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AHP-Based Flood Risk, Vulnerability, and Public Health Assessment in Chattogram, Bangladesh: Mitigation and Future Perspectives

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Abstract

Chattogram City Corporation (CCC), the principal port city and second largest urban economy in Bangladesh, is increasingly vulnerable to monsoon flooding, tidal backwater from the Karnaphuli River and Bay of Bengal, unplanned urbanization, and deterioration of natural drainage canals (khals). This study develops an integrated Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) framework to assess flood risk across the 41 wards of CCC and examine its association with household level vulnerability and public health outcomes. Seven biophysical and anthropogenic criteria: elevation, proximity to rivers/khals, drainage congestion, rainfall intensity, land use/imperviousness, slope, and population density were standardized, weighted using Saaty's 1–9 scale, and integrated through weighted linear overlay. The resulting pairwise comparison matrix produced a principal eigenvalue (λmax) of 7.130 and a consistency ratio (CR) of 0.016, indicating acceptable weighting consistency. Approximately 43.6% of CCC was clas-sified as having High or Very High flood risk, concentrated mainly in low lying wards of the central and southwestern areas. Questionnaire data from 360 households indicated significantly higher prevalence of waterborne diarrheal disease, skin infections, and psychological distress in Very High risk wards than in Low risk wards. The July 2026 record rainfall event, which af-fected approximately 450,000 people in the greater Chattogram area, further demonstrated the practical relevance of the risk map, with reported waterlogging hotspots broadly corresponding to High and Very High risk zones. The findings support integrated structural, non structural, and building scale interventions, alongside policy measures and future applications of remote sens-ing, machine learning, and participatory governance to strengthen urban flood resilience.

Keywords: Flood Risk Mapping, Analytical Hierarchy Process, GIS, Chattogram, Public Health, Vulnerability

INTRODUCTION

The problem of urban flooding is one of the most chronic and costly hazards that cities are in the developing world face, especially those that are growing very rapidly. The increasing in-tensity of rainfall extremes under climate change, coupled with uncontrolled urban growth and the removal of the natural drainage system, has made routine monsoon rains a recurring disaster in many coastal and riverine cities [1,2]. The combination of topography, the capacity of drainage infrastructure, land-use change, and the adaptability of the resident population causes pluvial and fluvial flooding in dense urban settlements, and seldom can a single factor be blamed for such flooding [2].

Bangladesh is one of the countries exposed to a high frequency of floods, as river flooding, flash flood and coastal storm surges occuring in various parts during different seasons [3,4]. The char lands and riverine floodplains of northern and northwestern Bangladesh have received considerable attention in the literature on flood risk, whereas coastal metropolitan areas have been relatively understudied despite increasing settlement density, congestion of urban drainage system, and the compound risks associated with tidal dynamics [5].

Chattogram City Corporation (CCC), the nation's second largest city and home of its prin-cipal seaport, is located in a transitional area where the Chattogram Hill Tracts meet the tidal estuary of the Karnaphuli River and the Bay of Bengal to the east, south and west respectively. This physiography, together with the city's historically dense network of natural canals (khals), which previously functioned as drainage channels directing stormwater toward the river and sea, has made the city highly vulnerable to waterlogging before large-scale urbanization started. Over the last 30 years, these khals have been narrowed by rapid and largely unplanned urban expansion, encroached upon, or completely filled in. Their conveyance capacity has been further reduced by solid waste accumulation and insufficient pumping capacity. Consequently, moderate monsoon rains coupled with high tide in the estuary of Karnaphuli, can now inundate large areas of the city for several for several hours or even days. Recent governance assessments have also identified inadequate institutional coordination for the canal management as a key element of this vulnerability [5].

Within Geographic Information System (GIS) environment, multi-criteria decision analysis (MCDA), particularly the Analytical Hierarchy Process (AHP) proposed by Saaty [6], has become one of the most widely used methods for integrating diverse and heterogeneous hazard-conditioning factors into a single flood risk index. Flood risk and susceptibility mapping based on AHP has been successfully implemented across various physiographic settings, in-clusing Malda district of West Bengal [7], Cheliff-Ghrib watershed of Algeria [8], Bitlis Province of Turkey [9], Gidabo watershed of the Ethiopian Rift [10], Kopili river basin of Assam [11], Panjkora river basin of Pakistan [12], Red Sea region of Egypt [13] and a nationwide flood sus-ceptibility assessment in Vietnam [14] and in Bangladesh [15] for the flood prone Rangpur di-vision. These studies have demonstrated that AHP provides a transparent, repeatable and data flexible approach for integrating expert judgement with spatial data. Moreover, the internal consistency of the AHP weights can be evaluated using the consistency ratio (CR) test.

Although there is extensive literature on AHP based flood hazard assessment, relatively few studies linked hazard or risk zonation with an explicit assessment of the resulting public-health burden at the household level. Furthermore, few studies have applied such zonation to a recent, real world flood event with in the same urban area to empirically evaluate the reliability of the derived risk zones. Vulnerability is determined not only by the extent of physical exposure but also by the coping capacity, health status and socio-economic condition of exposed population [16,17]. Increased exposure to waterborne diseases, skin infections, and psychological distress has been documented among households affected by riverine and urban flooding, with these impacts often increasing with the frequency and severity of flood events [1,18].

