

CASE STUDY

Analysis of the 2023 flood scenario for urban disaster management from a strategic management perspective

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ARTICLE INFO

Article History:

Received 02 February 2024

Revised 25 April 2024

Accepted 27 May 2024

Keywords:

Causes of floods

Consequences of floods

Disaster management

Flood factors

Sub-urban and urban management

ABSTRACT

**BACKGROUND AND OBJECTIVES:** Analyzing the flood scenario can help identify opportunities and difficulties for enhancing urban catastrophe management procedures and creating more resilient cities facing environmental threats like climate change. The primary goals of the case study were to summarize the key elements of the flood incidents in India between 2000 and 2016 and discuss the 2023 flood scenario in Chennai. This study also suggested technological interventions to ensure preparedness innovatively and recommended a strategic plan to address the issue that would evolve the involvement of all stakeholders in disaster management.

**METHODS:** A flood disaster analysis was based on meta-analytic and visualization methods. The factors contributing to effective mitigation for such unexpected and unforeseen happenings were considered for elaborate discussion and highlighted in this study. The urban development initiatives and their impact, especially during flood occurrences, were kept for discussion and analysis. The methodology is more qualitative, with references as the basis of analysis and further discussion. The meta-analytic approach ensures to cover all the frames of references that are notable from the perspective of contributing to urban development since urban areas contribute a lot to a nation's economic growth and other developmental aspects.

**FINDINGS:** The meta-analytic review of the case study contributes to the overall 75 percent of the cases by focusing on governance-level initiatives, precautionary measures, and post-situational steps that were taken to mitigate the issue in a congenial manner. This study identified the consequences and factors that contributed to such occurrences, primarily due to certain factors relevant to urbanization and encroachment effects, as well as other contributing factors that were found common in all occurrences. A framework or model used in this study for urban recovery was also formulated by the authors of this study.

**CONCLUSION:** These findings enable those strategic decision-makers to support the facts of such occurrences (especially in suburbs or urban areas) or any other incidents of disaster or crisis with crucial information that would pave the way for effective management of incidences and also help in framing policies with developmental perspectives in place while planning to convert suburbs to urban development shortly. The finding of the study supports the gap in overall studies based on flood occurrences and suitable remedies as well.

DOI: [10.22034/IJHCUM.2024.04.11](https://doi.org/10.22034/IJHCUM.2024.04.11)



NUMBER OF REFERENCES

66



NUMBER OF FIGURES

3



NUMBER OF TABLES

1

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Note: Discussion period for this manuscript open until January 1, 2025 on IJHCUM website at the "Show Article."

## INTRODUCTION

The year 2023 etched a grim mark on Chennai. The recorded rainfall was unprecedented and unleashed an urban deluge, leaving the city inundated. An exposed scenario of the city's vulnerabilities, and testing its mettle was witnessed. Yet, from the depths of this crisis arose a story of resilience and adaptation, adding a resolute commitment to a stronger future over devastation. The frequency of flood occurrences in urban areas has been noted in recent years (Rafiq et al., 2016). Those cities that were affected included Ahmedabad, Hyderabad, Delhi, Mumbai, Surat, Kolkata, Jamshedpur, Gurugram, Srinagar, Guwahati, and Chennai during the period from 2000 to 2016. A very recent flood incident was witnessed in Chennai in the year 2023, after 2015. The incidents in Chennai and other places indicate mainly urbanization, encroachments, water logging, and ignored warnings, respectively. Also, it is indicated by Sundarmoorthy et al., (2009). Uncontrolled urban sprawl has had some important consequences for urban floods and blocked natural drainage. In addition, urban lakes were filled and encroached upon. The emphasis on practical knowledge, simulations, and fostering a culture of preparedness showcases the transformative power of education in building communities that are not only aware but actively engaged in their safety and recovery (Jain and Singh 2023). The rapid growth of the metropolis, planned and unplanned, had resulted in the filling up of substantial portions of this once well-managed water management system, and this case, delving into the aftermath of the Chennai floods, offers a nuanced and in-depth exploration of the suburban city's response and recovery efforts. The study also envisaged the previous cases of floods in India from 2000 to 2016. It traces the transcending events as a mere series of chronicles. Further delving into the complex factors being interplayed had given shape to the sub-urban city's journey, from the immediate challenges of rescue and relief to the ongoing quest for long-term urban resilience. The study by Baghel (2016) also analyses the causes and factors behind the flood, the mitigation strategies adopted therein, and the consequences therein. The consequences may be like the Bangladesh floods of 1997 and 1998, which destroyed millions of homes, devastated crops on several million hectares of land, killed over 200,000 farm animals, and caused

enormous damage to the country's economic infrastructure (Mallick et al., 2005). An overall meta-analytic review of the study has been used to analyze and finally draw conclusions from the study. Navigating the labyrinthine complexities of urban disaster management involves a gap examination exposed by the flood, and the subsequent policy reforms undertaken to address it are also focused on in this study (Faisal et al., 2003). The city's commitment to fortifying its urban infrastructure, embracing climate-conscious practices, and empowering its urban communities with knowledge and preparedness is evident. When preparedness is considered, a research paper by Islam et al., (2016) highlights that it is important to enhance the preparedness of digital literacy in flood-prone areas so that schools can take advantage of digital media to get information about flood disasters and also quickly inform the school community to be prepared for disasters. The Mumbai experience would help plan response strategies for other large cities to cope with similar events in the future (Gupta 2007). The causes of flood occurrences were mainly factors that were direct and indirect. The case of the Chennai flood is a direct result of factors such as global climatic change. When there is a change in the weather pattern, heavy rainfall occurrences are witnessed. More than half of the occurrences of disaster had been recorded in Asian areas mainly as highlighted by the work of (Tingsanchali 2012). The situation further worsens due to urbanization initiatives such as encroachments, leaving no space for natural storage, and continuous developmental and redevelopment initiatives with land uses (Ramachandraiah 2011). This study focused on how several factors had combined only to worsen the situation of the flood rather than handling it in a better manner to reduce the loss to a certain extent. Furthermore, this study discussed the causes of the flooding, the damage to Kurnool's water and sanitation infrastructure, and the strategies used by the affected people to cope with the problems during and immediately after the floods. However, a contradictory statement has been argued that many blame this on urbanization and rampant real estate development (Baghel 2016). But a year ago, when rains flooded Gurgaon, the effects were felt the most in rural areas like Kankrola village. There are various types of floods. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer

floods, coastal floods, and glacial lake outburst floods. These various classes of floods are generated by different mechanisms (Slam *et al.*, 2016). To focus future research efforts and address important knowledge gaps, it is imperative to identify gaps in the current research on urban disaster management caused by floods. Numerous studies highlight how crucial interdisciplinary approaches are to managing urban disasters like floods (Eshghizadeh, 2024). Further study that effectively integrates perspectives from several disciplines, including hydrology, urban planning, social sciences, and engineering, is required to provide comprehensive solutions (Mei *et al.*, 2018). Although it is well acknowledged that community engagement is a crucial component of urban flood management, little is known about the best ways to involve a variety of stakeholders, especially marginalized and vulnerable communities. According to Pittare *et al.*, (2019), participatory approaches that empower communities and include local knowledge and viewpoints should be the focus of future research. There is a growing demand for study on practical adaptation techniques due to the increasing effects of climate change on urban flooding. The integration of adaptation measures into urban planning and policy frameworks, as well as their long-term effectiveness and scalability, remain little understood (Hallegatte *et al.*, 2020). Accessibility and data availability continue to be major obstacles in the field of urban flood management research. To enable evidence-based decision-making, more complete and standardized datasets are required, along with better access to data sources such as satellite imaging, real-time monitoring data, and socio-economic indicators (Thielen *et al.*, 2018). There is a dearth of knowledge regarding the difficulties associated with implementing policies and governing structures, despite the wealth of research on flood risk management plans and policies. Subsequent investigations must concentrate on the organizational obstacles, policy consistency, and stakeholder collaboration necessary to convert policy objectives into practical measures on the ground (Jiang *et al.*, 2018). When opposed to more general disaster management studies, there are a few special benefits to studying urban disaster management from a strategic management perspective for a particular occurrence like the 2023 flood scenario. In contrast to studies on general disaster management,

