Research Paper

Assessment of Seismic Vulnerability in Urban and Rural Health Service Centers of Hamadan Province Using Geographic Information Systems

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ABSTRACT

Background: Maintaining the performance of healthcare centers during an earthquake is essential. Evaluating the seismic vulnerability of these centers is a priority. This study aims to evaluate seismic vulnerability using geographic information systems (GIS) in urban and rural health service centers of Hamadan Province, Iran, in 2021.

Materials and Methods: This is a descriptive, analytical cross-sectional study that was conducted in comprehensive health centers. The data of this study were collected in the form of a questionnaire and a map and analyzed using the hierarchical analysis model. In the study, 10 criteria, such as the type of materials, the age of the building, the quality of the building, the number of floors, the area of the centers, as well as the distance from the existing fault lines, and the proximity to the hazardous centers, are defined using a valuation questionnaire, using the chain analysis method, weighting and prioritizing, and using GIS, vulnerability maps of comprehensive urban and rural health centers of Hamadan province were obtained.

Results: Among the indices, the distance from the fault index with a weight of 0.328 has the highest and the area distance with a weight of 0.17 has the lowest final weight. The vulnerability distribution of the centers included 46.99% very low vulnerability, 7.23% low vulnerability, 5.42% moderate vulnerability, 20.48% high vulnerability, and 19.88% very high vulnerability.

Conclusion: Considering that many urban and rural health service centers are vulnerable to seismic hazards, it is necessary to strengthen vulnerable centers against earthquakes.

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1. Introduction

Among the natural hazards, earthquake has particular importance. Iran is highly exposed to damage caused by an earthquake due to its location on the earth's earthquake belt [1]. The presence of active faults in Hamadan Province, Iran provides the potential for earthquakes with a magnitude of 6.1 and 6.7 on the Richter scale, which, along with the vulnerable structure of urban and rural health service centers, increases the possibility of casualties following an earthquake [2].

After the occurrence of such incidents, injured people are looking for health care and services. In addition to maintaining the health of employees, clients, equipment, and property, healthcare service centers must be able to continue functioning and respond to clients and victims caused by the earthquake [3, 4]. Iran's system of providing primary health services is a unique model in the region and a model for many countries in the world. This network provides valuable services to people with about 18 thousand health homes and 6 thousand urban and rural health centers across the country. The country's exposure to various natural and man-made hazards requires that the network system be ready to deal with these hazards and provide services to the affected people [5]. The vulnerability of health service centers due to risks is vital in crisis management [3]. If these centers are destroyed or damaged, they will not be able to provide services and will lack any functionality. Therefore, analyzing the vulnerability of health centers is one of the crucial steps in the crisis management process and one of the critical concerns of health managers, and it is considered one of the basic needs of the stages of prevention and preparedness against crisis; therefore, it is possible to reduce the negative effects of future crises by correctly understanding vulnerable tissues and adopting appropriate long-term and short-term policies [3, 5, 6].

One of the major problems after any accident is the lack of information and uncertainty about their accuracy. The geographic information system (GIS) can provide managers and decision-makers with the largest amount of information in an integrated manner by maintaining the three indicators of speed, accuracy, and flexibility. One of the crucial measures in the pre-crisis preparation phase is to prepare vulnerability maps of urban and rural health service centers in that region. GIS provides the possibility that information can be viewed and analyzed simultaneously and integrated, and is a valuable tool to reduce chaos and disorder in crisis management [6].

Because Hamadan City is one of the areas with earthquakes and damage to buildings, including health and treatment centers throughout history, to reduce these damages, it is necessary to check the vulnerability of health and treatment centers against earthquakes and to strengthen the existing buildings [6]. On the other hand, few studies have been conducted in this field; therefore, this study aims to estimate the seismic vulnerability of urban and rural health service centers in Hamadan Province against earthquakes using GIS.

