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# Investigating the Vulnerability of Mehdishahr County to Natural Hazards with a Comprehensive Risk and Crisis Management Approach

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**Original Article**

## Abstract

**INTRODUCTION:** Today, natural crises have become an inseparable reality of human life, and one of the key measures to prevent the destructive consequences of natural disasters in any region is the identification and zoning of natural hazards. Therefore, the purpose of this research is to identify the factors affecting the occurrence and zoning of natural hazards within Mehdishahr county, Semnan province.

**METHODS:** This research was conducted using a mixed method(quantitative and qualitative) and the status of risk and crisis management in Mehdishahr was examined. Data were collected from existing documents, interviews with key stakeholders (local officials, experts, and representatives of local communities), and analysis of statistical data related to past incidents. Using the Analytic Hierarchy Process (AHP) method, the factors under study were compared in pairs and the weight of each was calculated.

**FINDINGS:** According to the findings, floods have the greatest impact on the riverbed and distance from it, the river parameter with 0.335 plays more than one-third of the flood risk, and land use with 0.096 has the lowest sensitivity. Also, faults with 0.370 are considered the most important and land type with 0.087 is the least important factor in causing earthquakes. Based on the results obtained from the AHP model, human factors, especially roads and paths, have the greatest impact on the occurrence of landslides, and along rivers they account for one-third of the factors affecting the occurrence of landslides.

**CONCLUSION:** Considering the factors affecting the occurrence of natural disasters in Mehdishahr county, some preventive measures are necessary to preserve natural resources and the environment, ensure sustainable economic and social development, and reduce vulnerability, including: changing land use and respecting the privacy of rivers, preventing construction on the banks of rivers, stabilizing and stabilizing slopes, observing building regulations, and strengthening local capacities through education, empowerment, and promoting public and specialized awareness.

**Keywords:** Crisis Management; Analytic Hierarchy Process (AHP); Sustainable development; Mehdishahr County.

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## Introduction

Crisis refers to the incidence of a natural and technological occurrence or one that is caused by man, resulting in severe damage to properties and loss of life and injury. (1) It have always been a part of human history, with humans always struggling to overcome them and bring them under control. With the passage of time and rise of modern cities, particularly following the Industrial Revolution, urban populations have continued to grow constantly. According to the World Bank, about 56% of the world's population lived in cities in 2020, and this figure is projected to reach 68% by 2050. (2)

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In the meantime, a key stage in crisis management is the analysis of risks and the assessment of vulnerabilities. This stage includes the identification and analysis of various risks and the assessment of weak spots in society's infrastructure, which could help provide necessary planning.

Crisis management effectively requires the accurate analysis of risks and the identification of the capacity of societies and organizations to deal with these risks. Vulnerability assessment also involves the analysis of weak spots in social, economic, and environmental situations. (3)

Due to its specific geographical situation and climatic diversity, Iran has been recognized as one of the countries with the highest known natural disasters worldwide. These geographical features have led to the incidence of such crises as earthquakes, floods, and typhoons, not to mention others, causing severe social and economic impacts on human lives. (4)

Iran's location in the Alpine-Himalayan earthquake belt also subjects it to earthquakes. Moreover, climatic changes have caused plenty of extreme hazards such as floods, droughts, dust storms, and other atmospheric phenomena. (5)

On the other hand, unbalanced development, unauthorized construction in high-risk areas, infrastructure deterioration, and lack of safety principles have increased the vulnerability of communities and infrastructure in different regions of Iran to natural disasters. (6) For example, the Metropol Complex in Abadan incident back in 2022 demonstrated that construction standards had not been met, which could have also led to human disasters and heavy economic damage. Natural and man-made disasters in Iran may cause considerable economic losses each year, resulting in the destruction of infrastructure, falling agricultural outputs, closing businesses, and rising healthcare expenses.

In addition, disasters can lead to population displacement, increased poverty, exacerbate inequalities, and the emergence of psychological and social problems. (7)

Effective crisis management is crucial in meeting sustainable development goals, as reducing disaster risks, preserving the environment, promoting social health and welfare, and ensuring sustainable economic growth will require a robust and effective crisis management system. (3) Therefore, it is critical to provide crisis planning and management to help reduce damages. Iran's exposure to regional crises has provided its crisis management system with valuable experiences in this connection. Utilizing such mechanisms as emergency systems and collaborating with NGOs such as the Red Crescent Society and mobilizing the public, this system could effectively control crises and reduce damages.

Natural hazards have long plagued human societies and have made up a part of human history. Today, there is a widening gap between human science findings and their capacity to preserve human lives and properties, with nature continuing its assault on human life. Meanwhile, sciences partly contribute to increasing these hazards, causing new forms of hazards with different implications originating from the improper utilization of technologies. (8) For this, it is increasingly becoming an urgent need to conduct research of this kind in cities like Mehdishahr, which is regarded as one of the most climatically desirable regions of Semnan, Iran, and is witnessing an increasing rate of construction each year. For this, necessary measures should be taken to manage crises in this city and minimize its vulnerability.

