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RISK EVALUATION OF CRISIS MANAGEMENT FACTORS BY GEOGRAPHICAL INFORMATION SYSTEM

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ABSTRACT

This paper deals with the application of GIS (Geographical Information System) in crisis management. One of the steps in crisis management process is to prevent and mitigate crisis, including the preparation of risk zonation map and risk assessment. Preparation of risk zonation map entails identification of all potential hazards. In this study, we classified the potential hazards into seven general groups and identified nine hazard-prone regions. Then we assessed the risks and prepared seven risk zonation maps for each major hazard in various regions using GIS. Next, using GIS analyses and the weights obtained for each major disaster, we combined all the maps to produce a comprehensive risk zonation map.

Keywords: Crisis Management, GIS, Risk Assessment, Risk Zonation Map

1. INTRODUCTION

Human settlements have long suffered from natural disasters. This somehow confirms the theory of geographical determinism (Yates & Paquette, 2011:7). The destructive impacts of natural disasters on urban settlements have remarkably increased in the course of time due to the expanded physical dimensions and the increased population (Givehchi et al. 2013: 102). According to the report of Human Settlements Foundation of the United Nations, natural disasters have killed around 200 million people in the first decade of the 21st century (Comfort, 2007: 170). Considering the huge mortality as the result of natural disasters, it should be recognized that man is still vulnerable to such disasters in spite of great scientific and technological advancements (Behzadfar & Shayan Nezhad, 2012: 9).

Natural disasters may inflict irreparable physical, mental and financial losses on people depending on social structure in terms of social classes and the affected locations (Crandall et al., 2010). When it comes to natural disasters, urban old fabrics are among the most vulnerable areas due to their old age and their weak social structures (Mendoca et al., 2007: 45). Considering high population concentration (particularly in developing countries), type of used materials and the old age of buildings in such areas, it is extremely essential to address the necessity of crisis management in old fabrics (Tsai & Chen, 2012: 472).

Crisis management in the time of natural disaster is a major concern in our country as it is located in Alps- Caucasus- Himalaya belt (Sasanpour &Mousavand, 2010: 29) and has too many old fabrics, particularly in urban areas. In this study we focus on the old fabric of Shoushtar city, which is prone to natural disasters due to its geographical situation. Considering the history of natural disasters in this city and the huge losses inflicted on its old fabric, special attention must be paid to crisis management and the location of optimal spaces, particularly multipurpose spaces, in order to improve relief and rescue process in the city. In this paper, we attempt to prioritize the selected spaces in order to locate appropriate areas for this purpose. In doing so, we take the following steps:

- Risk identification
- Risk weighting
- Preparing a comprehensive map

2. REVIEW OF LITERATURE

So far, a lot of research has been conducted on planning and management of natural disasters in residential regions, particularly in the cities and their vulnerable areas. Savadkoohi et al. (2010) conducted a study under title of "an introduction to organization of temporary accommodation (case study: crisis in Tehran)" and address the methods and techniques of crisis management in time of natural disasters with a focus on the city of Tehran. In another research entitled "the role of manmade factors in the intensification of consequences of natural disasters in big cities using fuzzy logic and GIS", Sasanpour & Mousavand assessed the vulnerability of district 5 of Tehran city in time of natural disasters. Using fuzzy logic, they estimated that around 60% of the region was in average vulnerability level. Shoja Araghi & Tavalaei (2011) located post-crisis relief centers using GIS in the district 6 of Tehran by adopting appropriate solutions to crisis management and temporary accommodation. Ahadnejad et al. (2011) conducted a study under title of "optimal location of temporary accommodation spaces in time of natural disasters using multi-criteria methods and GIS in the city of Zanjan" and evaluated the temporary accommodation spaces in the city of Zanjan using AHP method based on 14 parameters in the form of natural and human criteria. They reported that the insufficiency of green spaces was among the major problems in crisis management. Ebrahimzadeh et al. (2012) analyzed the vulnerability to natural disasters with an emphasis on the location of special spaces in the old fabric of Tabriz city. Using network analysis methods as well as AHP and GIS, with a focus on educational and health centers, they found that actually half of the region under study did not access to these centers.