which frequently concentrate on theoretical frameworks and overarching concepts, research on the flood scenario of 2023 would examine the particular difficulties, solutions, and results of that specific incident. It would take into account the particulars of the flood, the impacted urban area, the available resources, and the parties concerned. The research findings are made more urgent and useful by this temporal component since it can have a direct impact on current and future crisis management plans. Analyzing the strategic planning, coordination, and execution of organizations, governments, and other stakeholders' responses to disasters is a key component in approaching urban catastrophe management from a strategic management perspective used in this study (Arabiun *et al.*, 2024). The study can pinpoint specific lessons learned, difficulties encountered, and best practices used during the response and recovery stages by concentrating on a particular event, such as the flood of 2015. Future local and international catastrophe preparedness and management plans may benefit from these findings. A study on the flood scenario for 2023 would seek to provide practical recommendations for improving strategic management practices in urban catastrophe management through particular strategies and policies, in contrast to some studies that would mainly concentrate on theoretical frameworks or historical analyses (Comfort 2007; Rathore and Kumar 2019). A study on the flood scenario in 2023 would be specifically tailored to the unique characteristics and challenges of the affected urban area, including nuances of local governance, socio-economic disparities, infrastructure vulnerabilities, and cultural factors that influence disaster management practices and outcomes. Considering the complexity of urban catastrophe management, the study would emphasize the importance of multi-stakeholder participation and collaboration. This collaborative approach gives the submitted ideas more ownership and significance (Norris *et al.*, 2008). The study would highlight the need for continual learning and modification in disaster management protocols, drawing on the flood of 2023 (Faulkner 2001). Some difficulties could surface when considering urban catastrophe management from a strategic management standpoint, especially in light of the projected floods in 2023. It can be difficult to find precise and thorough

information about the flood of 2023, including its causes, effects, and countermeasures. The lack of data could make it more difficult to create strategic management strategies that work (Yuan and Liu 2018). Effective and efficient resource allocation is essential to disaster management. But in the wake of the 2023 flood, scarce resources combined with conflicting agendas could cause problems when allocating resources (Simonoff *et al.*, 2011). Collaboration between numerous authorities and stakeholders is frequently necessary for effective disaster management (Comfort and Wukich 2013). Studying urban disaster management from a strategic management perspective in the context of the projected floods in 2023 may present challenges in many phases, ranging from pre-disaster planning to post-disaster rehabilitation. As decision-makers balance conflicting demands for scarce resources during the response phase, resource allocation issues may surface. The best use of resources to meet the urgent needs of impacted people may be hampered by disagreements over priorities, political issues, or bureaucratic inefficiencies (Simonoff *et al.*, 2011). Throughout the disaster management process, including the response phase, coordination issues between various agencies and stakeholders may occur. Problems can continue during the lengthy phase of rehabilitation and reconstruction while communities work to rebuild and re-establish their means of subsistence in the wake of the 2023 flood. Proactive approaches, including thorough risk assessment, capacity-building programs, stakeholder involvement, and institutional reforms, are needed to address these issues and improve the efficacy of strategic management in urban catastrophe management (Comfort and Wukich 2013). Some stakeholders participating in disaster planning, response, and recovery operations may be impacted by the challenges associated with researching urban catastrophe management from a strategic management perspective in the context of the 2023 flood scenario. The difficulties in managing urban disasters strategically have an immediate impact on communities that are vulnerable to flooding. Urban disaster management agencies under government jurisdiction that oversee infrastructure, public safety, emergency response, and urban planning may face challenges in their strategic management. Enhancing the resilience of urban regions and improving

strategic management methods in disaster management requires collaborative efforts by governments, emergency responders, communities, Non-Governmental Organizations (NGOs), corporate sector actors, and academia to address these concerns. Numerous tactics and interventions have been used in an attempt to address the difficulties in researching urban catastrophe management from a strategic management perspective, especially in light of the projected floods in 2023. It has been suggested that community involvement techniques that strengthen social capital, empower locals, and encourage collaborative decision-making can improve resilience and encourage sustainable disaster management techniques. Urban catastrophe management difficulties are becoming better understood, and creative solutions are being developed, thanks to investments in research, innovation, and knowledge-sharing networks. Through the implementation of these strategies and actions, stakeholders can strengthen urban areas' resilience to future disasters and collaborate to overcome the difficulties associated with researching urban disaster management from a strategic management perspective (Yuan and Liu 2018). The present study does not address coastal flooding caused by storm surges (Kundzewicz *et al.*, 2014), and the type of flood found to be noted in the Chennai case has indicated the relevance of flash floods. The other factors may be due to geomorphological settings and geomorphic effects along with rainfall extremes that have led to flooding (Kale 2003). Inflow and out-flow limits of sewerage also contribute to flooding, as cited in the research work of Ray *et al.*, (2019). The case study's primary goal was to draw attention to the case while highlighting the key aspects of India's historical flood incidents from 2000 to 2016 and discussing the Chennai incident of 2023. The main and secondary goals were determined and thoroughly examined, using reference frames from a variety of research projects about India's floods. There are lots of studies about flood scenarios in urban and suburban environments, but the meta-analytic approach of attempting to explore the study has not been done by many researchers in previous studies. The importance of the study lies in the meta-analytic way of approaching flood issues from a strategic view rather than mere disaster management alone. Thus, the study aims to direct the learners'

attention toward the strategic management elements that need to be taken into account during disasters and the appropriate steps to take to manage them effectively. In December 2023, this study was carried out at the Kalasalingam Academy of Research and Education in Krishnankoil, Tamil Nadu India.

## MATERIALS AND METHODS

India experiences severe floods every year that cause millions of people to be displaced, property destruction, and fatalities. Undertake comprehensive case studies of previous flood incidents in particular Indian locations to comprehend the fundamental reasons, susceptibilities, and reactions. This can point out areas that need improvement and offer insightful information about how well-performing current techniques are. The purpose of this case study is to identify and investigate the primary and secondary objectives for improving India's flood resilience. Improving India's flood resilience primarily aims to lessen the susceptibility of ecosystems, infrastructure, and populations to flooding incidents. The secondary goals are to encompass actions like strengthening infrastructure resilience, advancing nature-based solutions, and developing early warning systems, like i) Increasing community preparedness: bolstering community-based flood preparedness and response mechanisms, such as awareness campaigns, evacuation planning, and capacity building, are among the secondary targets. ii) Sustainable Land Use Planning: Enforcing land-use planning laws to reduce development in regions vulnerable to flooding, protect natural floodplains, and encourage resilient urban planning, iii) Climate Change Adaptation: To address future uncertainties and shifting flood patterns, incorporate climate change adaptation methods into flood control planning and infrastructure development (Bahinipati and Patnaik, 2020), and (iv) Ecosystem Restoration: restoring damaged ecosystems, like wetlands, rivers, and coastal regions, to increase their potential to naturally avert flooding and to promote the general health of the ecosystem.

