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Modeling of access and spatial mobility changes associated with floods in the field of transportation and movement of vehicles in areas 3, 6 and 7 of Tehran

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Abstract

The expansion of urbanization and the changing natural conditions of waterways increase the likelihood of flooding in cities. In this paper, we model the flood-sensitive areas for vehicle movement in areas 3, 6 and 7 of Tehran and determine the critical area of the critical tissue against floods using the AHP method, GIS and PSO algorithm. For this purpose, land use, rivers, roads, subways, population density, traffic density, altitude and slope are selected as effective flood parameters in areas 3, 6 and 7 of Tehran and weighting of these parameters in the Expert software environment. Choice done. Then the results were transferred to GIS software environment and a map of flood-sensitive areas in three areas 3, 6 and 7 was prepared for vehicle movement. The results of flood risk in areas 3, 6, and 7 in Tehran show that areas with very low risk are 0.5%, areas with low risk are 6.8% and areas with medium to high risk are 25.7%. This indicates the movement of the vehicle in case of flood risk in the 7th district of Tehran, which is due to population density, building (land use), proximity to the central area to the canal, and the lack of proper drainage. While using the PSO algorithm, districts 6 and 7 of Tehran are flood-prone areas.

1. Introduction

Floods occur when the water level in a place exceeds the allowable limit, and according to researchers and experts, floods are a destructive phenomenon in which water flows from various sources and can be sudden or intentional (Fernandes et al., 2018; Desai et al., 2015; Santos and Reis, 2018; Prăvălie and Costache, 2013; Mishra and Sinha, 2020; Sarkar and Mondal, 2020).

In various parts of the world, natural factors like height, soil tissue, drainage compression, interval, vegetation, and others operate as flood triggers (Azareh et al., 2019; Hosseini et al., 2020 Floods frequently cause a catastrophic hazard to human life as well as a socioeconomic ruin (Hirabayashi et al., 2013; Costache, 2019), Also floods trigger human life and economic loss, as well as the demolition of agricultural products, harm to the ecosystem, and the extension of infectious illnesses (Shafapour et al., 2019; Isazade and Aliegigy, 2021).

With the occurrence of floods, many users downstream of the river are exposed to threats and dangers, and also floods occur due to heavy rainfall in the city due to the impenetrability of urban surfaces these floods often appear as flooding of roads and streets, houses, especially in low-lying areas of the city (Grimaldi et al., 2016; Grimaldi et al., 2018; Khorrami et al., 2019; Li et al., 2018; Li et al., 2016; Wright et al., 2018).

But no one knows when and how floods will occur, the hydraulic properties of urban drainage systems are affected by daily activities (for example, the discharge of solid waste into drainage systems), and the characteristics of surface runoff affect transportation and Urban relocation affects different areas of the city. Therefore, it is very difficult to determine the areas for moving the vehicle when the streets in the city are flooded (Bozorgy, 2007).

Based on the literature, research has been done on this subject, for example, Karahan et al. (2012) Estimated the parameters of the nonlinear masking method using the Hybrid Harmony Search (HHS) algorithm. The proposal was able to more accurately estimate the parameters of the Muskingham nonlinear model.

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Xu et al. (2017) used the Differential Evolution (DE) algorithm to estimate the parameters of the Musking model nonlinearly, comparing their results with those of HS, PSO, and GA, which were compared by other researchers. The results obtained from DE are not much different from other meta-exploration algorithms and can.

As mentioned previously, storm surges of sufficient strength can flood roadways and render them impassable for several hours to multiple days or weeks (Karim and Mimura, 2008; Kleinosky et al., 2006). The roads are not only interdicted by standing water, they are blocked by deposited debris, or may be destroyed by the force of the storm surge via hydrostatic uplift (Kelman and Spence, 2004). Aside from directly impacting the overall connectivity of the network, in the worst cases, local and regional damage to the streets may accelerate the balkanization process, where large portions of the road network are disconnected from the system at large, creating distinct sub-networks.

