Identification of Optimal Routes in Urban Physical Vulnerable Textures for Emergency Evacuation in Saqez City

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Abstract

One of the first crucial actions in crisis management that should be taken into account in high-vulnerability zones is the emergency evacuation of the populace. An ideal routing strategy is very helpful because quick action is required to evacuate high-risk areas. This study aims to identify the best routing strategy in Saqez's vulnerable physical region and identify strategies for evacuating the city's residents in emergency situations. Based on the opinions held by urban planning experts, the important variables in defining the high physical vulnerability zones and the best route were chosen. The Simple Additive Weighting (SAW) methodology was utilised to initially select the most vulnerable areas. Using the Network Analysis Method, the best paths for emergency population evacuation to safe zones and relief efforts were identified during the second stage (NAM). The findings demonstrated that zones 1, 6, 18, 19, 16, and 17, which are situated in the center, north-eastern, and south-western regions of Saqez, have the highest physical vulnerability and are unsafe during unexpected occurrences given the rating of the SAW technique. For access to fire stations, medical facilities, hospitals, and parks in Lines 1 and 2, the best routes were identified while taking into account the breadth and dist ance from incompatible uses and rivers. In terms of accessibility, path breadth, relief duration, and speed, it can be said that the major routes in Line 1 are the best choices for speedy relief.

Keywords: Safe route; Physical vulnerability; Emergency evacuation; Saqez; Simple Additive Weighting (SAW)

Introduction

The first natural hazards assessment computerized simulation researches in the United States "Components of a hazard (Assessment of needs, Loss potential, Population-at-risk, Vulnerability relationships, Natural hazard generator, Local conditions); Simulation of loss potential (Approach, Frequency of geophysical events, Specification of present level and future trend, Measuring effects of changing adjustments, Application); Earthquakes (Development of original model, Application of earthquake model to San Francisco, Catastrophe potential of Los Angeles earthquakes, Catastrophe potential of hypothetical California earthquakes, Simulation of earthquakes in central and eastern United States, Interpretation of results in terms of research and data needs); Hurricanes (Importance of wind and storm surge hazards, Development of wind model, Interpretation of wind results in terms of research and data needs, The storm surge hazard, Application of storm surge model, Interpretation of storm surge results in terms of research and data needs); Inland flooding (Population-at-risk and its vulnerability, Construction of a flood generator, Adjustments to the flood hazard, Time-phased changes in adjustments); Other hazards (Tornadoes, wind and hail, drought)." The amount of exposure is lacking from Friedman's 1975 research, but it has a specific role in natural hazards studies, which refer to exposed elements from a hazardous event being more vulnerable.

However, due to the degree of technology used or the difficulty in measuring the hazard due to the nature of hazards (e.g., mass movements, coastal erosion, and volcanoes), many environmental hazardous concerns suffer from a lack of well-documentation in mathematical models for better analysis (Douglas, 2007). The success of a risk assessment depends on who delivers it and the risk situation in a given location (Pighills et al., 2011). In Europe, for example, the tradition of environmental management has been to control specific risks (e.g., flood) with ineffective structural measures and intermittent non-structural measures that supported these activities. As a result, it is realised that there is an immediate need for a paradigm shift from defensive to proactive action toward a preventive culture by managing with an adequate adaptation system. Natural hazards assessment becomes a highly technical procedure with developments in risk management conceptions and concepts as a result of distinguishing solely between hazards maps and risk (as a potential hazard) maps (Ronvo et al., 2014; Janparvar et al., 2022).

An effective environmental and risk assessment requires knowledge of a complex system of ecosystems with a mix of known and unknown characteristics (Blasco and Picó, 2009), as well as current and future trends (Saha et al., 2021). When natural disasters are recognised in the United States alongside acts of terrorism and other emergency occurrences, the need for natural disaster assessment becomes clear (MacArthur and Siwek 2020). The situation is worse in the global south due to the length and likelihood of hazard occurrence; environmental causes account for the majority of deaths, diseases, and disabilities. The global mortality rate is estimated to be 25%, with less developed African nations like Sub-Saharan Africa accounting for approximately 35%. Because there is an urgent need to incorporate risk reduction measures at all levels of development planning, the likelihood effect of hazardous occurrences is quite high in developing countries. Estimating expected and unpredictable losses requires an effective spatial analysis, since all risk assessment mechanisms differ dependent on time and space (Van Westen et al., 2011).

Many vulnerability assessment methodologies are used to demonstrate vulnerable people and environmental interactions. However, several fundamental tools, such as scale, are available for developing structural notions of vulnerability assessment (Fekete et al., 2010). Assessing vulnerability on a large scale is difficult, if not impossible, due to the complicated process of the variables involved, and has low accuracy. As a result, monitoring the ecosystem function and quality provided by natural elements (e.g., meteorological, vegetation, and irrigation conditions) and their implications for human life is an effective environmental assessment strategy (Zhao et al., 2018). The current and future impacts of natural hazards should be considered in an effective environmental vulnerability assessment. Estimating current vulnerable people and the environment can be challenging at times due to the dynamics of other risks (for example, climate change), and it can also reduce estimation accuracy (Milly et al., 2008). Risk assessment is the first and most important step in risk management. (Aven, 2016) divided risk assessment priorities into three categories: hazard identification, hazard estimation, and socioeconomic impact evaluation (vulnerability assessment).

Since floods are the most common natural hazard in comparison to other hazards, vulnerability is the fundamental concept in flood risk management, with Asia accounting for more than half (45 %) of the natural risks associated with floods (UNFCCC, 2021). Flash floods are especially dangerous because their fast currents occur in areas where there is no warning.

Flooding can cause rapid erosion and morphological changes, making a location more flood-prone and shifting risks to active hazards. According to the resolution approved under the second committee's reports, the United Nations General Assembly designated the decade as the " International Decade for Natural Disaster Reduction" in 1987. In this report, earthquakes, cyclones, and floods were identified as the most common hazards, with floods being identified as more destructive than other hazards (UN Assembly General, 1988). Because the majority of floods are recorded in urban areas, the amount of literature on urban flood assessment is rapidly growing (Park et al., 2019; Hammond et al., 2018).

Cities are the top priority in flood vulnerability assessments, and cities with dense populations are especially vulnerable. Flood vulnerability assessment contributes to resilience at the lowest levels of decision-making (Liew and Che Ros, 2021). In recent years, European urban flood assessment has included land use classifications, ecological capacity (e.g., green infrastructure), and socioeconomic indices (Talkhabi et al., 2022). Urban flood management (Kumar et al., 2021) improves the quality of human life and the environment by relying on urban sustainable development and the actual implementation of the spatial justice principle (Shahraki et al., 2020). Rapid unplanned urban expansion disrupts urban hydrological systems (Ghalehteimouri et al., 2020; Devi et al., 2019) Furthermore, any type of formal or informal urban development can increase flood risk. Many efforts are being made to assess flood risk through historical hydrologic data analysis and numerical simulation (Faizah, 2015). Furthermore, urban sprawl and informal development encourage poor people to move to low-quality lands with low-quality materials (Ghalehteimouri et al., 2022), making flooding a more frequent hazard where poor people live in areas with inadequate urban infrastructure and unsuitable land for development (Park and Lee, 2019).