2. Materials and Methods

The present study is a descriptive/analytical cross-sectional study that was conducted in the urban and rural health service centers of Hamadan Province in 2021. Hamadan Province is the fourteenth in terms of population and the twenty-third in terms of area. The largest number of comprehensive health centers in this province is 35 urban and rural comprehensive health service centers in Hamadan City, 28 in Melayer City, and 19 in Kabudarahang City, Iran, respectively. In terms of the tectonic situation, Hamadan Province is located between two main active young faults of Zagros in the southwest and Auj in the northeast of the province [7]. The density of faults in two areas of Hamadan province is as follows: a) The north-eastern region of the province, including Qaraqaz mountains, Agh Darband mountains, Kharghan mountains, and Shah Qolak b) The central region of the Province, including the south and east parts of Hamadan City (Alvand mountain range in the south and Armenian mountain range in the east) [8].

In this study, to obtain the required information, a checklist and spatial data were used, in this way, physical and physical information from 166 urban and rural health centers, the location of fault lines, and also the location of hazardous centers in Hamadan Province were investigated. In this research, the number of 10 criteria of the type of materials, the age of the building, the quality of the building, the number of floors, the area of the centers, as well as the distance from the existing fault lines and the proximity to the hazardous centers (Table 1) were defined, using a valuation questionnaire, using the analytical hierarchy process (AHP), weighting and prioritizing and using GIS, vulnerability maps of comprehensive urban and rural health centers of Hamadan Province were obtained.

Table 1. Sub-criteria of vulnerability of urban and rural health service centers of Hamadan Province

Sub-criteria of Vulnerability		Classification
Distance from the fault (m)	0-1000	5
	1000-2000	4
	2000-3000	3
	3000-4000	2
	<4000	1
Distance from urban and rural water reservoirs (m)	0-150	5
	15-300	4
	300-450	3
	450-600	2
	<600	1
Distance from telecommunication towers (m)	0-150	5
	150-300	4
	300-450	3
	450-600	2
	<600	1
Distance from fuel station (m)	0-500	5
	500-1000	4
	1000-1500	3
	1500-2000	2
	<2000	1
Type of building materials	Metallic	1
	Concrete	2
	Metal brick	3
	Cement brick	4
	Clay and mud	5
The number of floors of buildings	1 floor	1
	2 floor	2
	3 floor	3
	4 floor	4
Quality of buildings	Newmade	1
	Renovator	2
	Maintainable	3
	Repair	4
	Destroyed and worn out	5

Sub-criteria of Vulnerability		Classification
Age of buildings (y)	0-5	1
	5-15	2
	15-30	3
	30-50	4
	>50	5
Area of building (m)	0-200	5
	200-400	4
	400-600	3
	600-800	2
	<800	1

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Based on Table 1, the vulnerability sub-criteria of comprehensive health centers have been classified. The distance from the fault is one of the sub-criteria. The more the distance of the health service center from the fault is smaller, the higher the value of its points in the classification will be. Distance from dangerous centers, such as urban and rural water reservoirs, telecommunication towers, and fuel stations are other sub-criteria of vulnerability. The more distance between the centers and these dangerous centers is smaller, the higher the value of its points in the classification will be. The type of building materials is also one of the sub-criteria of vulnerability. In this criterion, clay and mud have the highest vulnerability score in the classification. In the sub-criterion of the number of floors, the more the number of floors in health service centers is higher, the more vulnerable it will be. Regarding the quality of the building, the more the building is destroyed and worn out, it has a higher classification of vulnerability than the newly constructed buildings. Older buildings with less area get more points in vulnerability.

The valuation of effective natural criteria in earthquake damage zoning was done with the theory of technical experts. Then, based on the multi-criteria decision-making approach, the effective indicators of the vulnerability of the centers were examined using AHP. What is vital in calculating the AHP method is its consistency rate (CR). Checking the compatibility rate is a mechanism that determines the compatibility of comparative indicators. If CR<0.1, we accept the comparisons and derive the weight of the criteria. If CR>0.1, it is necessary to adjust the CR or adaptation rate to an acceptable level by making changes in the binary matrix [15]. To investigate the vulnerability caused by the earthquake in Hamadan Province by AHP, ten layers of information were used, including the distance from the fault, the number of floors of the buildings, the quality of the building, the type of materials, the age of the buildings, the area of the centers, and the distance from the hazardous centers. In this regard, the view of experts and specialists on the subject of earthquake vulnerability was used to apply their opinion and score the effective parameters on earthquake vulnerability zoning. In this research, the inconsistency index obtained from the AHP Extension software version 5 is equal to 0.0954, which indicates the compatibility of the matrices. According to the weight of each of the criteria, for each of the 10 criteria, the vulnerability map was prepared in the form of separate layers. To combine the layers, the weighted overlay method was used using GIS. Using this method, the weight of each index was affected in that index. With the determination of the weight of the layers, the layers were categorized or classified based on their importance and priority in physical development using GIS software. Each layer with a higher class number has more value and points. Then the layers related to each of the indicators were combined in GIS software and finally, the vulnerability map of urban and rural health service centers was extracted.

