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Structural Analysis of Flood Consequences and Prioritization of Flood Risk Management Strategies in Ahvaz City

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Original Article

Abstract

INTRODUCTION: Urban flooding is a major hazard for cities, and its consequences in Ahvaz involve interacting environmental, physical, infrastructural, social, and managerial conditions. This study aimed to analyze the structural interrelationships among flood consequence and damage-related variables in Ahvaz city and to identify and prioritize flood risk management strategies using structural analysis and expert assessment.

METHODS: This applied study used a sequential exploratory mixed-methods design. Data were obtained through documentary review, semi-structured interviews, and expert assessments from a purposively selected panel of 50 experts. Twenty-eight consequence variables were analyzed using a 28 × 28 cross-impact matrix and MICMAC software. Subsequently, 26 structural and non-structural flood risk management strategies were evaluated through a three-round Delphi process using a five-point Likert scale.

FINDINGS: Of the 784 cells in the cross-impact matrix, 752 were non-zero, yielding a filling rate of 95.92%. The mean influence score was highest for the economic–physical group (36.1), followed by the environmental (35.2) and social groups (33.3). Social variables showed the highest mean dependence (46.7), indicating a greater degree of dependence on other variables within the system. The variables with the greatest direct influence were destruction of the urban sewage system (44), damage to urban housing and clinics and health centers (42 each), and damage to transportation vehicles and drinking-water pollution (41 each). In the second Delphi round, the highest mean importance scores were assigned to cleaning and dredging the Karun River channel (4.94), improving the wastewater and stormwater collection network (4.91), and removing meanders from the Karun River (4.87). In contrast, constructing buildings on elevated, flood-safe sites with restrictions on development in flood-prone areas and preparedness for pre-flood evacuation received the lowest mean scores (3.00 each). In the third round, the assessments showed relative stability, with only limited changes in mean scores.

CONCLUSION: Flood consequences in Ahvaz city are highly interconnected, with wastewater infrastructure, housing, and health facilities among the variables exerting the greatest influence on other consequences. Expert assessments assigned higher importance to river-channel management and drainage infrastructure, whereas land-use control and pre-flood evacuation preparedness received lower importance scores.

Keywords: Urban flooding; Flood consequences; Structural analysis; MICMAC; Delphi; Risk management; Ahvaz.

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Introduction

Floods are among the most frequent natural hazards and can cause substantial losses to human life, infrastructure, public services, and economic and social assets (1). Their impacts extend beyond direct physical damage and may disrupt essential services and adversely affect human health and well-being. Globally, floods

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affected approximately 1.65 billion people, caused more than 100,000 deaths, and resulted in about US$650 billion in economic losses between 2000 and 2019 (2). Climate change is also altering precipitation patterns and increasing the likelihood of extreme precipitation events in many regions, adding to the challenges of flood risk management, particularly in urban areas (3).

Urban flood vulnerability is not determined solely by the characteristics of the hazard. It also reflects the interaction of physical, environmental, social, and economic conditions and the capacity of urban systems to prepare for, respond to, and recover from disruptive events (4–7). Urban flooding may occur when rainfall exceeds drainage capacity or when land-use and surface characteristics reduce infiltration. Consequently, urban development, infrastructure conditions, land-use change, and climate change can shape the severity of flood impacts and the vulnerability of exposed areas (5,6). Approaches such as GIS, fuzzy logic, and multi-criteria analysis have been widely used to assess and map flood vulnerability and risk and to support spatial decision-making (8–10).

The complexity of urban flood vulnerability has also increased attention to urban resilience, which emphasizes the capacity of urban systems to maintain or restore essential functions, adapt to changing conditions, and cope with disruption (11,12). Previous studies in Iran have examined urban and environmental resilience to natural hazards (13,14), climate change and future climatic conditions in the Dez basin (15), flood risk in the Gorganrood watershed (16), and hazards under future climate conditions in Iran (17), as well as urban resilience to floods in Qaemshahr, Urmia, and Gorgan (18–20). International studies have similarly addressed heavy rainfall characteristics and flash-flood processes (21,22) and the implications of urbanization and climate change for urban flood risk (5,6). These studies demonstrate the value of combining environmental, spatial, social, and managerial perspectives in understanding flood vulnerability.

Despite this body of research, a substantial part of the literature has focused on spatial assessment, vulnerability mapping, climate projections, or the evaluation of individual dimensions of resilience and risk. Such approaches are valuable for identifying vulnerable areas and relevant factors, but they provide less information about the mutual relationships among variables within the flood-vulnerability system. In particular, identifying which variables exert greater influence on other variables and which are more dependent on changes elsewhere in the system can provide a different basis for understanding the structure of flood vulnerability. A futures-oriented structural approach, such as the MICMAC method, can therefore complement conventional spatial and descriptive assessments by helping to identify key and driving variables within a complex system (23–25).

Ahvaz, as a major urban center in Khuzestan province, requires such a multidimensional perspective because flood vulnerability and its management involve interacting physical, environmental, social, economic, and managerial conditions. Accordingly, the present study examines the interrelationships among flood consequence variables in Ahvaz, which reflect the city's vulnerability to flooding, by analyzing their influence and dependence relationships with the MICMAC method. In addition, it evaluates flood risk management strategies from the perspective of experts. The study addresses two questions: a) which flood consequence variables have the greatest influence on, and dependence on, other variables in the system; and b) which structural and non-structural flood risk management strategies are considered important by experts?