The Multiple Criteria Decision Analysis (MCDA) is well-known as a useful tool for resolving problems in environmental studies and natural hazards assessment (Karimi et al., 2019; Rahmati et al., 2016). Flood assessment is a complicated natural hazards issue that necessitates multicriteria decision-making because flood management involves a variety of alternative solutions and evaluation criteria (Mudashiru et al., 2022). Integrating flood risk issues is not a single environmental issue; it involves several challenges. The MCDA's accuracy is improved by identifying the SAW approach as capable of ranking a number of problems when an option is included or omitted. However, each (MCDA) has its own set of weaknesses, strengths, and skills that reversal rank techniques accept (Shin et al., 2013). In their review paper titled

"A comparative assessment of flood susceptibility modelling using Multi-Criteria Decision-Making Analysis and Machine Learning Methods," the researchers present their findings. According to Khosravani et al., 2019, the Analytic Hierarchy Process (AHP) was the most widely used MCDA method in flood risk assessment (Khosravani et al., 2019).

The primary focus of this study is decision-making in urban flood risk assessment in order to choose the best route in the event of flooding. As a result, the number of identified criteria had to be calculated, and the SAW was extensively used in the Saqez flood assessment to determine the priority of each criterion. The most effective mix method for determining flood risk is the incorporation of AHP-SAW into MCDA.

Methodology

The current study is descriptive-analytic in nature, with data obtained through library research, field studies, urban land use mapping, detailed comprehensive urban plans, and 2016 census statistics. This study's analysis and evaluation scale is on a regional scale. The following 13 factors were used to evaluate the vulnerable physical textures: building skeletal structure, fine-grained urban texture, building material quality, population density, access to hospital and medical centers, distance from pedestrian having a width of less than 6 meters, having access points to firefighter station, accessibility to parks, number of apartment units, number of non-apartment units, and distance from the river. To analyse the best qualitative and quantitative data collected for appropriate selections (Afshari et al., 2010; Hekmatnia et al.,2022), As classical effective MCDA, the SAW model and the NAM were used. The AHP model was used to weight the above 13 factors based on expert opinions. The AHP provides a technical understanding of the hierarchical interactions and relationships between components (impacts, criteria, and alternatives) (Reza et al., 2011). Through the NAM, the ArcGIS Model Builder was used to provide the depicted optimal paths in vulnerable physical textures (Fig 1). The SAW decision-making model was used to rank the 22 neighbourhoods of Saqez city based on the number of vulnerable physical textures. As classical effective MCDA, the SAW model and the NAM were used. The AHP model was used to weight the above 13 factors based on expert opinions. The AHP provides a technical understanding of the hierarchical interactions and relationships between components (impacts, criteria, and alternatives) (Reza et al., 2011).

The ArcGIS Model Builder was used through the NAM to provide the depicted optimal paths in vulnerable physical textures (Fig 1). The SAW decision-making model was used to rank the 22 Saqez city neighbourhoods based on the number of vulnerable physical textures. Understanding the weight of each alternative of the importance of each criterion, building a decision matrix from the result of the match rating table on each alternative criterion, and finally normalising for optimised selection (Poorzahedy and Rezaei, 2013; Seyedmohammadi et al., 2018; Vlachokostas et al., 2021).

This method includes four phases: (a) quantifying the decision-making matrix; (b) providing a linear normalization of decision-making matrix quantities; (c) multiplying a normalized matrix by index weights and (d) selecting the best option (Mohammadzadeh et al., 2018).

The NAM is a system made up of interconnected elements such as edges (lines) and connection junctions (points) that show potential routes from one location to another. Passages and streets that play an important role in intra-city transportation are used as linear effects in network-based analyses. As a result, the results of such an analysis have a high degree of confidence and are represented as a hierarchical 4-stage process (Beheshtifar, 2012). In the first stage, enter the GIS environment via Network Analyst and activate the 'Network Analyst Closest Facility' command, introducing textures with the highest level of physical vulnerability as the source points where the greatest number of victims is predicted during unexpected events. Age, building skeleton, and material type are all criteria for specifying such points.

The second stage involves identifying medical centers, hospitals, fire stations, and parks as potential targets. The goal of this stage is to find the best, quickest, shortest, and most cost-effective route to services.

The third stage is to identify the barriers. In addition to the linear phenomenon, various criteria such as incompatible uses, lanes less than 6 meters wide, and proximity to rivers have been identified as barriers. At this stage, it is assumed that the routes' narrow width (less than 6 meters), incompatible uses, and proximity to rivers cause bridge destruction and route obstruction. This will make it difficult to provide relief to the victims and will effectively close the routes.

The fourth stage is NAM implementation. Following the specification of the source and target points, we must determine the optimal relief routes for the emergency evacuation of the population during unforeseen situations, taking into account the time constraints and access point limitations.

