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A Scenario-Based and Game-Based Geographical Information System (GIS) Approach for Earthquake Disaster Simulation and Crisis Mitigation

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Abstract: The current research study aims to introduce the experience of implementing a serious game using the concept of game-based GIS approach for crisis management during earthquake disasters. In this study, we aimed to develop a game-based GIS approach and examine its efficiency for simulating earthquake rescue management in Tabriz city. In designing this game, typical scenario-based, game-based GIS methods and techniques were employed, and the proposed approach was applied to crisis management. To achieve this goal, we addressed the technical details regarding the development and implementation of the scenario-based and game-based GIS approach. Based on the results, game-based simulations can be considered an efficient approach for disaster simulation and can improve the skills of rescue teams. The outcome of this application is an intellectual game that almost all users at any age can play, and the game can challenge their ability to solve critical issues. The results are critical for explaining the effectiveness of rescue teams and crisis management facilities. As we intended to develop an approach for the simulation of earthquake disasters and emergency responses, we therefore conclude that the results of this study can also be employed to improve the skills of rescue teams and citizens for dealing with crises resulting from earthquake disasters. As a result of this research, the developed tool is published, together with this paper, as an open source and can be employed for any scenario-based analysis in other case studies. By presenting a-state-of-the-art approach, the results of this research study can provide significant contribution to further the development of GIScience and its applications for disaster and risk mitigation and management.

Keywords: game-based GIS; earthquake crisis management; disaster simulation; Tabriz city

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1. Introduction

With recent improvements and the widespread deployment of telecommunication, mobility programs, and technologies integrated with lightweight mobile devices and terminals, pinpointing a location on the move has already turned out to be a common exercise. This intensive progress in GIScience together with scientific and technological advances allows governments, civil society organizations, and international non-governmental organizations (NGOs) to better deal with disaster risks [1]. The traditional approach to disaster risk management involves top-down, centralized processes in which governments, researchers, and disaster managers develop strategies and make decisions [2]. In this context, previous experiences and skills of citizens and rescue teams could be critical for emergency response and crisis management. It is well understood that GIS, as an interdisciplinary field of sciences, enables the integration of scenario-based spatial analysis approaches, such as disaster simulation, impact assessment, crisis management, and mitigation plans for natural disasters [3–5]. In the context of GIS-based spatial analysis, game-based GIS enables the development of experiments in which users can employ various behaviors in a game setting and will most likely receive immediate feedback. It makes no difference whether the decision made is positive or negative due to the lack of real-life consequences. What matters is that players can investigate multiple cause–effect relationships in the game's reality, which can then be extrapolated to real-world situations [1].

There have been significant attempts to use game engines, game development tools, and game communities as a basis of research that falls within the general purview of GIScience in recent years [6]. Game-based GIS is known as one of the standard and efficient approaches to overcome the challenges associated with effective rescue missions [7]. Game-based GIS refers to the integration of GIS technology in gaming to create location-based games, where real-world geographic data are used to create the game environments. In contrast to traditional training methods where everyone follows the prescribed steps and survives, a game-based GIS approach allows end users and citizens to follow and observe catastrophic situations in games and gain further critical information. Likewise, these games also provide sufficient insight for students (both in universities and schools) and allow the younger generation to practice fun games developed for disaster education in order to stimulate their interest and raise their awareness [8]. It is well understood that maps have always been an integral component of games as the contextual layer for a gaming experience [7,9]. Nowadays, GIS has become a necessary management information system in many organizations, especially in government decision-making departments [10,11]. GIS-based spatial analysis techniques have also been applied successfully in many fields, such as resource investigation and utilization, environmental modeling, disaster assessment and mapping, urban planning, decision-making and authorization, and project planning and construction [12].

GIS techniques and procedures are considered an effective methodology for analyzing decision problems [13]. Disaster management analysis is considered one of the important applications in the domains of GIScience [9]. A GIS-based spatial decision-making system provides a powerful technique for the analysis and prediction of future hazards. The integration of GIS spatial analysis with new technological trends, such as mobile and web-based techniques, allows the simulation of a disaster situation and can be used to develop a mitigation program. Serious games based on simulations are particularly appealing for raising awareness of various types of risks and facilitating the analysis of engineering complex systems. Players can gain a better understanding of risks, their likelihood of occurrence, and the consequences of their actions by being placed in a risky situation and allowed to try various ways of managing it. Exploring different strategies and their impact in a serious game provides players with some experiences, which are simulated but have mechanisms close to real-world situations, for managing major risks and disasters. To achieve this goal, a game-based GIS approach was designed and developed aiming to provide specific scenarios which can improve the knowledge and skills of rescue teams and citizens using simulations of disaster and emergency responses. Technically speaking, the use of a pedagogical scenario integrated with a set of rules should support players' experience by outlining the objectives and conditions of success. It will also enable the analysis of possible failures and interactions within the game with other players during the game world's evolution. Basically, we can incorporate these rules into a computer model as scenarios for developing an efficient emergency response. Finally, knowledge delivered in a more traditional manner (e.g., note cards) is an excellent complement, with the serious game serving as a motivator to gain knowledge from other sources.

Due to intensive progress in information technology and the availability of a variety of smartphones and location-based programs in recent years, digital games have received significant attention, which try to challenge the human mind in various modes [14–16]. It is well understood that because of the popularity of digital games, they can also be employed for educational purposes to improve the skills of citizens regarding disaster and emergency responses. Computer-based technology is considered a revolution in future human competence development, and serious games are emerging in a wide range of fields like education, medicine, training, scenario simulation, publications, national defense, and opinion polls. In this context, for example, three types of computer games can be simulated using computer techniques in which detailed facts are efficiently implemented. In the second type of computer games, predicting real situations is concomitant with uncertainty; therefore, these games are referred to as serious games, among which are games with the subject of crisis management. Since various factors participate in the occurrence of an incident or crisis in a complex condition, predicting and modeling these conditions might meet with uncertainty [15–19].

Integration of GIS spatial analysis and decision-making systems with computer games provides a powerful approach for simulating crisis management, which may lead to the practice of crisis management techniques. Table 1 shows previous research attempts that aimed to apply integrated geospatial approaches for disaster simulation and crisis management. Technically speaking, crisis management experts cannot train for their jobs with real-life events because every situation is different, and they cannot create a catastrophe just for training. Accordingly, training in the crisis management field can be supported by game-based GIS applications to reproduce as much as possible real-life situations for teaching best practices through manuals and real-life simulations [20]. GIS-based mobile mapping systems (MMS) by means of employing game-based GIS techniques and the capabilities of mobile systems (e.g., user friendly and positioning services through GPS) have been known as effective methods for disaster simulation and crisis management [21].

Within the MMS method, an all-around view camera, an angle meter, and a GPS antenna are mounted on a moving object, such as a car, and serial images can be recorded in association with GIS. Generally speaking, in the practice of a GIS-based MMS, information on the hazard under consideration and the evacuation space is written down on a map for sharing the disaster information and extracting the problem [21–24]. It is acknowledged that education and previous knowledge will support rescue teams, citizens, and stakeholders in obtaining valuable information and skills for mitigating the impacts of natural disasters. This is particularly important in applications such as emergency responses, where timely and accurate data can be critical to saving lives and mitigating the effects of disasters. For example, mobile apps can be used to collect data on the location and severity of natural disasters or to report infrastructure damage in real time. Based on the capacity of simulation and gaming to overcome the challenges faced when promoting community-based disaster management, the main objective of this research is to develop and propose a scenario-based, game-based GIS approach that can be employed for the simulation of disasters and the modeling of emergency responses.

Table 1. Review of the related literature on scenario-based, game-based GIS and emergency responses.