Methods

The study area was the city of Ahvaz, the capital of Khuzestan Province, Iran. The city is located at approximately 31°20′ N latitude and 48°40′ E longitude and covers an area of approximately 222 km². Ahvaz consists of eight urban districts. The Karun River passes through the city. Regional climatic characteristics, physical expansion and increasing impervious surfaces, weaknesses in parts of the surface-water drainage and wastewater collection systems, and some construction activities and land uses in flood-prone areas contribute to the city's exposure and vulnerability to flooding and urban inundation. Because some consequences considered in the study (for example, the evacuation of neighboring villages) extend beyond the city boundary, the variables describe the consequences of flooding in Ahvaz and its immediate surroundings.

Study design and participants

This applied study employed a sequential exploratory mixed-methods design comprising three stages: (a) identification of consequence

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variables; (b) structural cross-impact analysis; and (c) Delphi identification and prioritization of management strategies. The first stage was qualitative, whereas the second and third stages were quantitative. Findings from all three stages were subsequently interpreted together within a futures research framework.

A panel of 50 specialists, professionals, and managers was recruited using purposive and criterion-based sampling. Eligibility criteria included relevant university education or executive or research experience, familiarity with the conditions of Ahvaz, and specialized knowledge or professional experience in at least one of the following areas: flooding, disaster management, urban planning, urban infrastructure, environmental studies, water resources, water and wastewater management, or urban management. Participants were selected from the Governor-General's Office, the Municipality, the Governorate, and academic institutions. The same 50 experts participated in the interviews, the cross-impact assessment, and all Delphi rounds.

Of the 50 experts, 43 (86%) were male and 7 (14%) were female, and 29 (58%) held a master's or doctoral degree. By professional affiliation, 8 (16%) were academic experts (faculty members and postgraduate students), 10 (20%) were from the Governor-General's Office, 25 (50%) were from the Municipality, and 7 (14%) were from the Governorate.

Stage 1: Identification of variables

Documentary studies, a review of the theoretical foundations and research literature, and semi-structured interviews with experts were used to identify the consequences of flooding in Ahvaz. The identified items were reviewed by experts and adjusted to the local conditions of the study area. This process resulted in 28 consequence variables, classified into three groups: social (6 variables), economic–physical (16 variables), and environmental (6 variables).

Stage 2: Structural cross-impact analysis

The 28 variables were entered into a 28 × 28 structural cross-impact matrix (25). Experts assessed the direct influence of each variable on every other variable using a four-point scale: no influence (0), weak influence (1), moderate influence (2), and strong influence (3). The judgments of the experts were combined into a single matrix and analyzed using MICMAC software. Direct influence and dependence scores were obtained as the row and column sums of the matrix, respectively. The software also derives indirect influence through successive matrix multiplication (two iterations were performed), but only direct scores are reported in this article. The matrix filling rate was calculated as the proportion of non-zero cells.

Stage 3: Delphi identification and prioritization of strategies

The Delphi process was conducted in three successive rounds to identify and prioritize structural and non-structural strategies for flood hazard management in Ahvaz.

Round 1. An open-ended questionnaire was provided to all 50 experts, who were asked to propose the most important structural and non-structural strategies for managing and reducing flood hazard in Ahvaz. The responses were subjected to content review: duplicate items were removed, similar suggestions were merged, and conceptually related items were categorized. This resulted in 26 strategies (12 structural and 14 non-structural).

Round 2. The 26 strategies were presented to the same 50 experts in a closed-ended questionnaire. The importance of each strategy was rated on a five-point Likert scale from 1 (very low importance) to 5 (very high importance). The mean score and the percentage of expert agreement were calculated for each strategy. Strategies that did not reach the predefined minimum agreement level were carried forward for reassessment in the next round.

Round 3. The revised list was returned to the experts together with a summary of the Round 2 results, and experts could review and revise their ratings in light of the panel's views. Stability of views was assessed by examining changes in the mean scores. The third round showed relative stabilization with limited changes in the mean scores, so the final results were based on the consensus reached at this stage. A strategy was accepted when at least 70% of the experts rated it within the predefined acceptable importance range.

Content validity and data quality

Content validity was assessed through expert review of the initial lists of variables and strategies. Experts evaluated the items for relevance to the research topic, suitability for the conditions of Ahvaz, conceptual clarity, comprehensiveness, and suitability for analysis. Items considered irrelevant, ambiguous, or conceptually overlapping were removed, merged, or revised before the final

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instruments were used. In the Delphi stage, repeated rounds of inquiry, group feedback, and assessment of the stability of views across rounds were used to assess data quality. No formal reliability coefficient was calculated.

The MICMAC analysis identified the roles of flood consequence variables and the way their effects could propagate through the system, whereas the Delphi analysis identified the strategies that experts considered important for flood hazard management. The results of the two analyses were interpreted side by side within the futures research framework; no statistical relationship between them was tested.

Findings

A. Structure of the cross-impact matrix

The cross-impact matrix contained 784 cells (28 × 28), of which 752 received non-zero scores, corresponding to a filling rate of 95.92% (752/784). This high filling rate indicates that direct relationships were identified for most variable pairs. Thirty-two cells were assigned a score of 0, while 569, 130, and 53 cells received scores of 1, 2, and 3, respectively. Among the 752 non-zero relationships, 569 (75.7%) were weak, 130 (17.3%) were moderate, and 53 (7.0%) were strong. The system is therefore highly interconnected, with most relationships at the lowest non-zero intensity (Table 1).

