City

The major issues that coastal ecosystems face are storm surges, coastal erosion, saltwater intrusion, regular floods, and rising sea levels. Coastal cities are especially at risk because of these stressors. According to the Intergovernmental Panel on Climate Change [29], coastal communities should take proactive, integrated, and systemic steps to become more resilient to climate change instead of waiting for it to happen. It is because the coastal communities are mostly at higher risk. The proposed measures include adaptation strategies to make cities resilient to handle climate change and to relocate communities along the shore. The recommendations ought to be implemented by the government and municipal authorities along the shore. People from around the world have used and thought about "urban resilience" in diverse ways. The Rockefeller Foundation says that "urban resilience" is the capacity of a city's people, companies, and systems to survive and even develop when they are under a major stress or lose something quickly [26]. A system is strong if it can take shocks and not break down, and then it can go back to normal. One of the most essential aspects of strong systems is that they can handle a lot [30]. Resilience may also be seen as a process that never ends, that relates how cities react with and adapt when circumstances are hard [31-33]. Resilience is perpetually developing when examined from a process-based perspective. It does not remain constant. Authors refer to "resilience" as “how systems may evolve and grow throughout time” [34]. A city is strong if it can take shocks, work together during hard times, adapt to fit new situations, and go back to normal after problems. Resilience in international development implies that economies and cities can handle challenges and changes while maintaining important systems working and reducing the harm they do in the long run [35]. Being strong in cities requires being able to detect dangers coming, mitigate their worst consequences, get back to normal, keep people safe, and adapt, adjust, and move on when things go wrong.

Although existing resilience models, such as the Rockfekker city resilience framework and UNDRR indicators, provide comprehensive multi-sectoral metrics, they often lack spatial specificity for medium-sized coastal cities in developing countries. This limitation highlights the need for city-specific parameter identification grounded in empirical observation and geomorphological assessment, which this study attempts to address.

3. Parameters of Resilient City

The City Resilience Index (2016) suggests that a city can do three main things to make itself more resilient: First, focus on reducing the disasters from happening. Second, adapting to the situation. Third, work together and focus on the process. There should be two main parts to prevention: Power and backup. A strong system may be able to handle shocks without getting too damaged or breaking down because it has a well-designed and built design and physical asset management.

A "redundant" system is one that can handle problems, more demand, and unexpected needs well and cheaply. Response is a system that focuses on healing and getting results. Here are some of its features: One system that can change. 2. Smart. 3. Thought about. The main parts of Building Together/Process-oriented are: The main idea is to be open to all. 2. An all-encompassing approach.

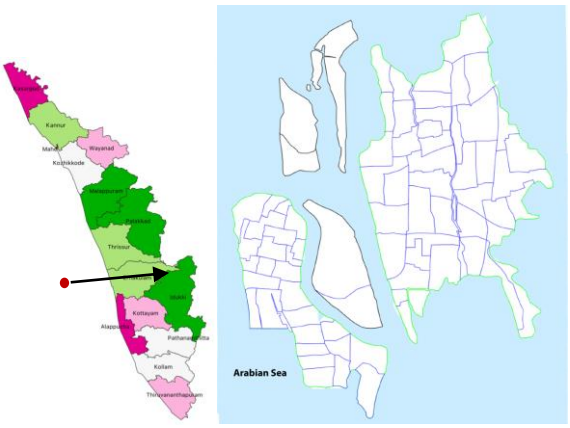
3.1. Relationship between Resilience and Vulnerability

Vulnerability is defined as susceptibility to harm and is characterized by exposure, sensitivity, and a lack of capacity to cope or recover from adverse events. In the context of climate change, sensitivity and resistance are negatively correlated. Being vulnerable makes it more likely that one will not be able to bounce back. The two ideas are closely related, so any study about vulnerability also leads to a study about resilience.