Assessing the impact of river floods on the transportation system with emphasis on travel demand is of great importance in Tehran to reduce the risk of floods in the future. In the field of climate change and urbanization, there is already a risk of increasing river floods. However, managing mass evacuations is so complex that it requires the coordination of government agencies, local authorities, and civil society members to ensure clear guidelines. Followed by the population to achieve effective and safe evacuation. When other emergency response processes are not sufficient to protect people's lives, widespread organized evacuation is the ultimate choice. It is a very serious and risky action that often affects many people. In terms of time, money and credit can be costly. In this paper, to process and interpret human and qualitative information along with quantitative information, we used AHP methods and the PSO algorithm to drain floods in areas 3, 6 and 7 of Tehran to move the vehicle. In addition, the AHP method can be consistent with human reasoning and is therefore able to integrate expert experience, which can be important for flood evacuation decisions in different urban areas.

2. Study area

Tehran, the capital of Iran and the center of Tehran province, is geographically situated at 51° 17′ to 51° 33′ East and 35°36′ to 35° 45′ North Figure 1. Tehran is composed of 22 regions, of which regions 3, 6 and 7 are very vulnerable to urban floods due to being mountainous and were selected as the study area in this paper.

3. Method and materials

In this paper, we weighted ground data including land use, rivers, roads, subways, population density, traffic density, altitude and slope using the AHP model from 1 to 9 and gave the most weight to river data. We allocated population, and passages considered the lowest weight for subway data. AHP method was used to make the weighting of the criteria compatible with the human mind and nature.

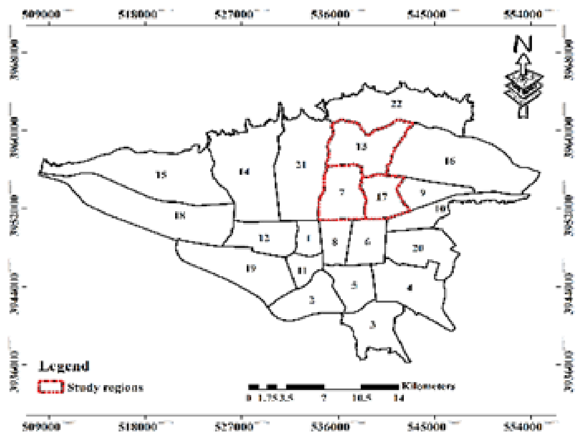

Figure 1. Study area

Because each of the variables had a different effect on the distribution of floods in the streets of districts 3, 6 and 7 of Tehran. To make the weighting of the criteria compatible with the human mind and nature, the AHP method was used in Expert Choice software.

Because each of the variables had a different effect on the distribution of floods in the streets of districts 3, 6 and 7 of Tehran. In the PSO algorithm, we used the values obtained from the AHP model, and our parameters in this algorithm were a distance from the river, a distance from the road, population density, slope and altitude.

In implementing the PSO algorithm, we made a comparison between the PSO method and local search.

3.1. Analytical Hierarchy process (AHP model)

The process of hierarchical analysis is one of the most popular multi-criteria decision-making methods, first invented by Thomas L. Saati in the 1970s. This method is used in a variety of decision-making situations from simple personal decisions to complex economic decisions. The process is based on three basic principles: model structure and judgment judging.

Criteria, inference from priorities Two important issues in this approach are consistency and consistency, and the length of time it takes to make judgments on a complex decision issue, especially as the number of options increases (Dagdeviren et al., 2009).

3.2. Particle swarm optimization (PSO)

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For an N-dimensional problem with solution P, the velocity of the i-th particle is calculated from Equation (1) (Kim et al., 2001).

$$x_{id}^{n+1} = x_{id}^{n} + v_{id}^{n+1} \quad (1)$$

According to experience, if the value of w is large at first and decreases during the optimization process, it gives better results, so equation (2) is used for w (McCarthy, 1983).

$$w_n = w_{max} - \frac{(w_{max-}w_{min})xn}{iter_{max}} \qquad (2)$$

Where is w_{max} the initial inertia, w_{min} the final inertia $iter_{max}$ is the maximum number of iterations of the algorithm.

4. Discussion and results

4.1. Investigating the effect of effective parameters on the occurrence of floods

Lithology: Lithology is an important variable in the field of potential for urban floods because it affects hydrological and hydrogeological conditions such as soil permeability and surface runoff (Miller et al., 1990; Siahkamari et al., 2018) Lithological map of regions 3, 6 and 7 using 1: 100000 and 1: 250,000 geological maps taken from the Geological Survey of Iran and prepared in the ArcGIS software environment. Most human activities such as urban planning and agricultural land are concentrated in areas 3, 6 and 7.