Table 1. Initial analysis of the cross-impact matrix (Source: Research findings)

Indicator	Value
Matrix dimensions	28 × 28
Iterations	2
Relationships with no influence (0)	32
Relationships with weak influence (1)	569
Relationships with moderate influence (2)	130
Relationships with strong influence (3)	53
Total non-zero relationships	752
Filling rate	95.92%

B. Influence and dependence by variable group

The economic–physical group had the highest total direct influence (577), followed by the environmental (211) and social (200) groups. The same order was not seen for dependence: the economic–physical group again recorded the highest total (525), but the social group (280) exceeded the environmental group (183). Because the economic–physical group contained 16 variables whereas the social and environmental groups each contained 6, per-variable means provide a more appropriate basis for comparison (Table 2).

Mean influence was similar across the groups, ranging from 33.3 (social) to 36.1 (economic–physical). Differences were greater for mean dependence. The social group had a mean dependence of 46.7 against a mean influence of 33.3; the corresponding values were 36.1 and 32.8 for the economic–physical group, and 35.2 and 30.5 for the environmental group. At the system level, total influence and total dependence were both 988 (mean 35.3). Social variables thus showed greater mean dependence than influence, whereas the economic–physical and environmental groups showed slightly greater influence than dependence.

Table 2. Influence and dependence totals and per-variable means by group

Group	Variables	Total influence	Total dependenc	Mean influence	Mean dependenc
Social	6	200	280	33.3	46.7
Economic–physical	16	577	525	36.1	32.8
Environmental	6	211	183	35.2	30.5
All variables	28	988	988	35.3	35.3

At the overall system level, total influence and total dependence were both 988, with a mean score of 35.3 for each. Thus, social variables showed greater mean dependence than mean influence, whereas the economic–physical and environmental groups showed slightly greater mean influence than mean dependence. Group-level results are presented in Table 2.

C. Influence and dependence of individual variables

In the social group, the highest influence scores were for loss of life and increased numbers of injured and missing persons (37) and disruption in access to primary health and medical services (37). The highest dependence scores were for disruption in access to primary health and medical services (51), social disorder (50), and disruption of social order and evacuation of villages neighboring Ahvaz (47 each).

In the economic–physical group, destruction of the urban sewage system had the highest influence score (44), followed by destruction of urban housing and of clinics and health centers (42 each), damage to transportation vehicles (41), and destruction of parks and green spaces (40). The highest dependence score was for loss of property and assets (44), followed by damage to the road and bridge network and destruction of urban housing (39 each).

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In the environmental group, drinking water pollution had the highest influence score (41), followed by loss of agricultural land (39) and destruction of vegetation and fauna resources (37). Flood-related waste and debris scored 36, and outbreak of infectious diseases 30. Dependence scores in this group ranged from 29 to 32, the highest being for soil erosion and loss of agricultural land (32 each). Scores for all 28 variables are given in Table 3.

