Improvement of Seismic Resilience in Urban Texture and Spaces, Using GIS Capabilities

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Abstract:

Many parts of the world are affected by unusual events, natural disasters and incidents that aim for people's life, property, and comfort and threaten their life and survival. Crises cause abundant and sometimes irreparable damages to countries and people along with adverse effects on social indexes.Therefore, identifying, appropriate planning, and optimal Resilient crisis management are of the highest priorities in various countries.Due to its great destruction power, expansion of the destruction area, lack of the possibility of predicting the occurrence time, continued losses and threats in the form of aftershocks, extensive injuries, and numerous problems in disaster relief, considering the destruction of the infrastructural installations and essential arteries, earthquake is a very important factor in crisis management. Meanwhile, based on the existing information 69% of Iran's surface is affected by active faults and is considered to be one of the countries prone to having earthquakes. Besides, the general weakness of structures has caused extensive casualties in disasters. In these situations control and managing crisis especially earthquakes are of extreme importance in the field of recognition, prediction and preparation before the occurrence, planning, control and guidance after the occurrence. Obviously, achieving this aim requires rapid and simple access to correct and updated information and complicated analysis carried out by specialists and managers. On the other hand, more than 80% of the required information in crises is spatial-natured and earth-referenced. Applying GIS and related technologies can be of considerable help in collection, storage, classification and analysis of related spatial and descriptive data; and play a determining role in identifying and direct application in both prediction and prevention, and direct dealing with events. In this article, we will study the role of GIS In planning urban Resilient and promotion helping dominate crises and their proper management, in order to reduce financial losses and injuries. Besides we try to examine the methods to identify and classify historical and worn structures with the aim of planning and priority setting of seismic improvements and retrofitting buildings against earthquakes. Given the fact that the greatest concentration of resilience in crises is on improving the city's cultural, social, economic, physical and organizational dimensions, the use of the capabilities of the GIS system is very useful given the rich information layers.

Key words: crisis management Resilient, unexpected events, GIS, seismic improvement, worn structures, historic structures

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1. Introduction

Iran is one of the 10 most vulnerable countries around the world and according to the registered statistics on 40 natural disasters in the world. So far, 31 of them have taken place in Iran. On the other hand, Iran has always been exposed to foreign encroachments due to the special political, social, geopolitical conditions, natural supplies and resources (such as oil), and the strategic location (such as being in close proximity to Hormoz strait).

Therefore in such a situation a decent programming in systematic and appropriate encounters with crises by governments is inevitable and of major priority in our country. In this direction, profiting from modern technologies of communication and information, and particularly GIS would be absolutely fundamental and inevitable due to the data volume, various imaginable crises, events, and the numerous things that have a hand in their occurrence and prevention, and the necessity of modeling and complex analysis and digestions.

Here, bearing in mind the expansion of discussions and priorities, we will analyze the application of GIS in management, prediction and dealing with earthquake while we have a brief look at the definitions and concepts of the most important crises, and the crucial role of GIS in this field.

2_The definition of crisis

Crises are the events, which lead to, or are intensified by natural factors or human activities and result in significant casualties and damages. To deal with them, we need fundamental, particular and urgent actions.

3_Crisis management

Crisis management is a practical science that is achieved through observation, examination and systematic analysis of crises, and is on the lookout for the proper methods and tools in order to prevent the crises or reducing their impacts and unfavorable results to a minimum, and providing a fast recovery of the condition.

In resilient crisis management, the aim in fact is to prepare and face the crisis properly and minimize the chances of occurrence or reduce destructive effects and the costs of its occurrence in all aspects: humane, economical, security, cultural and social. Names of some of the most important crises and their definitions are listed below:

Number	Crisis	Definition
1	Earthquake	The act of releasing the seismic energy which is transferred to the surface of the earth from the depth of it and results in destruction of structures and installations and casualties and economical damages which vary depending on the magnitude.
2	Flood	Mechanical pressure and rapid and intense flow of water along with turbulent flows on the surface of earth which results in massive destruction of the environment and carries people, animals, vehicles,… away in shallow depth.
3	Sliding and Buoyancy	Movement and replacement of parts of the earth due to various factors (such as flood and earthquake) which results in severe casualties and causes buildings, roads, installations and… to be buried away.
4	The blowing of severe winds	Rapid replacement of the air such as pressure and suck of wind, which affects numerous things in a short time and at times results in large-scale damages and destruction, Tsunami in eastern Asia, Hurricane Rita and Hurricane Catherine in America, are among the examples.