### *Insights theory on urban disaster management*

Research and practice in urban disaster management resulting from floods are guided by various pertinent ideas and frameworks. These ideas shed light on how social and environmental systems

interact, how disasters unfold, and what influences resilience and vulnerability in urban settings. The idea places a strong emphasis on how social and ecological systems are interrelated, how they have coevolved over time, and how human activity and environmental processes interact to shape catastrophe resilience and vulnerability (Folke *et al.*, 2016). A theory that concentrated on the integration of social and technical components of complex systems, like urban infrastructure and catastrophe management, was developed by Javadinejad *et al.*, (2020). The ability of systems to withstand shocks, adjust to changes, and continue operating is the core subject of resilience theory. Resilience theory highlights the value of developing adaptive capacity, encouraging learning, and improving flexibility in the context of urban catastrophe management to deal with and recover from flood disasters (Manyena 2017). Kong (2022) looked at the idea of how complex systems, such as cities and urban networks, self-organize, adapt, and evolve in response to both internal and external stimuli. These theoretical frameworks offer insights into strategies for fostering sustainable development, boosting adaptive ability, and constructing resilience in flood-prone urban regions, as well as conceptual frameworks for comprehending the intricacies of managing urban disasters caused by floods.

### *The emerging challenges the urban disaster management*

Inadequate risk assessment, a lack of strategic planning, or a lack of funding for disaster mitigation measures can all provide challenges during the preparedness stage. When a crisis strikes suddenly, like the flood of 2023, these problems may make it more difficult to respond effectively. As decision-makers balance conflicting demands for scarce resources during the response phase, resource allocation issues may surface. The best use of resources to meet the urgent needs of impacted people may be hampered by disagreements over priorities, political issues, or bureaucratic inefficiencies (Simonoff *et al.*, 2011). Problems can continue during the lengthy phase of rehabilitation and reconstruction while communities work to rebuild and re-establish their means of subsistence in the wake of the 2023 flood. Difficulties like insufficient financial resources, absence of planning for sustainable development, or strained social relations can impede attempts to strengthen

resilience against future calamities and extend the recovery period (Tierney 2019).

#### *Meta-analytic review and visualization method*

The various research studies conducted keeping the floods as the basis and their literary reviews are taken as the data for the case study analysis. Further, with the literary surveys done by previous researchers, the perspectives of analysis such as strategic, urbanization and its outcomes, environmental, governance, and mitigating avenues were focused, and results were drawn suitably. The major analysis envisages a meta-analytic approach to analyze the case of the Chennai floods, which occurred in 2023 in particular. Floods and their occurrences in various parts of India have been debated and elaborated from the perspectives of disaster management and precautionary measures, but the execution of the same has not been examined in previous studies. Hence, this case study analyses the possible impact of execution by the public sector (Amarasinghe et al., 2020), and the responses from the general public and other stakeholders are discussed. The samples included in this study are occurrences in India, as the climatic conditions and other similar or common factors were kept in mind when the study was conducted. The stakeholders should enhance the capacity of resilience, as indicated by Dixit (2003) that the vulnerability of people in risk-prone areas must be addressed by enhancing resilience capacity. During December 2023, Chennai witnessed an extraordinary flood, marked by unprecedented rainfall that surpassed any recorded one over a decade. The consequences were severe, with widespread flooding extending across the city and its surrounding suburbs. The incessant rains pushed rivers, lakes, and reservoirs beyond their capacity, triggering a catastrophic overflow. This flood laid bare the inherent vulnerabilities in Chennai's infrastructure, planning, and disaster preparedness. The city, known for its infrastructure designed to withstand conventional weather patterns, struggled to contend with the overwhelming volume of rainfall. The drainage systems were overwhelmed and unable to cope with the flood, leading to extensive waterlogging and subsequent flooding in various parts of the city. The inadequacies that existed in the infrastructure became glaringly apparent as streets turned into waterways, disrupting normal life and

causing significant property damage. Urban planning, a critical aspect of any city's resilience, faced scrutiny in the wake of the floods. Chennai's rapid urbanization and expansion were often noticed to be accompanied by encroachments on water bodies and inadequate land-use planning, which worsened the impact of the flood. The contribution of unregulated urban growth has led to a reduction in natural water absorption areas, leaving the city more susceptible to flooding during periods of heavy rainfall. Preparedness during disasters is a cornerstone of any city's resilience, which has taken a toll. The anticipation of the unforeseen magnitude of the rainfall revealed gaps in the city's response effect eventually. Though warnings from the meteorological department were given, the sheer intensity and prolonged duration of the rainfall exceeded expectations. At this juncture, there is a need for a disaster preparedness strategy that is more robust and adaptive and could account for extreme weather events beyond historical norms. The result of the flooding brought to light an immediate need for comprehensive measures to address the challenges posed by urbanization, climate change, and the limitations of existing infrastructure. The case study of Bhopal long ago had instances of calling upon solutions under uncontrollable situations as indicated in the work of Sundarmoorthy et al., (2009). The scale of the disaster emphasized the importance of re-evaluating and fortifying the city's resilience through innovative planning, infrastructure development, and proactive urban disaster management strategies. In essence, the unprecedented rainfall and subsequent flooding in Chennai in late 2023 were more than a mere natural disaster; they were indeed a wake-up call, urging a critical re-examination of the city's preparedness and adaptability in the face of increasingly unpredictable climatic conditions. The challenges posed by the deluge catalyzed the rethinking and reshaping of Chennai's landscape, to foster a more resilient and sustainable future.

#### *The scientific reason for the Chennai flood*

The 2015 Chennai floods were mostly brought in by a confluence of hydrological, climatic, and urban development variables. The unusually high rainfall in a brief amount of time, which overtaxed the city's water management and drainage systems, caused the floods. The North-East monsoon's effect and the development of a low-pressure system over the Bay

of Bengal were two meteorological elements that affected the amount and duration of the rainfall (IMD, 2015). The amount of rainfall that Chennai had during the 2015 monsoon season was too much for the city's drainage infrastructure to handle. Flooding was made worse by the encroachment of water bodies, inappropriate land use planning, and inadequate maintenance of storm water drains, which impeded water flow and resulted in waterlogging in low-lying regions (George *et al.*, 2022). Climate change is thought to play a role in many locations, including Chennai, when it comes to extreme weather events like flooding and high rainfall, even though it is not directly linked to the floods of 2015. Future rainfall events may become more frequent and intense due to rising temperatures and shifting precipitation patterns (Li *et al.*, 2017). A comprehensive strategy that incorporates water management, urban planning, weather forecasting, and disaster preparedness measures is needed to address the fundamental scientific causes of the 2015 Chennai floods.