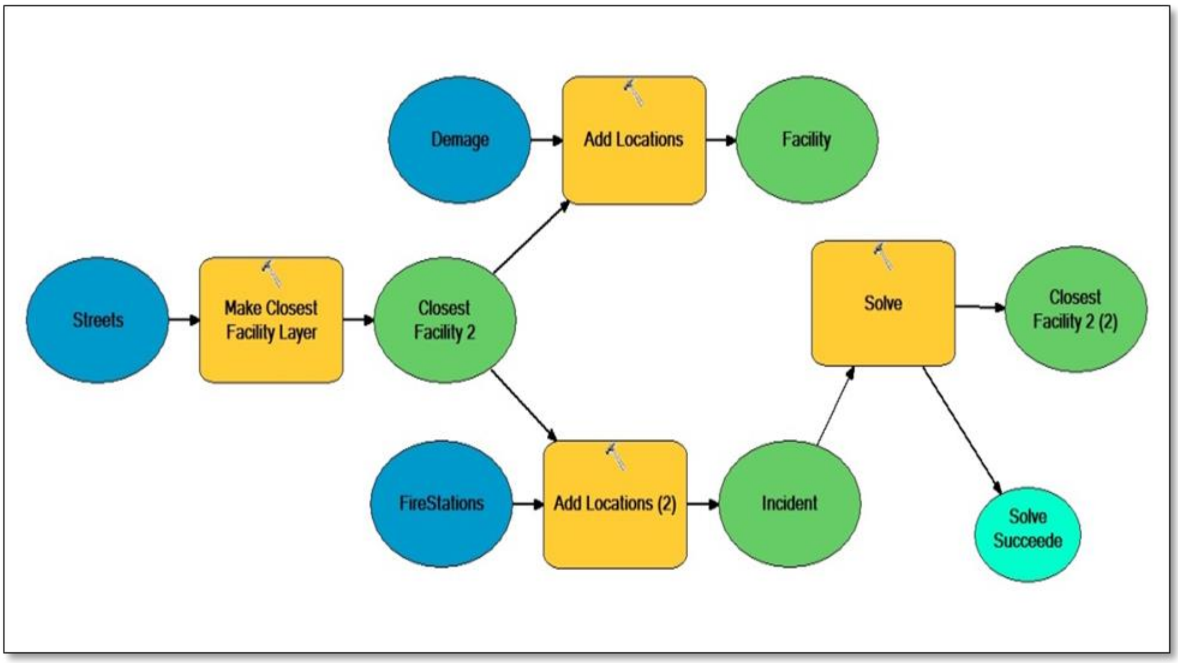

Fig. 1 Schematic flowchart of optimal relief routing modeling in vulnerable physical textures for the emergency evacuation of population during unforeseen events-Designed by the authors, 2020-08-20.

Study area

Saqez is the second largest city in Iran's Kurdistan province. Saqez is located in Kurdistan province, between 33°44 and 35°34 northern latitude and 45°34 and 47°.16 eastern longitude. The city's average elevation is 1496 meters above sea level. Saqez has a population of 165258 people, according to the 2016 census (Statistical center of Iran, 2016). The city's area is 15,982,463 square meters, or 12.49 % of the province's total area. (Heydari, 2012)

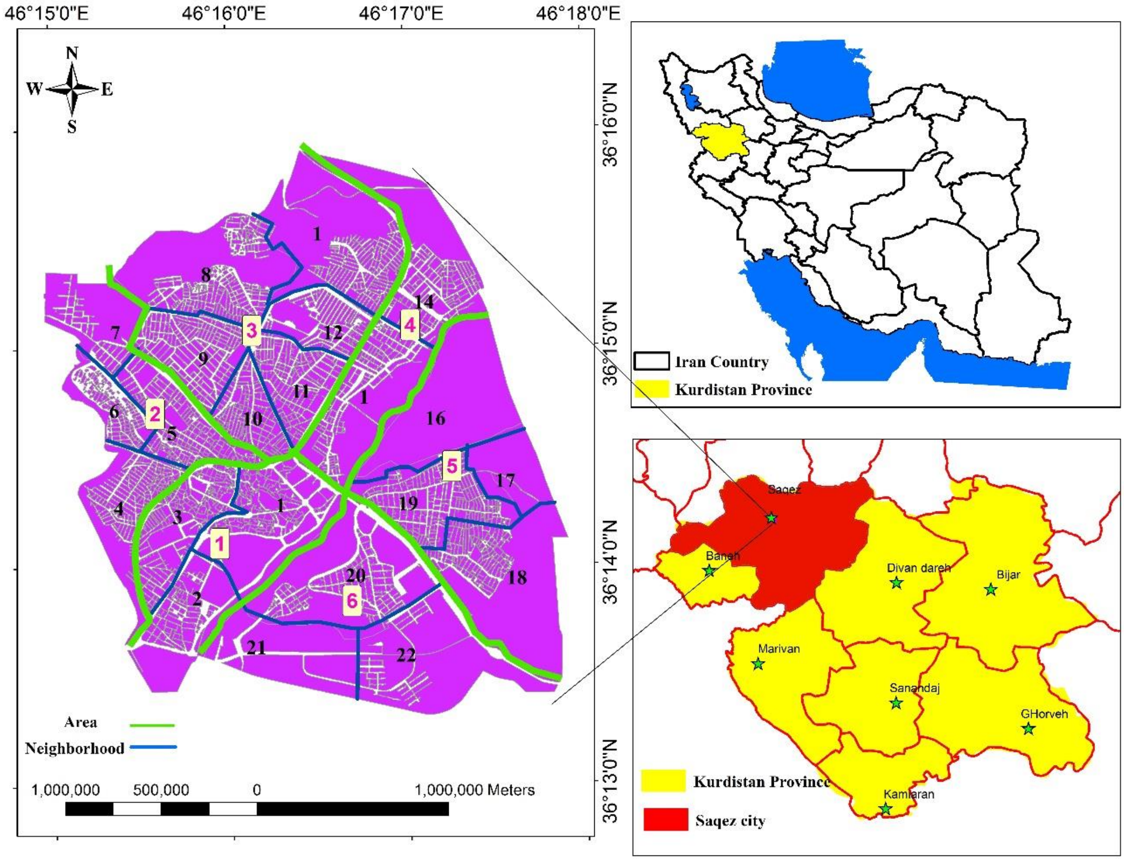

Fig. 2 Geographical status of Saqez city (Depicted by the authors)

Finding and discussion

Saqez is one of the cities that is constantly vulnerable to natural disasters, and as a result, incidents have occurred on occasion. Floods have always been a problem in the city due to factors such as climate change, the spread of rainstorms, low land penetrability, a lack of proper management of riverbanks and flood channels, insufficient capacity of existing canals, and a lack of drainage of river route reservoirs. Despite the aforementioned reasons and the occasional gusty winds, Saqez may be considered a hurricane-prone city. As a result of this issue, it has become increasingly important to focus on areas of high physical vulnerability as well as optimal routing for emergency population evacuation.

To find the best relief routes in vulnerable physical textures in unexpected scenarios, an attempt was made to first extract the effective criteria in vulnerable physical textures based on the opinions of experts and urban development professionals, and then rank the zones in terms of physical vulnerability using the SAW model and incorporating these factors throughout Saqez's 22 zones. In the following phase, the optimal relief routes for the emergency evacuation of the population during unforeseen disasters were discovered using NAM throughout high physical vulnerability zone.

1. SAW ranking technique

The SAW is one of the most fundamental multicriteria decision-making procedures for unstable, changeable, and unexpected issues. The results of SAW in this study can improve the process of choosing the best route and speed up the urban evacuation. Due to the sensitivity of this strategy, we took the following steps:

1.1 Quantifying the decision-making matrix: The first stage was to formulate spatial decision matrix comprising 22 criteria and 13 sub-criteria. Each cell or zone contains a value leading to the matrix formation.

