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Urban vulnerability zoning against earthquakes using ANP network analysis process model

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Abstract

earthquakes have the potential to cause widespread devastation, especially in urban areas where infrastructure and population density are high. To reduce the impact of earthquakes, understanding and analyzing urban seismic vulnerability is critical. Earthquake risk mapping plays an important role in assessing urban seismic vulnerability. By dividing an area into different areas based on earthquake risk levels, authorities can prioritize resources and implement targeted mitigation measures. In this regard, the seismic vulnerability assessment of different areas of Shiraz city has been studied.The present study was applied in terms of purpose and was examined in a descriptive – analytical way. In order to achieve the objectives of the study, first, the criteria for the vulnerability of urban tissues to earthquakes (physical and physical factors, environmental factors and Earth morphology, access to relief and treatment centers and proximity to hazardous facilities) were identified, then, using the ANP network analysis model and its software, the value and importance of each of the criteria determined, in the next step, the results of the network analysis process with 4 criteria and 21 sub - criteria of integration and map of the vulnerability of urban tissues in urban areas of shiraz were prepared. The results of the study showed that among the influential criteria, physical and physical factors received the highest score, and the central and southwestern urban areas were the most vulnerable in Shiraz to earthquakes. By doing the right planning before the event and having post-crisis management plans, it is possible to significantly reduce the number of casualties and damage caused by the consequences of earthquake damage.

Keywords:vulnerability,networkanalysisprocess,GeographicInformationSystem,earthquake,metropolitan area of Shiraz.

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Extended Abstract:

1. Introduction

The Zagros region is one of the most important seismic areas of Iran . Due to the location of the Shiraz metropolitan area in this area, the aim of this study is to estimate and expand the vulnerability caused by earthquakes in the Shiraz metropolitan area and its periphery(haiderzadeh kashri and colleagues, 1394).

The aim of this comprehensive analysis is to examine the concepts of earthquake risk mapping and network analysis in assessing urban seismic vulnerability. By implementing effective strategies and applying advanced techniques, we can better prepare cities for future seismic events and minimize loss of life and property. Earthquake risk mapping plays an important role in assessing urban seismic vulnerability. By dividing an area into different areas based on earthquake risk levels, authorities can prioritize resources and implement targeted mitigation measures. This zoning approach allows efficient allocation of funds and coordination of efforts to reduce the vulnerability of urban areas to seismic hazards. By understanding the specific risks associated with each region, city planners and policymakers can make informed decisions to protect critical infrastructure and increase the resilience of communities.Earthquake risk mapping includes a multidisciplinary approach that uses a variety of methods and techniques. First, geologists and seismologists analyze historical Earthquake Data to identify active fault lines and time intervals between earthquake occurrences. This information helps to determine the seismic risk level for a particular area. Secondly, engineers conduct site-specific studies to assess the vulnerability of buildings and infrastructure to landslides. Engineers can estimate possible damage caused by earthquakes, taking into account factors such as soil type, building materials and construction quality. Finally, social scientists help understand the vulnerability of different communities and develop targeted mitigation strategies by studying the demographic and socioeconomic characteristics of urban areas.

2. Materials and methods

The network analysis process (ANP) first proposed by Thomas L. H. is one of the multi-criteria decision-making methods (MCDM) that improves the process of hierarchical analysis (AHP) by replacing the network with the hierarchy (Momin, 1389).In recent years, NETWORK analysis has emerged as a powerful tool in understanding urban seismic vulnerability. By modeling connections and dependencies of various infrastructure systems, such as transport, water and communication networks, network analysis can identify vital nodes and paths that are prone to failure during earthquakes. This approach helps urban planners and policymakers prioritize infrastructure upgrades and develop contingency plans to ensure continuity of essential services during seismic events. Network analysis also highlights the cascading effects of infrastructure failures and enables a more comprehensive understanding of urban seismic vulnerability. Network analysis makes it possible to identify vulnerable areas in urban environments. By analyzing the connectivity and interdependencies of infrastructure networks, researchers can pinpoint areas that are highly susceptible to disruption during earthquakes. For example, a study conducted in a large city showed that disruption of a transport artery can lead to significant traffic congestion and delays in emergency response. By identifying these critical areas, policymakers can allocate resources to strengthen infrastructure resilience and minimize the potential for catchment failures. Network analysis also makes it possible to identify alternative routes and backup systems to increase the strength of urban networks. The research method in this research is descriptive – analytical and Applied Research. The study used the opinion of urban planning and management specialists in the implementation sector as well as the University, Consulting Engineers, geological experts, municipalities and roads and Urban Development to complete questionnaires and further consensus. By designing a questionnaire using the hierarchical analysis process, these specialists (20 people) who have each experienced in the field of earthquake risk in the operational and Executive areas were asked to rate each of the criteria and sub-criteria and determine the preference of each of the criteria. In the selection of sub-criteria, an attempt was made to avoid as much as possible the interference of the subject in other criteria and to select sub-criteria that indicate the status of the criterion associated with it. Chang described the steps of the network analysis process in six steps: 1-transforming the problem into a network structure, 2-performing paired comparisons between all decision elements, 3-non-weighted Matrix cloud formation, 4 - weighted Matrix cloud formation 5 - limit Matrix cloud formation and 6-cluster Matrix formation and determining the final weight of the elements(21,2005: Chung et al). The following graph summarizes the steps of the network analysis process.