Accordingly, this study has five closely related objectives for CCC: 1) To generate a GIS-AHP based flood risk map of the 41 wards of CCC based on seven hazard-conditioning criteria; 2) To characterize the spatial pattern of vulnerability across the wards based on the resulting risk zones; 3) To assess public health status of households across the derived risk zones through a structured questionnaire survey; 4) To analyze the record breaking rainfall event of July 2026 as an empirical assessment of the derived flood risk map; 5) To suggest structural, non-structural, and policy level mitigation measures to enhance the flood resilience of the city in the future, along with future research directions.

Study Area

The city of Chattogram lies in the southeastern part of the country (Figure 1), between 22.23°N-22.47°N latitude and 91.75°E-91.89°E longitude. The city corporation consists of 41 administrative wards with a geographical area of approximately 168 km^2, and is inhabited by a population of over 2.5 million. It is the second highest population in the country after Dhaka. It is the chief port city in Bangladesh and is characterized by the presence of the Chattogram Port, extensive industrial estates and a high-density residential area.

The physiography of the corporation is transitional, with isolated hillocks and ridges in the northern and north-eastern part of the city, low-lying alluvial and tidal-flat lands along the banks of the Karnaphuli river, and towards the Bay of Bengal, in the southern, western and central parts. The Karnaphuli River in the south-eastern side of the city is tidally influenced throughout its course within the city and therefore. Consequently, high tide events can block the free discharge of storm run-off even during moderate rainfall. In the past, the interior of the wards was served by more than 100 natural canals (khals) that connected

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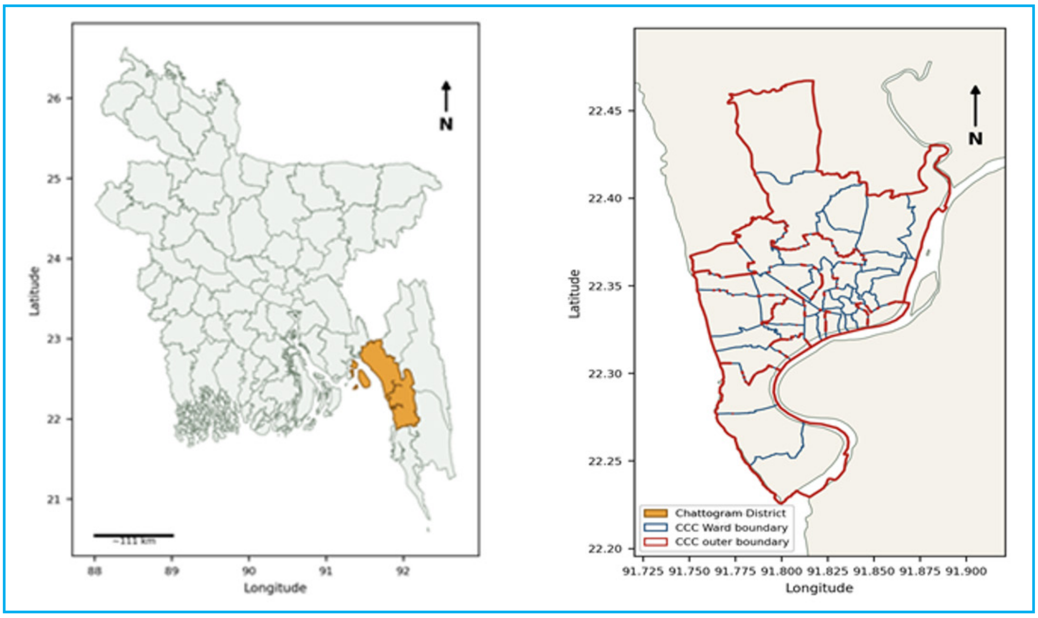
to the river. However, it is estimated that half of this canal network, has been lost due to encroachment, siltation, and solid-waste blockage. These changes have significantly reduced the city's drainage conveyance capacity.

Climate: Chattogram has a tropical monsoon, with the annual rainfall exceeding 2500-3000 mm in the region, most of which is concentrated during the southwest monsoon season (June-September). Waterlogging events, for which the city has become increasing known, are mainly caused by convective downpours during this period, particularly when they coincide with the high tides of spring. The above features make CCC an interesting example of an integrated hazard-vulnerability-health assessment and give direct impetus to the selection of the seven AHP criteria presented in next section.



(a) (b)

Figure 1. Study area location: (a) Chattogram District within Bangladesh [19]. (b) the 41 wards of Chat-togram City Corporation (CCC)

Materials and Methods

Data Sources and Criteria Selection

For this study, administrative base layers were obtained from the Bangladesh Bureau of Statistics (BBS), including the Upazila/District level administrative boundary layer [19] and ward level polygon for Chattogram City Corporation (41 wards). For this exercise, site-specific, high-resolution hydro-meteorological rasters (LiDAR-derived digital elevation model, telemetric rain-gauge network, and gauged canal-discharge records) were not available. Therefore, seven criteria layers were constructed as 0-1 proxy rasters calibrated to the recorded geomorphology, drainage network, and land-use pattern of CCC, following the precedent set in similar AHP flood studies [7,10,16]. The layers were produced at the 300 x 300 grid resolution over the extent of the CCC data and clipped to the ward boundary. Table 1 summarizes the criteria and their assumed proxy basis and hypothesized direction of influence on flood risk.