Table 1 Decision-making matrix

Neighborhoods	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
1	0.00	0.01	0.02	10.80	77.00	0.56	1.28	86.68	0.00	90.79	5.52	98.71	98.70
2	64.15	69.25	27.80	34.70	94.43	58.00	100.00	91.64	99.90	96.20	17.96	65.73	34.21
3	25.00	26.86	37.00	44.60	100.00	20.00	33.30	100.00	70.20	94.01	39.62	100.00	21.01
4	0.00	-30.82	21.50	60.02	43.12	10.00	3.55	87.06	79.80	95.69	53.71	58.19	11.09
5	13.34	0.13	27.90	68.80	100.00	23.00	53.40	95.29	28.80	92.13	55.41	100.00	90.71
6	-52.87	-18.02	12.30	73.90	34.09	8.00	74.41	24.27	78.90	98.95	40.62	100.00	86.96
7	1.97	15.01	25.30	34.60	100.00	36.00	78.74	0.04	78.50	96.83	24.82	96.85	74.42
8	-1.05	41.39	24.10	60.02	44.34	52.00	80.53	61.90	100.00	92.94	103.29	79.50	17.43
9	-2.04	55.81	32.20	70.70	92.49	45.00	73.66	52.74	91.20	92.46	59.67	100.00	79.78
10	-22.10	35.97	24.90	71.90	100.00	43.00	84.52	78.72	55.50	94.11	29.92	100.00	42.92
11	-11.15	-15.18	26.80	67.30	100.00	27.00	99.95	100.00	56.20	95.74	48.01	54.56	5.20
12	-14.39	-14.43	25.30	57.30	100.00	30.00	98.43	100.00	40.10	97.82	36.28	29.95	0.00
13	-14.54	-25.76	40.60	46.10	95.11	11.00	67.57	86.88	48.80	96.24	86.73	1.79	0.00
14	-14.46	35.49	26.30	52.00	92.06	32.00	74.56	41.82	35.90	93.14	72.94	0.00	0.00
15	11.51	20.93	29.00	28.80	78.99	26.00	66.29	77.46	5.60	96.32	39.15	29.10	24.18
16	-0.25	0.06	5.00	1.00	25.40	0.07	5.50	2.35	5.50	90.90	0.53	3.00	35.54
17	0.01	-10.00	15.00	2.50	20.40	10.80	10.20	5.40	30.50	99.03	2.93	4.00	38.40
18	-7.08	-34.10	41.60	39.10	52.52	7.00	20.32	17.96	35.50	95.02	67.87	0.00	0.00
19	-15.44	-25.90	29.40	81.30	50.00	9.00	29.79	72.84	20.20	93.97	75.73	0.00	54.80
20	44.80	-2.56	38.80	42.10	82.22	47.00	55.24	34.53	28.70	96.74	58.57	9.56	82.80
21	75.08	68.19	38.30	49.30	70.47	77.00	60.00	58.23	95.50	95.56	22.99	2.29	68.45
22	79.20	70.00	30.20	54.40	75.97	83.00	81.40	6.29	99.90	90.32	40.72	0.00	58.64
Sum	159.69	262.33	579.32	1051.24	1628.61	655.43	1252.64	1282.10	1185.20	2084.90	983.00	1033.23	925.24

1.2 Linear normalization of decision-making matrix quantities: At this point, using a normality measure is required in order for the indexes to be comparable. If the indexes are positive (increasing), Relation (1) is used; if they are negative (decreasing), Relation (2) is used.

Relation (1) $$n_{ij} = \frac{a_{ij}}{max a_{ij}}$$

Relation (2) $$n_{ij} = 1 - \frac{a_{ij}}{max a_{ij}}$$

Positive research indices are desired to the extent that they are remote from vulnerable zones such as rivers and conflicting uses. Negative (decreasing) indices, on the other hand, are those that are beneficial to the vulnerable texture by lowering it. Access to major and minor highways, as well as parks, medical facilities, hospitals, and fire stations, are just a few examples.

1.3 Multiplying normalized matrix by index weights (Weights derived from AHP model): The weight of each criterion calculated by the AHP model is multiplied by each individual normalized layer at this stage.

1.4 Selecting the best option: There is no need to be standardized the data because this technique is based on the defined ranks assigned to each choice. According to Relation (4), we use the SAW technique to select an option whose total of normalized quantities go beyond the sum of the other options. Table 2 shows the zone rankings based on the most recent SAW model findings.

$$(f_k(a_t)) \sum_{k=1}^{k} W_k . R_k = \frac{1}{T} \text{Relation (4)} \; V_{aj}$$

As a result of the SAW approach's rankings, the most physically vulnerable and risky zones in unanticipated occurrences are zones 1, 6, 18, 19, 16, and 17, which are located in the city's central, north-eastern, and south-western portions. Figure 3 depicts the regional distribution of physical vulnerability in various zones of Saqez.

Table 2 Ranking of the 22 zones of Saqez based on the SAW model.

Neighbourhoods	Score	Grade
16	0.0096	1
17	0.0139	2
18	0.0204	3
6	0.0262	4
1	0.0290	5
19	0.0292	6
4	0.0310	7
13	0.0341	8
12	0.0375	9
14	0.0413	10
11	0.0427	11
15	0.0429	12
7	0.0487	13
10	0.0532	14
20	0.0549	15
5	0.0555	16
3	0.0579	17
8	0.0611	18
9	0.0619	19
2	0.0809	20
22	0.0812	21
21	0.0813	22

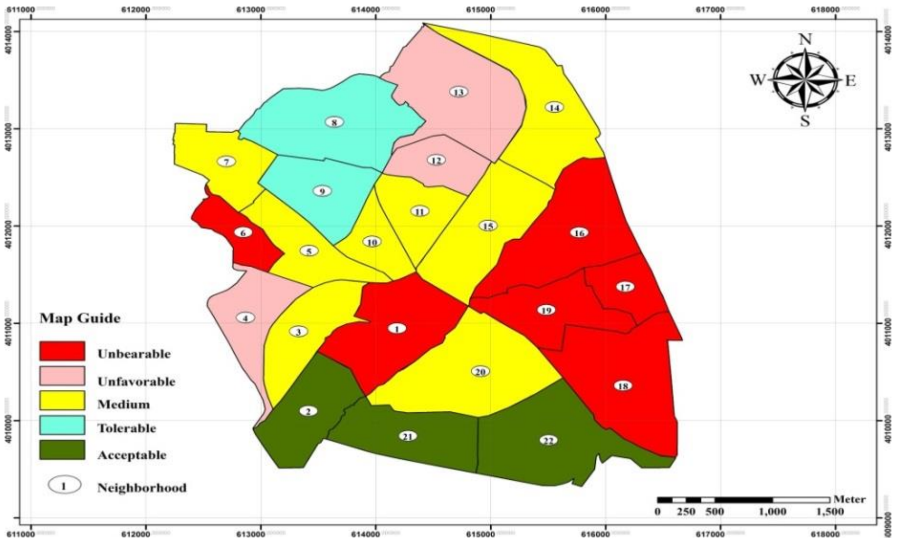

Fig. 3 Ranking of physical vulnerability of Saqez zones using SAW technique

2. Relief optimal routing in physically vulnerable textures via NAM

Since the goal of this paper is to find the shortest and nearest route in physically vulnerable textures in Saqez zones, it can be argued that discovering the shortest and nearest route is one of the most important network analysis capabilities. This study makes an attempt to identify nearby medical facilities, hospitals, and fire stations as safe sites for relief purposes, as well as to determine the best access routes and emergency evacuation routes to safe spots while taking obstacles and restrictions into account.