#### *Influencing the period and geographical area of flood scenario*

The issue of flooding in Chennai is not exclusive to any one particular period or place. Flooding can happen during the monsoon season, which is normally from October to December, but it can also happen outside of this time due to changes in rainfall patterns and the consequences of climate change. However, cyclones, depressions, or localized convective storms can cause extreme rainfall events and flooding outside of the monsoon season (George *et al.*, 2022). Chennai's suburban and rural areas are also impacted by flooding, in addition to the city's metropolitan sections. Flooding occurs in both urban and peri-urban settings due to factors like urban sprawl, the invasion of water bodies, and changes to natural drainage patterns (Kadaverugu *et al.*, 2022). Flooding is further complicated by coastal vulnerability, which puts low-lying coastal areas in danger of flooding during storm surges or cyclones (Li *et al.*, 2017). Acknowledging that flooding in Chennai is not limited to a particular time frame or geographic location allows stakeholders to create comprehensive flood management plans that take into account the various elements that increase the region's susceptibility to flooding.

## RESULTS AND DISCUSSION

Communities can lessen the vulnerability of people, property, and infrastructure to flooding disasters by integrating flood control infrastructure, early warning systems, community preparedness, ecosystem restoration, research and innovation, and natural flood management. (Oruonye 2012). Furthermore, it is possible to significantly reduce the vulnerability of people, property, and infrastructure to flooding events by incorporating these strategies into comprehensive flood risk management plans (Nkwunonwo *et al.*, 2020) that are customized to meet the unique needs and characteristics of each community (Bahinipati and Patnaik 2020). This will ultimately improve overall resilience and sustainability.

#### *Urban disaster management methods*

Flood-related urban disaster management calls for a diversified strategy that includes a range of techniques and tactics to reduce risks, improve readiness, and foster resilience. Early warning systems offer authorities advance notice of flood events through real-time data, monitoring, and forecasting. This allows authorities to promptly issue alerts and coordinate response operations. To spread alerts to communities at risk, Early Warning Systems (EWS) can comprise hydrological monitoring, weather forecasting, risk assessment, and communication channels (Thielen *et al.*, 2018). Zoning laws and land use planning serve to control urban development in flood-prone areas by reducing exposure to and vulnerability to flood hazards. Restricting construction in high-risk locations, safeguarding natural floodplains, and promoting green infrastructure are some measures to increase flood resilience (Jongman *et al.*, 2015). Infrastructure retrofits and upgrades can make cities more resilient to flooding by strengthening drainage systems, erecting flood barriers, and improving stormwater management infrastructure. Permeable pavements and rain gardens are two examples of green infrastructure options that can reduce flood risk while simultaneously having positive environmental effects (Li *et al.*, 2020). Building local resilience requires involving communities in flood risk awareness, preparation, and response activities. To improve community capacity for emergency response and recovery, techniques include participatory workshops, community-based

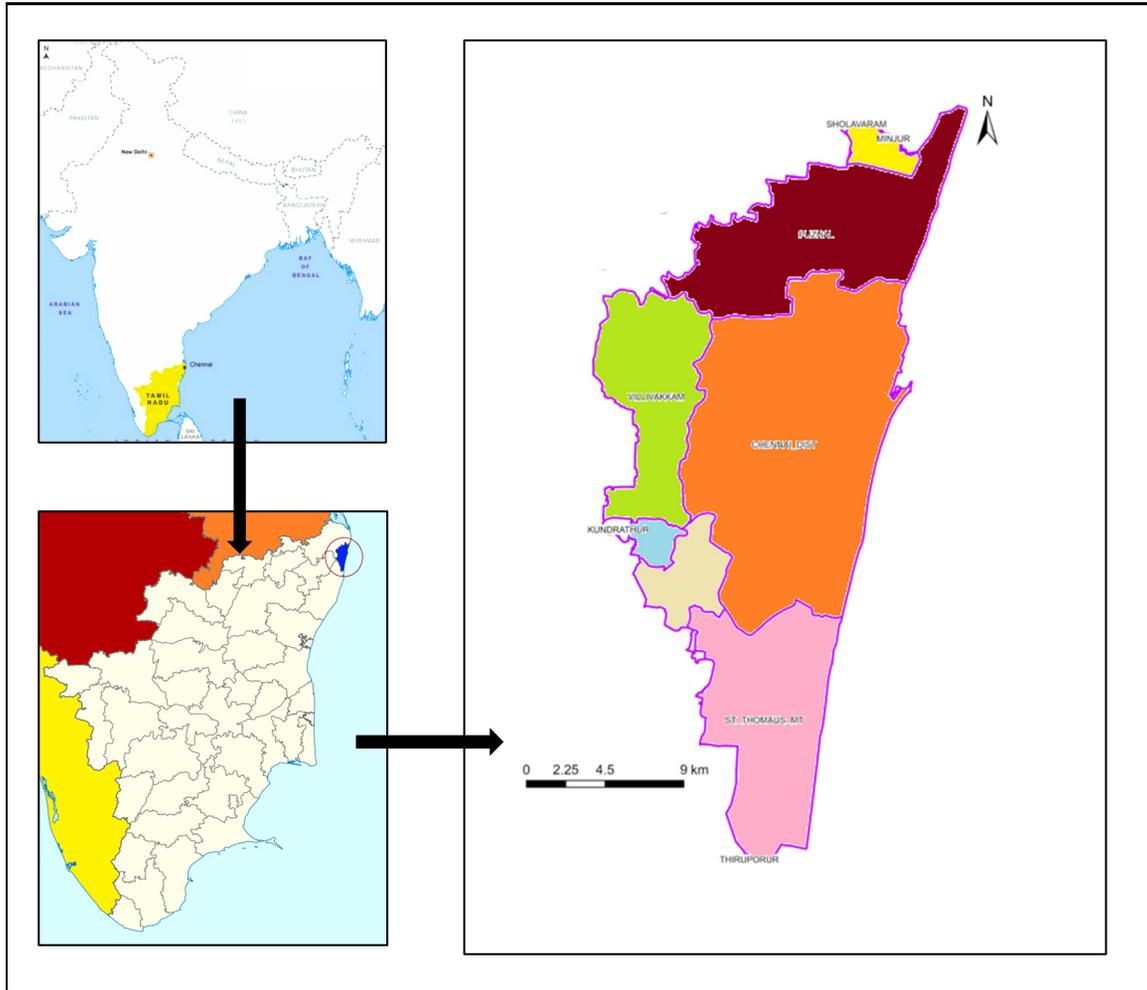


Fig. 1: Geographic location of the study area by INSAT-3D image of Chennai, India

flood risk mapping, and training programs (Koutsovili *et al.*, 2023). Coordination of flood risk management initiatives at the local, regional, and federal levels depends on strong governance structures and policy formulation. Disaster risk reduction can be mainstreamed into urban planning, development, and investment decisions with the aid of integrated approaches that take into account many sectors and stakeholders (Jiang *et al.*, 2018). The increased frequency and severity of floods in urban areas as a result of climate variability and change is the focus of methods for adapting to climate change. These tactics consist of mainstreaming climate issues into urban planning and development processes, ecosystem-based techniques, and resilient infrastructure design (Hallegatte *et al.*, 2020). Urban regions can

better prepare for floods and lessen their effects on infrastructure, people, and the environment by incorporating these techniques into comprehensive flood management plans.