Topic	Methodological Approach	Citation
Calculating earthquake damage building by building and seismic risk assessment	Volunteered geographic information and building-by-building exposure models, sensitivity analysis of seismic risk with probabilistic building exposure models	[25,26]
Seismic risk scenarios for residential buildings	Fragility and vulnerability curves and the Global Earthquake Model	[27]
Quality of crowdsourced geospatial building information	Integration of geospatial data approach based on the Open Street Map and volunteered geographic information platform	[28]
3D GIS platform for flood wargame	3D GIS and spatial analysis for risk simulation and emergency responses	[29]
A framework of simulation and gaming for enhancing community resilience against large-scale earthquakes	Simulation and gaming to enhance community resilience in coping and adaptive capacity, in addition to strategic planning for emergency management	[30,31]
Simulated seismic damage scenarios for disaster mitigation	Geospatial approach for damage scenario assessment	[32]

2. Materials and Methods

A scenario-based educational approach can play an important role in crisis management and contingency planning [33]. In this study, we aimed to develop a game-based GIS approach and examine its efficiency for simulating earthquake rescue management in Tabriz city. Figure 1 shows the location of the case study in Iran. The main methodological aspect of this research is presented in Figure 2. This research started with some imagination considering (a) the capacity of a local community to keep its pivotal functions during evacuation by anticipating and reducing the impacts of an earthquake disaster; (b) the ability to recover community life by managing shelters quickly; and (c) the ability to adapt to the new normalcy, such as daily life in the shelters, under complex conditions and following uncertainties after the occurrence of an earthquake disaster. Thus, the main scenario in this game is defined as follows: '***An earthquake with a definite intensity has caused damage and a crisis in the urban environment***'. This scenario was developed based on the relevant literature and the characteristics of the study area, such as socioeconomic, geographic, and geological settings [34–37]. As a result, some buildings were destroyed and some narrow walkways were blocked by falling debris and rubble. In addition, the crisis committee has predicted some sites to distribute rescue and relief efforts in some areas of the city. Accordingly, the present scenario emphasizes that for any relief effort, a rescue site can be anywhere in the urban environment. To run the game and its scenario, it is also necessary that there should be at least a path to the rescue site, which enables the rescue team and their equipment to be taken there and the rescue operation to be managed. In order to examine the efficiency of the intended scenario, we also considered the seismic and socioeconomic characteristics of the city based on previous studies [18,31] as well as discussions with local authorities and decision makers at the municipality of the city and the University of Tabriz.

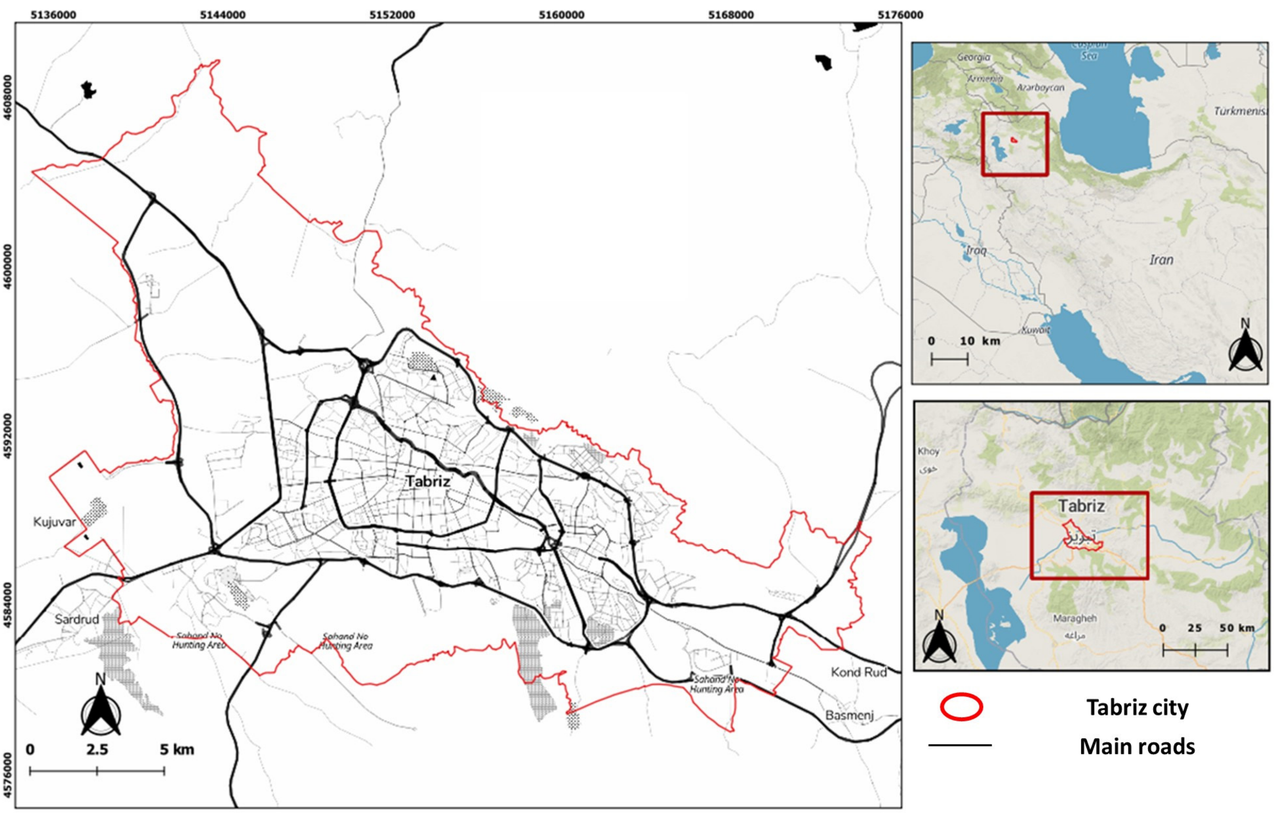

Figure 1. Location of the study area: Tabriz, East Azerbaijan, Iran.