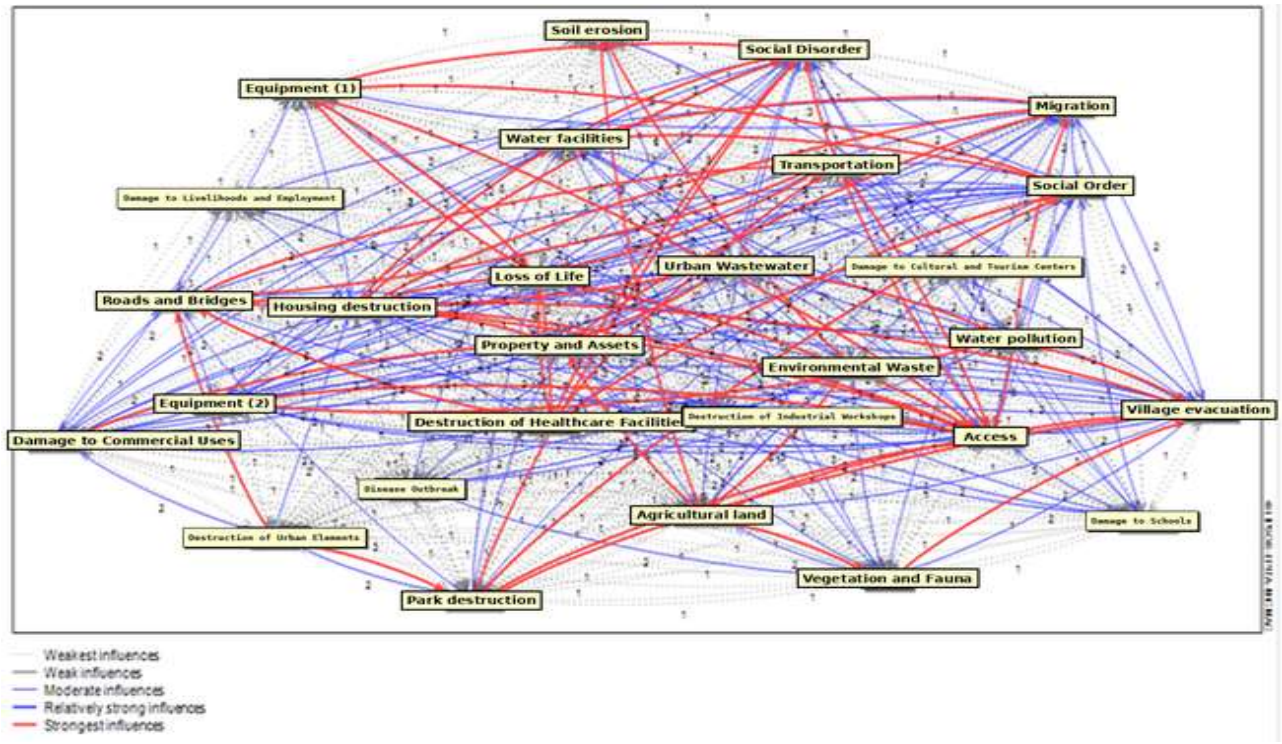


Figure 1. Direct influence graph with 100% coverage by variable (Source: Research findings)

Table 3. Direct influence and dependence of flood consequence variables in Ahvaz

Group	Variable	Influence	Dependence
Social	Loss of life and increased numbers of injured and missing persons	37	42
	Propensity to migrate	33	43
	Disruption of social order	30	47
	Social disorder	29	50
	Disruption in access to primary health and medical services	37	51
	Evacuation of villages neighboring Ahvaz	34	47
Economic–physical	Loss of property and assets	35	44
	Damage to the road and bridge network	35	39
	Destruction of parks and green spaces	40	29
	Destruction of urban elements	33	27
	Destruction of urban housing	42	39
	Damage to commercial uses (supermarkets, stores, etc.)	37	32
	Damage to transportation vehicles (particularly light and private vehicles)	41	33
	Destruction of and damage to urban equipment and infrastructure (water, electricity, gas, telephone, and internet)	38	37
	Destruction of clinics and health centers	42	32
	Destruction of medical and laboratory equipment	36	30
	Destruction of schools	32	28
	Damage to cultural and tourism centers	27	29
	Damage to livelihoods and employment	31	27
	Damage to water and wastewater facilities (drinking water supply system, pipelines, tanks, pumping stations, and treatment plants)	36	36
	Destruction of the urban sewage system	44	34
	Destruction of industrial workshops	28	29
Environmental	Drinking water pollution	41	30
	Soil erosion	28	32
	Loss of agricultural land	39	32
	Destruction of vegetation and fauna resources	37	30
	Flood-related waste and debris	36	29
	Outbreak of infectious diseases	30	30

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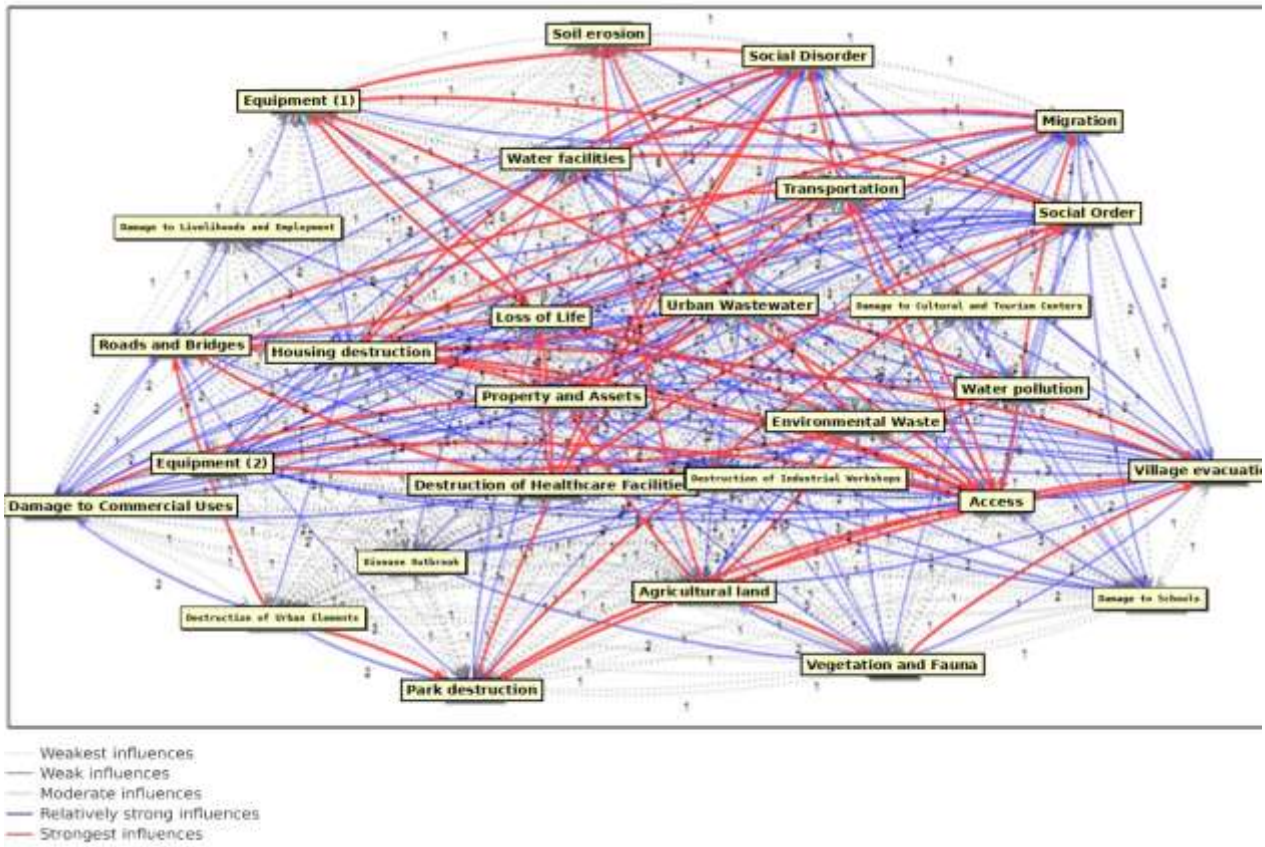