Among the foreign researchers who have addressed this issue we can mention Xu et al. (2008), Zhao (2010), Ansal et al. (2010), Ainuddin et al. (2013), and Dong & Shen (2013). Using statistical methods and GIS, they have emphasized the necessity of crisis management and planning in time of natural disasters, especially the organization and accommodation of affected people in the predicted spaces.

Pourmohammadi et al. (2006) conducted a study under title of "the role and application of GIS in the management of natural disasters in urban and rural areas (case study: Tabriz) and investigated the role of GIS in crisis management and relief-rescue process before, during and after crisis in the city of Tabriz. Asgari et al. (2006) investigated earthquake crisis management and mitigation solutions in the district 17 of Tehran and concluded that GIS may greatly help urban planners in crisis management. Adhami et al. (2009) studied the role of GIS in the prevention of management of crisis and found that GIS, combined with optimal personnel education, was able to enhance the efficiency of integrated crisis response system.

In a research entitled "investigation of the function of civic services in crisis management with GIS approach", Ali Asgari et al. (cited from Nesyani, 2010: 51) analyzed the role and function of civic services in crisis management using modern information technologies such as GIS. To represent its different dimensions, they also provided some examples of analyses on the city of Tabriz. Nesyani (2010: 51), in his thesis, analyzed district 8 of the city of Tabriz in terms of vulnerability to earthquake using SDSS in GIS environment. Hadizadeh Bazaz (2011) conducted a study on major problems of the cities in the management of natural disasters with a focus on Iran. In doing so, he analyzed and compared different natural disaster management patterns in various countries. Tudes (2009) conducted a feasibility study on geomorphological hazard prone areas in Adana, Turkey, using AHP model in GIS environment for the purpose of crisis management. He finally classified the city into different parts in terms of proneness.

Following the Tsunami of Sri Lanka in 2004, a series of studies were conducted in 2008 under the title of "A coastal hazard GIS for Sri Lanka". This huge disaster indicated that exhibition of risk-prone points on the map is vital to the protection of coastal people. Coastal hazard GIS is an efficient tools which can help decision makers to minimize the adverse impacts of natural disasters in coastal areas (including sea level rise, tsunami and erosion) on people, buildings, communicative ways, etc. In Geomantic Conference held in 2008, Parviz Garaei, a M.Sc. graduate in Eilam Agriculture and Natural Resources Research Institute and Arakhi, an assistant professor in Eilam University, presented a research under title of "study on AHP models and frequency ratio to prepare a risk zonation map in Eilam Dam basin using GIS technique".

3. RESEARCH METHOD

Geographical Situation

The city of Ghaenat is located in South Khorasan province. The city is situated in 33 degrees and 43 minutes of northern latitude and 59 degrees and 11 minutes of eastern longitude and is 1440 m above the seal level. It is 105 km distant from Birjand and Gonabad, 372 km distant from the south of Mashhad, and 1300 km distant from Tehran. According to the census of 2011, Ghaenat has a population of 66380 and is the second most populated city in South Khorasan province after Birjand (Iran Statistics Center, 2011).