5	Fire	This crisis can have either a human or natural origin, which will destruct and turn everything into ashes, such as huge fires in forests and pastures or industrial or residential regions.
6	Volcano	One of the natural crises including ejection of lava from the crater of volcanoes and explosion and eruption of hot and poisonous gases, volcanic material like dust and ash which result in annihilation of the environment, forests, structures and living creatures.
7	Wars and terrorist actions	One of the incidents with humans being the factors and normally results in human and economical casualties and destruction.
8	Crises, disputes, and terrorist acts	Humans also originate this kind of crises and they are most effective in economical, communicative, and cultural fields (such as computer crisis in the early 2000, electronic war (such as the 10th election), cultural invasion, economical sanctions and…)
9	Drought	Severe shortage in providing the drinking water; hygienic, industrial, agricultural use and Greenfield sites, which will have many aftermaths that are more economical and human casualties.
10	Epidemic diseases	Instances and serious casualties due to epidemic diseases can be seen in the past and even in the new era.

Table 1 – a selection of crises and their definitions

4_ History and concept of GIS

Technology of GIS originated more than 30 years ago in the business world, but its widespread use goes back to the recent few years only.

Geographic information system is in fact a system which has been created to receive, store, combine, process, analyze and exhibit the data that locally have been referenced to earth. This system normally consists of a reference computer base and software in keeping with its practice.

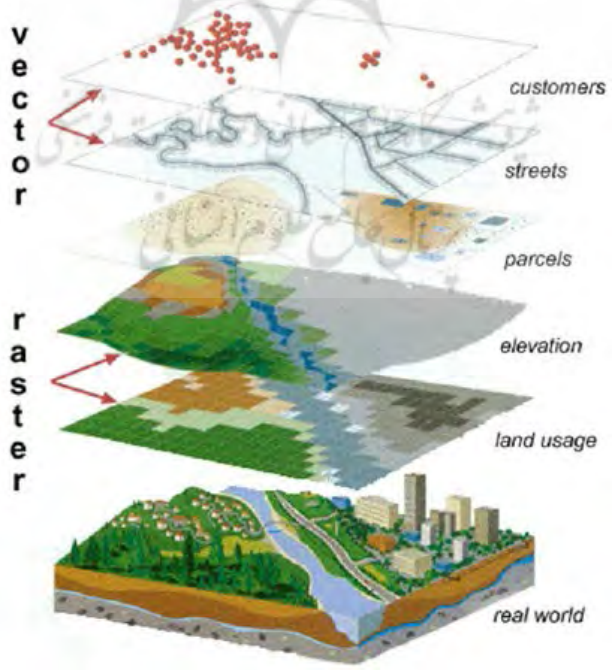


Table 1 – a selection of crises and their definitions

5_the role of information in crisis management

Access to information and valid and up-to-date local data in particular plays a decisive role in different procedures of crisis management. Bearing in mind that more than 80% of the required information in crises has a local nature, using modern technologies of GIS is crucial to the process of data management of crisis managements. while keeping in mind the numerous effective factors and provocation in strike of a crisis and its impacts and results, it can also be stated that by analyzing the layers of data throughout both procedures, before and after the crisis; geographic information system with special capabilities in modeling and data analysis can help the authorities and managers toward the proper decisions and actions.