3. Proposed routes for relief to access medical centers

The current study discovered 14 sanitary-medical centers suitable for relief purposes. Among these facilities are Sharif Abad, Shahid Afshari, Khatamol Anbiya, Zone 4, Number 9, Shahid Rajaee, Saqez Medical Center, Social Welfare Center, Physical Health Center, Medical Emergency, Zone 9, Zone 3, Blood Donation Center, and Patient Recovery Center. The following are the directions to the aforementioned facilities. Because of the presence of a Patient Recovery Medical Center, a Physical Health Center, and a Blood Donation Center in Zone 1, people can be evacuated more quickly and efficiently during a crisis within two minutes. Minor routes to Bisto Dovom Bahman St. and then to Haft-e-Tir Blvd. can be taken to get to the Patient Recovery Center on Line 1. This centre can also be reached via the major roads of Mellat and Emam streets. Take Emam and Mellat streets to get to the Physical Health Center and the Blood Donation Center. Take Bisto Dovom Bahman St. and then the minor route of Rahnema 3 alley to get to the Blood Donation Center on Line 2. The Arjomandi alley minor route also provides access to the Physical Health Medical Center. People can use the main routes of Hafez and Shohada streets in Line 1 to get to the Saqez health centre in zone 11 and the Health network in zone 5 for a faster and more efficient arrival. The population of zone 6 can be evacuated in an emergency by using the Social Welfare Center and the Health Center in Zone 4. Line 2 can also provide this type of access. Furthermore, in order to get to Health Center 4, people can take the minor routes of Zone 6 and then enter Sharif alley. Access to the Social Welfare Center is also possible via minor routes leading to Bidgol or via Tavanbakhshi 12-meter St. To get to the zone 3 medical emergency centre, take the minor routes of zone 6 to Kargar St. and then to Hajkamali alley. Line 2 allows access to Zahedi St. and then Dr. Khaledi Alley via minor routes in zones 18 and 19, and then to Sharif Abad Medical Center in zone 20. Moving toward Haft-e-Tir. and entering Baharestan St., Rahnema alley, and Yaser St. allows you to reach Shahid Afshari's medical center in zone 19. Line 2 provides similar access by heading toward Yaser Street.

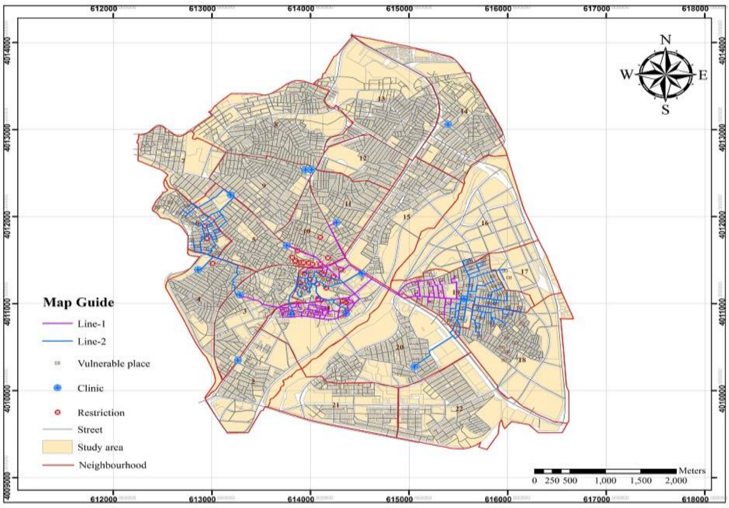

Fig. 4 Relief optimal routes to access medical centers

4. Proposed routes of relief to access hospitals

In this study, there are three hospitals in Saqez, located in zones 3, 12, and 18. The following are the services provided by these centers. People can pass through the minor routes and move toward Bisto Dovom Bahman St. via Emam and Mellat streets in Line 1 to access the time-worn textures of zone 1 and the emergency evacuation of population during crisis. Then, after passing through Moallem and Kholafaye Rashedin streets, people arrive at Pezeshk St., where they can gain access to the Social Welfare Hospital, which is located in Zone 12. Furthermore, through Line 1, access to Emam Khomeini hospital in Zone 3 is possible in four minutes via Mellat St. People in zone 1 can move toward Hafez Blvd via Bisto Dovom Bahman St to participate in an emergency evacuation via Line 2. After passing through Hafez Blvd., people enter the Rizan 3 minor route. People then enter Taraneh alley via Rezvan 1 and eventually arrive at Pezeshk St. People can enter Kargar St. after passing through the minor routes in order to have an emergency evacuation of the population located in Zone 6 of Line 1. People then enter Resalat St., followed by Shahrdari St., to gain access to Emam Khomeini Hospital, which is located in Zone 3. Using Line 2, passengers can get to Shohada St. via minor routes and then to Kholafaye Rashedin via Mottaghi St. and Farmehr Alley. People arriving at Pezeshk St. can access the Social Welfare Hospital, which is located in Zone 12. People in zones 16, 17, 18, and 19 can enter Haft-e-Tir via Lines 1 and 2 after passing through the minor routes, giving them access to the hospital in zone 18.

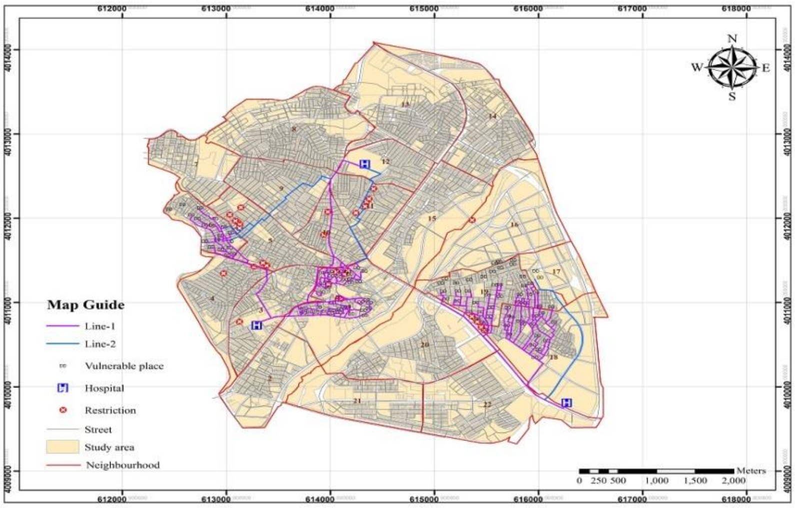

Fig. 5 Optimal relief routes to access hospitals

5. Proposed relief routes to access fire stations

In Saqez, there are two fire stations, one in zone 1 and one in zone 7. To have an emergency evacuation of the population in Line 1, enter Mellat St. and find access to the fire station in Zone 1 after passing through the zone's minor routes for four minutes. People from zones 16, 17, 18, and 19 arrive in Haft-e-Tir after taking the minor routes. People can access the fire station 1 by entering Mellat St. Through the minor routes of zone 6, people in line 2 can get to Saadi St., Fakhre Razi St., or Kargar St. After driving through these streets, people can enter Bisto Dovom Bahman St., pass through zone 1's minor routes, and reach the zone 1 fire station via Mellat St. To get to the zone 7 fire station, take the minor routes of zone 1 until you reach Azadi St. People can access this fire station after passing through Azadi St. and entering the main route of Shohada St. People on Line 2 can get to the main route of Montazeri St. by taking the minor routes of Zone 6. People can also access the fire station 7 by entering Fakhre Razi St. and passing through Andishe 2 alley.