## Methods

This research was conducted using a mixed method (quantitative and qualitative) and the status of risk and crisis management in Mehdishahr was examined. Data were collected from existing documents, interviews with 30 key stakeholders (local officials, experts, and representatives of local communities), and analysis of statistical data related to past incidents.

The purpose of this research is to assess the natural and environmental vulnerability of Mehdishahr County to natural hazards with an emphasis on earthquakes, floods, and landslides, which was conducted using Delphi methods and the Analytical Hierarchy Process Model. A combination of qualitative and quantitative methods was used to collect data. This stage included providing a structured questionnaire to experts and key individuals in the field of crisis management, as well as distributing and analyzing the questionnaire to the residents of the county, thereby examining the level of awareness and attitude of the community towards crises and existing weaknesses. (9&10)

The Delphi method is widely used in crisis management and vulnerability monitoring studies. In this way, a group of local experts and specialists



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in various environmental and social fields are selected as a Delphi panel and, through several stages of questioning and feedback, identify and prioritize vulnerability factors. (11)

In this study, 30 experts from different groups were used to achieve the desired goals. They prepared effective factors in crisis management in the areas of crisis management, passive defense and regional planning, natural geography and natural resources, and in the next stage, they gave points to each of these factors in pairs. (12)

***Assigning Final Scores to Options***

At this stage, coefficients of importance of indicators and sub-indicators for the pre-determined goal and coefficients of importance of options for each of the indicators and sub-indicators are calculated. Here at this stage, the final score of each option is calculated by combining the said coefficients of importance. To do so, the principle of hierarchical composition, which yields a priority vector that takes into account all judgments across all hierarchical levels, is used.

The first step in assessing environmental vulnerability is to identify the damaging or crisis-causing factors, which should be done using the Delphi method with the advice of experienced experts.

Mehdishahr County, like other regions of the country, is almost always damaged by several major factors, the most important of which are earthquakes, floods, and landslides.

The collected data are processed using special software such as Expert Choice for the AHP analysis aimed at analyzing qualitative data. (13) This analysis helps identify special patterns of vulnerability and the need to improve crisis management in the city of Mehdishahr. To identify seismic high-risk zones, such criteria as faults, materials of geological formations, soil science, land slope, land use, and land evaluation are examined.

It is important to analyze the flood hazard as one of the phenomena that cause huge economic losses. In other words, floods are among the most complicated and destructive natural disasters that endanger human life and property and result in adverse social and economic implications for society, more than any other disasters. (14) Floods in Iran are broadly divided into three types: floods caused by rain, a combination of snowmelt and rain, and snowmelt. In cold and mild regions across Iran, including the north and the northwest, and a large part of the west, floods caused by rain or a combination of snowmelt and rain are predominantly common (15) Meanwhile, to identify high-risk flooding zones, such criteria as river flows, earth slope, aspect, surface cover, land use, land slope, and soil are used. Also, slope failure is another phenomenon that causes huge losses and has gathered pace with human interference with the natural ecology over the last decade. (16)

To identify slope failure-related high-risk zones, such criteria as rivers, aspect, slope, land evaluation, geology, land use, soil, and surface cover are used.

After identifying the crisis-causing factors, the next stage uses credible resources and professionals' views on each of the crisis-causing factors to determine criteria for each of those factors. When determining the factors, attempts were made to identify and apply all the criteria affecting the factors causing the crisis, except for the cases where it was not possible to get information on some of the criteria.

After determining the factors and their relevant criteria, the valuation stage of each of the factors started where each of the criteria was valued by the extent to which they affected the crisis-causing factors. The valuation stage of the factors and criteria was performed using the AHP model and the Expert Choice software, with each of the criteria being compared to other criteria in pairs to distinguish how they may affect the system. Then in the next stage, the value obtained from each of the criteria is multiplied by a certain layer, as the GIS is used to overlay the criteria of each factor to eventually yield the final outputs of each factor. Finally, the outputs of each factor are calculated by overlaying the layers based on the weight of each factor using the GIS software, yielding the environmental vulnerability map of the city. (Figure 1)