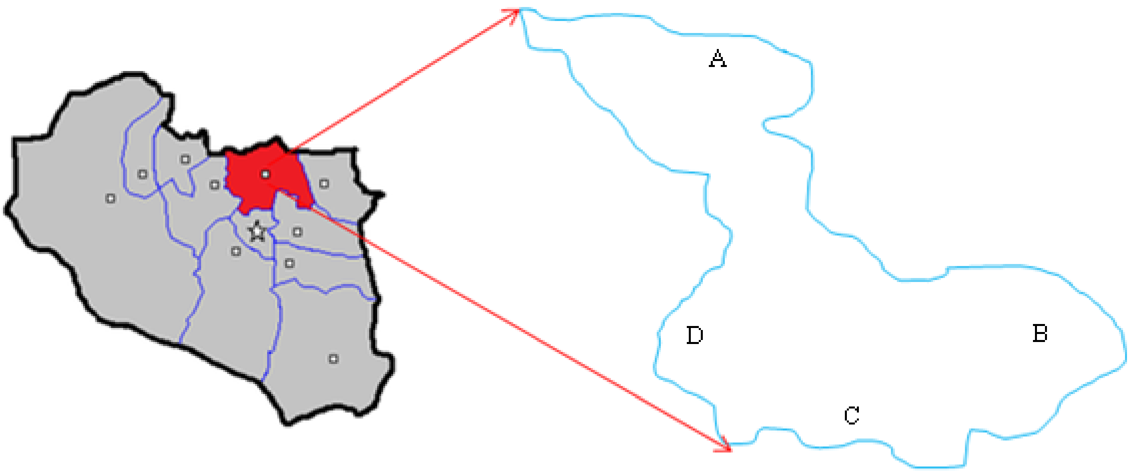


Figure 1: City of Ghaenat

Preparation of Data Layers

Using urban land use map and digital layer of Ghaenat city which had been received from Ghaenat Housing and Urban Planning Organization, we separated other land uses in GIS environment in order to extract the layers of construction concentration, open space, roads, old buildings and so on. Considering the old age of digital layer, we debugged it using Google Earth.

Preparation of Standard Maps

Map preparation is one of the important steps in the location of risk-prone areas. In the process of crisis management in hazard-prone regions, extraction of the required data layers is the first practical step in the research. We separated and valuated most of the layers based on the criteria and sub-criteria needed for locating hazard-prone areas by developing buffer and, in certain cases, by Query Builder icon. Then we depicted different layers of the region and saved them in the database in the form of raster layers with the capability of prioritization or reclassification.

METHODOLOGY

Before starting the analysis, we needed to investigate all potential hazards in the region. To do so, we studied domestic and foreign books and records. Next, by interviewing local safety experts in natural disasters organization, we extracted all potential natural hazards as well as the cycle of existing processes. Then we obtained the statistics on the recent natural disasters from the concerned authorities through the forms which we had prepared for this purpose. We classified the data through statistical analyses. By studying and analyzing the disasters happened during the recent years, we identified the natural hazards with higher probability of occurrence. After collecting the data and identifying potential hazards (based on the activities in the region) and studying the process of fighting against natural hazards, we prioritized them in terms of importance.

After prioritizing the disasters, we had to investigate the hazardous locations. To do so, we first investigated the structure and geographical features of the region. Then, by referring the databank of the province and using expert views, we analyzed the risky locations. At the same time, we studied the influential parameters in the occurrence of natural disasters and classified the potential hazards. Next, we identified the hazards which could possibly result in crisis and investigated the risk of each in various areas. After determining the risk of each area, we developed a model through combination of the data and zoned the region into different parts. In this step, we implemented the data on the map using GIS and prepared the data layers and the risk of each hazard in different locations in the form of a map. By combining different layers, we developed physical situation map of the region. Finally, we prepared the zonation map for each hazard based on the probability of occurrence in different locations and formed the general map through their combination.

Table 1: Symbols used for weighting the parameters

Symbol	Description
The intensity of *i*m risk in people dimension	Hi
The intensity of *i*m risk in the dimension of damage to property	Ai
The intensity of *i*m risk in environment dimension	Ei
The intensity of *i*m risk in the dimension of production and reputation	Oi
Weight of parameter of people	W_H
Weight of parameter of damage to property	W_A
Weight of environment parameter	W_E
Weight of parameter of production and reputation	W_O
Risk of people	$\partial_H=H_i*W_H$
Risk of property	$\partial_A=A_i*W_A$

Risk of environment	$\partial_E = E_i * W_E$
Risk of production	$\partial_O = O_i * W_O$
Final risk weight	$W = \sum \partial H, \partial A, \partial E, \partial O$

4. RESULTS

To compute the weight of hazards, we first measured the parameters of people, property, environment and production and reputation and then computed the weight of each hazard.

After obtaining the weights of parameters, we computed the weights and scores of hazards based on the specified criteria. In doing so, we first selected the qualified experts from Department General of Natural Disasters Organization using Delphi method. The qualification requirements were work experience in ports, educational qualifications, and working in the field of port operation safety. We prepared the questionnaires and delivered them to the experts. In the questionnaire table, each hazard was scored by the experts based on the said criteria. Then we compared the scores and held a session with the experts to discuss the objectives of study and the scoring. Then we gave back the questionnaires to the experts for revision. As some errors could possibly exist in computations, we used a statistical test to remove the scattered scores.