Number	Informational Layer	Usage in crisis management
1	Concentration and division of the population	Detecting the dangerous spots that inflict heavy casualties
2	The rescue squad centers	A sought-after plan for development and distribution of centers before striking of disasters and optimum management and proper guidance of performing teams.
3	Medical centers	A proper plan for facilitating and developing before the strike of a crisis and optimum management of transferring the injured and providing medical service during a crisis.
4	Routes and passages	Professional guidance of performing teams through a crisis, bearing in mind cases such as the width of the passages, access, and… predictions and modifications of routes in hazardous regions.
5	Mosques and governmental departments	As backup and service centers, providing the volunteers.
6	Greenfield sites	For temporary camps or rescue squads' serving spots
7	Geological zone scheming (such as geological information, pedology, and underground waters and…)	Modeling and analyzing the natural conditions of the earth in order to help the programming and proper crisis management to reduce its unfavorable impacts.
8	Seismic zone scheme	Verifying the perilous locations and avoiding constructions of dangerous industrial centers (such as chemical material factories) in these regions by remaining in the appropriate distance for residential centers or crowded structures and also programming the proper retrofitting of the structures
9	Determining the limits and categorizing different structures such as historical constructions,…	Programming a plan to modify the texture, access, retrofitting
10	Main arteries data (Water and sewage system, electricity grid,…)	Predicting the incidents and accident-prone spots, performing preventive actions in order to have the minimal damage and maximal service at the strike of a crisis.
11	Health GIS	In order to predict and model the crises of hygiene and health and epidemic diseases, and have a plan to prevent and properly confront the situation, proper distribution of services in keeping with the aforementioned cases.

Table 2 – A selection of the origin locations and their role in optimum crisis management

6_ the importance of earthquake amongst the other natural disasters

Due to the reasons listed bellow, earthquakes are of high importance in crisis management of natural disasters:

1) great destruction power
2) Expansion of the destruction area
3) little occurrence time
4) The lack of possibility to predict the occurrence time
5) Continued damages and threats in the form of aftershocks
6) Usual heavy casualties
7) Numerous problems with relief operations due to the destruction of infrastructural installations and lifelines

7_Earthquake in Iran:

Based on the existing information, more than 69% of the surface of Iran is affected by the active faults and is prone to earthquakes. In fact, Iran and Japan are the only countries in the world with almost their entire surface within the earthquake belt.

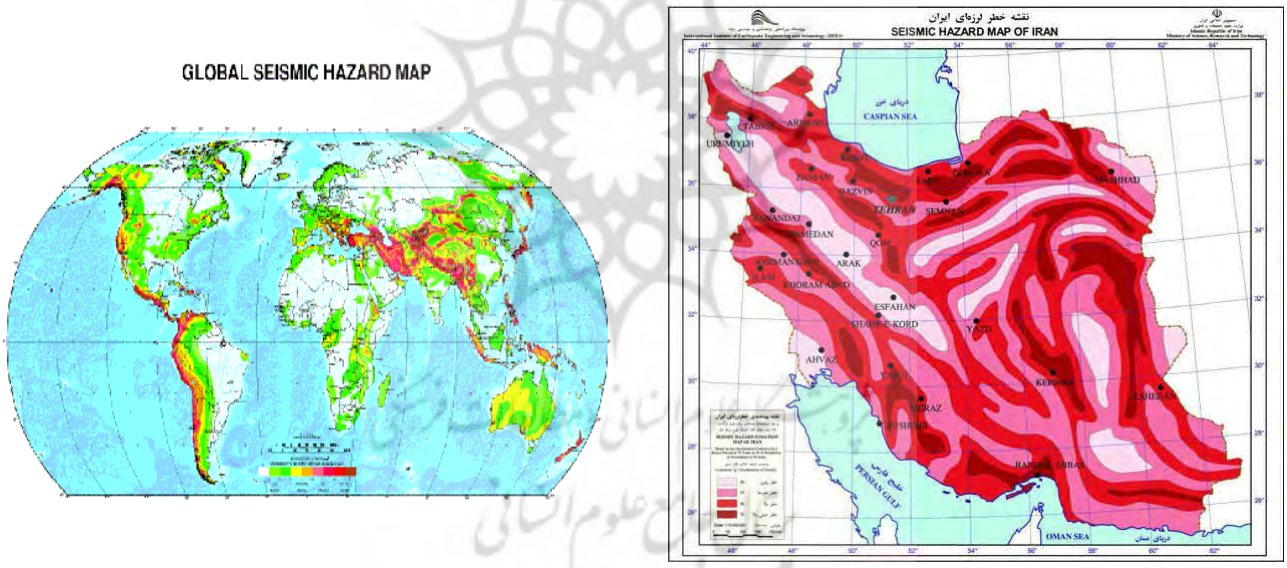


Figure 2. The overall seismic state of Iran, locally as well as the global earthquake belt