Soil: This parameter indicates soil quality based on the minimum amount of water infiltration (USDA, 1986). Soils are classified into four groups A, B, C and D in terms of hydrological characteristics. Group A soils have little potential for runoff production and Group D soils have more potential for urban runoff (Gittleman et al., 2017) to prepare a hydrological map of areas 3, 6 and 7 of Tehran from geological maps, land use as well as global data. Soil Hydrology Group from the NASA website was used in the Arc SWAT model.

Land use: According to Garcia Ruiz et al. (2008), land use in each region is very important for hydrological responses in different periods (García-Ruiz et al., 2008). Bakers et al. (2013) in their research showed that changes in land use can increase the likelihood of flooding in the region (Becker et al., 2013). In this article, to prepare the land use map of the region, the Landsat 8 OLI sensor product related to April 2022 was used.

Elevation classes: In general, there is an inverse relationship between flood risk and altitude. The frequency of floods decreases with increasing altitude, so lower altitudes are more sensitive to flooding (Khosravi et al., 2016). The map of the elevation classes of the region was prepared using the digital elevation model (DEM) with a spatial resolution of 12.5 meters on 4 floors.

Slope: A strong positive correlation can be found between the slope of the area and the surface flow velocity (Das et al., 2018). Areas experiencing a sudden drop in slope are likely to encounter large volumes of water, causing severe flooding in these areas (Pradhan et al., 2009). Slope maps of areas 3, 6 and 7 of Tehran were prepared using digital elevation model data with a spatial resolution of 12.5 meters in the Arc GIS software environment and four floors.

Distance from the river: This parameter is an important geomorphic factor that must be considered to prepare an accurate flood risk map. As the distance increases, the slope. The height increases. Areas far from the river channel are less vulnerable to floods (Das et al., 2018). In this paper, the distance map of waterways was prepared using Euclidean tools in the Arc GIS software and the distance values ranged from 0 to 3145 meters.

4.2. Flood modeling in areas 3, 6 and 7 of Tehran using the AHP method and PSO

Examination of the results obtained from Expert Choice software showed that among the effective factors in flood risk in areas 3, 6 and 7 of Tehran, distance from the river with a weight of 0.185, passages, height of 0.107, land use with a weight of 0.103, slope with a weight of 0.102, respectively. It has the highest weight and impact on the risk of urban floods in areas 3, 6 and 7 of Tehran for vehicle movement. Also, population density with a weight of 0.101, traffic density with a weight of 0.100 and metro with a weight of 0.99 have the least impact on the occurrence of flood damage in areas 3, 6 and 7 of Tehran in the movement of vehicles.

The results of this study with the results of Ahmadi et al. (2011) concluded that among the effective factors in urban floods, the distance from the river has the highest weight and impact, and also the study of Elsheikh et al. (2015) in Malaysia that Soils have the least impact on the occurrence of floods, respectively. Then, the final map of flood risk zoning in areas 3, 6 and 7 of Tehran in the movement of vehicles was prepared by combining different layers and applying the weight of each, which is shown in Figure 2. Figure 2. shows that the route of all canals and canals in areas 3, 6 and 7 are in the range of flood risk with high and very high intensity that Bahminafar et al. (2016) in the city of Shandiz, Mashhad, which was destroyed.

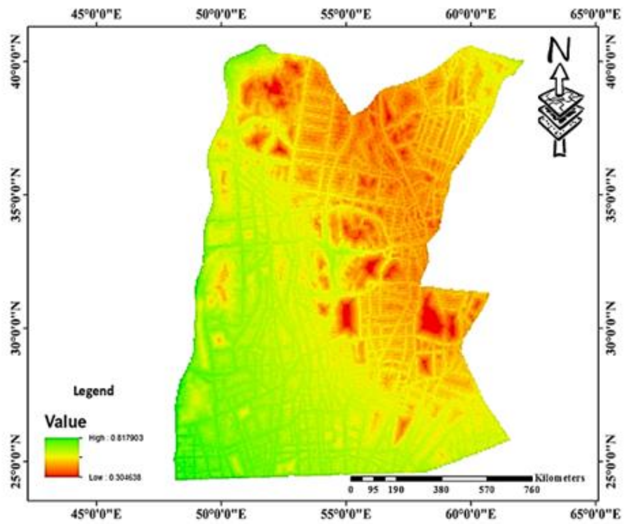

Figure 2. modeling changes in accessibility accompanying occurrence of flood.