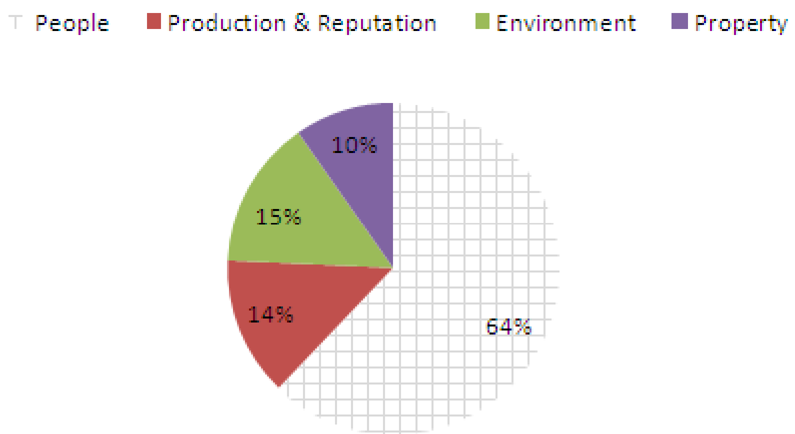
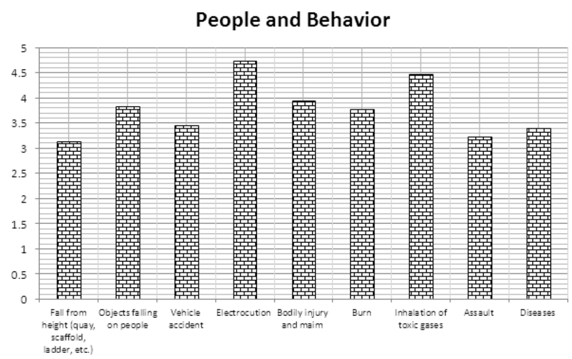
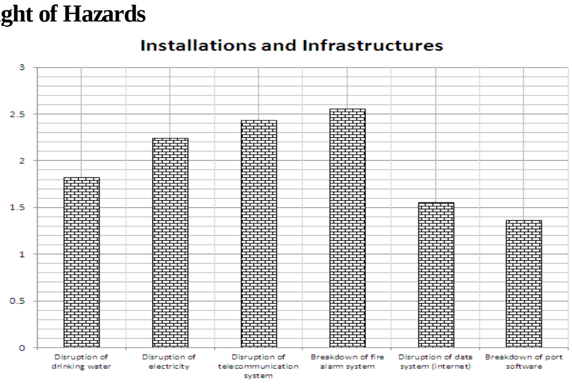