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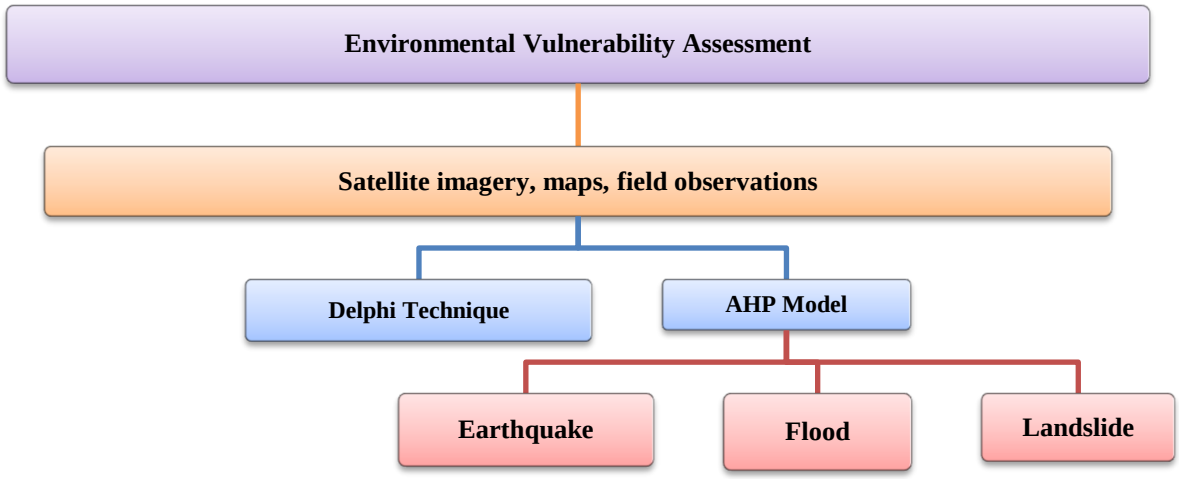


**Fig1.** Stages of the procedure

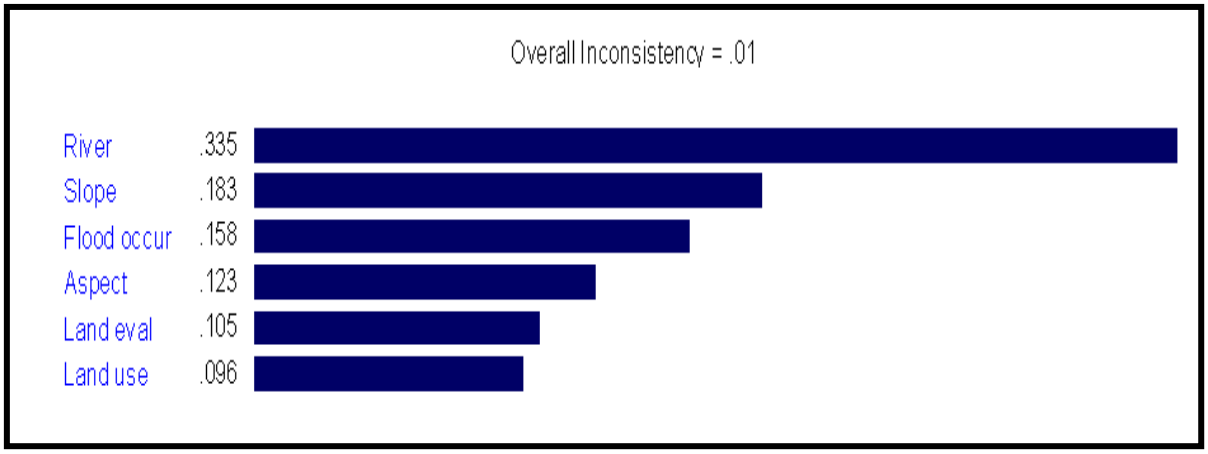


**Diagram 1:** Pairwise comparison of various parameters affecting flood occurrence

## Findings

### *The Area Under Study*

Mehdishahr or previously Sangsar is located in north of Semnan city and lies in the southern parts of the Alborz Mountain ranges, it is connected to Mazandaran province to the north, Semnan city to the south, the cities of Damghan and Semnan to the east, and Tehran and Mazandaran provinces to the west (Figure 2).

Mehdishahr county covers an area of 1943 km2 and is situated at 52° and 21' E, and 35° and 46' N. The tallest peak of the city is Shahmirzad Peak standing 3965 m high and is situated in the rural district of Chasm. This city must be regarded as a fully mountainous region for being situated in the south of Alborz Mountains. The average annual temperature stands at 3.8°, varying from -16° to 34° as the coldest and the hottest months of the year, respectively.

This research selected the studied area as a region with specific geographical and social features. The city represents a strategic situation in Semnan province, and for this, it is constantly subjected to natural hazards such as earthquakes, floods, and climatic phenomena. This region was selected due to the high importance of crisis management in vulnerable areas and their classification based on the need for a rapid response to crises. (17)