3.2. Site Selection of Coastal City

India has a total of 7,500 km of coastline, which includes about 5,500 km of mainland coastline and about 2,000 km of island coastline. There is a significant number of people living near the coast. Climate change and rising sea levels have bad effects on coastal towns and communities that put people's lives and jobs at risk. Kochi, a city on India's southwest coast, is growing quickly. It is between 9°45′ N and 10°20′ N, and 76°10′ E and 76°35′ E. The city of Ernakulam, which is in the district of Kerala, has a coastline that is 47 kilometres long. Kochi is mostly at or below mean sea level, and several estuaries fed by rivers that flow all year round run through the city. Because Kochi is near the equator and the sea, it has a tropical monsoon climate with moderate to high humidity and little change in temperature from season to season.

The average air temperature is between 20 and 35 degrees Celsius. Kochi Corporation is one of the biggest municipal corporations in the area. It covers about 94.88 square kilometres. The metropolitan area is almost 98 square kilometres in size and has a population of over 600,000. The backwaters in Kochi City take up about 23.31 square kilometres. Backwaters, canals, marshes, and ponds make up about 7.25% of the city, but this number has been going down quickly over time because the city is growing quickly, especially in the inner city. Figure 3 illustrates the site selection.



Map of Kerala. Map of Kochi City

Fig. 3 Site selection

3.3. Identification of Parameters based on the Issues Identified in the Primary Study

Coastal inundation, sea level rise, encroached canals, and construction in floodplains. Kochi is currently dealing with the following major issues:

- Coastal Inundation
- Sea Level Rise
- Coastal Flooding
- Precipitation
- Encroached canals and floodplain areas.

As per the primary study, coastal inundation, sea level rise, coastal precipitation that causes flooding, and encroached canals are the major issues of Kochi.

3.4. Coastal Inundation

Floods and coastal erosion get worse when the sea level rises, and storm surges happen. Coastal erosion often leads to flooding in low-lying coastal areas, which is made worse by storm surges, tides, and strong waves. When tropical cyclones or extratropical storms hit areas that are already weak, they cause deadly coastal flooding when the tides change and rivers overflow. At least 2.6 million people have died in the last 200 years because of flooding along the coast caused by storm surges. Climate change is making natural disasters happen more often and with more force, which further worsens the effects in low-lying areas. Because it is low and close to the coast, Kochi is prone to flooding. Tidal effects, heavy rain, and drainage systems that are weak or blocked make this vulnerability even worse. As cities grow, they take up more space in wetlands, which makes the city's natural flood-buffering ability weaker. Accurate flood damage assessments and inundation maps require an elevation map and a land use/land cover map. Digital elevation models and information about land use and cover must be combined to make flood risk assessment and coastal urban planning better. It makes it important to highlight the vulnerable zones. Figure 4 depicts coastal inundation in Kochi, and Figure 5 illustrates coastal flooding in Kochi.

Fig. 4 Coastal inundation in kochi

One of the major effects of climate change is Sea Level Rise (SLR). The two main reasons are global warming and the melting of glaciers. Sea levels are rising because of a number of things, such as the increase in ocean temperatures, which causes saltwater to expand, and the quick melting of ice on land, which adds more water to the oceans. The average yearly rise in sea level is about 3.3 mm, and this rate is getting faster as greenhouse gas emissions around the world keep going up. Increasing sea levels pose an immediate threat to Kochi and other coastal communities that are low-lying. Saltwater is constantly flowing into freshwater systems because of it. This puts additional stress on coastal buildings and species, and tidal storms occur more regularly. Rising sea levels pose a significant risk of coastal flooding and permanent land loss. The average beach slope and surface relief are two essential geomorphological features that may help in figuring out the level of hazard in an area. Low-lying areas or areas with gentle slopes are mostly at higher risk since even slight changes in sea level may create substantial floods upstream and damage near the beach.

3.5. Coastal Flooding

Kochi is a city in southwest India near the coast that is low to the earth. The coast is flooding more regularly and with greater intensity in this location, which is causing significant problems. Because it is adjacent to the Arabian Sea and has a unique layout with backwaters, canals, and bays that link to one another, storms, increasing sea levels, and high tides regularly flood the city.