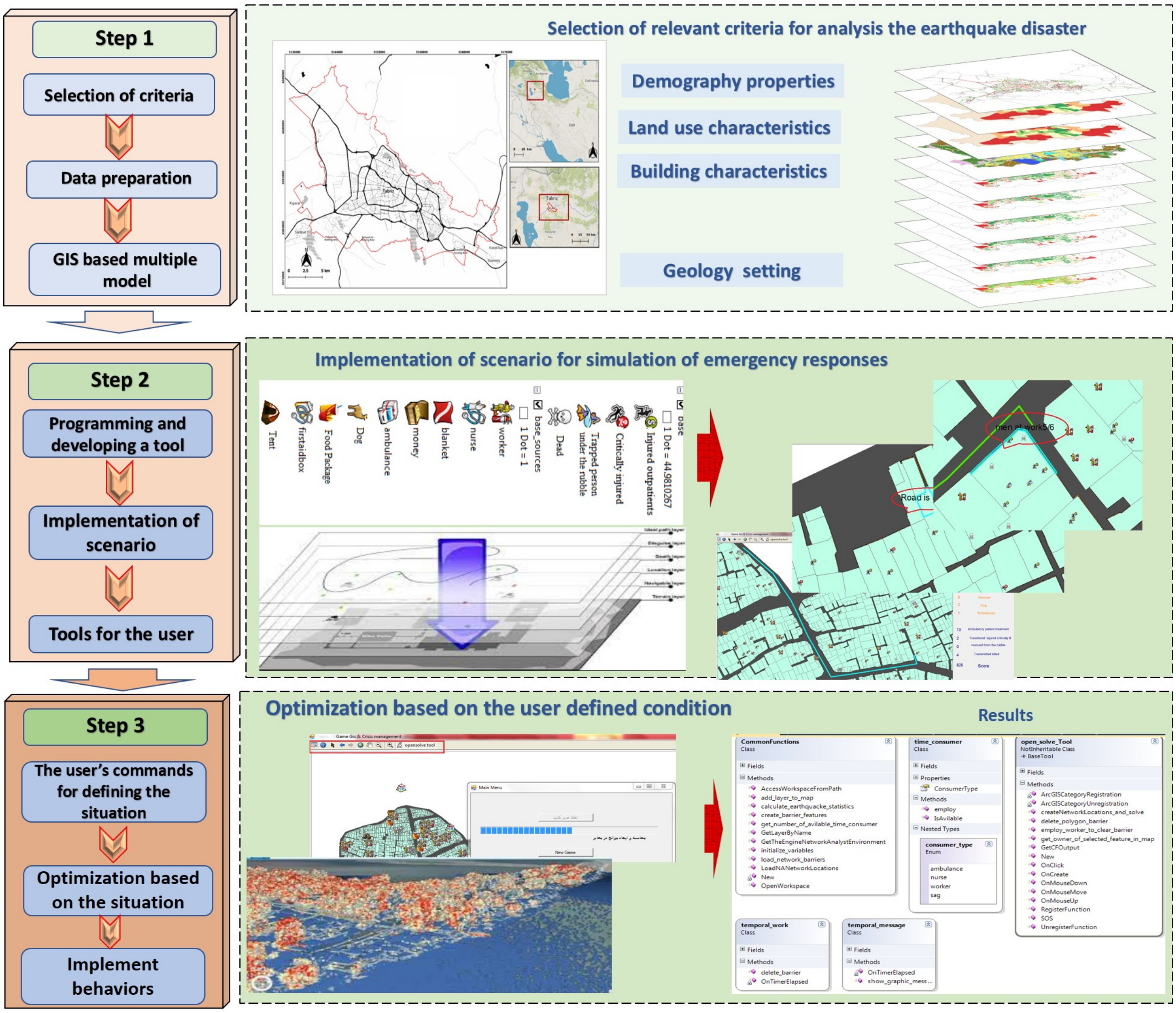

Figure 2. The main methodological scheme of the research.

Using the scenario-based, game-based GIS, the proposed game starts with the simulation of a disaster condition and emergency responses. In this context, the game provides some supplies of food, money, and relief items, such as blankets, tents, first aid kits, as well as ambulances, paramedics, and rescue dogs. Depending on their properties, the number of existing equipment or people may be reduced temporarily or absolutely. Entities such as workers, paramedics, and rescue dogs need some time to commensurate with the volume of work entrusted to them, and as long as they are busy with an assigned task, they are not allowed to be employed to do something else. Eliminating barriers, helping injured people and transferring them to a hospital, moving injured people and dead people away from rubbles to a free area, and searching to free people trapped under rubble are known as critical actions during disaster events.

These aid actions are organized by workers, paramedics, ambulances, and rescue dogs, and each requires the amount of time defined in the basic settings of the game. This approach was developed, and its efficiency was evaluated in a sub-area of Tabriz city, located northwest of Iran. Figure 3 presents the main scheme of the developed toolbox for running the game-based GIS. It is also known that support from residents, as well as other related organizations, would be critical to crisis management and mitigation. Thus, it could be included as part of possible scenario-based game modeling. In this context, a rescue team may also be provided with possible humanitarian assistance, such as donations of money, blankets, food, and drugs. As shown in the figure, the game can be run based on different scenarios, such as the availability of relief items and rescue personnel (e.g., number of ambulances and their capacity, tents, first aid kits, blankets, food packages, rescue dogs, and workers), the estimated time for operations (e.g., cleaning blocked pathways by workers, maximum time for searching each missing person by rescue dogs, and minimum time demanded to evaluate and treat injured people), the initial balance in available items, such as money, tents, blankets, nurses, and first aid kits, as well as awards for efficiency in each operation based on the progress that a user can observe in the field. It should be noted that the value of the "game speed factor" is determined based on the optimal condition for a rescue operation, and the target points show the actual rank based on the ongoing condition, which is determined by the user. It is also likely that some rescue equipment or group members are caught between passages, and after the efforts of the rescue team, they will be relieved and re-join the group, as indicated in Figure 4.

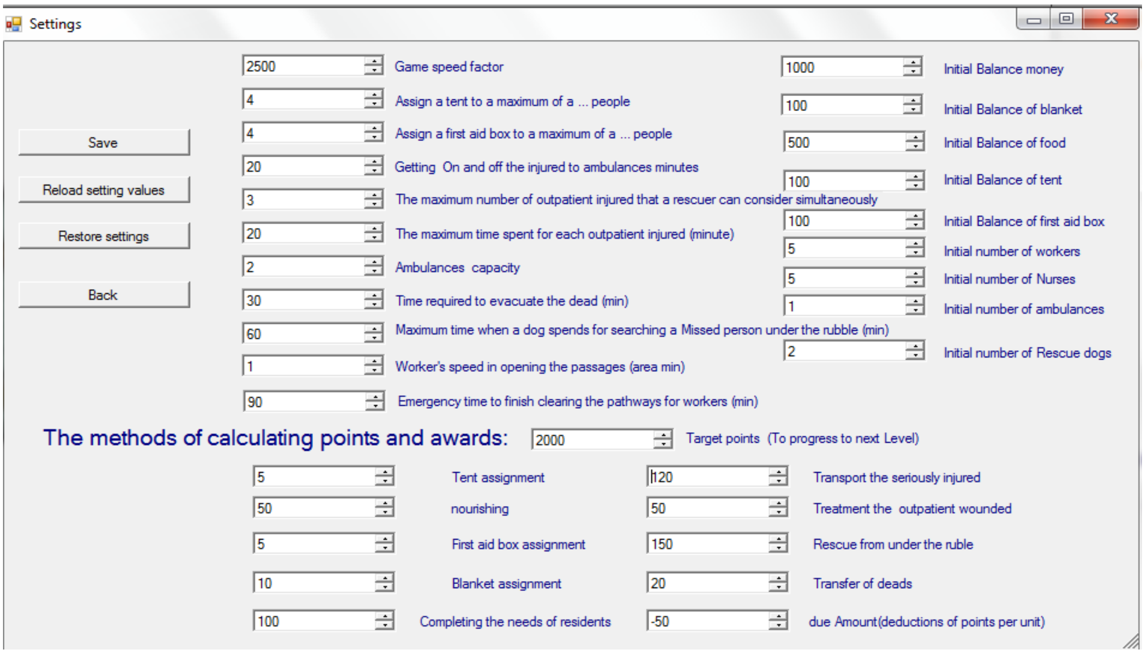

Figure 3. Initial values are defined for game settings (changeable by users). This figure shows the setting of a game that can be customized for any case study based on the characteristics determined by a user. Within this figure, the "game speed factor" is determined as the optimal condition for rescue operations, and the target points show the actual rank based on the ongoing condition, which is determined by the user.

2.1. Methods for Calculating and Obtaining Points and Awards

In the context of an earthquake hazard assessment, it is well understood that the damage caused by an earthquake depends on various related factors such as the distance from an active fault, the earthquake intensity, the geological setting, the type of residential regions, the materials used in buildings, the manufacturing technology used, the longevity of buildings, the street width, the number of floors (floor count), and the number of people living in a building, which can be adapted based on expert opinions in any case study [7–38]. Based on this consideration, the game has the capability to allow an end user to define the relevant factors. To achieve this goal, users' assessment and interest are two of the most critical factors to encourage users to continue playing the game and reach an optimal emergency response by identifying the suitable sites for locating equipment, food, etc.; distributing relief efforts; and supporting rescue teams. Thus, determining these factors during the game can promote the attractiveness of the game as well as motivation to continue playing the game. Generally speaking, the influence of some factors in this game is considered to be relative, and as a result, the occurrence of a hypothetical earthquake with a certain crisis intensity is calculated according to their influence. Incentives are one of the most influential factors in encouraging users to continue play.