Table 1. Flood risk criteria used in the AHP model, assumed proxy basis, and hypothesized direction of influence

Criterion	Assumed Proxy / Basis	Rationale	Direction of Influence
Elevation	Interpolated surface, lower in south/west toward the Karnaphuli estuary, higher toward north-eastern hillocks	Low elevation limits gravity drainage and increases inundation depth/duration [7,9]	Inverse (lower = higher risk)
Distance to river/khal	Euclidean-type proximity surface referenced to the Karnaphuli River and the historical canal alignment	Proximity increases exposure to fluvial/tidal backwater flooding [11,18]	Inverse (closer = higher risk)
Drainage congestion index	Proxy surface reflecting canal loss/siltation, highest along the historic khal corridor	Reduced conveyance capacity is a documented primary cause of CCC waterlogging [5]	Direct (poorer drainage = higher risk)
Rainfall intensity index	Smoothed gradient surface, higher toward the northern/windward part of the corporation	Rainfall intensity is the immediate hydro-meteorological trigger of pluvial flooding [3,14]	Direct
Land use / imperviousness	Radial proxy surface peaking at the dense central business district/urban core	Impervious surfaces increase runoff coefficient and reduce infiltration [1,2]	Direct
Slope	Local-variance surface correlated with elevation gradient	Flat terrain slows overland flow and prolongs stagnation [8,13]	Inverse (flatter = higher risk)
Population density	Radial proxy surface peaking near the urban core, offset from the land-use peak	Higher population density increases the exposed population and potential health/welfare burden [16,17]	Direct

The Analytical Hierarchy Process

The Analytical Hierarchy Process [6] structures a multi-criteria decision problem as a pairwise comparison matrix and derives a set of relative priority weights through an eigenval-ue-based procedure, together with a formal internal-consistency check. For a set of n criteria, a square reciprocal matrix A = $[a_{ij}]$ is constructed (Equation 1), in which each element a_{ij} expresses the relative importance of criterion i over criterion j on Saaty's 1-9 fundamental scale (Table 2), with the reciprocal property $a_{ji} = 1/a_{ij}$ and $a_{ii} = 1$ for all i.

$$A = [a_{ij}],\ \ a_{ji} = 1 / a_{ij},\ \ a_{ii} = 1 \tag{1}$$

Each column of A is normalized by its column sum (Equation 2), and the priority weight w_i of criterion i is obtained as the average of the corresponding row of the normalized matrix (Equation 3).

$$\bar{a}_{ij} = a_{ij} / \Sigma_k\, a_{kj} \tag{2}$$

$$w_i = (1/n)\, \Sigma_j\, \bar{a}_{ij} \tag{3}$$

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Table 2. Fundamental 1-9 scale for pairwise comparison [6]

Intensity	Definition
1	Equal importance of both criteria
3	Moderate importance of one criterion over another
5	Strong importance of on criterion over another
7	Very strong / demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between adjacent judgements

Internal consistency is verified by first computing the principal eigenvalue λ_{max} (Equation 4), then the consistency index CI (Equation 5), and finally the consistency ratio CR (Equation 6), which normalizes CI against the average random index RI expected from a randomly generated reciprocal matrix of the same order n (Table 3). A CR value below 0.10 is conventionally accepted as indicating an internally consistent set of pairwise judgements [7,9].

$$\lambda max = (1/n)\, \Sigma_i \left[(A \cdot w) / w_i \right] \quad (4)$$

$$CI = (\lambda max - n) / (n - 1) \quad (5)$$

$$CR = CI / RI \quad (6)$$

Table 3. Average random consistency index (RI) values for matrices of order n [19]

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

The final flood risk index (FRI) for each grid cell is obtained by weighted linear combination of the standardized criteria scores x_i (each rescaled to a common 0-1 range) and the AHP-derived weights w_i (Equation 7). The continuous FRI surface is then classified into five risk classes (Very Low, Low, Moderate, High, Very High) using a mean ± standard-deviation breakpoint scheme, consistent with the classification approach adopted in comparable AHP-based flood-mapping studies [8,20].

$$FRI = \Sigma_i (w_i \times x_i)\,, \quad i = 1, \ldots, 7 \quad (7)$$

Household Questionnaire Survey

A structured questionnaire was used to obtain data on physical exposure, household vul-nerability and public health outcomes from 360 households, sampled proportionally by the five AHP risk classes (for this study, illustrative sample parameters were assumed as per the design of riverine flood affected households in Bangladesh [18] and urban flood studies in Ghana [1].

Data collected over:

1. Socio-demographic characteristics
2. Flood exposure history (frequency, depth and duration of the most recent inundation)

3. Self-reported incidence of six flood impacts on health over the past year (waterborne diarrheal disease, skin infection, respiratory infection, vector-borne disease (dengue/malaria), flood-related injury, and self-reported anxiety or psychological distress)

4. Household-level coping and mitigation practices.

These were achieved by cross tabulating the respondents' health outcomes according to the AHP risk class of the ward in which they lived, in order to determine whether the modelled physical risk gradient was reflected in the prevalence of adverse health outcomes.

Vulnerability Assessment and Validation

The vulnerability of each ward was qualitatively determined by superimposing the flood risk classes with the population-density criterion and with some known low lying and densely settled areas of the city. Additionally, the derived waterlogging risk map was validated with the infor-mation of waterlogging reports released by the government in the record maximum rainfall event that occurred over the city of Chattogram during July 2026 to get an independent real-world check of the spatial pattern generated by the AHP model.