#### *Preparedness and early warning systems*

Chennai, being nestled along the Bay of Bengal, has long been accustomed to the seasonal challenges posed by cyclones and heavy rainfall, particularly during the northeast monsoon. This rendering of the geographical positioning of the city is susceptible to the whims of weather, making robust early warning systems imperative for the residents' safety and well-being. However, the floods that unfolded in 2023 brought to light significant deficiencies in these critical urban systems. Fig. 1 indicates the study

area in Chennai during the flood occurrence on December 5, 2023. A synthesis of the various case studies available from the Indian region indicates that often the absolute magnitude of a flood is not as important to the geomorphic effects as the flow stress and competence. Despite Chennai's historical vulnerability to weather-related adversities, the meteorological department, tasked with providing crucial early warnings, found itself grappling with the unprecedented scale of the rainfall (Dixit 2003). The forecasts, although issued, failed to accurately gauge the intensity and prolonged duration of the rainfall that eventually inundated the city. The gap between the predicted and actual weather conditions highlighted a critical flaw in the existing early warning mechanisms. About 80 percent (%) of the total annual rainfall is concentrated during the period, resulting in a very high discharge from rivers, causing extensive damage to life and property. The shortcomings in the forecasting and communication processes were swiftly recognized by authorities, who acknowledged the need for substantial improvements in the city's preparedness for such meteorological events. Amidst the issuance of warnings from the meteorological department, the unexpected severity of the rainfall underscored the urgency of refining the accuracy and reliability of these forecasts. A more sophisticated and adaptive early warning system was the need of the hour to anticipate and communicate the potential risks associated with extreme weather conditions effectively. The focal point for improvement shifted toward enhancing the precision of forecasting models and ensuring the efficient dissemination of timely and comprehensible warnings to vulnerable communities (Henonin *et al.*, 2013).

This involved the incorporation of advanced technologies, such as real-time weather monitoring systems, satellite imagery, and data analytics, to provide more accurate and detailed predictions. Additionally, efforts were directed at improving the communication channels to reach diverse segments of the population, including those in vulnerable areas. The lessons learned from the 2023 floods emphasized the critical role of early warning systems in minimizing the impact of natural disasters. The events prompted a re-evaluation of the existing protocols, the adoption of state-of-the-art technologies, and the development of more effective communication strategies. Chennai's urban journey toward bolstering its early warning

capabilities reflects a commitment to learning from past challenges and implementing measures to better protect its residents from the unpredictable forces of nature. Ultimately, the aim is to transform vulnerabilities into opportunities for improvement, ensuring a more resilient and responsive city in the face of future climatic uncertainties. The mitigation strategies hold importance in an overall manner, and those strategies may be both short-term and long-term. Those short-term measures include sealing off all hydraulic leakage, badly silted-up drains must be cleaned; and the encroachment of retention ponds must be stopped instantly. In the case of long-term measures, build public awareness through non-governmental organizations, undertake awareness campaigns ahead of flood occurrences, land use statutory provisions for all, mandatory floodproofing in buildings, etc.

#### *Response and relief operations*

A series of challenges related to the floods in 2023 were unrevealed during the initial response efforts, marked by delays and issues related to coordination among the diverse array of agencies involved. The complexity of the situation, aggravated by the unprecedented rainfall, necessitated a swift and cohesive response, which unfortunately encountered hurdles in the form of disjointed efforts and communication lapses. As the gravity of the situation became more apparent, a collective response gradually took shape. The local government, armed forces, the National Disaster Response Force (NDRF), and volunteer groups stepped forward, coordinating with rescue operations and providing much-needed relief to the affected population. Their combined efforts were crucial in mitigating the immediate impact of the disaster and offering assistance to those stranded in the deluge. However, the scale of the floods proved to be overwhelming, stretching the available resources to their limits. The collaboration among various agencies, though commendable, faced challenges in terms of urban resource allocation, efficient communication, and synchronized efforts. The sheer magnitude of the crisis underscored the necessity for a more streamlined and coordinated approach to manage such large-scale disasters. When looking into the increasing ramifications of such disasters, it has afflicted policy planners, scientists, researchers, academicians, and others

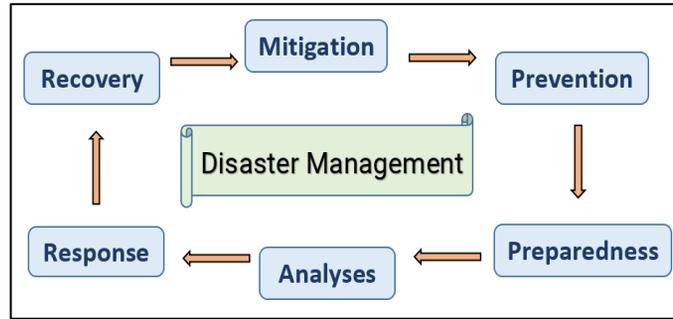


Fig. 2: Tamil Nadu state disaster policy document's disaster management continuum

concerned across the world to find out ways and means to deal with the emerging threats of this typical hydro-meteorological phenomenon (Ranjan 2017). Hence, the need for improved coordination and communication from all sides became evident as the response unfolded. The intricacies of managing a disaster of this scale required not only the commitment of various agencies but also a well-orchestrated collaboration that could efficiently deploy resources, share information, and address the evolving needs of the affected population (Qureshi 2011). This realization prompted a critical examination of the existing frameworks for disaster response.

#### *Policy reforms and institutional strengthening*

The comprehensive review of the urban disaster management framework in the aftermath of the Chennai floods reveals a city's commitment to adaptive governance. Recognizing the gaps exposed during the crisis, urban authorities embarked on a proactive journey to refine existing urban policies and formulate new ones. This approach to forward-looking emphasizes the importance of learning from past experiences and ensuring that policies and institutions are better equipped to navigate future disasters. By focusing on clear protocols, efficient coordination mechanisms, and robust governance structures, Chennai is not only addressing immediate concerns but also fortifying its ability to respond to future challenges with agility and effectiveness. Given the particular risks, vulnerabilities, and resources of Tamil Nadu, the state's disaster policy statement would probably include precise tactics, courses of action, and roles for every stage of the disaster management continuum (Fig. 2). To guarantee efficient disaster

management over the whole continuum, these strategies may also address institutional frameworks, collaborations with stakeholders at the state, district, and local levels, and coordination mechanisms (Tajpour and Razavi 2023).

#### *Investment in infrastructure and drainage systems*

Strategic investments in urban infrastructure are central to Chennai's goal of building resilience against future flood risks. Upgrading storm water drains, desilting water bodies, and constructing flood-resistant infrastructure are not mere responses to the immediate aftermath of the floods; they represent a commitment to sustainable urban development. Improving drainage systems enhances the city's capacity to manage excess rainfall effectively, preventing waterlogging and flooding. This approach recognizes that infrastructure is about rebuilding and creating a foundation for long-term resilience, aligning growth with environmental considerations. With the high density of population concentration in cities, urban floods are triggered, leading to a significant impact on human life and the economy of the country (Sundaram et al., 2021).