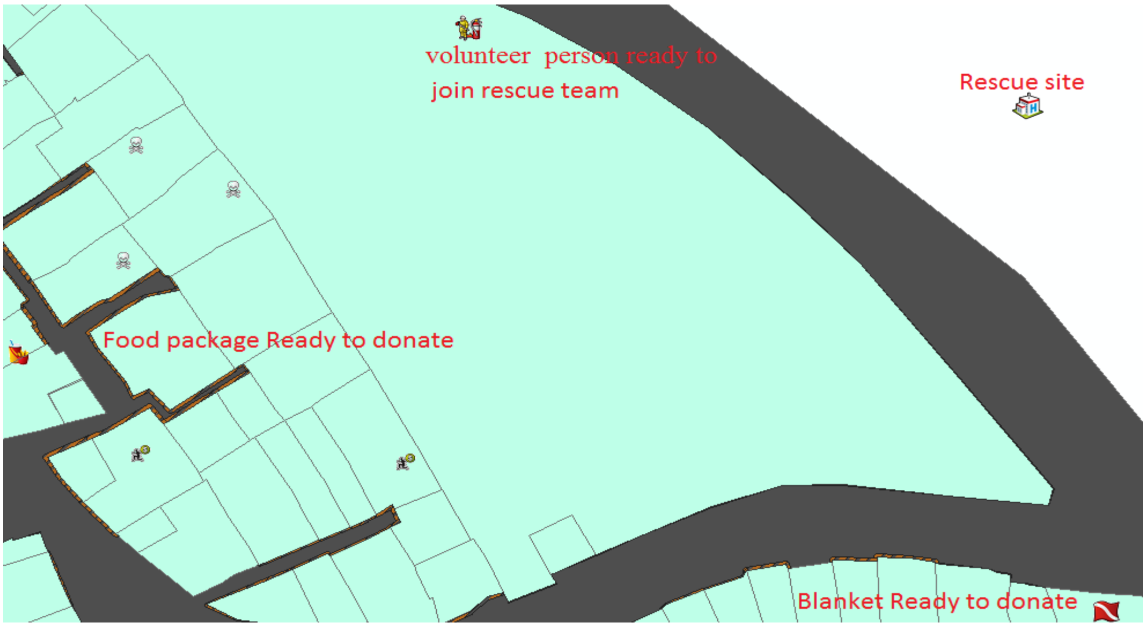

Figure 4. People may volunteer to perform manual work and relief operations to assist a rescue team. The rescue team may be provided with humanitarian assistance at a rescue site.

In this game, the top priority of scoring is set in accordance with humanitarian deeds and can be optimized by an end user based on the situation that occurs. This is the main reason why the priority in scoring is to rescue people from under rubble. Accordingly, based on the order of priority (which can be set by an end user), the next points are granted to the treatment of seriously injured people and supporting them by providing available relief items, such as food, first aid, blankets, and tents. Taking care of injured people and possibly providing relief items, such as blankets, food, and first aid kits, and freeing dead people from under rubble are considered a part of the game, as we have outlined in Figure 5. In addition, solely collecting items, such as clothing, tents, and money, does not count in the rating system, although all these items are necessary to carry out relief and rescue operations. Collecting these items alone can be considered the first step, and in the next step, these items are demanded to be made available to rescue operations. Accordingly, these items can yield a score or mark when their use results in the realization of one of the objectives of relief and rescue.

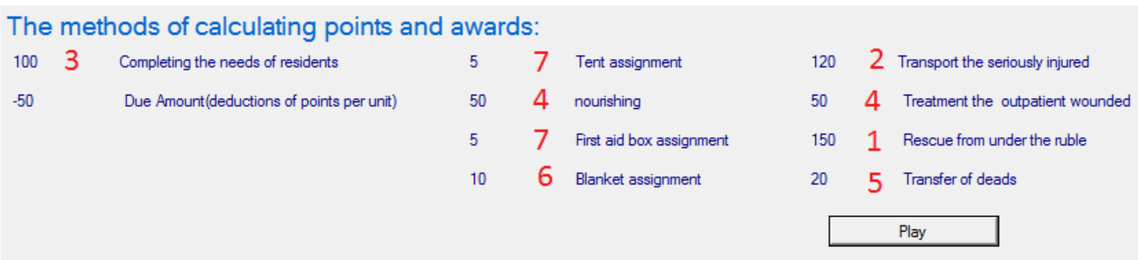

Figure 5. Priority of rating in accordance with humanitarian deeds.

2.2. Selection of Relevant Criteria and Preparation

To simulate a crisis and examine the capability of the proposed game-based GIS in crisis management, it was applied to earthquake crisis management in a partial area of Tabriz city based on the available data. The application case includes the formation of a spatial database, the formation of a dataset with a network of streets and urban transportation, the development of a model to simulate building rubbles, programming, and the implementation of the scenario under consideration.

The emphasis of this game simulation is to provide a representation of a disaster situation and how to support rescue teams to attain a sufficient emergency response. Therefore, preparing a schema close to reality requires information about the ground realities. In the context of earthquake modeling, each building in an urban region must be evaluated using a synthetic vulnerability value that takes into consideration several relevant factors, including the building's age, structural geometry, mechanical qualities of the materials used, level of construction quality, and geological features of the location. Table 2 shows the list of criteria employed in this study, Figures 6–8 show the spatial distribution and variety of selected criteria in the city. Because of this, even for a simulated appraisal, a sizable quantity of information is required to produce an accurate estimate of the seismic vulnerability of a single existing building [39–42].

Table 2. Land-use and demographic data from the Municipality of Tabriz, 2022.

Data	Subclass	Sources and Scale
Land-use characteristics	Administrative educational services Urban facilities Commercial Recreational Industrial Residential areas Agriculture and livestock Transportation	Municipality of Tabriz, on a scale of 1/2000
Population density (inhabitants/km^2)	16–125 126–206 207–369 370–756 757–2089	Municipality of Tabriz, on a scale of 1/2000
Building characteristics	Age Material Structural geometry and mechanical qualities of the materials used Level of construction quality	Municipality of Tabriz, on a scale of 1/2000
Urban road and traffic	Road network Traffic volume	Municipality of Tabriz and Traffic Police of Tabriz, on a scale of 1/2000

Within this study, the relevant criteria were identified based on previous studies [39–42], interviews with local experts, and consideration of the geological setting and properties of the study area. Accordingly, we employed the data collected from a survey analysis and field reports. It is worth indicating that Tabriz is known as a critical city in Iran and has always been threatened by earthquakes. Due to unbalanced development, about 502 hectares of slums and informal settlements, as well as 2500 hectares of urban worn-out textures, with a population between 400.000 and 700.000 people have developed over the past four decades. These areas were developed and constructed in the vicinity of an active fault [43]. Using the field analysis, we obtained information regarding the type of construction materials, shape and size of building, number of floors, age of buildings, and number of residents in each building. These data were accordingly added as attribute information for the urban parcel layer on a scale of 1/2000, which were obtained from the Municipality of Tabriz (Figure 6). Accordingly, all geometric edits and standardization were applied to develop the GIS format layer for future analysis. The most important indicators in this database include the two-dimensional geometric and attributive characteristics of buildings and urban characteristics.