Iran has witnessed some formidable earthquakes. Based on the statistics, in the last 30 years, earthquakes have caused more than 6% of casualties. As almost daily earthquakes with Richter magnitude of less than 4، every month an earthquake with Richter magnitude of 4, every year an earthquake with Richter magnitude of almost 6, Or in every 10 years an earthquake with Richter magnitude of 7 have occurred.

Figure 3. General weakness of structures and severe earthquake vulnerability in Bam city

Number	Location	Year	Casualty and damage
1	Boo'een Zahra, near Qazvin	1341	Around 12000 people
2	Tabas	1357	Around 40000 people
3	Manjeel, province of Geelaan	1369	Around 25000 people
4	Bam, province of Ker-man	1382	Around 27000 people

Table 3_Iran's contemporary (recent) earthquakes with heavy casualties

Figure 4- Severe urban tissue damage in the earthquake in Bam

These statistics and similar ones to this are illustrating the fact that most of the casualties and damages due to an earthquake are related to small, remote towns and villages, which are affected by the traditional structure of mud bricks or brick buildings including brick bearing walls in them.

Identifying the active faults based on seismic data is really difficult in the continental borderline areas, Iran being one of them. Basically in such areas, being earthquake-prone is not limited to single and separated faults, and is at times influenced by the width of a few-kilometer wide fault. This adds to the complications of analyses.

Most of the effective earthquakes in Iran have been with Richter magnitude of 6 to 7.4 with little or average focal depth; and in some cases have reached a distance of 5 kilometers near the surface of the earth; for instance, the earthquake of Avoj with 5 kilometers of depth, and Bam with 8 kilometers of depth. Thus, the specification of the earthquakes in Iran can generally be cited as the following table:

Number	Features
1	Magnitude of 6 to 7.4 Richter
2	Little or average focal depth
3	Effectiveness in small areas with heavy casualties
4	Dependence of being prone to earthquake on a series of faults in a wide , hundreds of kilometers, perimeter of faults
5	Severe damage to the residential buildings and heavy human casualties due to the traditional and non-resistant structures

Table 4_General specifications of the earthquakes in Iran and their effects

8_worn and vulnerable structures:

There are various points of views concerning the definition of worn structures. These areas consist of old and worn buildings with improper passage width and access, which are usually located in the central parts, middle layers, or the suburbs of big cities.

Secretariat of Planning and Architecture Council of the country, has declared some indices to identify the worn structures, based on which the vulnerable structures can be categorized in four groups according to table 5:

Number	Naming	Definition
1	Historic structure	Buildings and spaces formed and registered in the national statistics before the 1300 (Persia), or have the capability to be registered are of cultural and historical worth and According to the High Council of Urban planning and architecture, these structures are under regulations of Cultural Heritage and Tourism Organization.
2	Old structure	Those parts of the urban structure formed before 1300 (Persia), but due to exhaustion and lack of anatomical safety standards, strength and urban infrastructure services, have lower residence status despite enjoying the identity values. Engaging in alterations of these structures are different from the other ones, and the actions toward renewing and improvements will be performable in form of special plans

3	Worn structure	This title is referred to some within the legal realm of cities which are vulnerable due to worn structures, not having proper access to roadway, facilities, services and urban infrastructures, and are of low spatial, environmental and economical value. These structures do not have the chance of auto-renewing due to their owners' unfavorable economy and the financiers are not interested in investing their money in these buildings.
4	Marginal structures or unofficial settlements	These structures are mostly the settlements for rural immigrants or the poor class of the city, and are created without the license and out of the programs of official area planning and legal urban development. These structures normally lack decent property documents, and just like the worn structures have poor skeletal features and urban infrastructure

table 5_ Division of worn out texture based on indicators of the Supreme Council of Architecture and Urban Development of Iran