Figure 2: Weight of Hazards





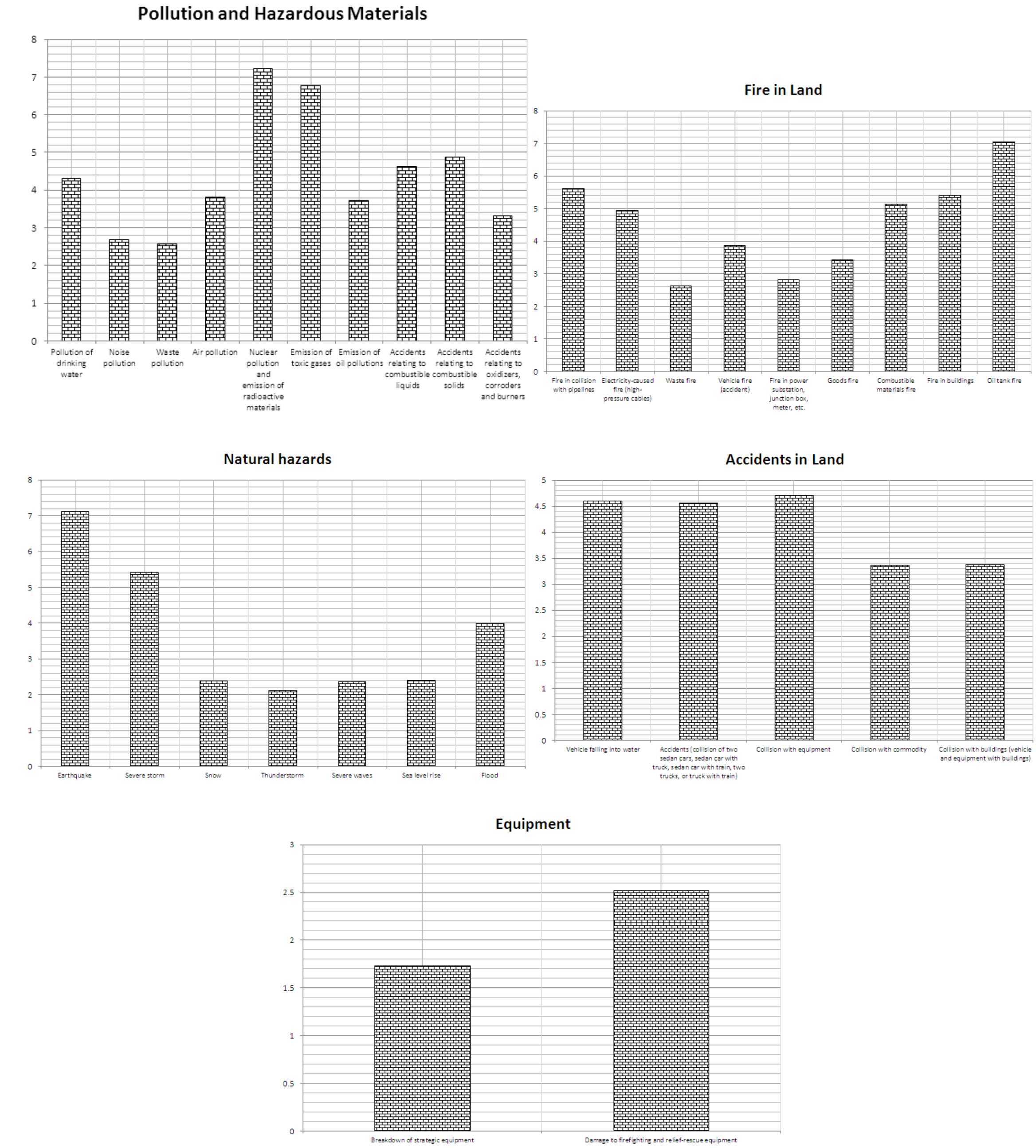


Figure 3: Computation of Weights

The risk scores are according to risk severity rating table, risk probability rating table and contact level rating table. Through the multiplication, we obtained the scores of risk probability rating table, risk severity rating table and contact level rating table. After computing the risk rating for each minor hazard, we computed the general risk rating for seven categories. The figure above illustrates the risk ratings for each hazard. To determine risk ratings for general categories, we computed the average weight based on the weights of sub-hazards. To do so, we first represented the relation for obtaining the weighted average from a series of data and then performed the necessary computations.