Natural routes with urban development as well as the expansion of the city along the riverbed and non-compliance with engineering principles and improper design of structures such as bridges are exacerbating floods in the region. In the PSO algorithm, we made a comparison between the PSO method and local search, which is shown in Figure 3. Identification of flood sensitivity points in areas 3, 6 and 7 of Tehran for moving the device has almost the same performance as the PSO algorithm when flooding roads due to flooding for vehicle movement in areas 3, 6 and 7 of Tehran, while the local PSO search algorithm for areas 3, 6 and 7 has the best high-cost function. It was 0.68%, but the PSO algorithm obtained close to 0.6% using this function Figure 4.

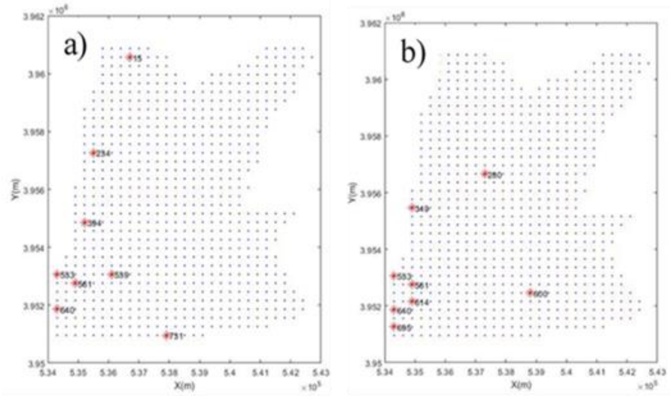

Figure 3. a) Identification of flood sensitive points in areas 3, 6 and 7 of Tehran for vehicle movement with PSO algorithm, b) Identification of flood sensitivity points in areas 3, 6 and 7 of Tehran for vehicle movement by local search of PSO algorithm

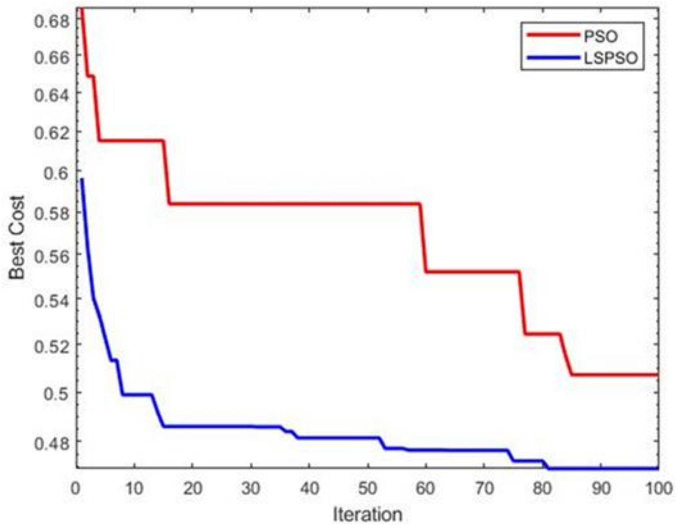

Figure 4. Comparison of PSO algorithm and local search of PSO algorithm

5. Conclusion

In this paper, modeling to identify flood-prone and flood-prone areas for vehicle movement in areas 3, 6 and 7 of Tehran and they are better and more efficient management during floods, flood risk zoning using the AHP model, GIS and PSO algorithm to be examined. By examining the results of Expert Choice software and PSO algorithm, the most effective factors in case of flood risk for the vehicle can be identified and by prioritizing them, effective solutions can be adopted during urban floods.

The results of flood risk in areas 3, 6 and 7 in Tehran show that areas with very low risk are 0.5%, areas with low risk are 6.8% and areas with medium to high risk are 25.7%. This indicates the movement of the vehicle in case of flood risk in the 7th district of Tehran, which is due to population density, building (land use), proximity to the central area to the canal and the lack of proper drainage. Is. While using the PSO algorithm, districts 6 and 7 of Tehran are flood-prone areas.

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