9_Features and conditions of the worn structures

Number	specification	Description
1	Lifetime and technical features	They are mostly old, and if new, lacking technical standards in a way that is obvious from the appearance. These structures do not have the strength to resist the earthquakes with an average Richter magnitude.
2	Density of the structure, number plate sizes and number of floors	These structures have a high density and the size of number plates are small with areas of an average of 200 square meters and normally built in one or two floors.
3	Type of construction materials and used structures	They mostly own mud bricks, or bricks and iron (bearing walls), disobeying the rule of horizontal tie beams (hanks), and lacking foundations and infrastructure.
4	Passages and access	The widths of the passages are normally less than 6 meters and their permeability coefficient is less than 0.3. Routes are mostly dead-ends and considered for pedestrians only.
5	Public services and urban infrastructure	These structures suffer from severe shortages in service, and infrastructures such as green sites and public places.

Table 6_ General conditions of worn structures

10_critical importance of worn structures in crises management, earthquakes in particular:

According to the aforementioned descriptions and specifications, the most important problems in the field of crisis management of worn and vulnerable structures can be listed as the following:

Number	Issues	Adverse results and consequences in the event of crisis
1	Concentrated structure with dense population	Casualties and severe injuries
2	Old and mostly non-resistant buildings	High liability and severe destruction, increase in human and economical casualties

3	Narrow and mostly deadened passages	Blockage of major routes and lack of the possibility of proper and fast rescue operations
4	Poor public services and infrastructure	Lack of access to adequate space and necessary facilities for rescue operations as well as support and temporary accommodation.

Table 7. The most important problems and issues in crisis management of the worn structures

11_identification and determination indices for worn and vulnerable structures:

Worn structures are normally defined based on vulnerable blocks and can be classified as bellow:

1) A block consisting of 50% worn structures and improper or vulnerable residential buildings

By vulnerable buildings, we mean those lacking a proper structural system (metallic, concrete skeleton or horizontal tie beams in brick buildings); or buildings construction of which contradicts the 2800 rulebook of earthquake in Iran.

2) Dense blocks with a minimum of 50% of properties, which have a less than 200 meters area.

3) Blocks with a minimum of 50% of passages being dead-ended or having less than 6 meters of width. In other words, having a less than 0.3 of permeability coefficient.

12_Required actions to create GIS with capability of identifying and extracting worn structures:

As was mentioned, GIS defines the possibility of spatial storing and locating complications and descriptive information in an environment. In addition, it provides the feature of simultaneous analysis of spatial and descriptive information- a strong tool to model, plan and manage through problems and discussions, especially civil management.

In order to create worn structures in GIS plans, this system must have the possibility to identify the worn structures according to the fixed indices, or based on the definition of the new ones, and also have the possibility of planning maps of zone scheme and worn structures, estimation of area, structure, and price, based on the spatial conditions in different parts of the city.

To do this, the required spatial and descriptive complications must be identified an taken using field method, which includes types of structures, types of ceilings (multiplicative rooms, block joists), types of infrastructure and foundation, condition of obeying the rulebook of 2800, type of construction material, and the lifetime of structure. Informational fields related to the subject of worn structure must be designed and added in the data structure in forms of required tables.

Poly sack in blocks must be defined and the data such as the number of registered number plates on the block, and the audit number of the block and the average price of each unit of earth, must be inserted; and that way, the connection between the registered number plates and building blocks can be tracked using the block number field.

In order to identify the object structures, considering the feature of programming in the GIS software, the appropriate algorithms must be written to calculate the field of blocks and the area of the neighbor streets, the width of passages of each block and determine if they are dead-ends, and calculate the permeability coefficient for each block.

13_how to extract worn and vulnerable structures in GIS:

Figure 5- Extracting worn tissues in the GIS environment, based on the first and second groups of defined indicators

There are two paths to take to determine and extract the worn and vulnerable structures in GIS according to the three defined indices in part 13. If the first and second groups of the defined indices are being considered, this layer will be produced easily considering the analysis features of GIS descriptive information and defined fields in database.

If the third group of indices are being considered, the extraction will be done based on the relating algorithm in the software, as mentioned above.