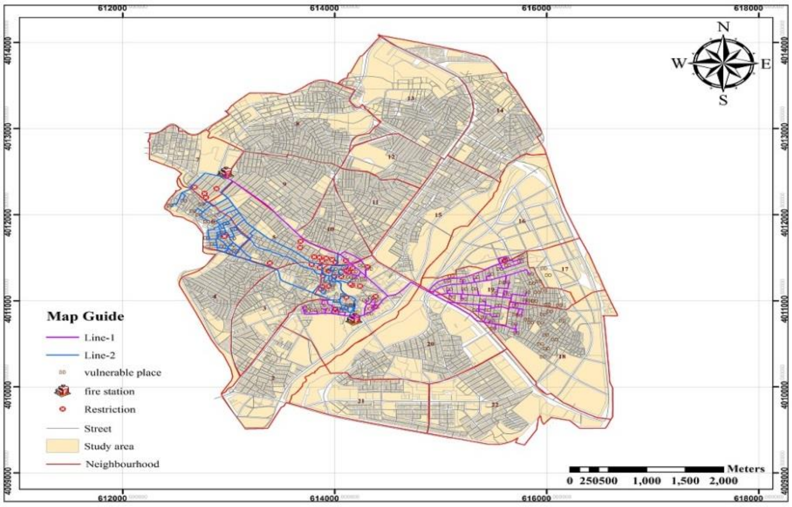

Fig. 6 Optimal relief routes to access parks

6. Proposed relief routes to access parks

In Saqez, there are eight parks. The following is the procedure for gaining access to each of these parks for the purpose of population evacuation in the event of an emergency. Shekoofe Park, in Zone 5, is reachable by Line 1 via Shohada St. Other worn textures in Zone6 can be reached via minor routes such as Tavanbakhshi16-meter and Shekoofe16-meter streets, in addition to Line2. Shekoofe Park is a 3-minute drive from Zone1's center texture. People can take the secondary route of Farhang 2nd alley in Line 2 to get to the parks in Zone 9. People can get to Laleh 4th alley via Montazeri St., and then to Farhang alley via the main route of Shohada St. Bidgol alley can also be reached via Montazeri St. and Farhang alley via Shohada St.

People can also take Line 1 from Shohada St. to Koodak Park, which is located in the heart of Saqez. Proceed toward the big routes of Mellat and Emam streets via Azadi St. to reach the other smaller ways found in zone1's core texture. Line 2 users can connect to the other minor lines in Zone 1's center texture by taking Azadei St. to Bisto Dovom Bahman St. People in Zone 6 can move to Saadi, Fakhre Razi, and Kargar St. for an emergency evacuation and access to Koodak Park via Bisto Dovom Bahman St., in addition to the three major routes mentioned above, to find access to Zone 6's time-worn textures. To get to Moulavi Park in Zone 1, take Daneshjoo Blvd. toward Kerefto St. and continue to the destination.

Line 2 passengers can get to Moulavi Park in Zone 6 by taking the small route of 3rd Rahnema, which passes through Kargar and Emam streets. Line 1 will guide passengers to Kousar Park via Azadi, Mellat, Emam, and Kereftoo streets. People can also take Kerefto Street to

Daneshjoo Street to get to Haft-e-main Tir's Street, from which they can access the other major routes in Zone 19. Line 2 passengers can access the minor routes of Ammar St. and Entezami Alley via Zahedi St. The routes described above allow people to access the time-worn textures in zones 18 and 19. Take the Haft-e-Tir main route for 3 minutes, then the minor routes of Rahnema alley, Baharestan, Yaser, and Keshavarz streets in zones 16, 17, 18, and 19. To reach the park in zone 16, take the minor routes of Rahnema alley, Baharestan, Yaser, and Keshavarz streets in zones 16, 17, 18, and 19. People heading to Mamosta Heyman Square can take Line 1 to Haft-e-Tir, where they can connect to the other routes in Zone 1. Passengers on Line 2 can take Khodyary alley to Arghavan 2nd alley, then Behrang alley to the park.

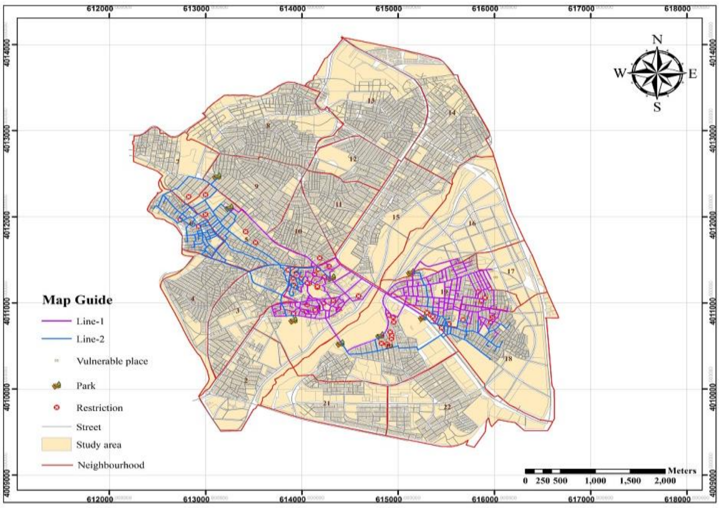

Fig. 7 Optimal relief routes to access the parks

The solution must work within a set of constraints. Among them were a peak population assigned to a rescue center as well as a lower (or threshold) population. The lowest and highest peoples were determined using "generic" and "specific" factors based on the circumstances at each proposed site (e.g., area available, accessibility, characteristics of surrounding buildings). As a result, we developed an evacuation plan for this study that details the optimum assembly locations, rescue centers, evacuation routes, traffic control procedures, and times for direct family member rescue. Depending on the nature of the disaster, the time frame for designing and implementing an action plan is only a few hours in the case of no-notice disasters.