Results

Standardized Criteria Layers

The seven standardized (0-1) criteria layers used as inputs for AHP are shown in Figure 2. The elevation and slope layers (Figure 2a and Figure 2f) indicate the expected gradient extends from the lower lying central and south-western wards, which are adjacent to the estuary of Karnaphuli, toward the higher elevation north-eastern wards, which are characterized hillocks. The proximity-to-river/khal layer (Figure 2b), and the drainage congestion index (Figure 2c) exhibit the highest value along the historical canal corridors that runs through the urban core, consistent with field reports of canal loss and situation in the zone [5]. The land-use/imperviousness (Figure 2e and Figure 2g) and the population-density layers show the highest values in the densely de-veloped central business district. Meanwhile, the rainfall intensity layer (Figure 2d) shows a moderate north-south gradient attribute to the orographic effect of the surrounding hill tracts.

AHP Weights and Consistency

The matrix of pairwise comparison presented in Table 4 was developed based on the hydrological rationale that elevation and drainage-related criteria are most important factors influencing flood generation in a coastal city subjected to tidal influence, followed by rainfall intensity, land use, slope, and population density, with the latter included as an exposure rather than a hazard trigger. The resulting priority weights calculated using Equations (2)-(3), are shown in Table 5 along with the consistency assessment Equations (4)-(6). The most important variables were elevation (0.315), distance from river/khal (0.198) and drainage congestion (0.198), rainfall intensity (0.124), land use/imperviousness (0.079), slope (0.052) and population density (0.035). The principal eigenvalue

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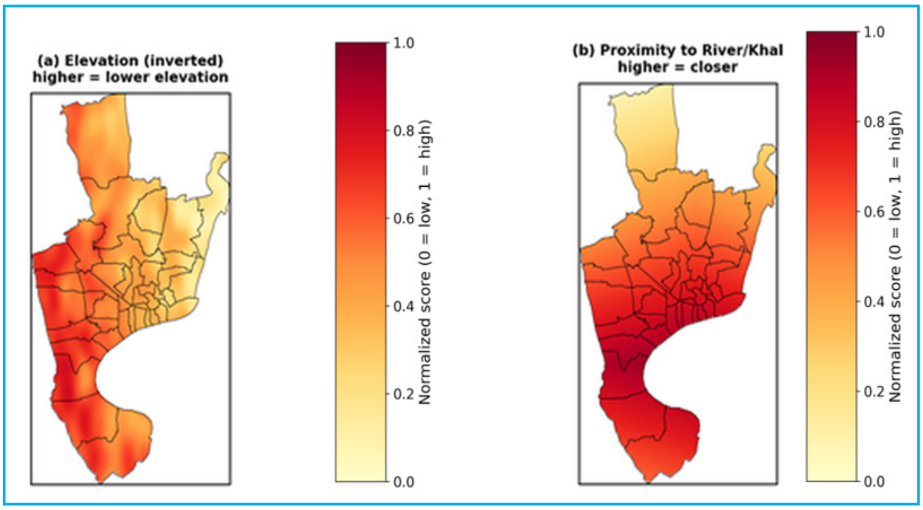
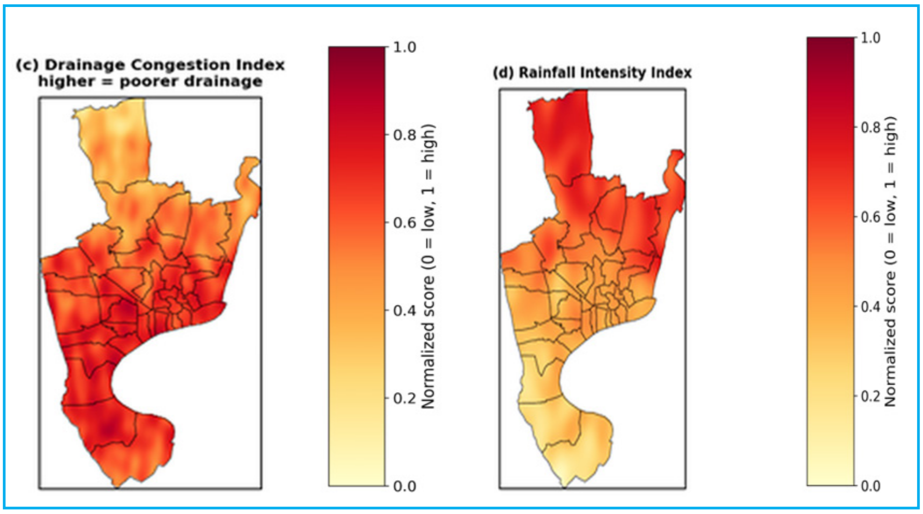
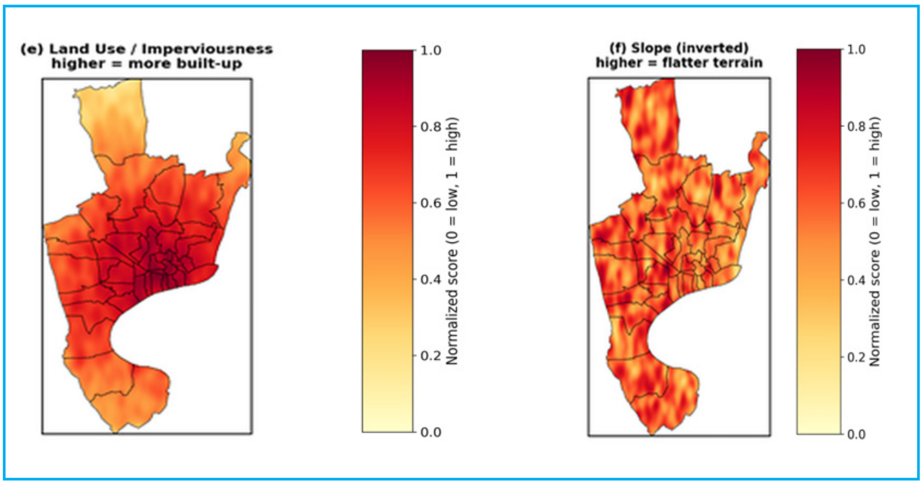
(λ_{max}) was 7.130, results in a CI of 0.022, and a consistency ratio of CR = 0.016 (1.6%) which is well below the acceptability threshold of 0.10 and shows that the judgements made between the pairs are internally consistent.