Figure 2. Direct influence graph with 75% coverage by variable (Source: Research findings)

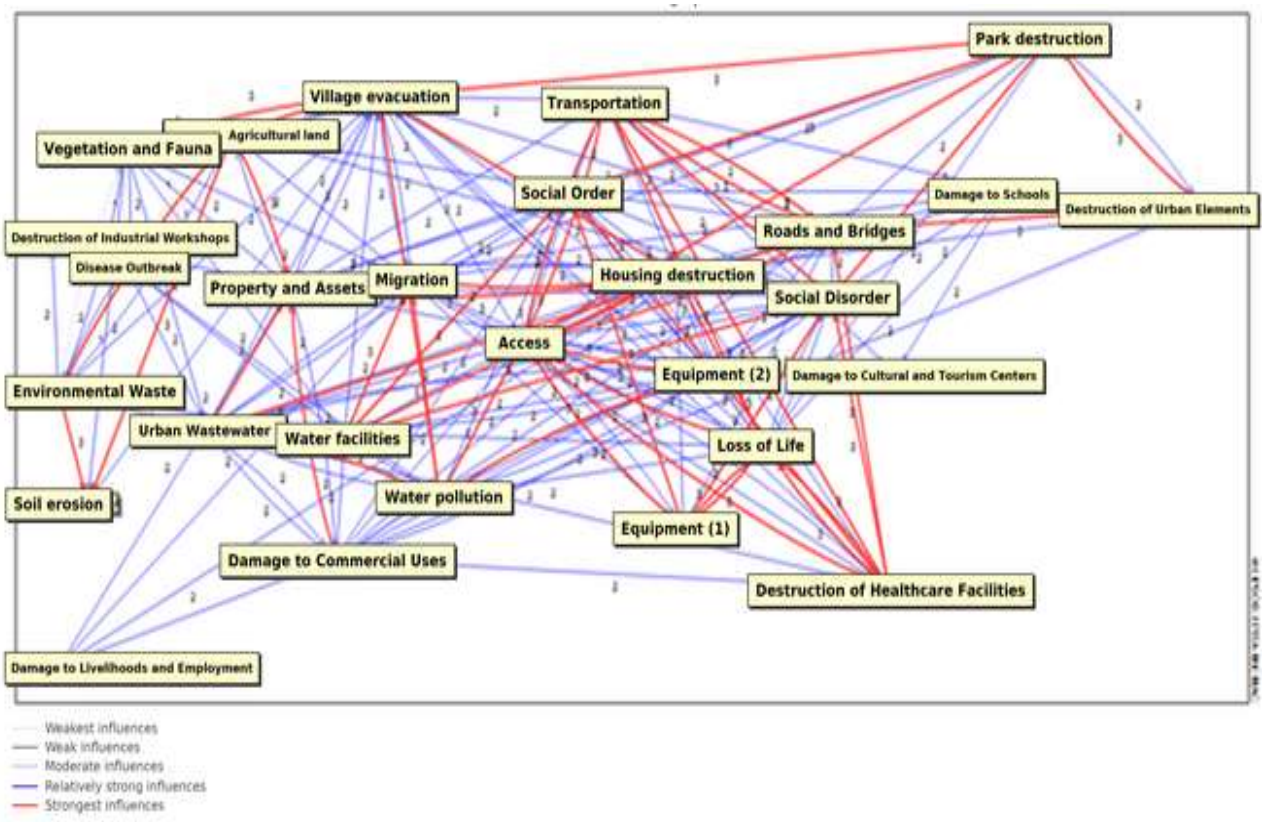


Figure 3. Direct influence graph with 25% coverage by variable (Source: Research findings)