Conclusion

Optimal routing is an important part of crisis management in high-risk areas. This type of routing is critical in relief operations because it can direct people to safe routes and locations. To identify areas of high physical vulnerability, this study evaluated 13 criteria across all 22 zones of Saqez city. Zones 1, 6, 16, 17, 18, and 19 in the city's central, north-eastern, and south-western parts were determined to be unsafe with high physical vulnerability during the unforeseen events after data analysis and classification using the SAW model. Indeed, because of their high physical vulnerability, these zones are threatened by widespread inefficiency, which leads to increased inefficiency and decay. Following the identification of high physical vulnerability zones, the researchers devised optimal routes from vulnerable textures (source) to each target location (medical centers, hospitals, fire stations, and parks) in order to provide transportation vehicle services for evacuation and relief purposes while accounting for movement time and distance.

As a result, using existing information and maps, the vital routes of Lines 1 and 2 were identified in order to proceed with evacuation and relief services for vulnerable zones during an emergency. Such routes have adequate widths for all relief vehicles and have been identified and selected along the linear phenomena while considering various criteria such as incompatible uses and distance from rivers as barriers. The routing and access to fire stations results revealed six zones with high physical vulnerability, and it takes four minutes to reach the two fire stations in zones 1 and 7.

St. Mellat Hateh Tir Blvd and St. Shohada Blvd provide better access and relief given the source locations and access to the destination. People in zones 3, 1, 4, 5, 11, 9, 19, and 20 can reach the 14 medical centers in under two minutes, according to routing and access data. Bahman 22nd, Mellat, Emam, Hafez, Shohada, and Baharestan streets, as well as Tir 7th Blvd, are now faster and more efficient. Furthermore, despite the availability of three hospitals in zones 3, 12, and 18, the optimal routing results for accessing Saqez hospitals revealed that it is possible to have a faster and more convenient access to the hospitals within four minutes via Emam, Mellat, Bahman 22nd, Moallem, Kholafaye Rashedin, Pezeshk, Kargar, Resalat, and Shardari streets, as well as Ha Finally, the optimal routing results for park access revealed that a 3-minute drive allows access to 8 parks in zones 1, 5, 9, 16, and 20. The routes of Shohada, Azadi, Mellat, Emam, Daneshjoo, and Kerefto streets, as well as Haft-e-Tir, provide more convenient relief access.

The best evacuation location is determined using simulations and/or empirical methods. In this study, it was expected that people would evacuate via the route that required the least amount of travel time or distance. This study, in contrast to earlier work, optimizes the number and initial positions of people for a people-based emergency evacuation. Additionally, it designates exits and pathways for those being evacuated while taking into consideration human collaboration.

References

Afshari, A., Mojahed, M., & Yusuff, R.M. (2010). Simple Additive Weighting approach to personnel selection problem. *International Journal of Innovation, Management and Technology, 1*(5), 511.

Assembly, U.G. (1988). *International decade for natural disaster reduction: Report of the secretary-general.* 43rd Session, Agenda Item, 86.

Aven, T. (2016). Risk assessment and risk management: Review of recent advances on their foundation. *European Journal of Operational Research, 253*(1), 1-13. https://doi.org/10.1016/j.ejor.2015.12.023

Beheshtifar, J. (2012). *Analysis of Spatial-Locational Distribution of Health Care and Medical Services and Its Optimalization: (Case Study: Health Care Centers and Hospitals of Jahrom City)*[Doctoral dissertation, University of Sistan and Baluchestan].

Blasco, C., & Picó, Y. (2009). Prospects for combining chemical and biological methods for integrated environmental assessment. *TrAC Trends in Analytical Chemistry, 28*(6), 745-757. https://doi.org/10.1016/j.trac.2009.04.010

Devi, N. N., Sridharan, B., & Kuiry, S. N. (2019). Impact of urban sprawl on future flooding in Chennai city, India. *Journal of Hydrology, 574*, 486-496. https://doi.org/10.1016/j.jhydrol.2019.04.041

Douglas, J. (2007). Physical vulnerability modelling in natural hazard risk assessment. *Natural Hazards and Earth System Sciences, 7*(2), 283-288. https://doi.org/10.5194/nhess-7-283-2007

Faizah, C. R. (2015). *Study on early for casting of flood through Historical Hydrologic Data Analysis and Numerical Simulation in Kelantan Watershed, Malaysia*[Doctoral dissertation, University of Tokyo]. https://ci.nii.ac.jp/naid/500001040233/?l=en

Fekete, A., Damm, M., & Birkmann, J. (2010). Scales as a challenge for vulnerability assessment. *Natural Hazards, 55*(3), 729-747. https://doi.org/10.1007/s11069-009-9445-5

Friedman, D. G. (1975). *Computer simulation in natural hazard assessment.* National Science Foundation.

Ghalehteimouri, K. J., Hatami, A., & Asadzadeh, H. (2020). Measuring the quality of life and city competitiveness: A methodological framework for the Iranian metropolis. *Journal of Urban Culture Research, 21,* 90-111. https://doi.org/10.14456/jucr.2020.14

Ghalehteimouri, K. J., Nasr, T., & Bakhtiari, L. (2022). *A Scenario-based approach for sustainable urban regeneration analysis in Radial-concentric ring cities: A case in Hamedan, Iran. City and Environment Interactions.* https://doi.org/10.1016/j.cacint.2022.100089

Ghalehteimouri, K. J., Shamaei, A., & Ros, F. B. C. (2021). Effectiveness of spatial justice in sustainable development and classification of sustainability in Tehran province. *Regional Statistics, 11*(2), 52-80 https://doi.org:10.15196/RS110201

Hammond, M., Chen, A. S., Batica, J., Butler, D., Djordjević, S., Gourbesville, P., ... & Veerbeek, W. (2018). A new flood risk assessment framework for evaluating the effectiveness of policies to improve urban flood resilience. *Urban Water Journal, 15*(5), 427-436. https://doi.org/10.1080/1573062X.2018.1508598

Hekmatnia, H., Mousavi, M. N., Ghalehteimouri, K. J., Shamsoddini, A., Kashkouli, A. B., & Jamshidi, A. (2022). Population Aging Tendencies in Islamic Countries Between 1950-2020: A Geographical Assessment. *Journal of Population and Social Studies [JPSS], 30,* 36-53. http://doi.org/10.25133/JPSSv302022.003

Heydari, A. (2012). Spatial-Physical Analysis of Future development of Saqez city with point on Smart Urban Growth Indicators by Entropy Shannon Model. *Geography and Urban Development, 1*(2), 67-94. https://dx.doi.org/10.22067/gusd.v0i0.18024

Karimi, H., Amiri, S., Huang, J., & Karimi, A. (2019). Integrating GIS and multi-criteria decision analysis for landfill site selection, case study: Javanrood County in Iran. *International Journal of Environmental Science and Technology, 16*(11), 7305-7318. https://doi.org/10.1007/s13762-018-2151-7