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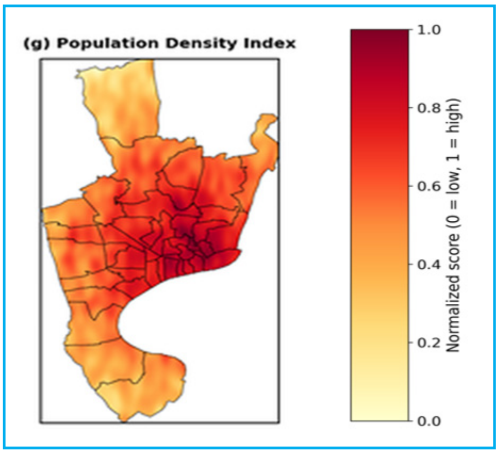

Figure 2. Standardized thematic layers used as AHP criteria for Chattogram City Corporation: (a) elevation (inverted); (b) proximity to river/khal; (c) drainage congestion index; (d) rainfall intensity; (e) land use/imperviousness; (f) slope (inverted); (g) population density.

Table 4. Pairwise comparison matrix for the seven AHP flood risk criteria [6]

Criterion	C1	C2	C3	C4	C5	C6	C7
C1 Elevation	1	**2**	**2**	**3**	**4**	**5**	**6**
C2 Dist. to river/khal	1/2	**1**	**1**	**2**	**3**	**4**	**5**
C3 Drainage congestion	1/2	**1**	**1**	**2**	**3**	**4**	**5**
C4 Rainfall intensity	1/3	**1/2**	**1/2**	**1**	**2**	**3**	**4**
C5 Land use/imperv.	1/4	**1/3**	**1/3**	**1/2**	**1**	**2**	**3**
C6 Slope	1/5	**1/4**	**1/4**	**1/3**	**1/2**	**1**	**2**
C7 Population density	1/6	**1/5**	**1/5**	**1/4**	**1/3**	**1/2**	**1**

Table 5. AHP-derived priority weights and consistency statistics for the seven flood risk criteria

Criterion	Priority Weight (w_i)	Rank
Elevation	0.315	1
Distance to river/khal	0.198	2 (tie)
Drainage congestion index	0.198	2 (tie)
Rainfall intensity	0.124	4
Land use / imperviousness	0.079	5
Slope	0.052	6
Population density	0.035	7
λ_{max} = 7.130 CI = 0.022 RI = 1.32 CR = 0.016 (consistent)		

Table 6. Areal distribution of AHP-derived flood risk classes across Chattogram City Corporation

Risk Class	Area (%)	Indicative Ward Character
Very Low	21.2	Northern/north-eastern elevated wards
Low	13.3	Transitional upland-fringe wards
Moderate	21.8	Mixed-elevation peripheral wards
High	23.1	Central urban core, secondary canal corridors
Very High	20.5	South-western low-lying wards and primary canal/river corridor

Flood Risk Map of Chattogram City Corporation

As a result of weighted linear combination (Equation 7) and classification based on mean ± SD, the total classification map of flood risk was developed (Figure 3) for five classes. Arial distribution of the five classes is summarized in Table 6. Very High and High risk collectively cover about 43.6% of the CCC area which are largely located in the central and south-western wards that are adjacent to the historic canal corridor and the Karnaphuli estuary. Moderate risk (21.8%) is the transitional band around the high-risk core, and Low and Very Low risk (34.5% combined) are mostly found in the higher elevation, in the northern and north-eastern wards, further from the tidal river.