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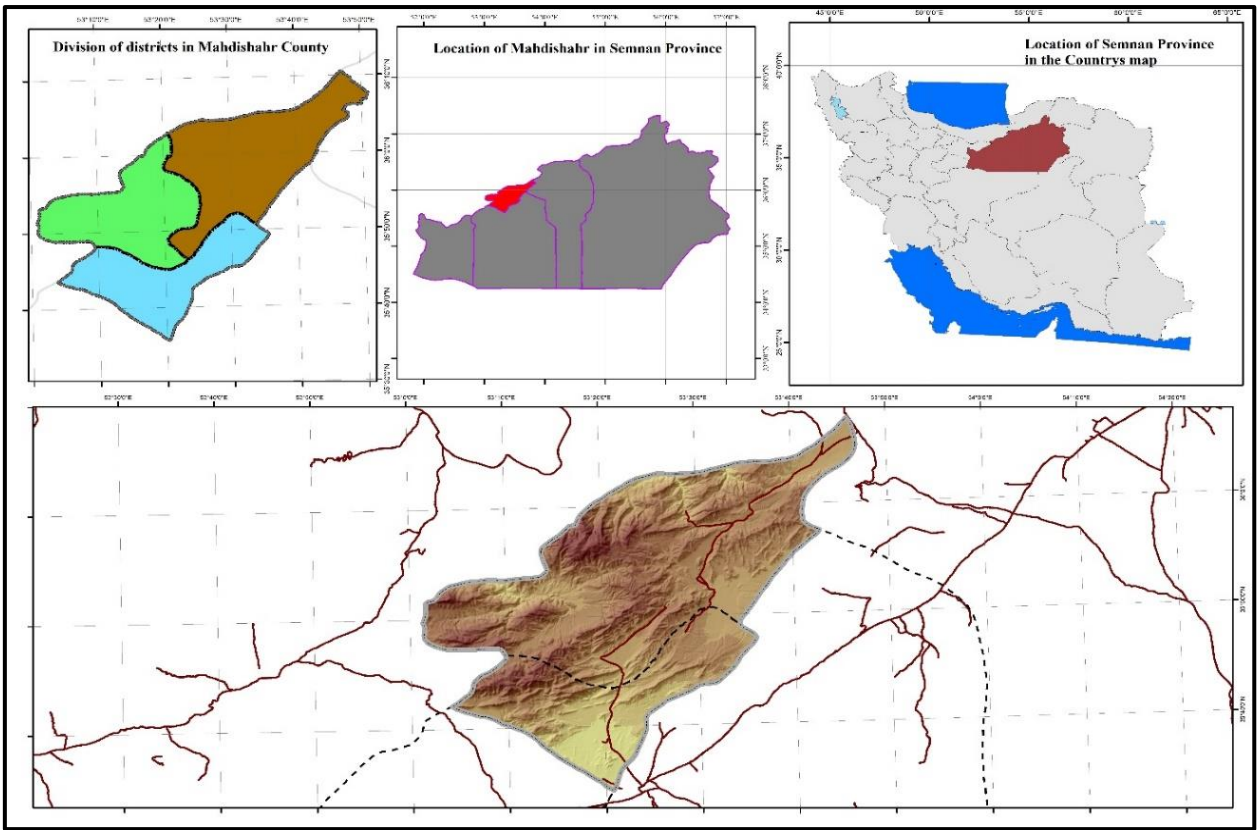


**Figure 2:** Location of Mehdishahr county in administrative divisions

### *Flood Hazard Zoning*

Man has been struggling with flood hazards since old times. The destructive impacts of floods in the past were much lower, which was primarily due to the failure of the ecological balance affecting runoffs, and human activities in floodplain regions. Today, rising population and consequently, rising food, housing, and recreational demands, on the one hand, and the existence of fertile land and accessibility to water on the outskirts of rivers, on the other hand, have led to a rising population rate in these regions. Also, increased demographic density in flood-prone areas requires taking measures to reduce harmful impacts. For this, it is imperative to make policies and take regional crisis management measures to help identify river characteristics and their functioning, and to deal with the losses that may originate from flooding with certain return periods.

To provide flood hazard zoning in the area under study, all the stages, explained in the earthquake part, were performed. The six layers of rivers, slopes, aspect, land evaluation, land use, and occurred flood spots were used to examine the flooding hazard of the area. Meanwhile, the Expert Choice software was used to assign weights to each of the layers and the sub-criteria. (Diagram 1).

Based on this model, it is observed that rivers have the greatest impact on flooding in Mehdishahr county. In other words, the distance from rivers plays a significant role in the level of vulnerability, and the closer the area is to the river, the greater the probability of flooding. According to the results, the river parameter with 0.335 plays more than a third of the risk of flooding, and land use with 0.096 has the lowest sensitivity.

Figure 2 shows that the highest risk of flooding in the county is related to the banks of the rivers, especially in the central and northwestern parts, and these areas also include the highest number of floods in the region.

### *Earthquake Hazard Zoning*

Iran's seismic hazard maps provided by the country's International Earthquake

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Research Institute show that the city of Mehdishahr fall under high-risk regions, which is due to the geological faults in the region.

Here, the region features numerous faults of different aspects contributing most to the occurrence of earthquakes in the area.