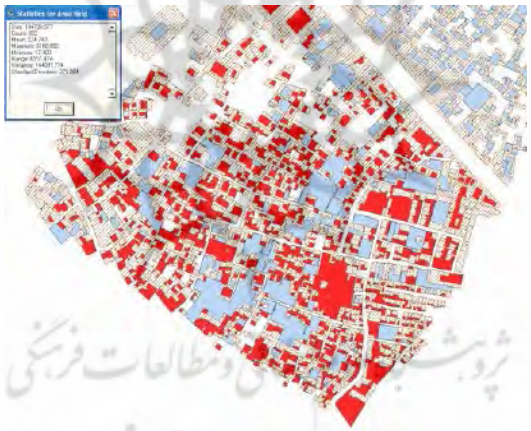


Figure 6- Extraction of worn tissues in the GIS environment, based on the third group of defined indicators

14_ Isfahan:

Continuing through the study, we will examine Isfahan in order for the issues to be tangible. This large city is a unique and appropriate sample in this field, having special seismic conditions, enjoying many valuable and beautiful historic structures, and a vast range of various worn structures along with a proper GIS with more than 230 layers of classified information for use in urban management.

14.1. Isfahan's seismic condition:

Isfahan is located in the Sanandaj-Sirjaan zone. Little seismic activity is one of the outward features of this structural zone. The same feature has caused an insufficient attention towards and scant studies on the earthquake seismicity of this region.

According to the records of Isfahan's earthquake seismicity and a registered record of more than a

hundred earthquakes with more than 2 to 5 Richter magnitude in the carried out studies in years 1355 to 1357 (Persia), and also during the years 2000 to 2003 (Christian); an absolute necessity of exactness in tectonic earthquake conditions of this area is recognized.

According to the latest examinations run in a hundred-kilometer perimeter of Isfahan, there are many faults around the city including 63 important active ones, and they are tens and some hundreds of kilometers long and are usually categorized in 6 major groups with various directions. Based on these studies, there are some important and active faults around Isfahan with distinctive directions. The registration of the earthquakes in south and southwest of Isfahan have been on the crossing of several faults with different directions.

Also, the probable maximum magnitude of earthquakes in this area due to the movements and activities of the faults have been predicted to be 7.34 Richter which is related to some faults including the ones in northeast of Isfahan, Najaf Aabad, and south of Isfahan with 165،245،235 kilometers of length. The maximal horizontal acceleration due to the movements of the faults in Isfahan, which has been calculated via analysis methods, is 47% of the acceleration of gravity and related to the same faults in northeast and south of Isfahan. This number has a significant difference with the maximal horizontal acceleration of 25%, which was determined according to the third edition of the 2800 rulebook of earthquakes for City of Isfahan.

Bearing in mind the volume of industry and culture of the country being centered in this area, these conclusions add to the importance of regional zone scheming and compatibility with GIS plans in order to have a proper analysis and determine the hazardous areas, program the seismic retrofitting and renewing of the structures, and be perfectly prepared to deal with the probable events and earthquakes.

The following image shows the dispersion of earthquake focuses between the years of 1355 to 1357 (Persia) in this area and the second image shows those results along with the data registered in the years 2000 to 2003 (Christian). The third image provides us with the range of active faults, and the forth satellite image is one that puts all the above results together with a classification, giving a clear sight of the seismic situation of this range.

Number	Description
1	Being located in Sanandaj-Sirjaan zone with the outward feature of being little seismically active
2	Occurrence of historic earthquakes in the past
3	Registered records of tens of earthquakes with 2 to 5 Richter magnitude between the years of 1355 to 1357, and 2000 to 2003
4	Identifying the existence of faults throughout the hundred-kilometer perimeter of Isfahan with at least 63 important active ones
5	Existence of several faults in suburbs of Isfahan, with the most important being located in northeast, Najafaabad, south and southwest of Isfahan with lengths of 165, 245 and 235 kilometers
6	The maximal magnitude of the earthquakes occurring due to the movements of faults in Isfahan is predicted to be 7.34 Richter
7	The maximal horizontal acceleration calculated using analysis methods is 45% of the acceleration of gravity

Table 8_Seismic features of Isfahan

14.2. GIS and worn structures in Isfahan:

According to its long cultural history, the large city of Isfahan is filled with worn structures and also valuable cultural heritage, and due to its various attractions including employment, has a considerable number of vulnerable margin structures, especially in north and northeast. Therefore, considering these conditions is it necessary to provide information layers on vulnerable structures in the city to help the optimum management of prevention, reconstruction and seismic retrofitting, and plan to deal with potential crises. On the other hand, the production and application of GIS of Isfahan with more than 230 information layers by the city council has put Isfahan in the list of pioneers in the field of GIS, and paved the road and can be walked by planning and allocate the necessary funding needs.