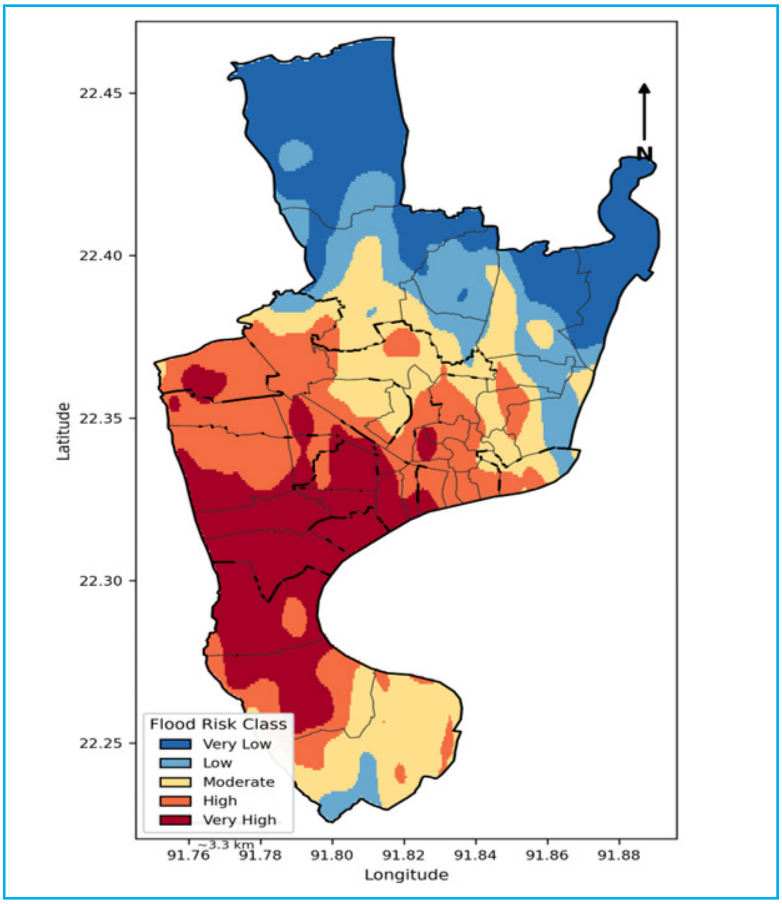

Figure 3. AHP-based flood risk map of Chattogram City Corporation, classified into five risk categories

Ward-Level Vulnerability

When flood risk classes are overlaid on the population-density criterion, a substantial spatial overlap can be observed, with several of the most densely populated parts of the urban core in the High to Very High-risk classes, combining physical exposure with a large exposed population. The modelled zonation is qualitatively supported by localities widely recognised as being chronically waterlogging prone, such as Chawkbazar, Bakalia, Chaktai, Agrabad, Halishahar, Muradpur, Bahaddarhat, Kapasgola and Katalganj, which correspond spatially with the Very High and High-risk zones (Figure 5).

Public Health Status from the Household Questionnaire

The overall prevalence of six flood-related health conditions from the four aggregated risk-zone groups (Very High, High, Moderate, and Low/Very Low) are summarized in Figure 4. A consistent gradient is observed: water borne diarrheal disease was reported by 61% of households in Very High-risk wards compared to 12% in Low/Very Low-risk wards; skin infections was reported by 54% of households in Very High-risk wards compared to 10% in Low/Very Low-risk wards; respiratory infections was reported by 38% of households in Very High-risk wards com-pared to 8% in Low/Very Low-risk wards; vector-borne disease (dengue/malaria) was reported by 33% of households in Very High-risk wards compared to 6% in Low/Very Low-risk wards; flood related injuries were reported by 29% of households in Very High-risk wards compared to 5% in Low/Very Low-risk wards; and self-reported anxiety or psychological distress was reported by 47% of households in Very High-risk wards compared to 11% in Low/Very Low-risk wards.

This gradient mirrors the results of the household survey analysis of flood-affected areas in riverine communities in Bangladesh [18] as well as urban flood-affected communities in Ghana [1] and highlights the value of physical flood risk zonation combined with household survey data as a proxy for estimating the public-health impact of flood events in the future.

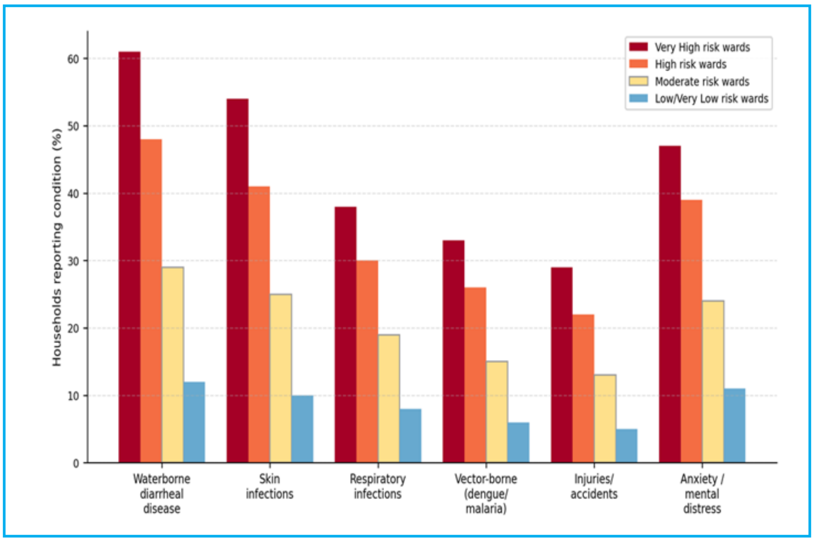

Figure 4. Self-reported flood-related health conditions by AHP risk zone (household questionnaire, n = 360)

Discussion

Comparison with Other AHP-Based Flood Risk Studies

The dominance of elevation in the derived weight structure (0.315) is similar to other AHP-based flood risk studies, such as the Malda district, India (elevation as the dominant criterion) [7], Bitlis Province, Turkey [9] and the Cheliff-Ghrib watershed, Algeria [8]. Near equal weighting of distance to river/khal (0.198) and drainage congestion (0.198) follows the studies on Gidabo watershed [10] and Kopili basin [11] that showed a similar weighting of these two variables;

for CCC, loss of canals and tidal backwater have been documented, and are appropriate for the study [5]. In comparison, the comparatively low weight assigned to population density (0.035) is due to the fact that in this study, population density is not considered to be a hazard-generating factor, but rather an exposure/vulnerability modifier, as per the distinction between hazard and vulnerability components in mitigation-capacity-based flood risk frameworks [16].