Changes in the summer rain patterns, the loss of natural barriers like mangroves and marshes, and uncontrolled expansion have all made this weak area worse. Over the last 10 years, the frequency of rain along the coast and in the towns of Kochi has increased. Big storms have hurt a number of companies, homes, and governmental services, including hospitals and transportation. Heavy rain is usually to blame for these types of disasters. But increasing sea levels, reduced natural drainage, and congested or poorly maintained urban drainage systems have all made the devastation worse.

Fig. 5 Coastal flooding in kochi

3.6. Precipitation

Most of Kochi's rain falls between June and September, when the weather in the southwest comes through. This city gets over 3,000 mm of rain a year, which makes it one of the wettest cities in India. The quantity of rain that falls varies with the temperature. The river flows through towns and sometimes floods, which has a huge influence on the animals that live there. Over the last several years, this rain has transformed. It used to be lengthy and moderate, but now it is shorter and powerful. Kochi's water flow system becomes overly full when it rains a lot, which leads to flash floods and protracted periods of flooding. These effects are strongest in Panampilly Nagar, Kaloor, and MG Road areas. All of these places are bustling and significant. Researchers have determined that Kerala has been hit by heavy rain over the last several decades. Kochi is the seaside town that has expanded the most. In 2018, the city had over 1,400 mm of rain in 20 days. The major area got soaked. The ways we water today do not function well enough since they were built for cooler weather. Just a little rain may cause floods in key locations at work and at home. June and August are the worst months for rain in Kochi during the rainy season, since it rains considerably more. The city's natural sewage system is suffering due to Encroached ditches, lakes, streams, and floodplains that used to be utilized to transfer and store water. Because natural sewage systems have been damaged, flooding is more likely to arise. It traps more water, making it difficult for water to flow. The height and drainage systems of Kochi are two of the most important physical factors that affect how well the city can withstand disasters. Floods are less dangerous for places that lie in high elevation areas compared to the low-lying areas. Floods destroy buildings, roads, and other infrastructure by flooding canals and making it harder for water to drain, which makes the water sit longer and do more damage. Other coastal towns have become more vulnerable to floods, and the effects of disasters have gotten worse because of less drainage and canals that have gotten too close.

3.7. Urban Hydrology and the Function of Canals and Floodplains

The Thevara-Perandoor Canal, the Kalvathy Canal, the Edapally Canal, and other smaller canals were important parts of Kochi's canal system in the past. They connected the city's interior districts to the Arabian Sea and Vembanad Lake, and drained excess rainwater. During the monsoon season, the nearby floodplains and marshes acted as natural barriers, holding onto extra water and making the floods less severe. These interconnected natural systems were important for the city's hydro-ecological balance. On the other hand, rapid urbanisation has slowly moved into these waterways. Housing developments, transport infrastructure, and informal settlements have taken up large parts of canals, making them narrower, filling them in, or completely blocking them. Research shows that encroachment and siltation have greatly reduced the carrying capacity of Kochi's canal network. This has made it harder for rainwater to move through a large part of the system. The Kalvathy Canal in West Kochi is an example of this decline. The drainage path that used to be significant is now completely blocked by solid waste, illegal buildings, and thick plants, which makes the water flow much less. Floodplain reclamation for homes and businesses in Ponnurunni, Elamkulam, and Edapally has led to more surface runoff and less natural storage space. This means that these areas are likely to get flooded even when it does not rain much, which makes life in the city less pleasant for everyone. The areas located in low elevation zones with poor drainage patterns have low resilience in comparison to areas located in the higher elevation zones.