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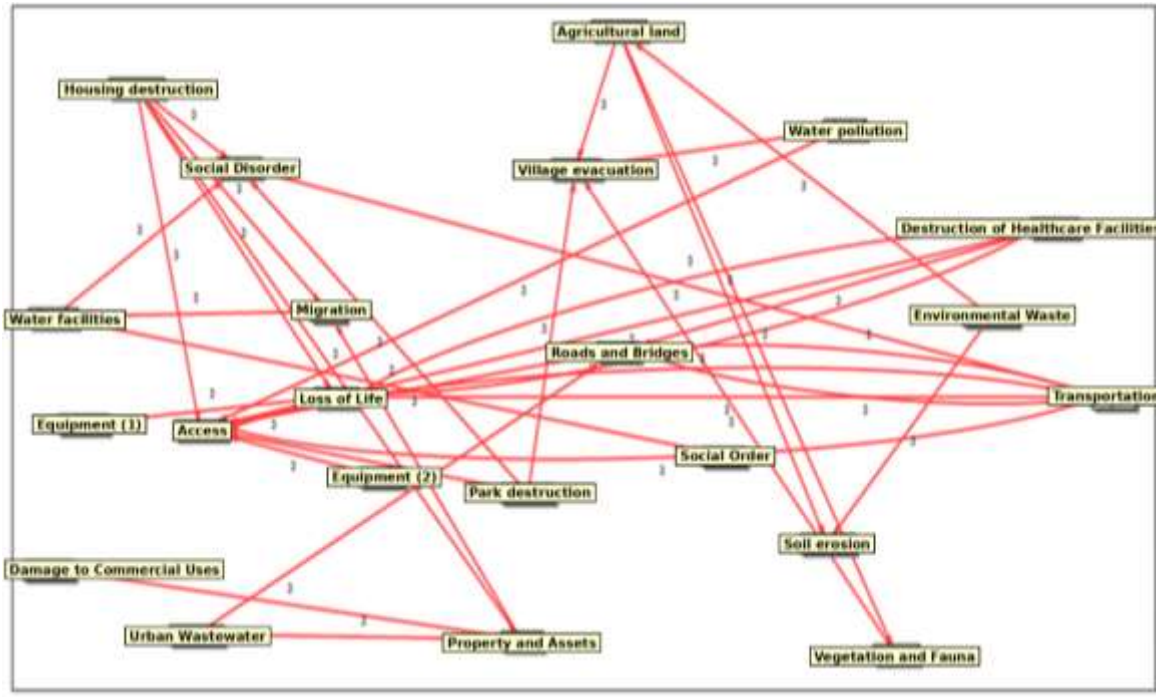


Figure 4. Direct influence graph with 5% coverage by variable (Source: Research findings)

Table 4. Flood risk management strategies identified in the first Delphi round

No.	Strategy	Frequency (n)
1	Cleaning and dredging the Karun River channel	50
2	Removal of meanders from the Karun River and establishment of a suitable alignment	48
3	Stabilization or protection of riverbanks and unstable slopes using protective coverings	42
4	Construction of transverse walls to modify the flow pattern and divert flow from erodible sections	40
5	Construction of longitudinal structures, such as flood-control walls, to increase flow conveyance capacity and protect adjacent land	50
6	Construction of upstream flood diversion channels or structures	50
7	Construction of upstream detention or open dams	50
8	Artificial recharge of groundwater resources through flood spreading, recharge wells, and induced methods	50
9	Improvement of the wastewater and stormwater collection network	50
10	Construction of trenches around critical facilities for water conveyance	40
11	Construction of buildings on elevated and flood-safe sites and prevention of development in flood-prone areas	48
12	Temporary protection of buildings using earth embankments, such as sandbags, or temporary flood-control walls in areas exposed to flooding	38
13	Public information dissemination and use of flood forecasting and warning systems	50
14	Delineation of the riverbed and river corridor and prevention of land-use changes within the corridor	50
15	Prevention of unnecessary recreational development along the Karun River	44
16	Preparation of flood inundation and zoning maps	50
17	Public education and awareness activities on floods	50
18	Preparedness for timely and rapid evacuation of people and valuable property before flooding	43
19	Continuous monitoring of the Karun River and communication with the Meteorological Organization to forecast rainfall and estimate flood intensity and duration	40
20	Issuance of timely warnings according to the level of risk in each designated flood-prone zone	46
21	Protection of major access routes and prevention of blockage of waterways during floods	43
22	Strengthening disaster management	48
23	Establishment of community-based relief centers and monitoring their preparedness	50
24	Increasing machinery and equipment for repairing flood-related damage	46
25	Prevention of overlapping responsibilities and organizational confusion among agencies responsible for assistance to flood-affected areas	41
26	Provision of temporary shelter sites	48

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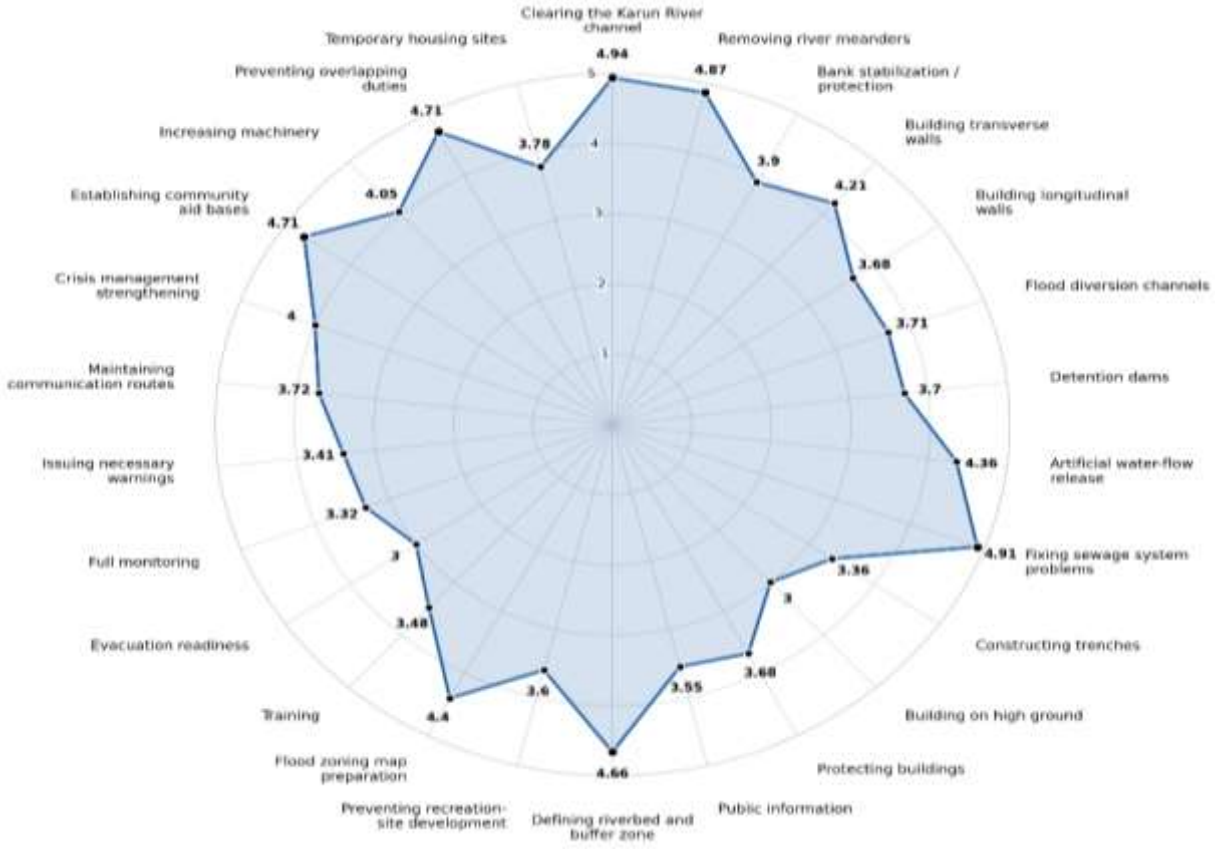