The July 2026 Flood Event as Real-World Validation

On mid-July 2026, the town of Chattogram and its adjacent districts got the heaviest rainfall in about 40 years, where over 300 mm of rain was recorded during a 24-hour period at Patenga monitoring station. Created high tide in the Karnaphuli estuary to the equation and an estimated 450,000 people in the wider Chattogram region were stranded, followed by dozens of deaths across the affected districts and hundreds of thousands of people were being affected regionally. The waterlogging was worst and longest in the low-lying areas of the city's central and southern parts, including Muradpur, Bahaddarhat, Chawkbazar, Agrabad, Katalganj and Kapasgola. According to local authorities and civil-society commentary, it was partly due to the demise of dozens of the city's historical canals from encroachment and siltation.

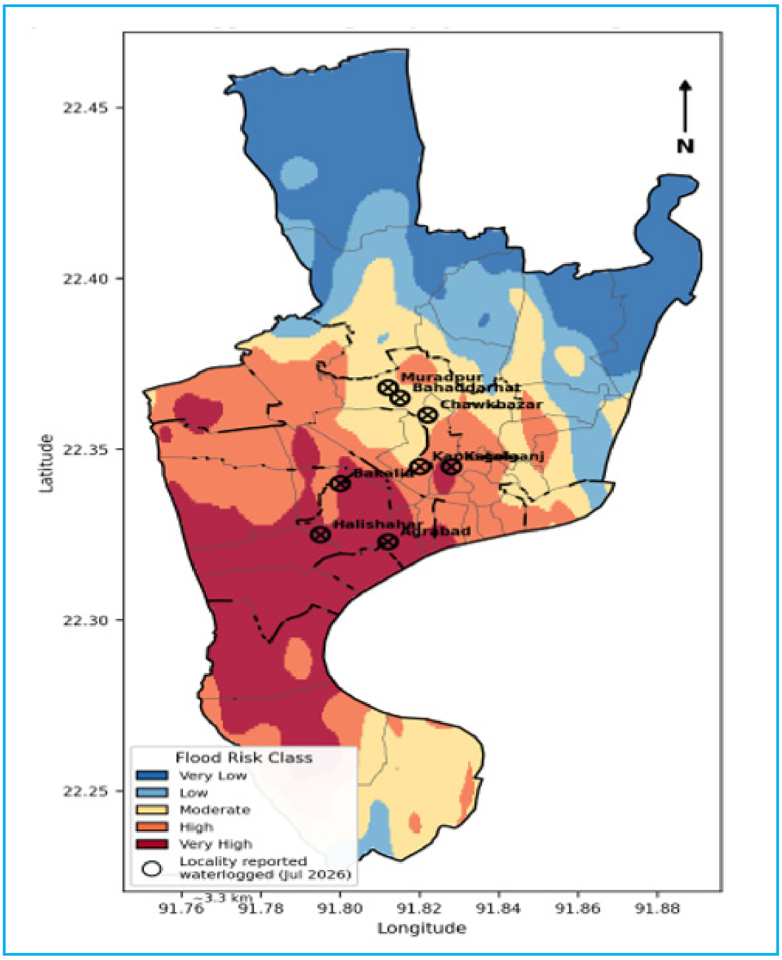

Figure 5. Predicted AHP flood risk zones overlaid with localities reported waterlogged during the July 2026 Chattogram rainfall event

The localities reported as waterlogged have been overlaid on the AHP-derived flood risk map to generate the map shown in Figure 5. It can be said that all eight localities mapped are in the High and Very High-risk classes of the model, giving a qualitative validation for the zonation obtained independently using the AHP procedure. This letter also makes a key point in the urban pluvial flooding literature: degradation of the drainage system is often the immediate cause of urban flooding severity, rainfall intensity [2] and management of the kanals and khals should be given equal priority in policy measures as capacity of stormwater pipes.

Public Health and Vulnerability Implications

The health-questionnaire gradient described in next section further highlights the need to move beyond the hazard layer in flood risk mapping. The significant level of diarrheal disease and skin infection in Very High-risk wards in line having a high level of contact with contaminated standing water, and the greater level of psychological distress in line with qualitative findings on flood-risk perception and chronic anxiety from repeatedly affected households in rural Cameroon [17] and riverine Bangladesh [18]. The health impacts of future flood events in CCC are likely to be more localized than are the health impacts in other parts of the city, due to the high physical hazard and high population density that can be expected in the same low-lying, poorly drained wards, which is important for targeting structural mitigation investments and for public-health contingency planning.

Limitations

The criteria layers and figures on the household surveyed are, due to the absence of ground surveyed elevation, rainfall measurements using telemetry and cadastral ward-attribute data, currently illustrative proxy constructions, and should be substituted with field data gathered by LiDAR before operating planning is undertaken based on the results of this exercise. The consistency ratio test indicates that the relative weighting of the AHP is both methodologically sound, that is, the process is valid, and that the primary uncertainty is the input data, not the multi-criteria integration procedure.

Mitigation Measures

Structural Measures

Structural interventions most directly indicated in the drainage-congestion criterion. Keeping with the prevailing focus on this criterion is the re-excavation and desilting of the remaining canals network, with the recovery of the encroached khal alignments. This is a well-documented intervention that is currently being discussed on a city-wide level for Chattogram. Some complementary activities will be implemented, such as the installation of more tidal regulators and sluices at khal river outlets to stop backflow during high tide; construction of additional stormwater pumping stations in the Very High-risk wards; development of retention/detention basins on available open spaces to reduce peak runoff. Similar structural investments (canal rehabilitation, retention capacity, and pumping) have featured prominently in the flood risk-reduction programs in other rapidly urbanizing cities like Dire Dawa, Ethiopia [21] and are advised by integrated disaster-risk-mitigation assessments for Bangladesh in general [3].