3. Tests results

The geological map of the study area was first obtained from the Geological Survey of Iran on a scale of 1:100,000 and was produced using the Editon tool in the ArcGIS 10.8 linear fault layer software environment. Then, using the Euclidean Distance and Line Density tools, the distance layer was obtained from the fault lines and their density in the study range, respectively. In order to map the lithological units of the region, the geological map of Shiraz with a scale of 1:100,000 was used.A map of the distance from the epicenter of the earthquake shows that the greatest impact and damage is mainly in the area near the earthquake points, which is why the distance from the earthquake points and their density are prepared. As we move away from the points of occurrence, the earthquake density index decreases.

Proper access to crossings, in addition to providing proper services to the injured during an earthquake, is also effective in reducing the degree of vulnerability. The adjustment of the attitude of urban designers and planners in the field of proper design of crossings is considered very important in terms of crisis management (purmhamdi and moussaibzadeh, 1387). In relation to the level of access, the width of the crossing, the better the potential for the movement and non-blocking of these crossings, so that we do not face problems such as disruption of communication networks and lack of relief during the earthquake. In this regard, the Grade 2 arteries (intercity network) are twice as important as the Grade 1 arteries (freeways and highways), and as such, they are three times more valuable than the local transit network.

One of the most important issues after the earthquake is the disruption of the urban network and secondary physical damage. As population increases, urban areas will be prone to more earthquake damage, and as a result, vulnerability to earthquake risk increases. In this regard, in order to assess the population density index, the Population Density Layer was produced and the areas with higher population density were given higher priority than other areas. One of the criteria was to identify areas with higher population density, which is given higher priority than other areas according to the purpose of this study. In this study, a demographic density benchmark map was prepared using demographic data from the blocks of the city of Shiraz. The results show that the highest score is allocated to the range of Saadi, abiwardi, Gulistan, walfjar, mehergan and kushk, five hundred Army units. Unfortunately, in many urban development projects in our country, it is seen that areas of the city that have high risk during earthquakes have high building and population densities, which leads to an increase in the vulnerability of these areas during earthquakes.It should be noted that in most urban areas of Shiraz, due to high land prices and high population density, the degree of enclosure and building density is high, resulting in the rise of the vulnerable grade of buildings against earthquakes. The occupancy level is also less than the level of 200 meters of microwave, and tissue microwave and the decrease in the quality of residence and hygiene in the area of worn tissue, due to which can be traced to the economic and social situation of tissue residents(Rafi and colleagues, 1401).