3.8. Connection to Floods in Urban Areas

Filling in natural drainage outlets and building on canals has made urban flooding in Kochi much worse. When these channels are blocked, floodwaters do not flow into nearby towns as easily. During the 2018 Kerala floods and other big floods that followed, the central Kochi suburbs, especially MG Road and Kadavanthra, were severely and continuously flooded because the drainage systems were blocked and too small. Floods are obviously dangerous, but mosquitoes also like stagnant water that comes from blocked canals. Because of this, diseases spread by vectors, like dengue and chikungunya, have become more common. The health effects are worse in low-income areas near canals and floodplains that are getting closer, where it is already hard to get basic sanitation, healthcare, and preventive measures. Figure 6 illustrates the canals of Kochi.

Fig. 6 Canals of Kochi

3.9. Finalization of Parameters of Resilience

The integration of primary survey data, spatial observations, and expert consultations suggests the strong associations between low-lying zones, enchroached canals, and recurrent flooding events.

The parameter framework was structured into three interrelated dimensions: (1) Physical resilience, which focuses on elevation, slope, drainage, etc, (2) Environmental resilience, which focuses on canal systems, wetlands, and mangroves, etc., and (3) Institutional aspects of resilience addressing regulatory enforcements and disaster management capacity. Table 1 presents the finalized parameters of resilience.

Table 1. Finalization of parameters of resilience

Resilience Dimensions/ Parameters	Relevance to Kochi City	Issues Addressed
Physical Dimensions	Resilience in Infrastructure	Inadequate and aging drainage infrastructure fails during intense precipitation. Poor urban planning leads to flooding in low-lying areas.
Natural Dimensions	Ecological and Environmental Resilience	Encroached canals and wetlands reduce natural flood absorption. Coastal inundation worsens due to erosion and degradation of mangroves. Sea Level Rise and Coastal Flooding.
Institutional Dimensions	Policy Framework and Disaster Management Capacity	Weak enforcement of the Coastal Regulation Zone(CRZ) and land use policies allows encroachments.

3.10. Urban Resilience in Indian Cities

India's coastal cities face interconnected resilience issues due to factors such as vulnerability, urbanisation, and others. will now look at some case studies from India that are related to the issue to help us understand it better.

- Mumbai: The Brihan Mumbai Storm Water Drain (BRIMSTOWAD) Project in Mumbai shows how to make city infrastructure, like stormwater drains and pumping stations, better so they can handle more rain. This project is a good example of a resilience approach that is based on technology. Research indicates that resilience principles have not been adequately incorporated into land-use planning, even though these interventions enhanced flood management capabilities in the short term. These methods have become less effective over time because of more land reclamation, the removal of natural drainage channels, and a lack of cooperation between infrastructure development and spatial planning. They are only a temporary fix for a bigger problem.
- Chennai has nature-based interventions.
  In 2015, Chennai saw several catastrophic storms; therefore, the city made a variety of steps to make its facilities better. Some of these initiatives included protecting floodplains and restoring wetlands. The city took these measures to make the environment healthier and to help it cope with storms better. One way to improve government control is to employ the Climate Disaster Resilience Index. Even if people do not always follow the rules and planners do not always think about how things work in the actual world, it is still hard to produce long-term resilient outcomes.
- Kolkata: Ecosystems for Urban Resilience. The East Kolkata Wetlands are a complete system that collects trash, stops the rain, and offers people work. They are one of the few examples in Kolkata of how ecosystems may assist a city in developing. These areas protect the city from storms and heavy rain, which makes it simpler for people to live there. It is hard for them to stay alive for a long period since the government is not performing efficiently, and more people are moving in. This puts their home and their chances of survival in danger. To keep the benefits of resilience, as we saw in Kolkata, we need strong protections for institutions and city planning that is connected. It does, however, show how useful ecosystem-based solutions may be.

The review of the above cities shows that if the resilience measures are solely focused on engineered solutions, they lack long-term advantages that need to be integrated with ecosystem conservation and institutional collaborations. Hence, this asserts that Kochi requires the integrated resilience framework combining physical planning, governance, and ecosystem restoration.