Figure 5. Factors affecting flood risk management strategies in Ahvaz city in the second Delphi round

D. Direct influence graphs

Direct relationships were also examined using MICMAC graphs at 100%, 75%, 25%, and 5% matrix coverage. These graphs illustrate the structure and relative intensity of the direct relationships, with more prominent lines indicating stronger relationships (Figures 1–4). Across the system, the variables with the highest direct influence and dependence are those listed in section C.

E. Identification of Flood Risk Management Strategies in the first Delphi round

A total of 26 strategies were identified in Round 1 (12 structural and 14 non-structural; Table 4). The frequency reported for each strategy is the number of experts who mentioned it or emphasized its importance in that round. Frequently mentioned structural strategies included cleaning and dredging the Karun River channel, construction of longitudinal structures such as flood-control walls, upstream flood diversion channels or structures, upstream detention or open dams, artificial recharge of groundwater, and improvement of the wastewater and stormwater collection network. Frequently mentioned non-structural strategies included public information dissemination and flood forecasting and warning, delineation of the riverbed and river corridor with prevention of land-use change within it, flood inundation mapping, public education, and community-based relief centers. Temporary protection of buildings with earth embankments or temporary flood-control walls, and trenches around critical facilities, were mentioned less often.

Among the non-structural strategies, frequently mentioned items included public information dissemination and flood forecasting and warning systems; delineation of the riverbed and river corridor and prevention of land-use changes within the corridor; preparation of flood inundation maps; public education on floods; and establishment of community-based relief centers.

Strategies such as temporary protection of buildings using earth embankments or temporary flood-control walls and construction of trenches around critical facilities were mentioned less frequently than several other proposed strategies (Table 4)

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F. Evaluation of strategies by the expert panel

In the second Delphi round, experts rated the 26 strategies on a five-point Likert scale; higher means indicate greater perceived importance. The Round 2 means are reported here; in Round 3 the means changed only slightly.

The highest mean scores were for cleaning and dredging the Karun River channel (4.94), improvement of the wastewater and stormwater collection network (4.91), and removal of meanders from the Karun River and establishment of a suitable alignment (4.87). Other highly rated strategies were community relief centers and preparedness monitoring (4.72), prevention of overlapping institutional responsibilities (4.71), riverbed and corridor delineation with land-use control within the corridor (4.66), and preparation of a flood zoning map (4.40).

The lowest scores were for flood-safe construction and restriction of development in flood-prone areas (3.00) and timely evacuation preparedness (3.00), followed by continuous monitoring of the Karun River and coordination with the Meteorological Organization (3.32), construction of trenches around critical facilities (3.36), warning systems (3.41), public education (3.48), and public information (3.55). The overall mean across the 26 strategies was 3.95; the mean was 4.03 for the 12 structural and 3.89 for the 14 non-structural strategies. Differences between the two categories were not tested statistically.

Discussion and Conclusion

The high matrix filling rate indicates that, from the perspective of the expert panel, flood consequences in Ahvaz are not confined to a single sector. The variables with the highest direct influence scores were destruction of the urban sewage system, damage to housing and to clinics and health centers, damage to vehicles, and drinking water pollution. The variables with the highest dependence scores were mainly social, including disruption in access to health services, social disorder, and evacuation of villages neighboring Ahvaz. This pattern suggests that several social consequences depend heavily on other variables in the system, including physical and infrastructural consequences, and is consistent with conceptualizations of vulnerability as a multidimensional phenomenon involving interacting physical, social, economic, and environmental factors (5–7).