14.3. Zone scheming of earthquake risks and prioritizing the seismic improvements in the 14 areas of City of Isfahan:

According to the given descriptions on geologic information and extracting the layers of worn structures, we can act on providing fine zoning of earthquake risks and prioritizing the seismic improvements in City of Isfahan. Zone scheme of the areas based on environmental factors means categorizing the geographical regions into distinctive degrees according to their reaction to natural disasters. Then a categorization system will be defined as a list of areas, lined from the most unsafe ones in an earthquake to the most resistant ones based on the indices defined in the classification of the worn structures.

If this goal is achieved, the chance of planning, allocating the necessary funds and projects of improvement and retrofitting will be provided in the shortest time considering the priorities.

We can also start a more complete and realistic zone scheming of the city and classifying the 14 areas of it, in case of the completion of various layers of information in GIS, such as technical specifications of the buildings, condition of passages and access, population density, green sites, probable facilities to deal with a crisis, sensitive centers, and appropriate grading. We can even reach comprehensive plans for crisis management and city development planning through defining the project, and examining and fine zoning the city while identifying the soil, active faults and their effectiveness to various areas, and combining this layer of data with the risk information. Tendency to construct, population density, and growth of city near the active or dangerous faults, or more exactness about designing of the routes of subways or essential arteries, or even considering the special regional arrangements for constructions can be cited as some comprehensive plans.

14.4. Zone scheming of earthquake risks and prioritizing the seismic improvements in the province:

Similar to the model given for the city, we can perform in two stages for the province:

First stage:

In this stage each factor participating in the occurrence of an earthquake such as active faults and their distance from the population, industrial, or historic centers; previous seismic records; and geologic features; can be categorized and rated. Their zone scheme plans can be prepared and by matching them the final zone scheme plan of earthquake risks in the province based on geotechnical factors will be developed.