3.11. Policy Implications

The study's findings may significantly influence the construction and adaptation strategies of coastal municipalities in response to climate change. You may locate sites that are at great danger by looking at factors like how the land is utilized, how effectively it drains, and how high it is. These factors might assist with establishing plans for infrastructure, picking zones, and obeying growth control rules, particularly in regions of Kochi that are low-lying and regularly flood. The report suggests that one of the key purposes of policy should be to safeguard natural water systems, such as rivers, lakes, and floodplains. Cities need these to be ready for calamities. Cities, disaster management

organizations, and planning groups need to work together more to ensure the plan is put into action.

4. Discussions

The findings indicate that Kochi's urban resilience is influenced more by its geographical position and hydrological circumstances than by particular construction initiatives. The low terrain and most of the rivers and floodplains increase exposure to floods. Waterlogging may happen even when it does not rain much, as seen by the polls and the field surveys. This is because there are not many natural methods for water to get rid of it and keep it. The resilience cannot be achieved by merely putting in pumping systems and bigger drains for a longer duration. Planning for resilience means thinking about system-based solutions like getting institutions ready, maintaining natural water networks, and taking care of land as a whole.

Recent research suggests that local landforms and marine processes are particularly crucial for making the world more resilient. Regular measurements do not always take this into account. This research examines the distinct behaviours of floods in Indian coastal communities and proposes an effective planning approach that considers these variations. The study's results support the notion that context-specific resilience frameworks are superior to universal models for both designing communities and adapting to climate change. The novelty of research lies in the development of a specific Urban resilience framework derived from the vulnerabilities, primary and empirical studies in an Indian coastal city. This study identifies the context-specific parameters. This research addresses this gap by identifying resilience parameters derived directly from local vulnerabilities observed in Kochi, such as low elevation, encroached canals, altered drainage patterns, land use change, and increasing precipitation intensity.

4.1. Limitations of the Study

There are several elements regarding the research that are not right and need to be spoken about. The research does not include the social and economic dimensions of resilience, such as how much money you make (income levels), how dangerous your work is (livelihood vulnerability), or how well you can get along with new people in your community (community adaptive capacity). All of these elements make the economy and society more stable. This was left out so that the emphasis could be on the environmental and physical variables that impact resilience, which have a lot to do with how people in Kochi deal with the weather.

Last but not least, the major survey was based on the opinions of a small number of individuals. This meant that it did not fully indicate how the climate will evolve over time or what the worst-case scenarios for the future may be. Because of these problems, it is evident that further study has to be done in a more thorough and careful way.

5. Conclusion

The research examined solutions applicable to coastal cities and discussed their significance, looked at ideas from across the world regarding how to make cities more robust, and pointed out their shortcomings when employed in Indian cities. This research can help planners and researchers who may assist with designing cities like Kochi, Kerala. A city or region is considered to be resilient if it can endure the consequences of climate change, such as increasing sea levels, marine floods, and storm surges, and yet be able to adapt and evolve in ways that retain its capacity to do so. Looking at Kochi's current construction plans and procedures, and seeing how it stacks up against the criteria for resistance that have previously been established. These elements can be utilized to come up with laws and plans for making communities better. The research looked at elements including the elevation, slope, drainage system, usage, and quantity of rain. The objectives of this research were accomplished by elucidating the concept of resilience and detailing its characteristics. It primarily examined physical parameters. The criteria and notion of resilience that were established in this study might be utilized to generate policy and strategic planning proposals if additional research is done on strong coastal communities. The city may have to adjust things to cope with climate change.

While the analytical emphasis was placed on physical and environmental parameters, the study highlights the necessity of strengthening institutional coordination for an integrated resilience framework. The proposed framework provides a structured planning tool for master planning, zoning, disaster management strategies, and site-specific strategies for Indian coastal cities.

Future research should integrate socio-economic vulnerability indicators and qualitative resilience indexing methods to develop a comprehensive multidimensional framework. There is a chance that Geographic Information Systems (GIS) may someday help make flood models, climate predictions, and ongoing data analysis better.

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