To zone the earthquake hazard in the city of Mehdishahr, the five parameters of fault, geology, slope, land use, and land evaluation were used. The AHP technique showed that among the parameters, faults contributed the most. It was also revealed that the factors of fault and land evaluation were the most and the least important factors involved in earthquakes at 0.370 and 0.087, respectively (Diagram 2).

Following the layer of faults come geological features that had the highest impact on the intensity of destruction caused by earthquakes in the region. Figure 3 demonstrates the earthquake hazard zoning of Mehdishahr county. The Figure shows that the areas where the faults have expanded, especially overthrust and main faults, were in the high-risk areas. These faults are seen scattering in the eastern and central regions of the city, demonstrating a higher seismic hazard in the central and northeastern parts and a lower seismic hazard in the southern parts due to the type of the faults.

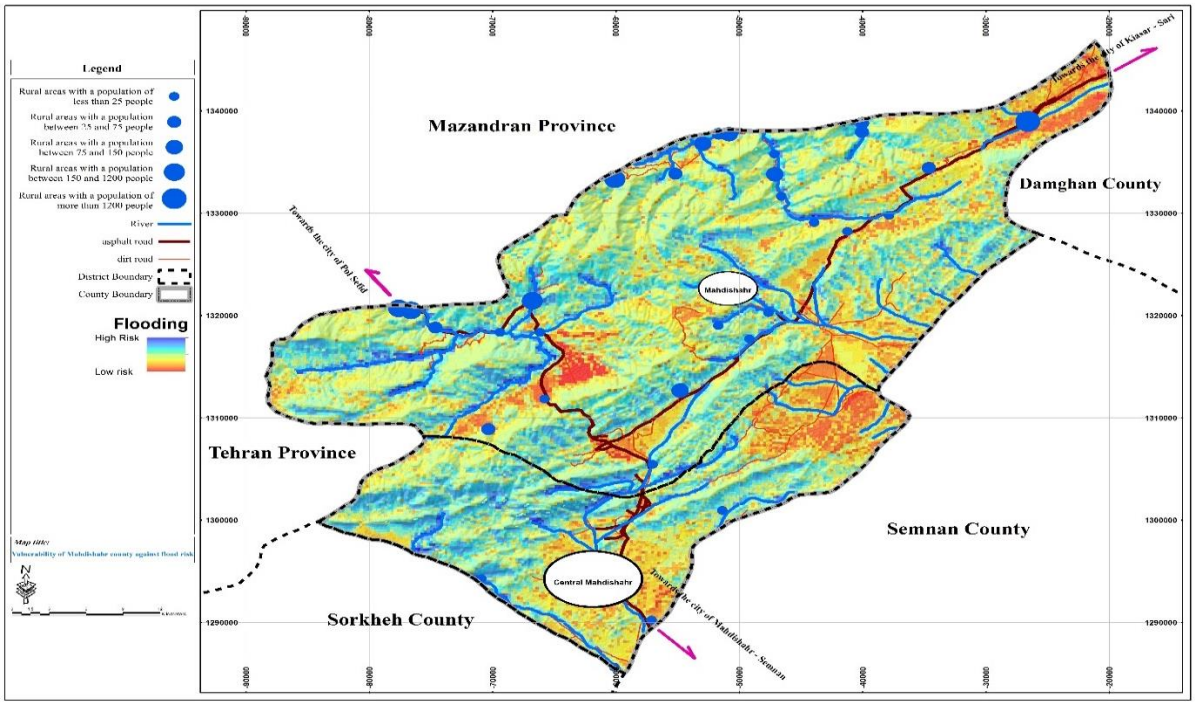


**Fig 3.** Vulnerability of Mehdishahr county to flooding hazard

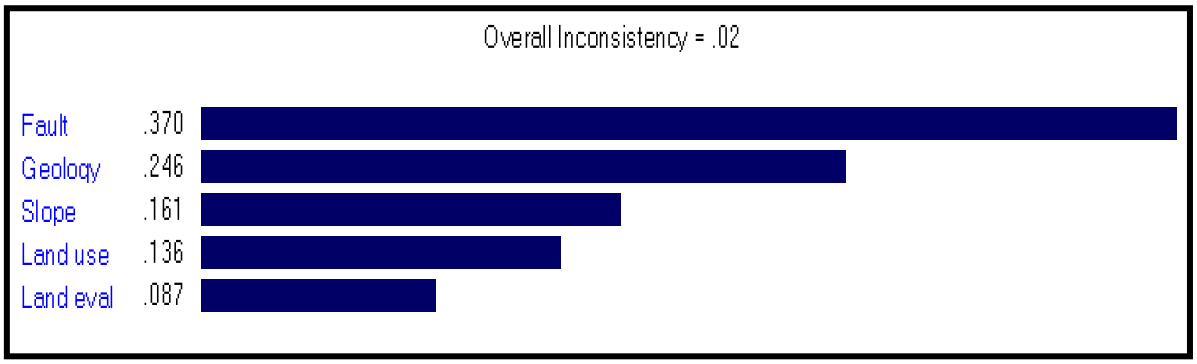


**Diagram 2:** Pairwise comparison of various parameters in causing earthquakes



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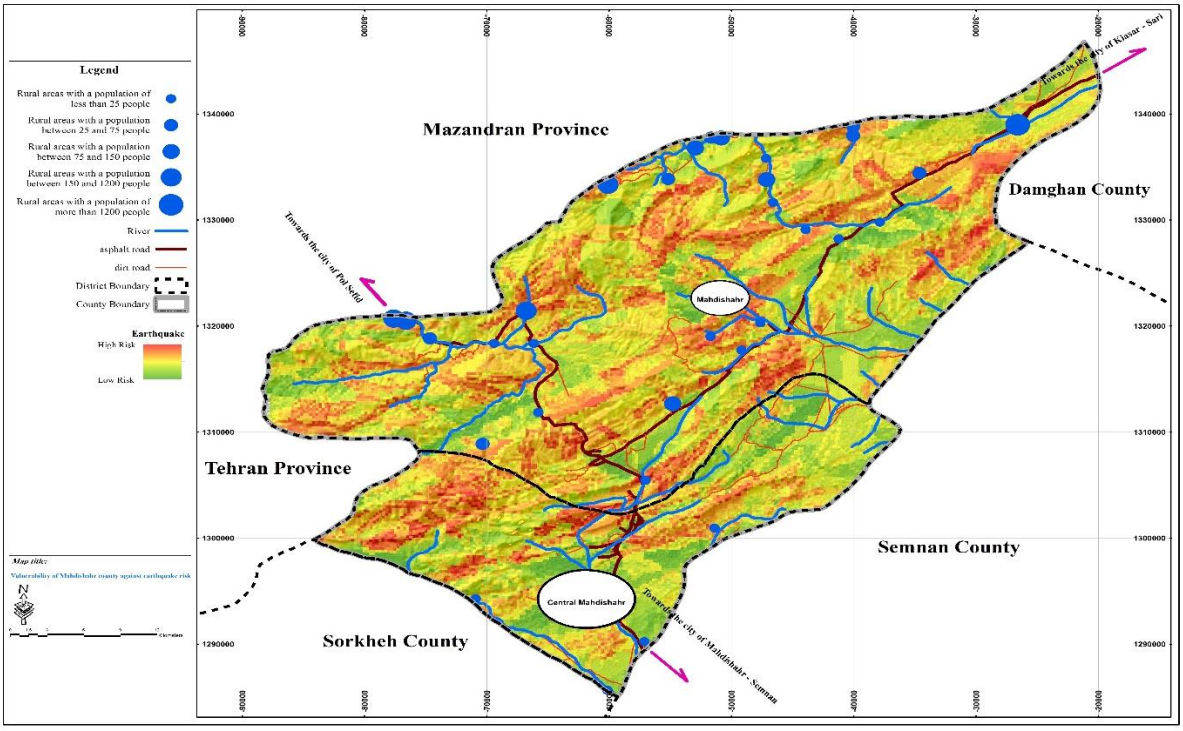


**Fig 3.** Earthquake Hazard Zoning in the Limits of Mehdishahr county

***Landslide Hazard Zoning***

Landslides sometimes occur in the city of Mehdishahr limits due to steep slopes, soil material, ground tectonics, freezing conditions, temporal conditions, and the presence of water. To zone landslide hazards in the city limits, the eight parameters of rivers, aspect, slope, land evaluation, geology, land use, roads, and occurred landslides are used, with all stages, performed