#### *Climate change adaptation*

Chennai's recognition of the interconnected challenges arising from climate change and urban development is driving a paradigm shift. The city's commitment to sustainable practices, such as green infrastructure, sustainable land-use planning, and preserving natural water absorption areas, reflects a forward-thinking approach. The lessons learned from the floods catalyze the incorporation of climate considerations into planning and development strategies. This strategic planning not only adapts

Table 1: 24-hour rainfall statistics comparison in Chennai for 2015 and 2023

Station	December 4, 2023 (24 h rainfall)	December 3-5, 2023 (48 h rainfall)	December 1, 2015 (24 h rainfall)
Nungambakkam	24 cm	47 cm	29 cm
Meenambakkam	19 cm	42 cm	35 cm
Tambaram	24 cm	41 cm	49 cm
Chembarambakkam	21 cm	37 cm	47 cm

to the immediate aftermath of the floods but also strategically prepares for a future where climate change could exacerbate the frequency and intensity of extreme weather events. Moreover, the ongoing development strategies must take climate risk into account and address the persistent adaptation deficit (Bahinipati and Patnaik 2020). The concerns about the trends in losses associated with natural disasters in developed countries are magnified when placed in the context of developing nations. Natural hazards result in significant loss of life and serious economic, environmental, and social impacts that greatly retard the development process (Subrahmanyam 1988). The precipitation recorded by the India Meteorological Department (IMD) on December 4, 2023, is presented in Table 1.

From Table 1, it may be observed that less precipitation than on December 1, 2015, based on 24-hour observations. On the other hand, the amount of precipitation was higher on December 3, to 5, 2023, based on 48-hour observations, than on December 1, 2015. The extreme intensity of the rains that battered the city and its suburbs may be seen by looking at IMD's 48-hour window, which also reveals that the rainfall total exceeded 2015. However, after evaluating the flood damage in Chennai's urban and suburban areas, it becomes clear that, in contrast to 2023, the flood damage in 2015 was greater because of the Chembarambakkam reservoir's mishandling on December 1, 2015, when water was unexpectedly released. The Adyar River overflowed due to the massive water release, and this could result in significant flood damage.

#### *Capacity building and training*

The post-flood capacity-building initiatives in Chennai showcase a commitment to addressing gaps in disaster response. By placing increased emphasis on training programs for government officials, first

responders, and community volunteers, the city aims to enhance overall preparedness for future calamities. Workshops on disaster management, search and rescue operations, and medical assistance empower individuals and teams with essential skills and knowledge. The grassroots focus on community volunteers not only strengthens local resilience but also contributes to a more coordinated and effective overall response. The commitment to continuous learning and improvement through regular drills and simulations exemplifies an adaptive and resilient response framework (Singh and Kumar 2017). In the case of the National Flood Control Program, which was launched in the country in 1954, since then, sizeable progress has been made in structural and non-structural flood protection measures. A range of experts with crisis and disaster response training may be among the emergency service workers participating in rescue operations. These employees frequently collaborate to offer help and support in times of need. In order to prevent fatalities, reduce injuries, and aid populations impacted by emergencies and disasters, these experts collaborate with public and private groups. Their work is crucial for easing the effects of crises and promoting healing.

#### *Technology integration in urban disaster management*

Chennai's strategic shift towards technology integration in urban disaster management reflects a commitment to innovation. Real-time monitoring systems, satellite imagery, and Geographic Information Systems (GIS) provide decision-makers with timely and accurate information, improving overall decision-making processes during emergencies. The integration of advanced technologies not only enhances situational awareness but also contributes to a more coordinated and collaborative approach among the various agencies involved in disaster response. The post-flood emphasis on staying ahead of evolving climatic conditions showcases

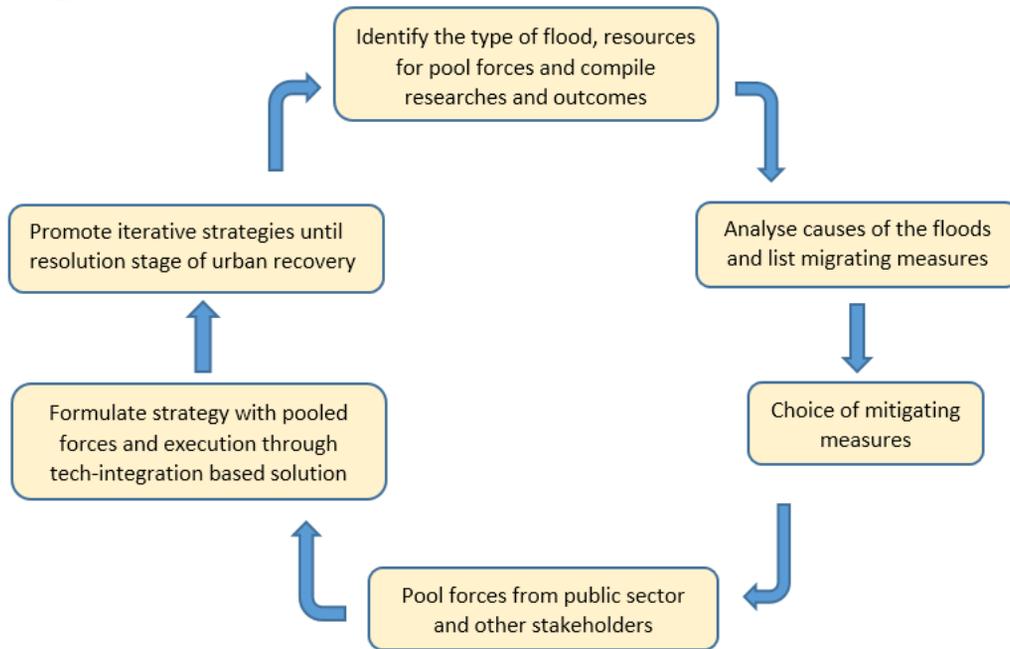


Fig. 3: Proposed strategic management model framework for urban recovery

the transformative power of technology in building a more resilient and adaptive disaster management framework. A study indicated that a machine learning and image processing-based solution is proposed for flood management (Munawar 2020). Hence, based on the framework suggested, machine learning tools or any other appropriate tools suiting the need can be developed to overcome flood-based issues. The floods in Delhi are recorded as a case study by Gosain et al., (2009), where it is mentioned that the city has been experiencing floods of various magnitudes in the past due to floods in the Yamuna and the Najafgarh Drain systems.

#### Monitoring and evaluation framework

The establishment of a comprehensive monitoring and evaluation framework in Chennai is a significant step towards strengthening urban disaster management (Fig. 3). Regular drills, simulations, and post-disaster assessments contribute to a dynamic and adaptive urban disaster management framework.

By systematically assessing the effectiveness of response mechanisms, authorities gain valuable insights into the overall strengths and weaknesses of their strategies. This evidence-based approach

facilitates informed decision-making, ensuring that the city remains resilient and responsive to evolving risks and challenges. A framework that would resolve such issues should be formulated and executed effectively. Executing aspects such as restoration of existing wetlands, proper planning of urban development, improving preparedness and relief services, and increasing coordination between different provincial and federal departments involved in water management and flood protection are the few steps that can significantly improve the capacity to protect and manage floods in the country (Qureshi 2011).

#### International collaboration

The international collaboration that emerged in response to the Chennai floods underscores the interconnectedness of global efforts in disaster management. Financial aid, expertise, and technology from various countries and international organizations reflect a shared understanding of the global implications of such disasters. The collaboration goes beyond immediate recovery, contributing to a global dialogue on the importance of preparedness, adaptive strategies, and the role of technology in

mitigating the impact of climate-related events. The support received serves as a testament to the shared responsibility of the global community in addressing the challenges posed by extreme weather events. From an international perspective, similar cases in Pakistan, as elaborated by [Yaqub et al., \(2015\)](#), indicate that flooding is the most overwhelming natural hazard in Pakistan due to diverse ecosystems and occurs mainly due to the heavy monsoon rains throughout the country.