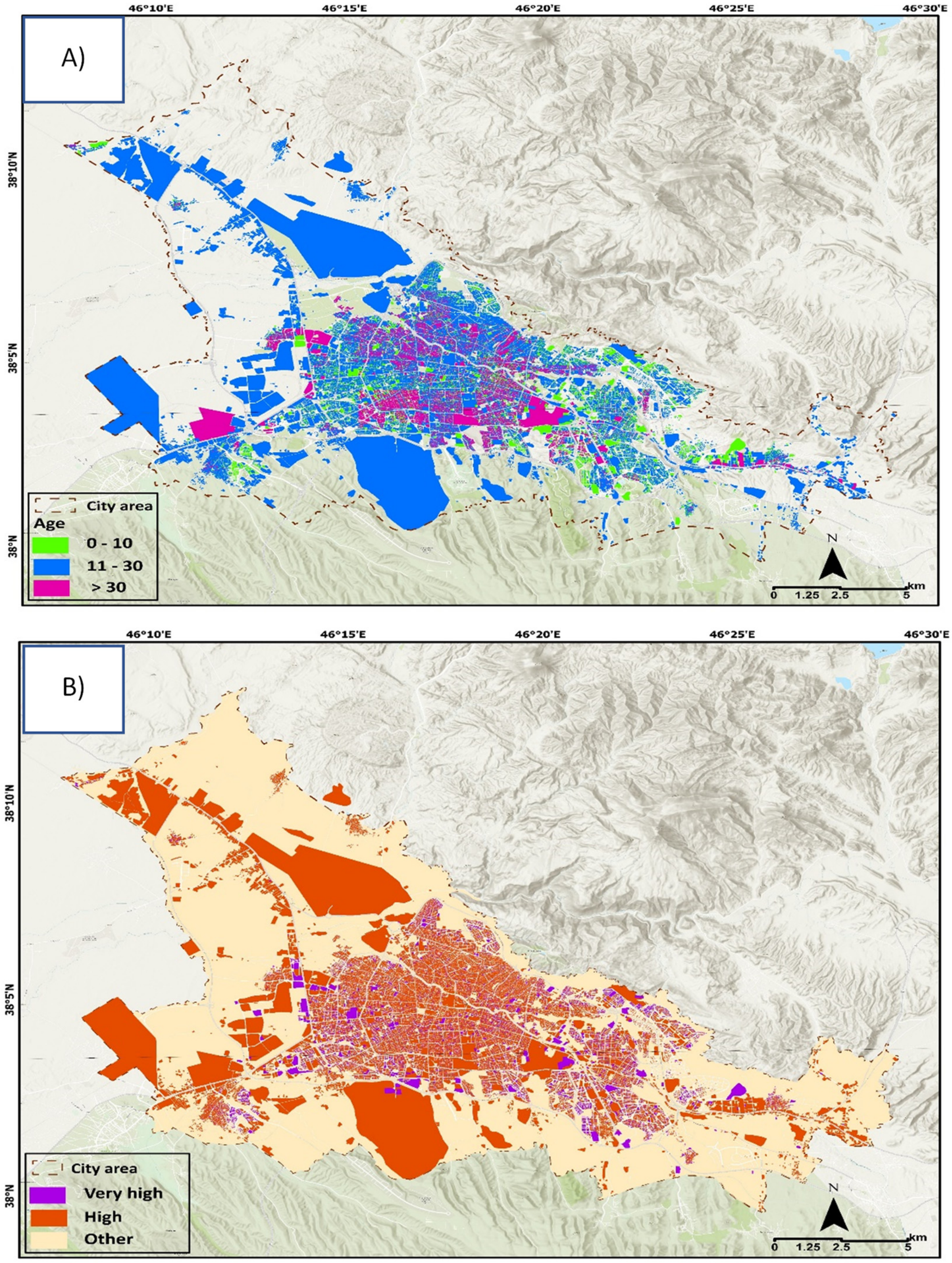

Figure 6. Spatial distribution of building age and material quality. The high and very high areas are the areas that are most prone to earthquake disasters. (**A**) shows the population age in the city and the possible vulnerability of the population to an earthquake, and (**B**) shows the age of the building and the risk of damage in an earthquake due to the building's age, poor material, and lack of relevant standards.

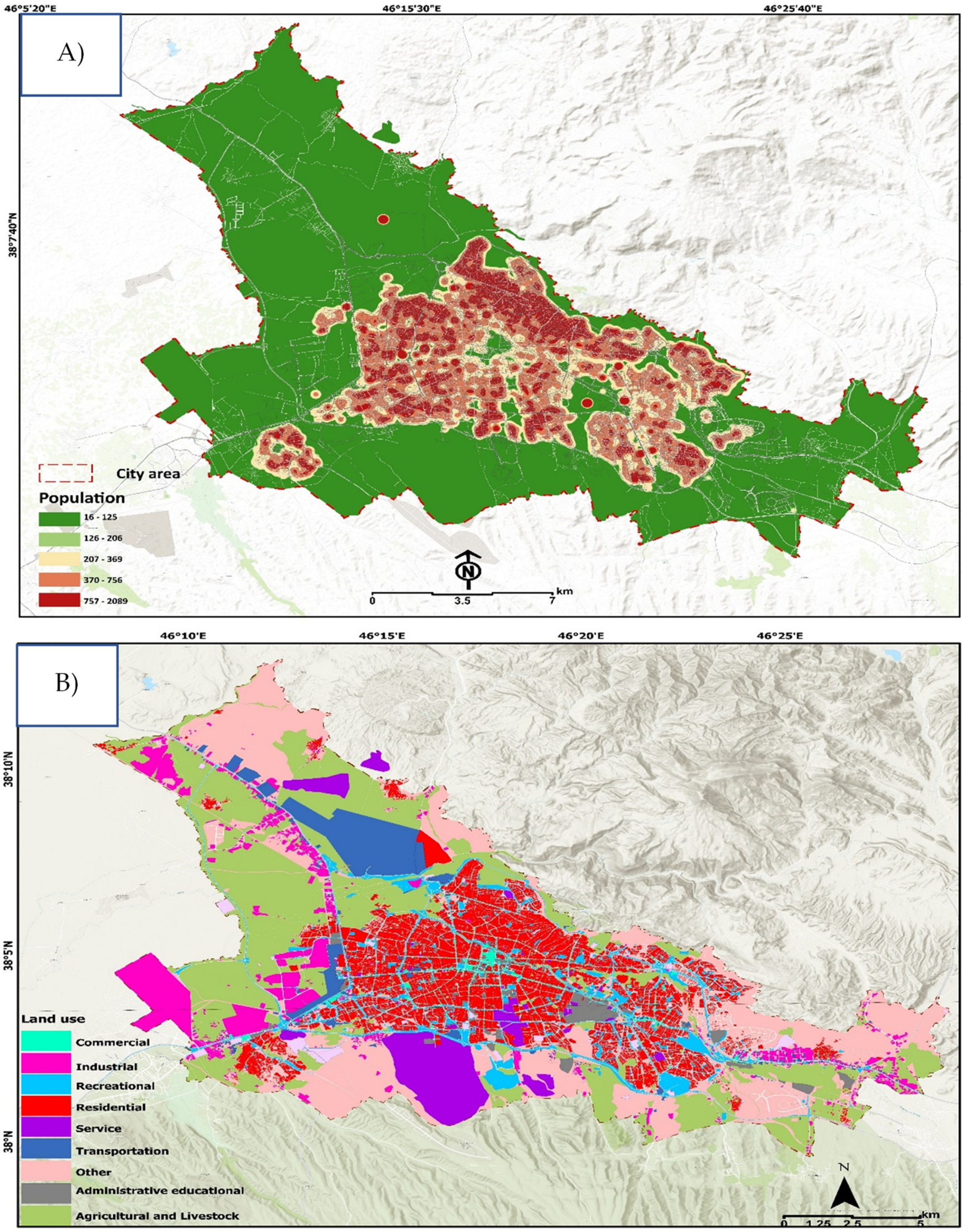

Figure 7. Spatial distribution of population density and land use. (**A**) shows the population density of the city and areas more prone to earthquakes, and (**B**) shows the land use/cover pattern of the city and possible damages in each area, as well as available areas for camping, such as green space areas, by rescue teams.