for zoning the floods and earthquakes, being examined based on these parameters. The AHP model findings showed that human factors, especially roads and routes, were highly effective in landslides, and, along with rivers, they accounted for around one-third of the factors affecting the occurrence of landslides. Meanwhile, roads contributed most to the occurrence of landslides at 0.192, followed by land evaluation which held the lowest impact at 0.073. Diagram 3 below demonstrates the pairwise comparison of the factors affecting the occurrence of landslides.

These parameters were finally used to prepare the landslide hazard zoning map within the city limits. Central and northwestern parts saw the highest risk of landslides, due to the presence of such features as rivers and roads constructed, as well as steep slopes. An overview of the likelihood of landslide occurrence risks suggests that most landslides have occurred around rivers and roads, which has been due to slope failure and topographic disruption. Therefore, rivers, roads, and slopes can be regarded as the main factors affecting the occurrence of landslides in the city of Mehdishahr. Figure 4 below demonstrates the vulnerability of Mehdishahr county to the landslide hazard.

In addition, findings from zoning natural hazards (e.g., floods, earthquakes, and landslides) in the area under study were used to analyze environmental vulnerability. In this process, all layers turned into a specific scale, and then, layers of floods, earthquakes, and landslides were combined to provide a Figure of environmental vulnerability in the GIS environment. The coefficients of each of the factors were used to summarize the layers. Figure 5 below demonstrates the overall vulnerability of Mehdishahr county to environmental threats.