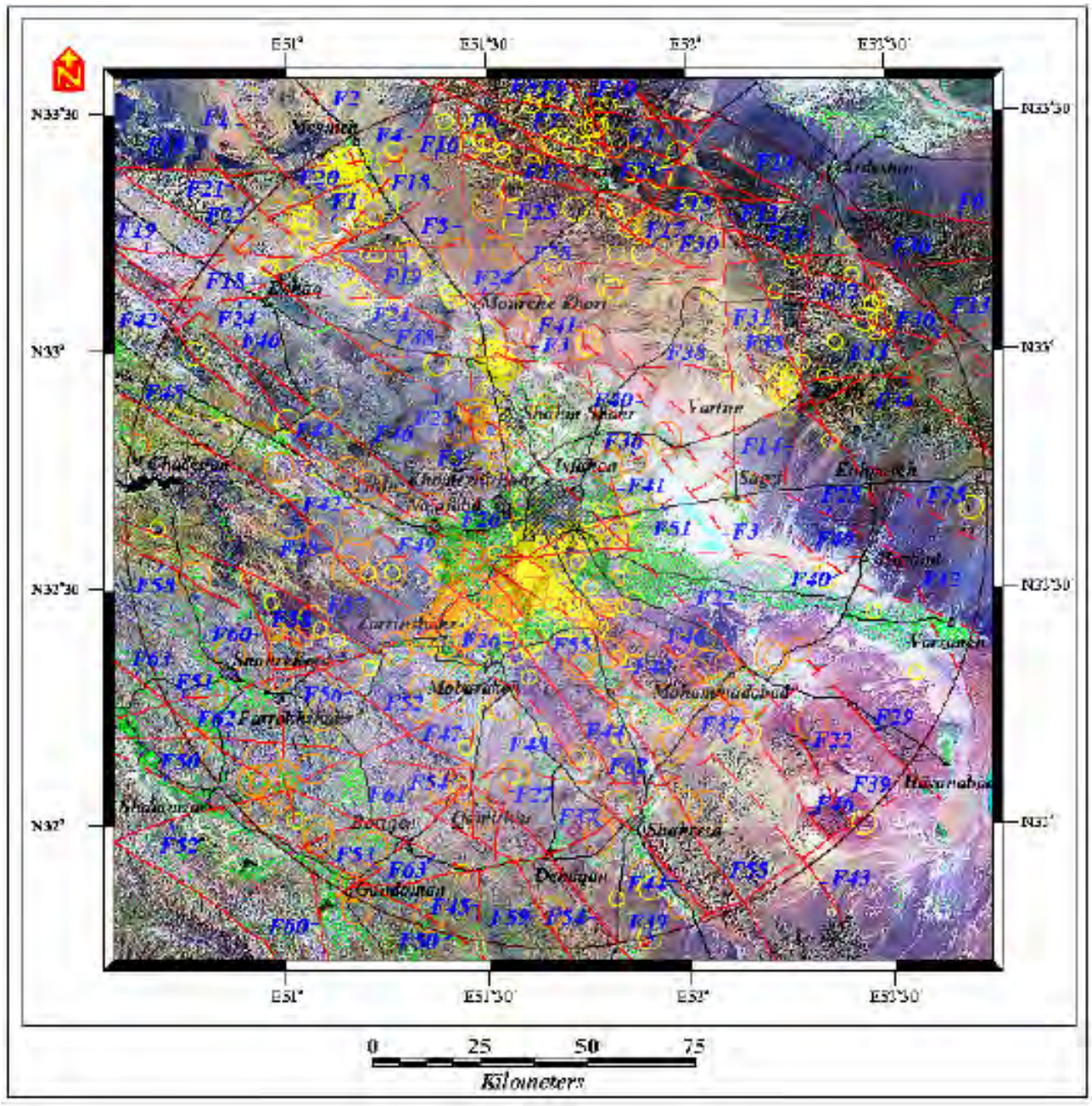
Second stage:

In this stage, the strength of the urban and rural buildings will be examined based on the construction materials, the structural system used in them, and also their age.

According to their strength against earthquakes, the materials can be divided into three groups of durable, semi-durable and non-durable. Their age can be divided based on a useful life under 20 years or over it. After a proper evaluation, the possibility of prioritiz-

ing the risk of each town will be determined based on human factors in construction.

Finally, by overlapping the results of the first and second stages of the zoning map of earthquake risk due to geotechnical factors and also human ones, and construction; the chance of a proper planning and crisis management of earthquakes in two aspects of prevention and improvement, seismic improvement, also a proper prediction of area and range of probable risks, considering and providing the required accommodations and facilities to control and guide the crises in case of a credible occurrence in the province.



15_Conclusion:

According to the aforementioned subjects and examinations, applications of spatial information systems with special features to adapt the information layers, data analysis and modeling crises in different stages of the cycle of crisis management plays a significant role in showing the hidden aspects of incidents, lack of doubt in managers to make decisions, and creation of possibility to plan and act with the minimal errors. This will help minimize the amount of error in planning actions to improve urban resilience to deal with crises.

Meanwhile, bearing in mind the significance of earthquake amongst the other natural disasters considering all aspects such as impossibility to predict the precise time of occurrence, expansion of the influenced area, expansion of casualties and damages especially in towns and villages with worn and non-resistant structures, puts a high value on the face of seismic zone scheme and providing vulnerability plans in urban and provincial areas using the powers of GIS. this is so important that with the help of this system and prepared plans we can act on rebuilding seismic improvement of structures before the occurrence of crisis along with identifying and large programming and renewing the worn and vulnerable structures; also proper allocation of resources, uniform distribution of rescue squads suitable for the region.

In this direction, we can also act aptly having the correct estimation of the event at the time of an earthquake to guide the rescue teams towards rebuilding and renewing the area.

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