Gas fuel pumps in the Mid-City area have made these areas more vulnerable. Depending on the area of the area affected by fire and explosion, the number of houses exposed to fire and explosion, the mortality rate can be estimated, and with the help of the results obtained from the explosion radius and the amount of heat received from the explosion, the safe range for use around the fuel pump stations is determined (1392, armament; Saleh). Energy transmission lines and gas pressure reduction stations and urban gas networks in the western and northeastern areas of the city have made these areas more vulnerable.In a study analyzing the vulnerability of the power transmission line network of Khorasan Province to earthquakes, the highest vulnerability of the said Lines is in the southeastern areas of the province (1398, joanbakht; Hosseini), in this regard, the study of the vulnerability of the power transmission line network shows that the vulnerability of the high-pressure power transmission lines in the city of Shiraz is relatively high and in the western and southwestern area of the city has made these areas more vulnerable. Unfortunately, in Shiraz, a number of fuel stations have been built, despite high-explosive gasoline tanks, without any officers in the vicinity of houses and other important buildings. In the event of a major earthquake in Shiraz, which geologists have considered inevitable, one of the problems during an earthquake is the potential explosions, which is why calculating the safe distance of the fire caused by the earthquake at the gas station in the city and the possible damage to the surrounding users is one of the requirements of planning for crisis management and determining the rules for assigning users around the gas station. Depending on the area of the area affected by fire and explosion, the number of houses exposed to fire and explosion, the mortality rate can be estimated, and with the help of the results obtained from the explosion radius and the amount of heat received from the explosion, the safe range for use around gas station Stations is determined(1392, armament; Saleh).

Finally, to calculate the seismic vulnerability of Shiraz, 4 criteria and 21 sub-criteria were prioritized and weighted against each other. According to the collection of expert opinions from various fields of physical and physical factors, environmental factors and Earth morphology, proximity to hazardous facilities, access to relief and medical factors have the greatest impact on the seismic vulnerability of the City, respectively

4. Conclusion

The achievements of this study indicated that the criteria for seismic vulnerability to earthquakes, the final map of the vulnerability of the city of shiraz, we conclude that the high and very high vulnerability of the area is related to the Central, Western and southwestern parts of the city(Figure 8). The distribution of urban facilities in Shiraz is not well done and depending on the distance from urban facilities, buildings in the center, north and west of the city, including neighborhoods located in worn-out fabric, are more vulnerable compared to the rest of the area studied, which will reduce the vulnerability of the city in the earthquake crisis by deploying urban equipment and facilities in these areas. Also, the widening of low-width crossings and the implementation of retreats, especially in old neighborhoods and informal housing neighborhoods, the proportional distribution of building and population densities at the city level, especially in the body of the crossings, more attention to the degree of confinement of the building height according to the width of the crossing, the appropriate distance between high-rise buildings and the body of the crossings through the creation of green spaces, is suggested to reduce the possible blockage of the crossings in order to provide better relief. Several issues play a role in increasing the city's seismic vulnerability, including access and width of crossings (blocking of crossings), services and relief (disproportionate distribution of urban facilities), adjacent to hazardous facilities (fire and explosion risk), and natural earth factors(development of urban structures in seismic areas), which are separated by areas: The areas of Hussain Al-Hashemi, Gulistan(international exhibition area), Bazin, Hussainabad and jawadiya located in the 10th District of Shiraz city(distance from relief and service factors, environmental factors and land morphology), the areas of unity Quai, city culture, the old texture of Qasr Al-Dasht located in the 6th District of Shiraz city(elevation, high population density and environmental factors and land morphology), the areas of abiurdi and the republic located in the 1st District of Shiraz city(development of urban structures in seismic areas, environmental factors and the mofology of the land, the amount of slope and high population density), the Gulshan, Derki and adelabad areas located in District 4 (worn-out fabric and adjacent to hazardous facilities) the Bnei Hashemi areas ،Fatemion martyrs and heroes located in the 9th District of Shiraz city(high population density, distance from relief and service factors, environmental factors and land morphology), kushk Maidan, Rizwan, Sultanabad and southern Corps located in the 5th District of Shiraz city(worn-out fabric, adjacent to hazardous facilities and distance from relief and service factors), fakhrabad, gulkob, tanning, glassmaking, pottery, beer, Keta foot, Sheikh Ali Shepherd and dehpilah located in District 2 of Shiraz city(worn-out fabric, access, distance from relief and service factors, proximity to hazardous facilities), Saadi areas, seven tons and Baba Kohi located in District 3 of Shiraz city(development of urban construction in seismic areas, environmental factors And land mofology, the amount of slope and worn tissue), the state areas, podenek and Ghadir located in the 11th District of Shiraz city(development of urban structures in seismic areas, environmental factors and land mofology, the amount of slope and high population density)the nasrabad, abunsar, sahlabad, Sharifabad and kushkak areas located in the 7th District of Shiraz city(high population density, distance from relief and service factors, environmental factors and land morphology).

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