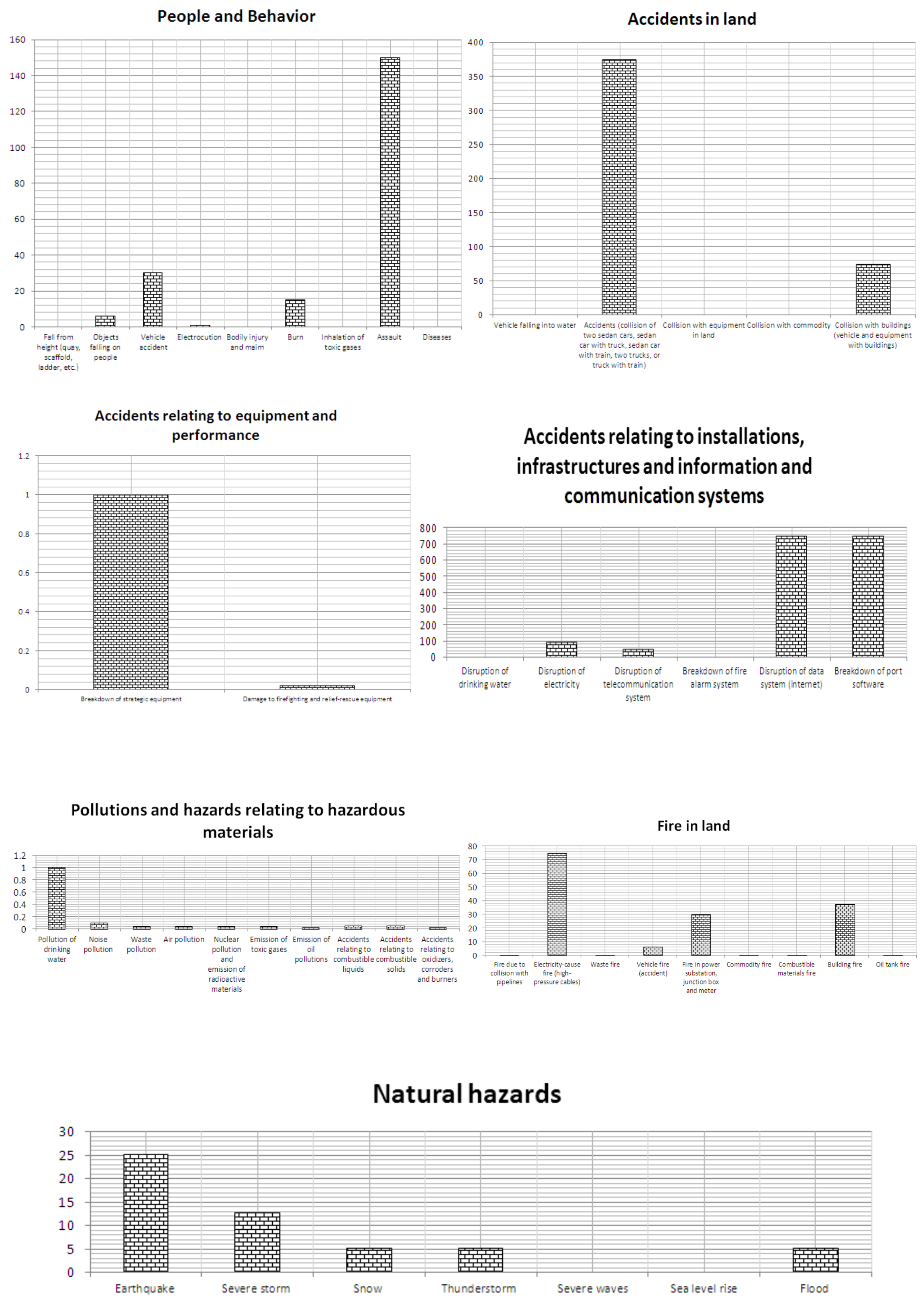


Figure 4: Computation of Risk

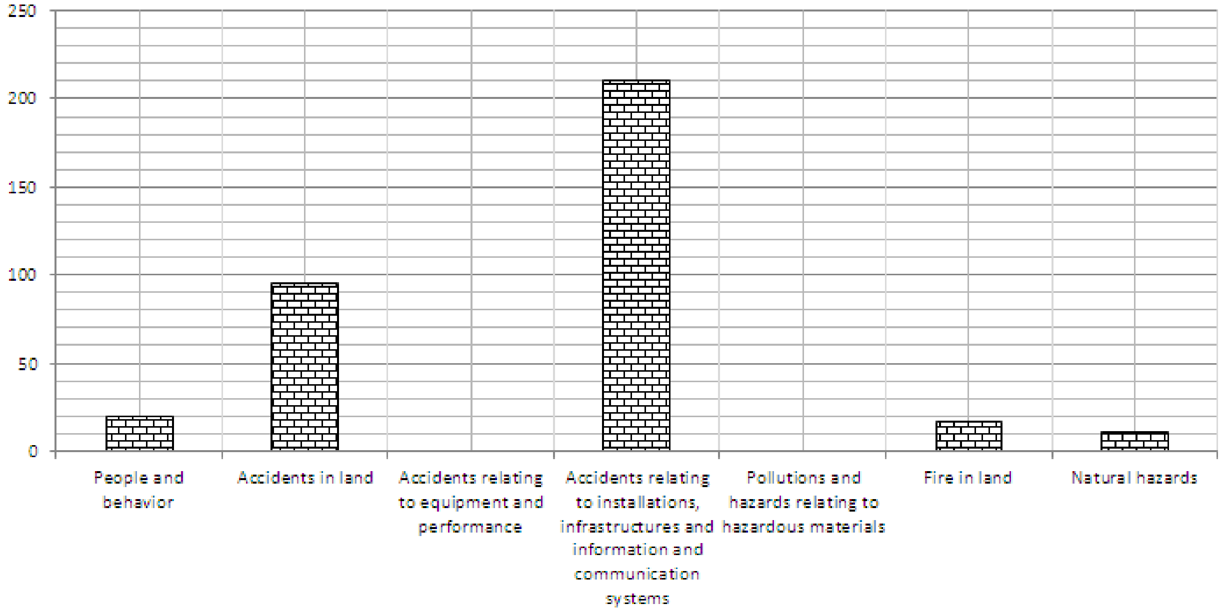


Figure 5: Final Risk Rating

By weighted averaging of sub-hazards, we computed the ratings of all general categories (seven categories). The hazards with rating of higher than 200 were classified as high risk, hazards with the rating between 90-200 were classified as middle risk, and hazards with the rating of below 91 were classified as low risk. Thus, we obtained the risk ratings for seven general categories.