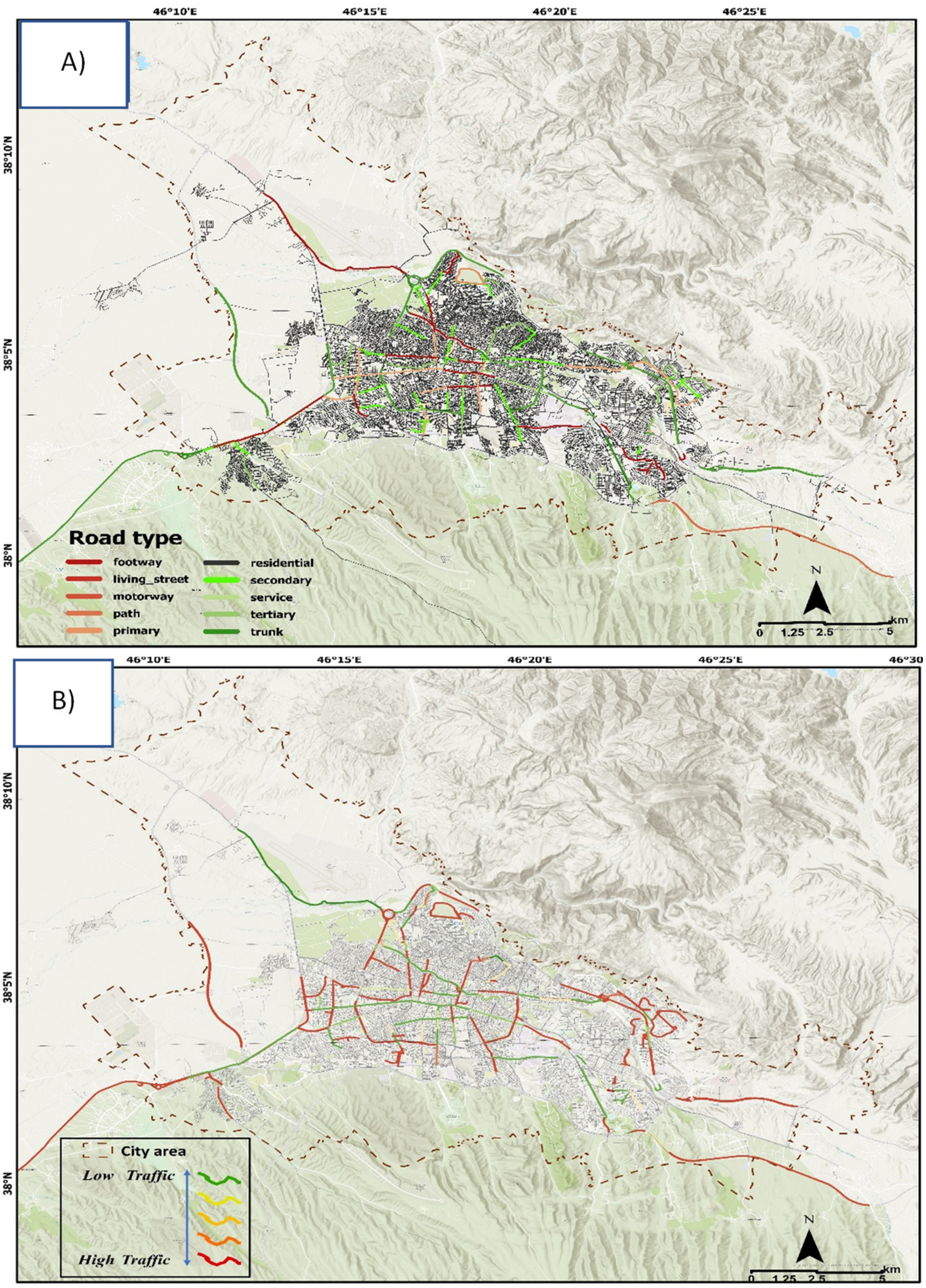

Figure 8. Spatial distribution of road type and traffic volume in Tabriz. (**A**) Road types in the city and different types of roads and their capacities that can be used during a rescue operation. (**B**) Traffic volume is represented from a low volume to a high volume using green, yellow, and red lines.

A recognized urban network is critical to emergency response and crisis management. Thus, we also employed a detailed urban network in this study. The spatial data of streets and city parcels were obtained from the Municipality of Tabriz on the scale of 1/2000 and updated through field observations and high-resolution satellite images. Accordingly, the polygon format of the urban network was created based on a linear urban network dataset. We also employed the traffic volume data and annual urban traffic hotspots (Figure 8) obtained from our previous study as one of the most causal factors for rescue management [4].

2.3. Definition of a Model to Create Building Rubble

It is important to analyze the impacts of earthquakes on different types of buildings as well as the resistance strategies proposed so far [44]. Although during the implementation of this game, it is possible to apply any theory with regard to the scope and kind of building demolition in the face of an earthquake of any magnitude, the main focus in the design of the game is on how to implement it in the context of GIS and spatial analysis. Thus, according to the characteristics, materials, age, and number of stories of each building, a general formula was developed and applied. The formula calculates the magnitude and intensity of the earthquake being simulated, the characteristics of each building, and the amount of destruction and debris around the building. Finally, a cutting from the intersection of streets and rubble parts is created, and pieces of remaining debris are employed as a barrier in the next stages of processing.

2.4. Programming and Implementation of the Scenario

The ArcGIS software developed by the company ESRI provides the possibility of using developer interfaces, such as NET, to add new features to the software or to design a standalone application, such as Arc Objects. When starting, the game program, according to the level of progress of the game, first introduces the intensity of an earthquake to the model of debris formation. After simulating debris, the remaining features in the passages are loaded in the context of a polygon barrier layer related to the database of network analysis. In doing so, the game aims to calculate relevant statistics and estimate the number of dead, injured, and trapped people under debris. The basis of these statistical calculations is the severity and magnitude of the earthquake as well as the characteristics of buildings, such as the number of inhabitants in each building and their age. Furthermore, affecting by the number of people in each building and whether they are vigilant or sleeping, the time of the earthquake is considered.

Apart from all these issues, due to uncertainty, random functions are applied to calculate the final statistics. Moreover, to account for the possibility of donations, motivation, interest, and excitement and to prevent the game from coming to a stop in the most difficult conditions, according to a random procedure, several relief items and personnel, including food, tents, money, a worker, a rescuer, a rescue dog, and an ambulance are provided between the blocks (Figure 9). To investigate the user-friendliness of the tool, it was played by 20 users (students and experts) using different devices such as computers, tablets, and mobile devices. For this goal, their interactions were recorded using Google Analytics to produce a respective script. It is worth mentioning that Google Analytics records all user clicks along with other anonymous user information, such as location and the browser employed. The script stores the scores of each user starting at different levels of the game in a database. These features make it possible to track users to determine which parts of an area are less visited and which puzzles are more difficult. These capabilities enable the tracking of users to ascertain which areas may receive less traffic and have more challenging problems.

2.4.1. How to Display

User-friendly and attractive symbols are indeed critical characteristics for developing an engaging game, particularly when targeting the young generation including students, as potential users. In this game, relevant symbols are employed to display game items and entities. For this purpose, appropriate symbols for workers, rescuers, rescue dogs, ambulances, food packages, blankets, tents, and cash are used accordingly. Figure 10 presents the symbols that are applied through the game.

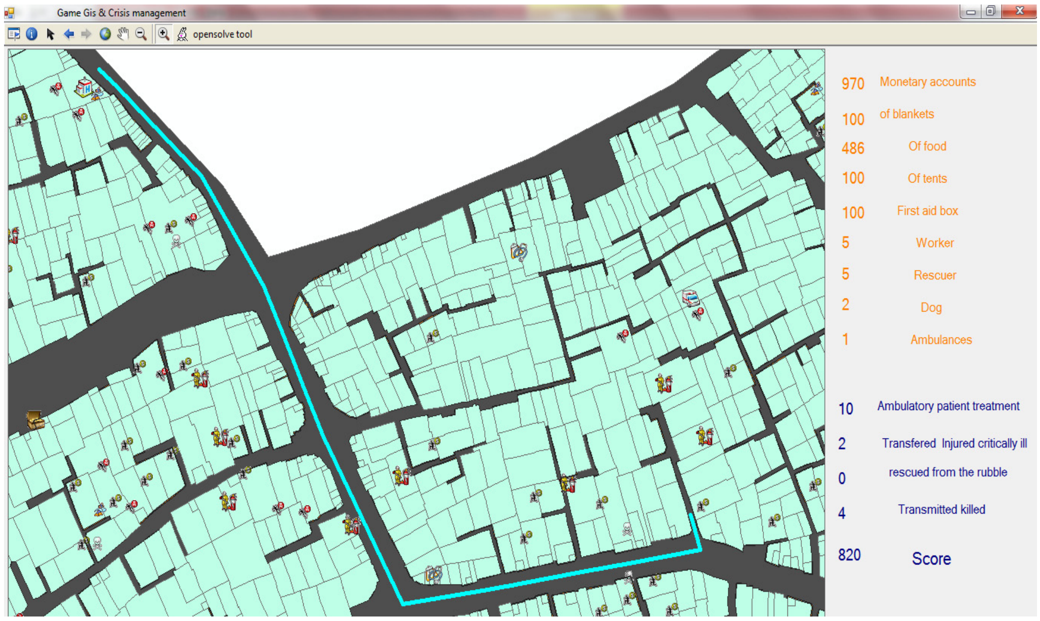

Figure 9. A screenshot of the game's user interface.