3. Results

The results of the frequency distribution of the vulnerability sub-criteria of 166 urban and rural health service centers in Hamadan Province in this study showed that the majority of centers have metal frames (54.81)91, one floor (54.8)91, age 0-5 years (49.39)82, fresh (40.96)68 and have an area of 401-600 m (47.59)79 (Table 2). Also, the data indicate that the more the distance from the fault is smaller, the higher the value of its points in

Table 2. Frequency distribution of vulnerability sub-criteria of urban and rural health service centers in Hamadan province

Criteria	Sub-Criteria	No. (%)
Type of materials	Brick	74(44.57)
	Steel structure	91(54.81)
	Clay and mud	1(0.62)
	Sum	166(100)
Number of floors	1 floor	91(54.8)
	2 floors	65(39.15)
	3 floors	7(4.21)
	4 floors	3(1.83)
	Sum	166(100)
The age of the building (y)	0-5	82(49.39)
	6-15	11(6.62)
	16-30	21(12.65)
	31-50	21(12.65)
	>50	18(10.82)
	Sum	166(100)
Quality of building	Newmade	68(40.96)
	Renovator	25(15.06)
	Repair	21(12.65)
	Maintainable	33(19.87)
	Destroyed and worn out	19(11.46)
	Sum	166(100)
The area of the centers (m)	200-400	11(6.62)
	401-600	79(47.59)
	601-800	31(18.67)
	<800	45(27.12)
	Sum	166(100)

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the classification will be. Proximity to high-risk areas, such as fuel stations, water tanks, and telecommunication towers affects the vulnerability of centers. The type of materials and structure also has a crucial effect on the stability of buildings. Metal skeletons and reinforced concrete are less vulnerable than other materials. As the height and number of floors increase, the vulnerability of buildings increases. The quality of newly constructed, repaired, or demolished buildings is the main indicator for vulnerability assessment. The older the building is and the more it is part of destroyed buildings, the more points it has in the classification (Figure 1).