#### *Community education and awareness*

Chennai's proactive recognition of the vital role community education plays in disaster management is evident in the initiatives launched post-floods. Educational campaigns, evacuation procedures, emergency contacts, and adherence to building codes form the pillars of urban community engagement. The city aims to empower urban residents with knowledge, establishing a crucial foundation for building resilience at the grassroots level. While elaborating on the strategies to overcome such flood-related issues, attempts were made to efficiently and precisely map villages in the Indian subcontinent during floods via a three-stage approach that uses Polarimetric Synthetic Aperture Radar (PSAR) data. When the deluge occurred in West Bengal (Murshidabad) in 2020, the main aspect to be noted was that the people had lost physical and telephonic contact with the outside world, and food and civil supplies became the first concern of the district administration ([Roy 2000](#)). The people should manage the water resources directly, through gram panchayats, regional panchayats, or, at best, through district panchayats ([Mishra 2001](#)).

#### *Legacy and ongoing urban challenges*

Chennai acknowledges its ongoing challenges that require sustained attention despite the significant progress made. The balance between rapid urbanization and sustainable development remains a key challenge, necessitating careful urban planning and strategic initiatives. The same is highlighted as evidence in the study by [Parida and Prasad Das \(2020\)](#), as the results further show that states with better financial development experience higher per capita Gross State Domestic Product (GSDP) growth, supported by additional capital expenditure, enrolment in higher education, better

road infrastructure, and higher urbanization. Ongoing maintenance and upgrading of infrastructure are essential to ensure longevity and resilience, addressing vulnerabilities that could lead to similar disasters. Addressing socioeconomic disparities is integral to building social resilience, and Chennai's commitment to ongoing improvement sets a precedent for other urban cities facing similar challenges ([Sanjeev 2009](#)). The city leverages the legacy of the disaster to shape policies and practices for long-term resilience, emphasizing the importance of an integrated and holistic approach. Thereby, overall flood management policies in general are essential to minimize the adverse impacts of floods on the growth of real per capita Gross Domestic Product (GDP) ([Parida et al., 2021](#)). The study by [Panwar and Sen \(2020\)](#) found floods to have diverse impacts across economic sectors, the extent of which is influenced by the state-wise levels of human development and the underlying intensities of the flooding events. Various reasons, such as heavy rain during monsoon periods, lack of river connectivity, rapid urbanization, and illegal construction in urban areas with inadequate drainage and reservoir systems, are responsible for increasing the risk of exposure to floods in Indian states ([Parida 2020](#)). On the other hand, [Baghel \(2016\)](#) indicated that floods result from the overflow of land areas, temporary backwater effects in sewers and local drainage channels, the creation of unsanitary conditions, the deposition of materials in stream channels during flood recession, the rise of groundwater coincident with increased stream flow, and other problems. In general, it is said to be of great difficulty when it comes to handling the challenges of floods, and due to the loss of the live capacity of reservoirs caused by the entrapping of suspended sediments, flood management faces challenges and in their studies, they have spotted to either manage the flood or, if one is not able to manage, then they have to live with floods ([Ghosh et al., 2023](#)). This study involves research on urban-based flood management to validate the techniques already utilized for managing or handling urban disasters due to flood hazards. Based on real-time data, probabilistic forecasting, and enhanced communication channels, a prior study assessed the effectiveness of the European Flood Awareness System (EFAS) in delivering early flood warnings, to improve flood preparedness and response in urban

areas (Thielen et al., 2018). Koutsovili et al., (2023) investigated the usefulness of integrating local knowledge and viewpoints into flood management plans, as well as the efficacy of participatory mapping in evaluating flood risk at the community level in flood risk assessment and decision-making processes. The usefulness of green infrastructure in lowering the risk of urban flooding by improving infiltration, decreasing runoff, and offering several environmental advantages was investigated by Mei et al., (2018). The integration of environmentally friendly alternatives, such as rain gardens and permeable pavements, into urban planning and development plans is emphasized in this study. Jiang et al., (2021) investigated China's urban flood risk management governance to pinpoint the main obstacles to policy implementation and stakeholder coordination. It also emphasized the necessity of institutional reforms and strengthened governance mechanisms to successfully address urban flood hazards. Guo et al., (2021) assessed the use of emerging technology, nature-based solutions, and conventional engineering techniques to reduce the danger of flooding in metropolitan settings. Li et al., (2022) revealed, in a manner comparable to our work, the impact of climate change on flood risk assessments and prospects for enhancing the precision and dependability of risk assessments through sophisticated modeling approaches and scenario analysis. A few of the studies managed urban disasters caused by flooding by using modern technologies. Wang and Xie (2018) examined the use of remote sensing methods for mapping urban floods and determining the danger of flooding in urban areas. Prashar et al., (2023) evaluated the multifaceted character of urban resilience, taking into account its institutional, social, economic, and physical aspects and the study also looked at a variety of metrics and indicators that are used to evaluate urban flood resilience and guide decision-making. Similar to Wang and Xie (2018), Liu and Ma (2022) looked at how Artificial Intelligence (AI) and Geographic Information Systems (GIS) could be used to control urban floods by anticipating flood hazards, analyzing spatial data, and enhancing decision-making. These recent studies, which cover areas like the integration of AI and GIS, flood control systems, climate change adaptation, remote sensing applications, and urban flood resilience assessment, offer insightful information about current research

findings and trends in urban disaster management due to floods.

#### *Recommendations*

The case study suggested the following flood control actions based on its findings:

1. Combining structural and non-structural solutions lowers the danger of flooding.
2. Zoning laws, building rules, and floodplain mapping are used in the implementation of land-use planning regulations to identify high-risk zones and prohibit construction in areas susceptible to flooding.
3. To manage water flow and lessen the effects of floods, physical structures like levees, flood barriers, dams, and reservoirs are built and maintained.
4. Creating and putting into place reliable early warning systems that anticipate floods and promptly notify populations in danger using cutting-edge technology.
5. Providing training on flood response and evacuating techniques, informing communities about the hazards of flooding, and encouraging the creation of community-based flood management plans.
6. Incorporating adaptation strategies into infrastructure design and planning, as well as taking into account the possible effects of climate change on flood hazards.
7. Rehabilitating damaged ecosystems, like wetlands, rivers, and coastal regions, to improve their innate capacity to absorb and store water and reduce flooding.
8. Putting money into research and development to increase resilience to extreme weather occurrences, create innovative solutions for reducing flood risk, and better understand flood dynamics.
9. Increasing readiness and lowering the chance of disaster, invest in early warning systems and emergency response infrastructure.
10. Reducing exposure to flood dangers, enhancing the enforcement of land-use rules, and providing incentives for sustainable development practices.
11. Ensuring long-term viability, incorporating climate resilience concerns into infrastructure planning and design.
12. Giving conservation and restoration of ecosystems top priority to improve natural flood mitigation and support biodiversity conservation.

### *Limitations of the study*

1. Historical data and scenario planning are frequently used in strategic management approaches to predict and get ready for disasters. However, special or unanticipated difficulties that were not taken into consideration in earlier risk assessments or strategic plans might arise in the event of a flood in 2023.

2. Complex socio-economic, political, and environmental variables define urban areas (Torres et al., 2021).

3. The interconnectedness of these systems may be difficult for strategic management approaches to fully grasp and handle, which could leave gaps or oversights in disaster management plans.