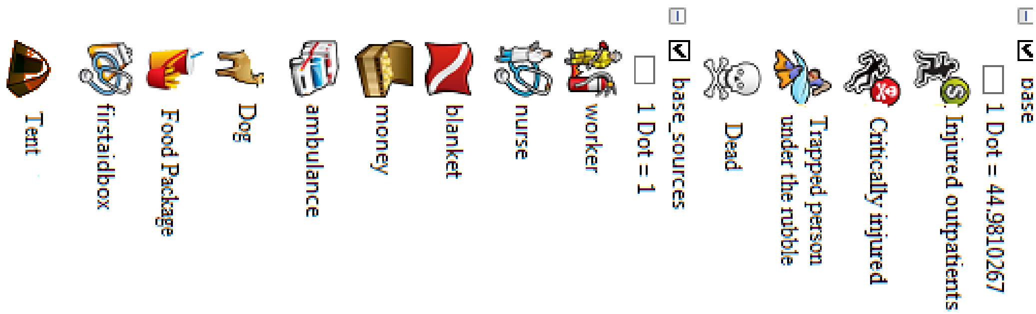

Figure 10. This figure shows some simple symbols which are used in the game.

2.4.2. Tools for Users

To display the game interface, a two-dimensional map viewer is applied. In addition to this map viewer, the basic tools included in the ArcGIS software, such as pan, zoom, full extent, and identify, are also employed for operation with the tool. The most important tool used in the game is called open-solve (Figure 11), which is a customized tool. Based on this tool, end users can navigate their mouse cursor anywhere on the map and make clicks. The use of this tool is so that after clicking the mouse, initially, the type of complication clicked (barrier, building block, or corridor) can be selected. Then, the clicking point is introduced as a data point in a network analyzer database, and the "solve" command can be performed. If the result of the network analysis is positive, it indicates that there is at least one way that the rescue teams can select for the emergency response. The tool also enables users to have access to other available ways and select the optimal one based on their priorities. However, if any problem arises with regard to maintaining the condition of the command, a message will be displayed accordingly to express the reason and support the end users in the next steps.

2.5. Condition for the Implementation of User Commands: Informal

Based on the previous steps mentioned, if an end user clicks on a place with the mouse, the command can be processed based on the determined conditions. These conditions will be based on the assumption that if the clicked feature is a barrier, the barrier polygon area will be estimated. Then, according to the values adjusted in the setting of the game, each worker's speed in clearing blocked passages is determined, and finally, the number of workers needed to remove barriers within a specified time is calculated. If the number of workers available is greater than or equal to the number of workers needed, the command "purging the passage" runs. Otherwise, a message indicating "men at work" is displayed (Figure 12). Some food and money are subtracted from the inventory in return for employing each worker. Therefore, another condition for the implementation of a user's commands is the availability of sufficient funds and food.

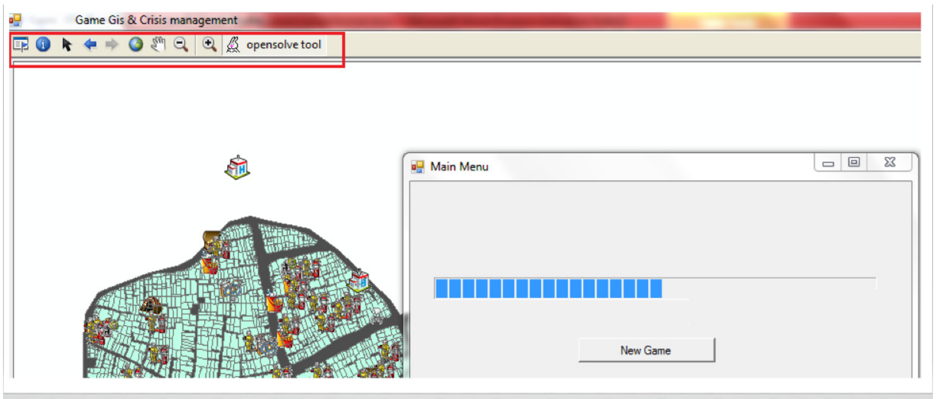

Figure 11. Common ArcGIS tools used in this game.

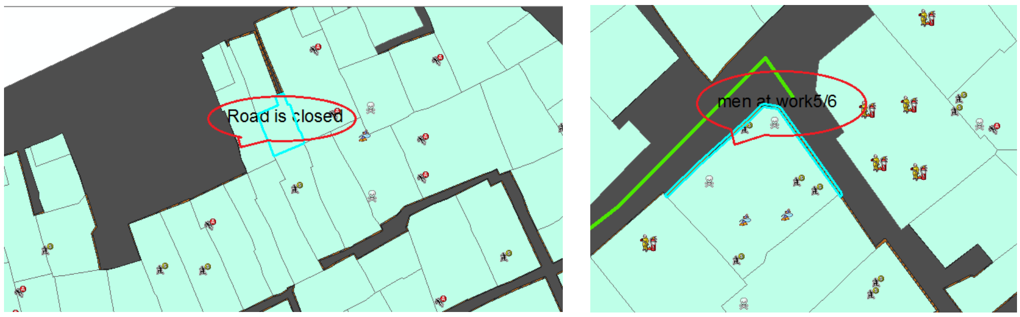

Figure 12. Two sample images taken when no path is found or when the number of workers is not enough to purge a barrier.

In the developed tool, with the start of a command's execution, the number of workers employed will be temporarily deducted from the balance of workers. If the clicked issue is a building block, donated and available items (such as food and blankets) will primarily be added to the inventory. Proportionally, the number of injured people will temporarily be deducted from the rescuers' inventory while they are being treated. In addition to paramedics, for the treatment of critically injured people, workers (e.g., victims) are also used to carry them out of the rubble area. If the number of critically injured people reaches a certain number, ambulances are utilized to transfer them to a hospital. It is worth mentioning that the ambulances' travel time is calculated according to the output result of the network analysis. Rescue dogs are used to find people trapped under rubble. Finding and freeing missing people from under rubble is a probabilistic issue. Thus, a random function is used, and at any time of employment, a rescue dog can be busy searching for almost two hours. During this period, a trapped person under rubble might be found or another attempt might be needed. In the case of having an adequate inventory, using combination keys, a user can be granted the advantage of assigning donated items to the residents of a building. Of course, this should be done with caution so that the inventory items needed to accomplish the mission do not diminish.

2.6. Condition Required for the Next Step

From the beginning, users are required to create minimum points and goals. Accordingly, one stage is completed with the quorum points added to the next one. After indicating the details of the acquired scores, the game starts again by increasing the intensity of the earthquake and simulating a new critical situation.

2.7. Components of the Program and Implementation Behaviors

Within this game, it is assumed that some entities, such as workers, rescuers, rescue dogs, and ambulances, are temporarily deducted from the inventory. There is a behavior for these entities in a class called "time consumer". To create each of the entities, it suffices to create an instance of the aforementioned class. Any object created from this class has its own special timer, which, and with the completion of the proposed time, introduces the object to the entire inventory. There is also another class called "temporal work" in which a timer is also used. If the determined time runs out, the completion of the work is announced, and the appropriate command is carried out. For instance, with the completion of the removal of one of the barriers, the order to clear the polygon barrier from the network analysis is immediately issued. Likewise, a class called "temporal message" performs the task of indicating and then deleting a graphic message (Figure 13).