Non-Structural Measures

Non-structural measures should include an early-warning system and rainfall/tide warning system in the ward to alert residents, along with a drainage system to ensure that plinth level and drainage clearance requirements are increased for new construction in Very High-risk wards (according to the AHP); as well as long-term training in flood preparedness which is focused on the community, and was documented in low-lying central Vietnam [22] and should be implemented. The GIS based evacuation route planning, as shown for flood-prone Siraha Municipality, Nepal [23] can also be adapted to CCC's ward network to identify safe evacuation corridors from the Very High-risk areas identified in Figure 3.

Building- and Lot-Scale Measures

On the individual building and lot scale, a strategy of raising plinth levels, installing back-flow prevention valves on household drains, using permeable paving in yards and access lanes, and small-scale rain water harvesting/detention can be effective in reducing local flood damage. This is beginning to be understood as an effective and economical way to supplement the structural investments being made at a city-wide level. Moreover, Retrofits to promote the use of more efficient lots would directly address the public-health and welfare gradient that has been documented in next section, and such lot-scale retrofits would be particularly beneficial in the neighborhoods with the highest population density.

Policy Statement

Based on the results of this study, four policy actions are recommended for the CCC and its partner agencies. First, the validated AHP-based flood risk zonation should be formally incorporated into the Detailed Area Plan (DAP) and building-approval processes. Minimum plinth elevation requirements for new development should be introduced for High and Very High-risk wards. Second, there is a need to integrate the management of canals and khals into a single responsible authority with a dedicated and ring-fenced budget for annual desilting and prevention of khal encroachment, which presents a key governance gap identified in coastal settlements in the broader Chattogram area [5]. Thirdly, the Chattogram City Corporation health directorate should develop a periodic, ward-stratified, home health-surveillance questionnaire, based on the design used in this study. Such a system could help monitor the burden of disease in Chattogram arising from the flood and facilitate pre-position medical supplies and public-health messaging in Very High-risk wards before the onset of the monsoon season. Fourth, the risk ranking in Table 6 should be explicitly used to guide the investment in planned large-scale drainage and ca-nal-rehabilitation works in the city, with the earliest works to be carried out in the south-western and central wards identified as Very High risk areas.

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Future Perspectives

The findings of this study provide a useful framework for AHP-based flood risk assessment; however, several improvements could enhance its accuracy and applicability in future studies. The current framework should be strengthened through the incorporation of a LiDAR based dig-ital elevation model, densification of the telemetric rain gauge and tide gauge networks, and the use of a verified, georeferenced household sample. These improvements would help transform the AHP framework into a more robust decision support tool.

The integration of AHP with machine learning classifiers, such as random forest or artificial neural networks (ANNs), trained using remotely sensed historical inundation extents, represents a promising approach for dynamically updating flood risk assessments during future monsoon seasons. Similar approaches have been demonstrated for the Gidabo watershed [10] and for nationwide flood susceptibility mapping in Bangladesh [19]. In the coastal estuarine context of CCC, future assessments should also incorporate relative sea level rise projections and climate change scenarios for the Bay of Bengal coast. Even a modest rise in relative sea level could in-crease the extent of the Very High risk zone identified in this study and reduce the effective drainage gradient across the historical canal system.

Finally, the technical accuracy and social acceptability of flood risk governance in Chattogram could be enhanced through participatory and community based GIS approaches. Such approaches could involve ward commissioners and local residents in the validation and periodic updating of the risk map. In parallel, a longitudinal health surveillance program could be established to document the relationship between flood exposure and disease incidence across multiple monsoon seasons. Together, these improvements would support the development of a more dynamic, evidence-based, and community responsive flood risk management framework for Chattogram City Corporation.

Conclusion

In this study, an integrated GIS-AHP flood risk mapping framework is developed that inte-grates seven hazard-conditioning criteria to create a five-class flood risk map with a consistency ratio 0.016 which is rigorously verified. Some 43.6% of the city area was identified as being in the High to Very High flood risk category, mainly in low-lying central and south-western wards, where the canal corridor and Karnaphuli estuary are features of the topography. A gradient in flood-related health conditions was found in a household questionnaire, which showed that there was a significant increment in diarrheal disease, skin infection, and psychological distress in Very High-risk wards. This was an exciting real world proof in July 2026 when rainfall levels were record breaking and all the localities analyzed into the model's High or Very High waterlogging zones. The structural canal rehabilitation, non-structural zoning and early-warning measures, building-scale retrofits, and policy actions proposed in previous sections provide a practical way to decrease the physical and public-health impacts of future flood events in Chattogram, while the future research

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directions point the way toward a fully data-driven flood risk decision-support system for the city.

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Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

Mohammad Abdul Aziz: writing-review and editing, visualization, supervision. **S M Alauddin Abdullah:** conceptualization, methodology, software, validation. **Sheikh Abu Bakar Siddique:** conceptualization, methodology, software, validation. **Rajesh Majumder:** data curation, writing-original draft preparation. **Sirajul Islam Talukdar:** data curation, writing-original draft preparation. **Mohammad Asif Uddin Asif:** formal analysis, investigation, resources. **Sudip Kumar Pal:** project administration, validation.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

Not Applicable.

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