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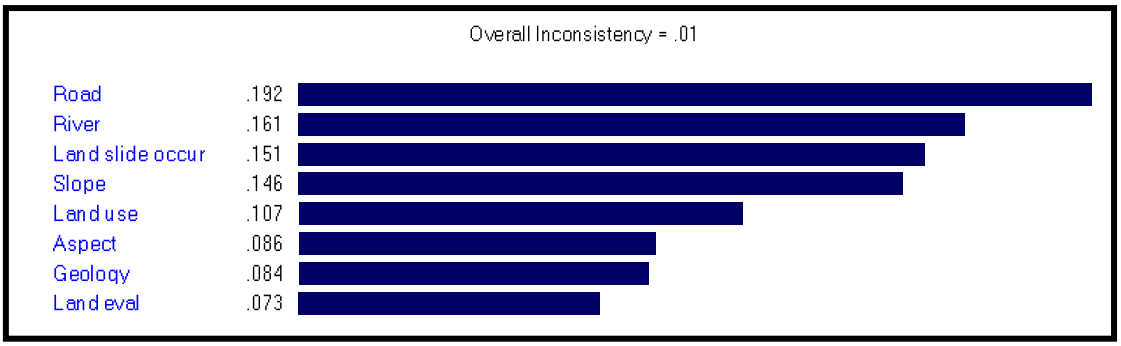


**Diagram 3:** Pairwise comparison of factors affecting the occurrence of landslides in the Mehdishahr county

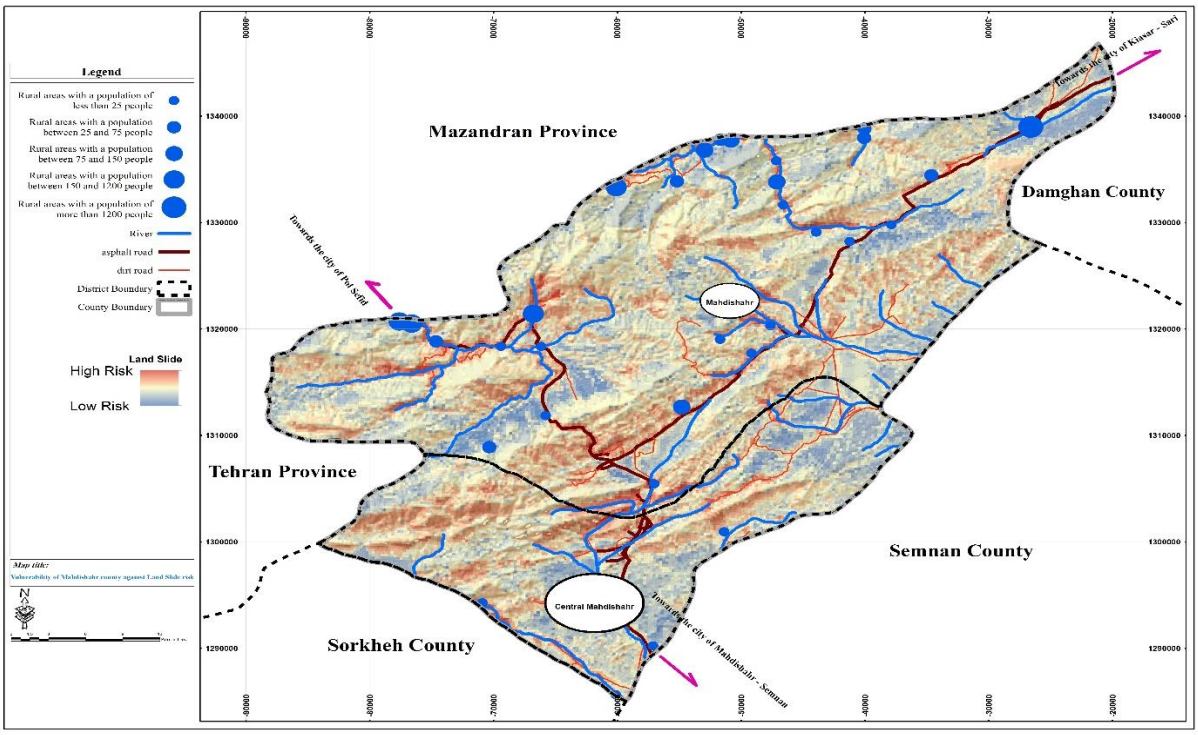


**Figure 4:** Vulnerability of Mehdishahr county to landslide hazard

## Discussion and Conclusion

The goal of this study was to identify and analyze the vulnerabilities of Mehdishahr county based on a crisis management perspective. Findings indicated that various factors including geographical, social, and economic features contributed to the vulnerabilities. Findings also showed changing land use, failing infrastructure against natural disasters, and the absence of comprehensive crisis management programs, not to mention others, were among the key factors involved in the vulnerabilities. These findings were in line with previous findings showing that developing cities were more exposed to hazards due to their rapid population rise and ineffective infrastructure.