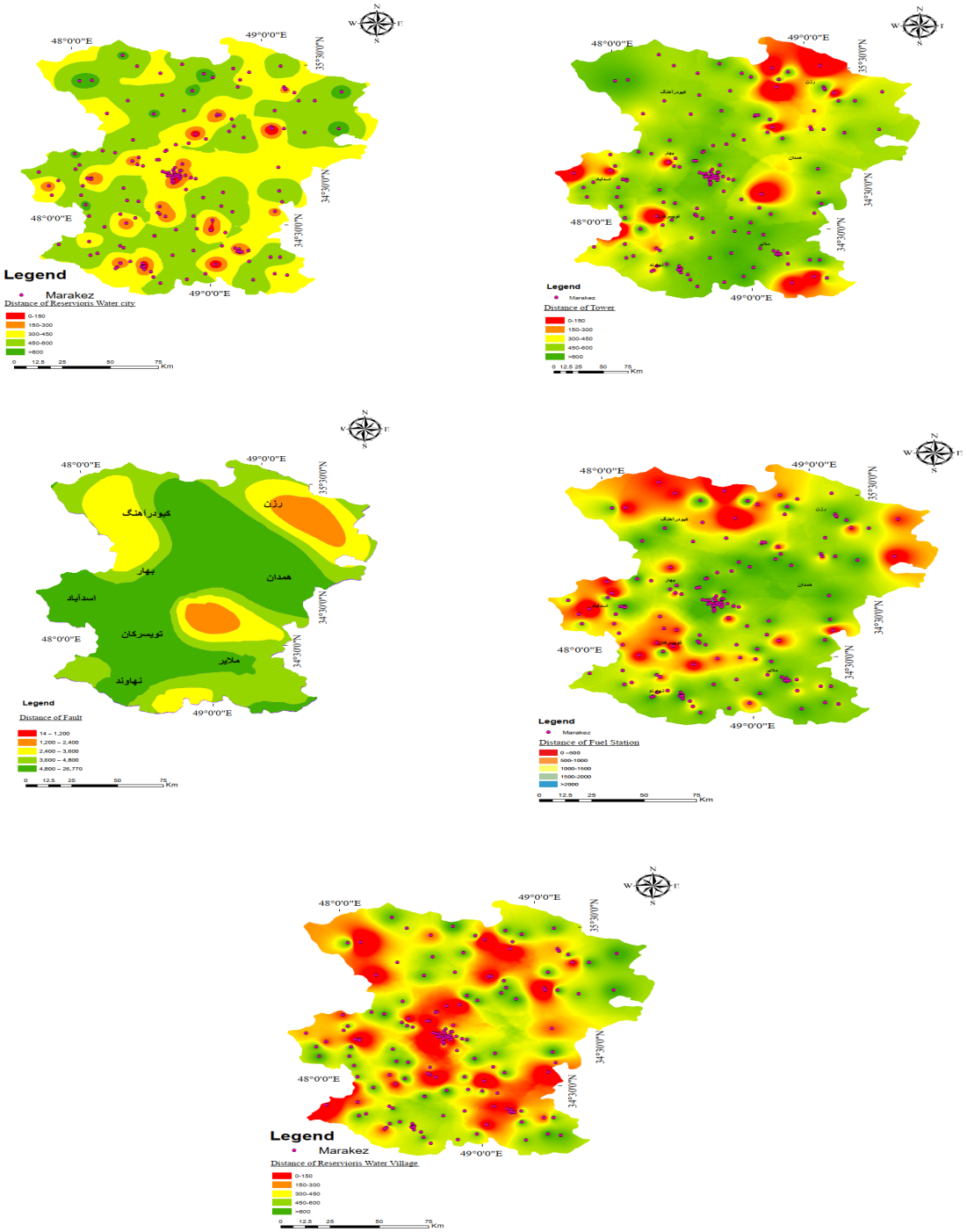

Figure 1. Classification of the distance of health centers from dangerous centers

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Figure 2 shows the set of layers corresponding to the sub-criteria related to the vulnerability of urban and rural health service centers in Hamadan Province.

According to the defined indicators, after creating the raster layers and classifying them, the calculated weights were applied to the layers in the Arc GIS software and the final map of the vulnerability of the health centers of Hamadan Province to earthquakes was prepared, which is shown in Figure 3.

In investigating vulnerability zoning, it was determined that in terms of vulnerability, 46.99% of centers have a very low vulnerability, 7.23% low vulnerability, 42.5% medium vulnerability, 20.48% high vulnerability, and 19.88% have a very high vulnerability. The highest vulnerability is in urban centers