Khosravi, K., Shahabi, H., Pham, B. T., Adamowski, J., Shirzadi, A., Pradhan, B., ... & Prakash, I. (2019). A comparative assessment of flood susceptibility modeling using multi-criteria decision-making analysis and machine learning methods. *Journal of Hydrology, 573*, 311-323. https://doi.org/10.1016/j.jhydrol.2019.03.073

Kumar, N., Liu, X., Narayanasamydamodaran, S., & Pandey, K. K. (2021). A systematic review comparing urban flood management practices in India to China's sponge city program. *Sustainability, 13*(11), 6346. https://doi.org/10.3390/su13116346

Liew, D.Y.C., & Che Ros, F. (2021). *"Quantitative Assessment of Flood Vulnerability in Malaysia"*, Alias, N.E., Haniffah, M.R.M. and Harun, S. (Ed.). Water Management and Sustainability in Asia (Community, Environment and Disaster Risk Management, 23, Emerald Publishing Limited, Bingley, pp. 25-32. https://doi.org/10.1108/S2040-726220210000023009

MacArthur, J., & Siwek, S. (2020). *Smart, Shared, and Social: Enhancing All-Hazards Recovery Plans with Demand Management Technologies (No. FTA Report No. 0151). United States.* Federal Transit Administration. Office of Research, Demonstration, and Innovation. https://doi.org/10.21949/1506050

Memariani, A., & Amini, A., & Alinezhad, A. (2009). Sensitivity analysis of simple additive weighting method (saw): the results of change in the weight of one attribute on the final ranking of alternatives. *Journal of Industrial Engineering, 4*(4), 13-18.

Milly, P. C., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P., & Stouffer, R. J. (2008). Stationarity is dead: Whither water management?. *Science, 319(*5863), 573-574. https://doi.org/10.1126/science.1151915

Mohammadzadeh, A. K., Ghafoori, S., Mohammadian, A., Mohammadkazemi, R., Mahbanooei, B., & Ghasemi, R. (2018). A fuzzy analytic network process (FANP) approach for prioritizing internet of things challenges in Iran. *Technology in Society, 53*, 124-134. https://doi.org/10.1016/j.techsoc.2018.01.007

Mudashiru, R. B., Sabtu, N., Abdullah, R., Saleh, A., & Abustan, I. (2022). Optimality of flood influencing factors for flood hazard mapping: An evaluation of two multi-criteria decision-making methods. *Journal of Hydrology, 612*, 128055. https://doi.org/10.1016/j.jhydrol. 2022.128055

Park, K., & Lee, M. H. (2019). The development and application of the urban flood risk assessment model for reflecting upon urban planning elements. *Water, 11*(5), 920. https://doi.org/10.3390/w11050920

Pighills, A. C., Torgerson, D. J., Sheldon, T. A., Drummond, A. E., & Bland, J. M. (2011). Environmental assessment and modification to prevent falls in older people. *Journal of the American Geriatrics Society, 59*(1), 26-33. https://doi.org/10.1111/j.1532-5415.2010.03221.x

Poorzahedy, H., & Rezaei, A. (2013). Peer evaluation of multi-attribute analysis techniques: Case of a light rail transit network choice. *Scientia Iranica, 20*(3), 371-386. https://doi.org/10.1016/j.scient.2012.12.031

Rahmati, O., Zeinivand, H., & Besharat, M. (2016). Flood hazard zoning in Yasooj region, Iran, using GIS and multi-criteria decision analysis. *Geomatics, Natural Hazards and Risk, 7*(3), 1000-1017. https://doi.org/10.1080/19475705.2015.1045043

Reza, B., Sadiq, R., & Hewage, K. (2011). Sustainability assessment of flooring systems in the city of Tehran: An AHP-based life cycle analysis. *Construction and Building Materials, 25*(4), 2053-2066. http://dx.doi.org/10.1016/j.conbuildmat.2010.11.041

Ronco, P., Gallina, V., Torresan, S., Zabeo, A., Semenzin, E., Critto, A., & Marcomini, A. (2014). The KULTURisk Regional Risk Assessment methodology for water-related natural hazards–Part 1: Physical–environmental assessment. *Hydrology and Earth System Sciences, 18*(12), 5399-5414. http://www.hydrol-earth-syst-sci-discuss.net/11/7827/2014/

Saha, A., Pal, S. C., Santosh, M., Janizadeh, S., Chowdhuri, I., Norouzi, A., ... & Chakrabortty, R. (2021). Modelling multi-hazard threats to cultural heritage sites and environmental sustainability: The present and future scenarios. *Journal of Cleaner Production, 320*, 128713. https://doi.org/10.1016/j.jclepro.2021.128713

Seyedmohammadi, J., Sarmadian, F., Jafarzadeh, A. A., Ghorbani, M. A., & Shahbazi, F. (2018). Application of SAW, TOPSIS and fuzzy TOPSIS models in cultivation priority planning for maize, rapeseed and soybean crops. *Geoderma, 310*, 178-190. https://doi.org/10.1016/j.geoderma.2017.09.012

Shahraki, S. Z., Sauri, D., Serra, P., Modugno, S., Seifolddini, F., & Pourahmad, A. (2011). Urban sprawl pattern and land-use change detection in Yazd, Iran. *Habitat International, 35*(4), 521-528. https://doi.org/10.1016/j.habitatint.2011.02.004

Shin, Y. B., Lee, S., Chun, S. G., & Chung, D. (2013). A critical review of popular multi-criteria decision making methodologies. *Issues in Information Systems, 14*(1), 358-365.

Talkhabi, H., Ghalehteimouri, K. J., Mehranjani, M. S., Zanganeh, A., & Karami, T. (2022). Spatial and temporal population change in the Tehran Metropolitan Region and its consequences on urban decline and sprawl. *Ecological Informatics, 70*, 101731. https://doi.org/10.1016/j.ecoinf.2022.101731

UNFCCC. (01 SEP, 2021). Climate change leads to more extreme weather, but early warnings save lives. https://unfccc.int/news/climate-change-leads-to-more-extreme-weather-but-early-warnings-save-lives

Van Westen, C. J., Alkema, D., Damen, M. C. J., Kerle, N., & Kingma, N. C. (2011). *Multi-hazard risk assessment*. ITC School on Disaster Geoinformation Management.

Vlachokostas, C., Michailidou, A. V., & Achillas, C. (2020). Multi-criteria decision analysis towards promoting waste-to-energy management strategies: a critical review. *Renewable and Sustainable Energy Reviews, 138,* 110563. https://doi.org/10.1016/j.rser.2020.110563

Zhao, J., Ji, G., Tian, Y., Chen, Y., & Wang, Z. (2018). Environmental vulnerability assessment for mainland China based on entropy method. *Ecological Indicators, 91*, 410-422. https://doi.org/10.1016/j.ecolind.2018.04.016