4. This uncertainty and risk ambiguity may be difficult for strategic management viewpoints to take into account, which could result in less-than-ideal decision-making and response plans.

5. Coordination and cooperation between many stakeholders, such as local communities, non-governmental organizations, and government agencies, are necessary for effective disaster management (Arabiun et al., 2024).

6. The application of integrated strategic management methodologies, however, may be hampered by institutional fragmentation, competing priorities, and governance issues.

### *Future scope of this study*

Future research on a strategic management approach to managing urban disasters caused by flooding can help in creating an urban population that is more sustainable, adaptable, and resilient to flood hazards.

1. The incorporation of cutting-edge technologies like artificial intelligence, machine learning, remote sensing, and GIS into strategic management frameworks for urban disaster management can be the subject of future research.

2. Research in the future can concentrate on creating frameworks for adaptive risk assessment that take complexity, ambiguity, and changing urban dynamics into consideration.

3. Future studies can look into community-based adaptation strategies, participatory approaches, and citizen science initiatives that improve social cohesion, give people more authority, and make communities more resilient to flooding.

4. New governance frameworks and public-private partnerships that support coordinated action, resource sharing, and knowledge exchange can be the subject of future research.

5. Nature-based remedies, climate-resilient infrastructure design, and policy interventions that improve urban resilience to climate-related risks can all be explored in future research.

6. Research in the future can concentrate on institutional reforms, policy analysis, and capacity-building programs that support institutional resilience, policy coherence, and adaptive governance in the face of urban floods.

7. Future research can help academia, government, business, and civil society work together to co-create knowledge, co-produce solutions, and promote learning at all levels and in various sectors.

### **CONCLUSION**

Numerous studies have been conducted on flood scenarios in urban and suburban environments, but few researchers have attempted to analyze the study using a meta-analytic approach in earlier studies. The meta-analytic approach to the flood challenges from a strategic standpoint, rather than only focusing on disaster management, is what makes the study so important. To assure readiness in a forward-thinking manner, the study aims to analyze all flood events, address the problem from strategic perspectives, and offer technical treatments. The technical intervention that the study recommends supports the scientific approach to solving the problem of evolving the involvement of all stakeholders in disaster management, particularly in metropolitan regions that are critical to the development of the country. Besides pointing out the gaps in previous research on flood incidents and appropriate solutions, the findings of this study also provide support. This case study aims to determine and explore the main and secondary goals for enhancing India's flood resilience. Reducing ecological, infrastructure, and population sensitivity to flooding events is the main goal of increasing India's flood resilience. The initiatives that fall under the category of secondary goals include establishing early warning systems, enhancing the resilience of infrastructure, and improving nature-based solutions. Undertake comprehensive case studies of previous flood incidents in particular Indian locations to comprehend the fundamental reasons,

susceptibilities, and reactions. This can provide useful information about how well-performing current tactics are as well as highlight areas that need development. The case study of the Chennai floods in 2023 provides a comprehensive and integrated model for urban disaster management. Chennai's response exemplifies a commitment to learning, adapting, and building a more resilient and disaster-ready urban environment. Calibration of the flood model is somewhat of a procedure to address the challenges of uncertainty. The city's journey serves as a blueprint for other regions facing similar vulnerabilities, highlighting the importance of proactive policies, sustainable infrastructure, community engagement, and global collaboration. Chennai's commitment to ongoing improvement, evidenced by its acknowledgment of ongoing challenges and proactive strategies to address them, stands as a testament to the transformative power of resilience in the face of adversity. Population increases result in more urbanization, more impervious areas, less infiltration, and greater flood peaks and runoff. The case intends to assess the efficacy of Chennai's pre-flood planning and disaster preparedness measures, focusing on the implementation of principles such as forecasting, scenario planning, and resource allocation. Given the post-flood assessment, one can be in a position to evaluate the assessments conducted to identify the vulnerabilities on the one hand and determine their impact on the other. This also ensures informing future planning efforts and assessing whether Chennai is in a position to embrace the principle of continuous improvement and learn from its experiences. The emergency response does not end with the event but continues through the clean-up and resettlement stages. People will want to know what assistance will be made available, who is responsible, and how to go about seeking that assistance. Public sector authorities should develop clearly defined response policies and programs in advance. Over the years, Chennai has continued to evolve and implement lessons learned. It serves as an inspiration for urban cities worldwide seeking to build a brighter and more resilient future. Using scenario-based technologies to improve emergency response and management plans for flood disasters is one of the study's main conclusions. The study emphasizes the significance of using scenario-based technology to overcome the difficulties associated with flood catastrophes and

enhance the efficacy of urban disaster management by offering a structured framework for decision-making and response planning in the face of flood disasters. The research findings are made more urgent and useful by this temporal component since it can have a direct impact on current and future crisis management plans. Analyzing the strategic planning, coordination, and execution of organizations, governments, and other stakeholders' responses to disasters is a key component in approaching urban catastrophe management from a strategic management perspective. Thus, this case study provides a framework for understanding and addressing the complex challenges associated with floods in India, leveraging insights from diverse research projects and reference frames to inform policy and decision-making. By prioritizing the main and secondary goals outlined in this case study and implementing recommended strategies, India can enhance its resilience to floods, protect vulnerable communities, and build a more sustainable and resilient future. The study can pinpoint specific lessons learned, difficulties encountered, and best practices used during the response and recovery stages by concentrating on a particular event, such as the flood of 2023. Future local and international catastrophe preparedness and management plans may benefit from these findings.

#### **ACKNOWLEDGEMENT**

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The authors of this study express their gratitude to all the contributors who shared their views during the occurrence of floods in the Chennai area. Those contributors included the public, reporters, non-profit organizations, and government officials who supported the authors throughout the process of carrying out this case study.

#### **AUTHOR CONTRIBUTIONS**

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R. Thirumurugan contributed the main content in terms of the introduction of the case study and the objectives. S. Kundhavai conducted the literature review and analysis. D. Sivakumar contributed critical thought to make the manuscript technically sound and also helped in drawing the results and interpretation of the meta-analytic review. S.B. Inayath Ahamed compiled the content, completed some of the manuscript writing, and added his contribution in terms of recent literature reviews that

were required for the case analysis.

### CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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### PUBLISHER'S NOTE

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### ABBREVIATIONS

ABBREVIATIONS	DEFINITION
%	Percent
AI	Artificial Intelligence
cm	Centimetre

EWS	Early Warning Systems
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GSDP	Gross State Domestic Product
H	Hour
IMD	India Meteorological Department
INSAT-3D	Indian National Satellite System – three-dimension
NDRF	National Disaster Response Force
NGOs	Non-Government Organizations
PSAR	Polarimetric Synthetic Aperture Radar

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**HOW TO CITE THIS ARTICLE**

Thirumurugan, R.; Kundhavai, S.; Sivakumar, D.; Inayath Ahamed, S.B., (2024). Analysis of the 2023 flood scenario for urban disaster management from a strategic management perspective. *Int. J. Hum. Capital Urban Manage.*, 9(4): 715-734.

DOI: [10.22034/IJHCUM.2024.04.11](https://doi.org/10.22034/IJHCUM.2024.04.11)

URL: [https://www.ijhcum.net/article\\_713413.html](https://www.ijhcum.net/article_713413.html)