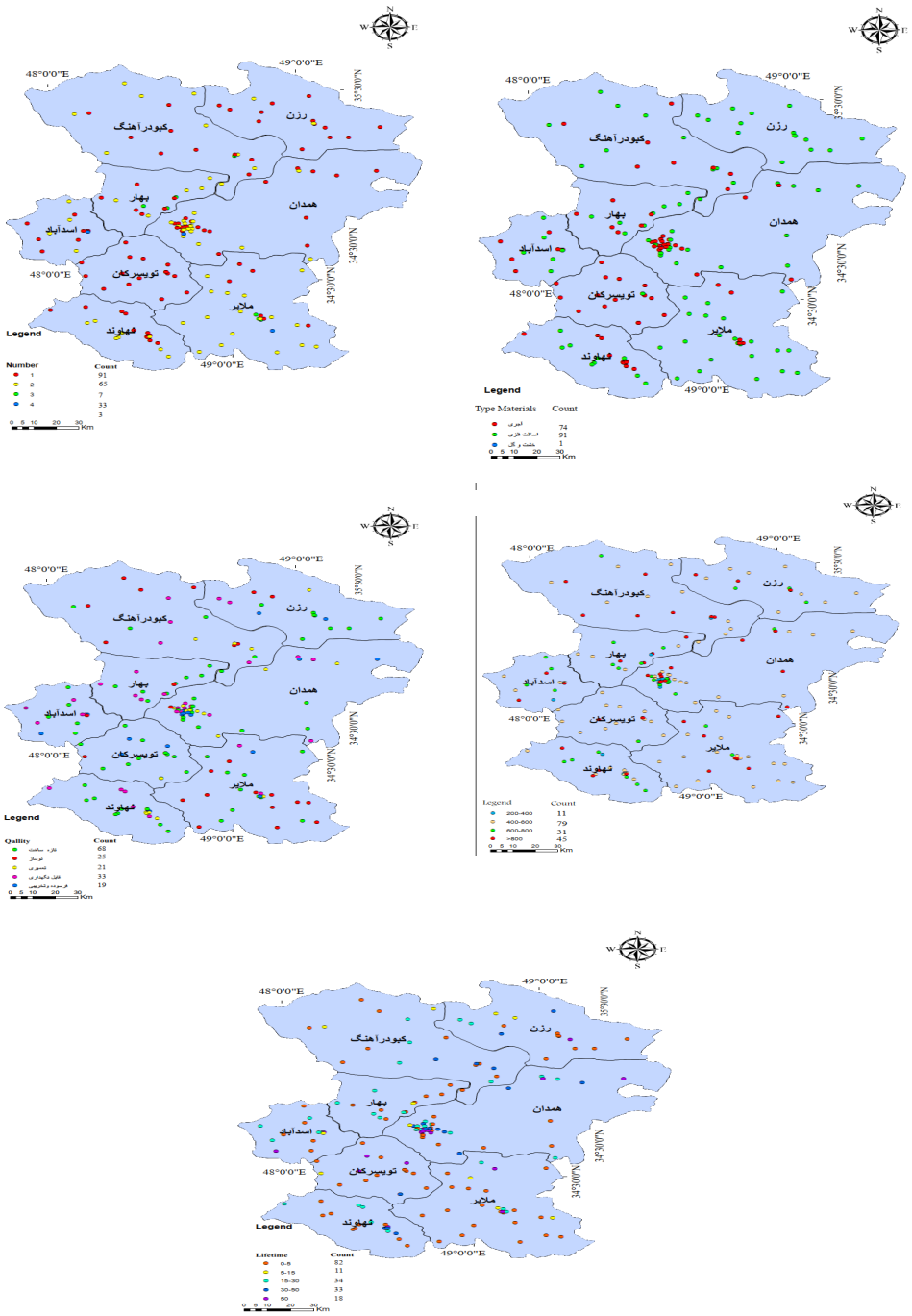

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Figure 2. The set of layers corresponding to the sub-criteria related to the vulnerability of urban and rural health service centers in Hamadan province

by 31%, and urban and rural centers, respectively with 20% have high vulnerability and 19% have very high vulnerability.

4. Discussion

This study was conducted to evaluate the seismic vulnerability of urban and rural health service centers in Hamadan Province using GIS and with the help of 10 physical vulnerability criteria, such as type of materials, building age, building quality, number of floors, area, distance from the fault, and proximity to risk centers. Several studies have evaluated the physical characteristics of sensitive and administrative buildings and centers. Banica et al.'s study in 2017 titled urban resilience based

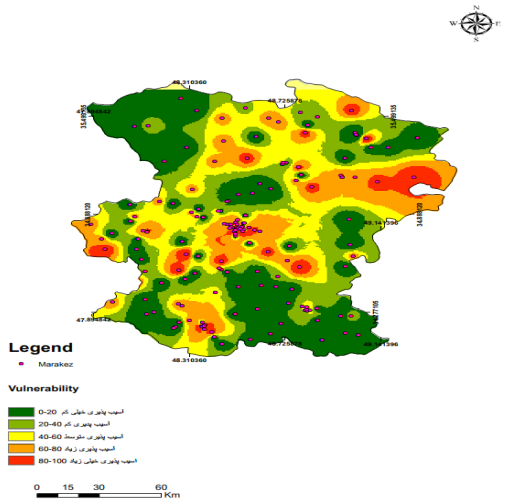

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Figure 3. The final map of vulnerability of urban and rural health service centers in Hamadan Province