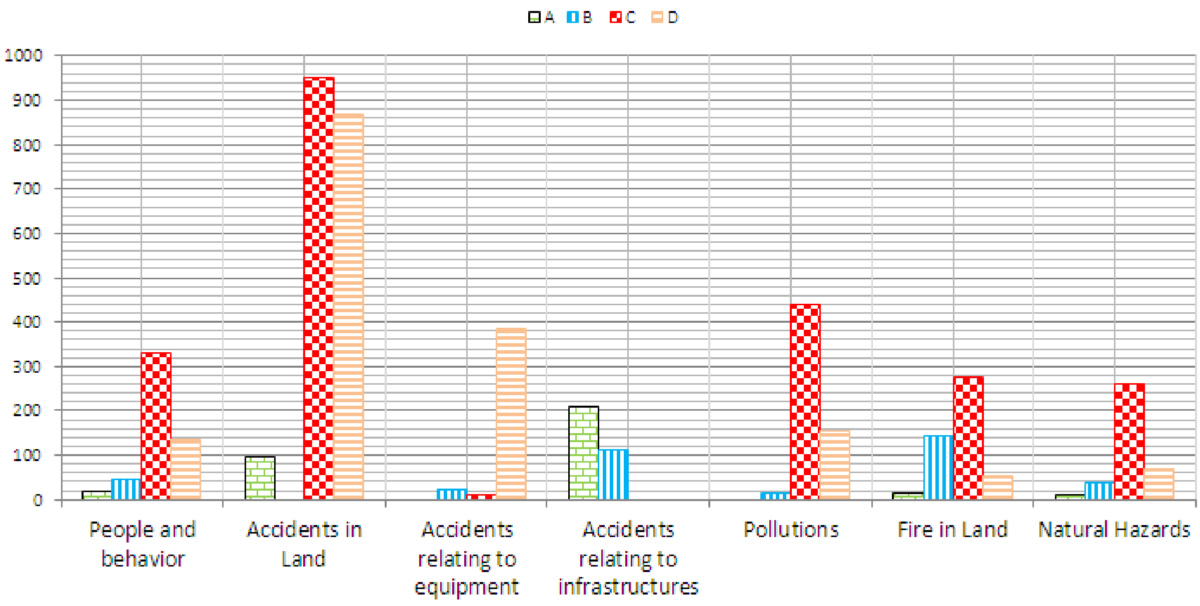


Table 6: Rating of different hazards in various regions of port

To produce risk zonation maps, we obtained the required databank maps from natural disasters organization. To prepare a general risk zonation map, we first produced a zonation map for each major hazard. Then, based on the score of each hazard in the region and its weight compared with other hazards, we obtained a weighted average in ARC GIS software environment from the related layers and finally produced a general map. The first step in preparing risk zonation maps for different hazards was to identify the required layers for making necessary analyses. The layers of risk assessment criteria were used to prepare zonation maps. In the second step, the fields of the layers are scored. The layers with the score of more than 200 were classified as high risk regions, shown by red color in the map. The layers with the rating of between 91-200 in each field were classified as middle risk regions, shown by yellow color in the map. And the regions with the rating of less than 91 were classified as low-risk regions, shown by green color in the map. To produce a comprehensive map to embrace all hazards, we first obtained the weight of each hazard using the weight of minor hazards. In doing so, we first computed total weight of minor hazards and then divided the total weight of minor hazards in each general hazard by the said aggregate. The result represented the weight of each major hazard.

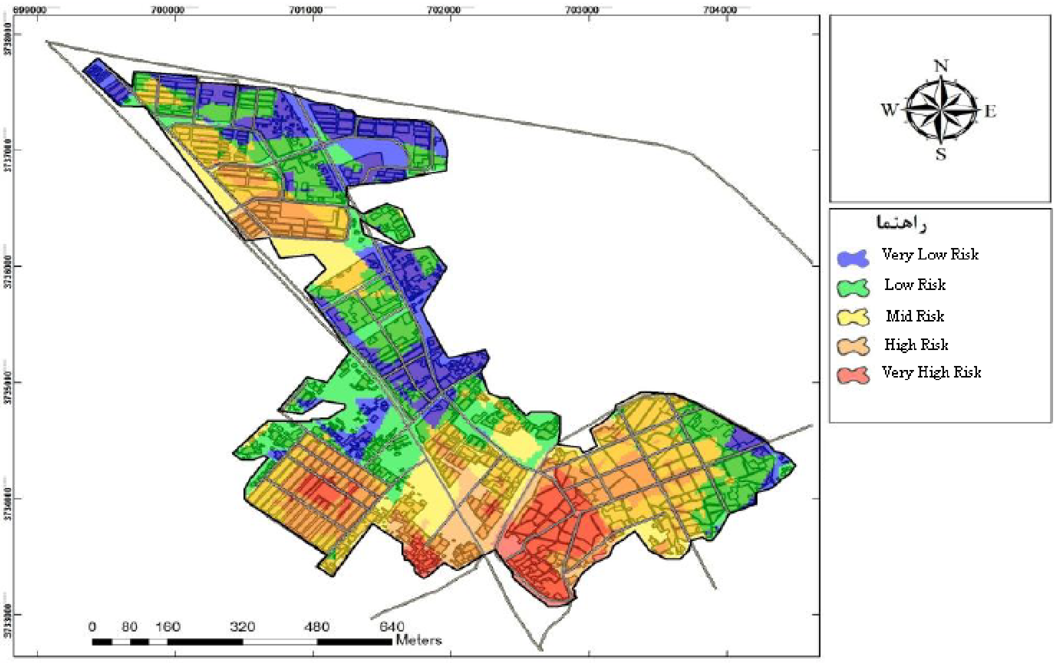


Figure7. Risk zonation map of Ghaen City

CONCLUSION

In this paper, we dealt with the application of GIS in crisis management. In doing so, we delineated the concepts and processes concerned with the ports as well as crisis management. Prevention and mitigation of natural disasters usually entails preparation of risk zonation maps. GIS is an efficient tool which is able to make different kinds of geographical and descriptive analyses. In order to produce risk zonation map for Ghaen city as our case study, we first identified the potential hazards. Then, using data banks and the views of qualified experts, we identified the major hazards and classified them into seven general categories. Next, based on the goals of crisis management, we selected four parameters of people, property, environment, and production and reputation in order to weight the hazards. After weighting these four parameters, we weighted general hazards using risk assessment methods.

Since geographical features play a key role in map preparation, we selected four regions for the purpose of risk assessment. Then, we assessed the risk of general hazards in the selected areas. According to the results, we classified the regions into low risk, middle risk and high risk areas. In the next step, using the geographical layers which we had obtained from the databank, we added risk assessment data to the layers. Finally, we produced risk zonation maps for each of the seven categories.

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