Recent research has demonstrated that unstable infrastructure and failure to meet urban planning objectives could increase natural hazards (18), as the rising climatic change implications, such as changing rain and temperature patterns could increase the vulnerability of less developed areas. (19)

As stated above, it is highly imperative to execute crisis management approaches to reduce vulnerability by strengthening



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infrastructure and promoting public awareness-raising. (20)

Local entities are required to collaborate with professionals to hold training programs for residents so that they would gain the necessary preparation to deal with crises. Findings showed that Mehdishahr crisis management needs to formulate comprehensive strategies to better identify vulnerabilities and challenges and to take key steps in this regard. Public and local organizations are also suggested to take serious measures to improve infrastructure and establish rapid emergency warning systems. It was also found that analyzing environmental vulnerability cannot alone help to preserve and improve the quality of the environment; rather, research findings should be provided to planners and policy-makers to execute civil projects that would reduce the level of vulnerabilities in relevant areas.

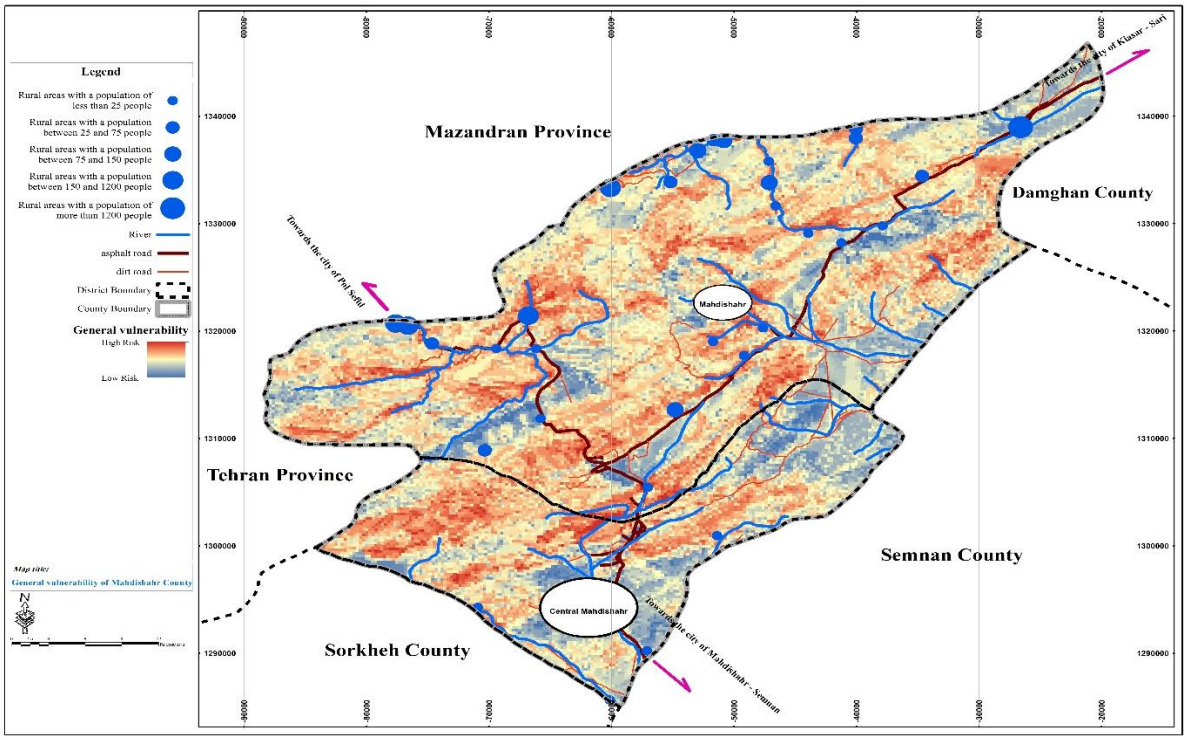


**Figure 5:** Overall vulnerability of Mehdishahr county to natural hazards

## Ethical Considerations

All ethical principles have been considered in this article. Participants were informed about the purpose of the research and the steps of its implementation.

## Funding/Support

This research project was undertaken without any financial support from any specific organization or department.

## Author's Contributions

This research is the result of teamwork as follows: Aliasghar Hodaei and Maryam Mollashahi were responsible for conceptualization, methodology, data collection and analysis, and writing. Vahid Feizi was responsible for reviewing the texts, conducting experiments, interpreting data, conducting correspondence, and editing and submitting the final version of the article to the journal. However, Ali Khodadad had specific contributions such as project supervision and management.

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