Experts assigned the highest ratings to cleaning and dredging the Karun River channel, improving the wastewater and stormwater network, and removing river meanders. The high rating for the wastewater and stormwater network is noteworthy because destruction of the urban sewage system also had the highest influence score among the consequence variables. This represents convergence between two separate analytical components of the study rather than a statistically tested relationship. Relief centers (4.72) and clearer inter-agency responsibilities (4.71) also received high ratings. These priorities are consistent with the high dependence of access to health services and social order on other consequences, and with the emphasis that resilience frameworks place on institutional coordination and response capacity (11,12). Multi-agency deliberation has likewise been described as important for complex public-policy problems

Building on flood-safe sites and restricting development in flood-prone areas (3.00), evacuation preparedness (3.00), river monitoring (3.32), warning systems (3.41), public education (3.48), and public information (3.55) were rated below the overall panel mean (3.95). Flood zoning and risk mapping (9,10) and written warning-response planning are widely discussed in the flood-management literature, so these ratings warrant further examination. Notably, delineation of the river corridor with land-use control within it was rated high (4.66), whereas the broader strategy of building on safe sites and restricting development in flood-prone areas was rated lowest; the two overlap conceptually, and the data do not explain the difference. Possible explanations, such as perceived implementation constraints, the institutional composition of the panel, or perceptions that existing arrangements are adequate, remain speculative. The relatively low ratings should not be interpreted as evidence that these measures are unimportant for flood risk management.

Within both the structural and the non-structural groups, individual strategies varied notably in their ratings, so the structural/non-structural distinction alone did not account for the panel's priorities. The highest-rated structural strategies concerned the river and drainage system, whereas the highest-rated non-structural strategies concerned relief capacity, institutional coordination, corridor delineation, and flood zoning (4.40).

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Previous studies have linked urban development and drainage capacity (5,6) and rainfall variability (21,22) to urban flood risk. The present study did not measure these factors directly. Its contribution lies in examining the structural relationships among flood consequence variables in Ahvaz and documenting local experts' priorities for management strategies, which complements earlier work on flood-risk prediction and resilience assessment (11,16,18,19).

Overall, the findings indicate substantial interconnection among flood consequence variables in Ahvaz and suggest that flood risk management there has both infrastructural and institutional dimensions. Measures that received lower ratings require further investigation before being treated as lower-priority components of flood risk management.

Limitations

The findings reflect the perceptions of a single expert panel in one city and should not be generalized without caution. Half of the panel came from the Municipality, and the panel did not include representatives of the Water and Wastewater Company or the Regional Water Company, to which some recommendations are addressed. Agreement percentages and measures of dispersion for the Delphi rounds are not reported here; Round 2 means are presented, and no statistical comparison between strategy categories or between the MICMAC and Delphi results was made. Only direct influence and dependence scores are reported, and some consequence variables overlap conceptually (for example, social disorder and disruption of social order), which may affect the influence–dependence structure.

Based on the structural analysis and Delphi findings, the following recommendations are proposed:

- Improve and maintain wastewater and stormwater networks. Given the high Delphi rating for network improvement (4.91) and the high influence of sewage-system damage (44), upgrading, expanding, and maintaining urban drainage and wastewater networks should receive particular attention.
- Strengthen Karun River management and protect its corridor. River-channel cleaning and dredging (4.94), together with management of river meanders and critical locations (4.87), should be addressed through hydraulic assessment and environmental review. The riverbed and corridor should be clearly delineated and protected, and land-use changes within flood-prone areas controlled through appropriate planning measures.
- Integrate flood-risk information into urban planning. Flood inundation maps (4.40) should be incorporated into land-use planning, construction permitting, and urban development decisions to guide development away from exposed areas.
- Protect critical infrastructure and maintain essential services. The flood vulnerability of health facilities, housing, water and wastewater systems, electricity, gas, telecommunications, and transport infrastructure should be assessed, and measures applied to reduce disruption at the most exposed and influential sites while maintaining continuity of essential health services.
- Strengthen inter-agency coordination and local response capacity. Clear responsibilities and coordination mechanisms should be established among the Municipality, the Water and Wastewater Company, the Regional Water Company, disaster management authorities, and other relevant agencies (4.71). Neighborhood relief centers should be established and equipped to support emergency response and essential needs (4.72).
- Develop integrated monitoring, early warning, evacuation, and shelter arrangements. Monitoring of rainfall, river conditions, drainage networks, and urban waterlogging should be strengthened, with timely information provided to responsible agencies and the public. Evacuation routes, safe locations, and temporary shelters should be identified and periodically reviewed and exercised.
- Use a phased, evidence-based approach to investment. Resource allocation should consider both MICMAC influence rankings and Delphi ratings, together with cost, feasibility, and hydraulic and environmental requirements. Measures with lower Delphi ratings, particularly monitoring, warning, evacuation, and related preparedness measures (3.00–3.55), should have their local relevance and priority evaluated through further assessment or pilot implementation before final investment decisions

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Compliance with Ethical Guidelines

Ethical principles were observed throughout the study. The purpose and procedures were explained to all experts, and informed consent was obtained before the interviews and Delphi assessment. Participation was voluntary, and participants could decline to answer or withdraw at any time. The confidentiality of participants' identities and information was maintained.

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Authors' Contributions

In this article, Seyed Mehdi Mousavi Dehmordi contributed to the study conception, research design, data collection, data analysis, and preparation of the initial manuscript. Azadeh Arbabi Sabzevari contributed to the study design, interpretation of the findings, and critical revision of the manuscript. Tuba Amir Azodi and Fatemeh Adibi Saadinejad contributed to the methodology, data analysis, and critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Conflict of Interest

The authors declare no conflict of interest.

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