on GIS in Lassi City, Romania, showed that all physical and physical indicators should be examined to assess seismic vulnerability [9]. Albolescu's study to evaluate the seismic vulnerability of schools in Slovi, Romania, showed that schools that are old and high are more vulnerable [10]. In the current study, one of the criteria is the age of the building, which considering that 10% of the urban and rural health service centers of Hamadan Province has a long history, therefore, it is considered one of the main and influential factors on the vulnerability of buildings, which should be paid more attention. Mazumdar et al.'s study in 2018 titled seismic vulnerability assessment of buildings and facilities in Chittagong, Bangladesh based on GIS showed that 38% of healthcare centers have low efficiency during earthquakes and cannot have their activity structure [11]. Considering that this study is based on the GIS and uses the criterion of fault lines to determine the seismic vulnerability, it is consistent with the conducted study, but it did not choose other indicators and criteria and it is not consistent with the results of the conducted study. Alam et al.'s study in 2018 aimed at assessing the seismic vulnerability of residential neighborhoods in Mymensingh, Bangladesh, using AHP models, showed that 37 residential neighborhoods are highly vulnerable, 55 are highly vulnerable, 75 are moderately vulnerable, and 74 are in the low category of vulnerability [12]. This study is consistent with the present study regarding the division of vulnerable areas. The results of the study conducted by Santa-Cruz et al. in 2017, which was conducted to assess the seismic risk in 41 hospitals in Lima City, Italy, indicated high damages in the hospitals of the city, which was most likely due to structural vulnerability [13]. Jonidi et al.'s study was conducted to assess the structural vulnerability of health centers in Tehran Province. The tool of this study was a checklist for assessing the condition of buildings in healthcare centers in Tehran Province. This study showed that the total vulnerability of buildings in healthcare centers in Tehran Province was about 73.08% [5], while the overall vulnerability in healthcare centers in Hamadan Province was 19.8% which is not comparable with the centers of Tehran. In addition, the current study, unlike the study of Junadi, which is a single variable, investigated 10 variables at the same time using the software of the location situation, which is critical in terms of this issue. One of the other issues in the discussion of the vulnerability of health centers is the age and longevity of the buildings. Mobaraki et al.'s study in 2018, titled physical vulnerability assessment, showed that among the physical criteria, the type of materials, the life of the building, and the wear and tear of the building's fabric have more weight. These measures are more effective in destroying buildings and causing financial and human damage [14]. In the study conducted, 18 centers over 50 years old and 33 centers between 3 and 50 years old existed, considering that the level of worn-out is influential in vulnerability in addition to other parameters. This study is consistent with the present study. According to the statistics of new constructions and repairs of worn-out buildings in 2020, the highest quality of buildings is in Malayer City.

The older the building is and part of worn-out and destroyed buildings, the more points it has in the classification. The useful life of the building is considered to be 50 years in the design regulation. The useful life of the building (year of completion of the building index) by the materials used in its construction indicates

the amount of depreciation and worn-out of the building, or it expresses the durability and strength. The analysis conducted shows that the life of the building is one of the crucial parameters in the degree of vulnerability of urban areas and the longer the life of buildings, the higher the degree of vulnerability and vice versa. This factor is also related to the quality of buildings, which increases casualties and damages during earthquakes and the blocking of communication routes. The longer the life of the buildings, paying attention to the increase in worn-out and the use of less durable materials in the past, the resistance of the building against earthquakes decreases, and the vulnerability increases [12].

5. Conclusion

Considering that many urban and rural health service centers in Hamadan Province are vulnerable to earthquake hazards, it is necessary to make vulnerable centers resistant to earthquakes. Proximity is considered another damaging factor to health service centers; therefore, the implementation of the plan to build health centers by considering the distance from the fault lines, as well as paying attention to the age and quality of the materials of the centers, retrofitting the buildings related to health services can be a vital measure to reduce vulnerability during disasters. Considering the many capabilities of GIS and the need to use it in healthcare systems, it seems necessary and useful for researchers and health managers to pay more attention to other capabilities of this software.

The limitations of this study were the non-cooperation of some organizations due to security reasons that were beyond the control of the researchers.

Ethical Considerations

Compliance with ethical guidelines

This design has been approved by the Research Ethics Committee of Hamadan University of Medical Sciences (Code: IR.UMSHA.REC.1399.935, No.: 9911218320).

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Authors' contributions

Conceptualization, supervision, methodology, investigation, data analysis, writing the original draft, review & editing: All authors; Data collection: Arezou Karampourian;

Conflict of interest

The authors declared no conflict of interest.

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