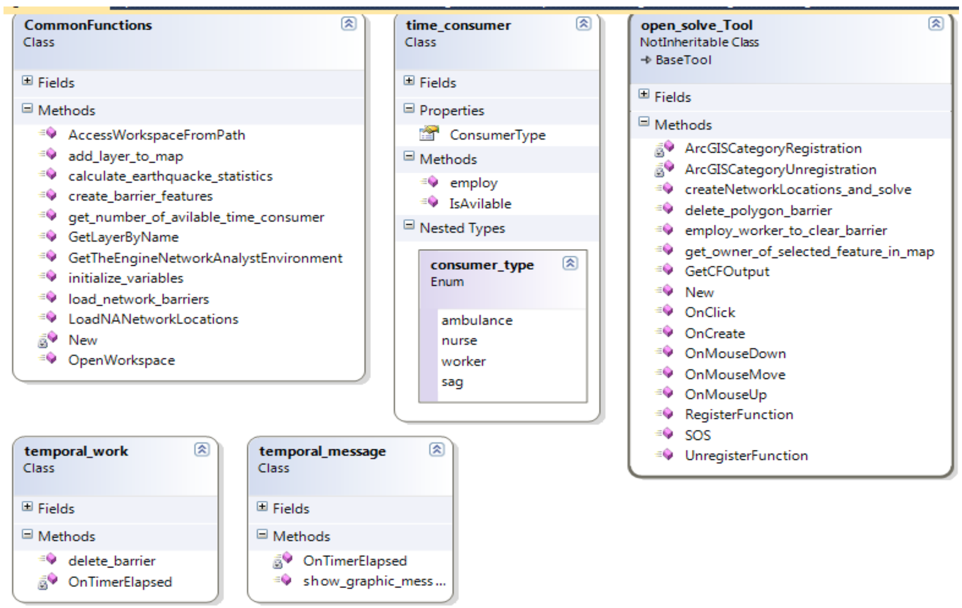

Figure 13. A diagram of some important classes used in this game.

3. Results and Discussion

3.1. General Results and Outline

In this study, we developed a game-based GIS approach for the simulation of disasters and emergency responses. The results of this study indicated that game-based GIS can be employed for emergency responses to earthquake disasters. In order to examine the efficiency of the game, a survey analysis was carried out examining related factors, including user-friendliness, functionality, flexibility, complexity, hardware compatibility, ability to integrate with other apps' output, overall reliability, and overall performance.

Based on the results and the positive feedback that we obtained from 20 users who played the game, it can be concluded that game-based simulation can be considered an efficient approach for disaster simulation and improving the skills of rescue teams. It is well understood that the early experiences of rescue teams can be critical for crisis management of disasters. Thus, the simulation performed in this study not only allows the evaluation of a disaster situation and the improvement of the skills of rescue teams, but it also supports the identification of critical actions that might affect the efficiency and functionality of rescue missions. As a result of this study, an open-source tool is published with this paper. The outcome of this application is an intellectual game that almost all users at any age can play, which challenges their ability to solve critical issues. Because the tool was developed as open source for users, it is expected that problems will be resolved and promoted with a focus on technical problems by developers.

Due to the unexpected context of natural hazards and disasters, particularly earthquakes, it is well understood that education and previous knowledge of rescue teams and citizens will support residents and stakeholders in gaining valuable information to improve emergency responses and risk management skills. In addition, based on our results, it turns out that cultural backgrounds and supports (e.g., donating food and medical drugs, and supporting injured people) might also be essential to mitigate the impacts of natural hazards and disasters and need to be taken into account when developing mitigation scenarios for disaster management.

Based on recent progress in information technology and access to a variety of social media platforms, many people spend a significant portion of their time playing computer games. Playing game may have a positive or negative psychological effect on people, especially on the young generation including students. Therefore, it is worthwhile to invest in and pay attention to games with an educational purpose. In fact, aside from being fun, some tips are also provided to inform users throughout a game. Based on this capability, from primary schools to higher education, games have long been used as vehicles for teaching geography, frequently in exercises simulating the world outside the classroom and requiring students to engage in role-play [45]. The application of games for educational purposes has been designed to produce a variety of perceptual, cognitive, and behavioral effects on students, particularly knowledge acquisition, content comprehension, and affective and motivational outcomes [46].

The use of maps for communication has always been significant among the geospatial community, and modern "smart maps" demonstrate how sophisticated the design principles of maps are. A "story map", which combines text, interactive maps, video, and audio in a linear manner and under a straightforward user interface, has recently emerged as an innovative and significant method for disseminating GIS results [47]. Using a smart map in the context of game-based GIS could lead to the development of an efficient approach for disaster mitigation and emergency response. The use of games in geographical teaching has grown in popularity since they became more prominent in GIScience in the 1960s. Based on the intensive capability of games, the variety of games used in schools, colleges, and universities has also grown significantly, particularly in the last three decades due to the growth of digital games. In this context, game-based GIS takes the advantage of spatial and location-based analysis and service to simulate disasters and the functionality of rescue teams in emergency responses. It is well understood that, for many students across the age spectrum, games have become a pervasive element in daily life outside of the classroom. As a result, students are frequently exposed to serious games and edutainment outside of a formal educational setting [45]. Thus, based on the characteristics of games considered to be interesting for many users and particularly for the young generation, this capability can be efficiently employed for educating and improving their knowledge regarding disasters. In this game, by using the basic tools of the GIS software, in addition to achieving the goals of the game, the teaching of basic GIS concepts is conducted [46]. With this interpretation, it will be beneficial to pay more attention to these programs. In particular, the GIS software provides the ability to design and display three-dimensional urban environments, such as City Engine and other open-access platforms [48].

From the IT perspective, the software capabilities that are currently available in the e-learning sector were not initially created explicitly for game production, but if used creatively, they can allow users to build engaging and instructional games. To summarize, research on the junction of game studies and legacy, backed by a multidisciplinary team of experts, without the use of well-known gaming engines, is this study's main contribution [7]. Based on the case-study results, using the developed tool to perform more accurate calculations, provide a three-dimensional environment close to the real-life environment, and develop a game under a networking group, it is possible to provide an opportunity for people living in an urban neighborhood to experience the occurrence of a crisis in their vicinity and estimate the results. Obviously, by playing the game again, a user can become familiar with the weaknesses of the neighborhood over time, and the game may also be useful in the assessment, prevention, and elimination of risk factors.

3.2. Technical Issues

In the context of computer games, it is widely acknowledged that developing a game requires expertise in programming along with the use of many different types of software. This method allows the creation of games in a time- and cost-efficient way [7]. Dynamism and pace of performance are factors that play a significant role in determining the quality of a game. Due to the increasing volume of information and the use of relatively complicated graphic symbols, the updating rate of maps in the proposed game-based GIS was slightly delayed after making some changes (for example, deleting a feature). It seems that a precise definition of the updated range and the utility of partial refreshment can solve this problem. It also appears that if symbols were used to display messages, it would have a better quality than using graphical items. If the formula for calculating the number of debris were updated so that in addition to the cross-sectional area of debris, it would calculate the volume, and if, simultaneously, it would provide a better accuracy in estimating the number of debris resulting from the earthquake, the results would be slightly closer to reality. Also, if dynamic symbols were used in the display instead of fixed notation symbols, the game would be doubly attractive.

4. Conclusions

Previous knowledge and experiences are the most important criteria for gaining skills in crisis management and providing efficient support in rescue activities during an unexpected disaster, such as an earthquake. Due to the catastrophic context of natural hazards and disasters, there is a high need to study this issue in the field of natural hazards and rescue missions and programs. In this context, scenario-based and game-based GIS approaches can be critical to studying natural hazard processes, as well as better recognizing efficient control measures. Recent developments in telecommunications and social media have led to intensive progress in GIScience as an interdisciplinary field of sciences. Integration of GIScience spatial analysis with computer-based programs such as games leads to the development of an efficient approach for the simulation of disasters and the practice of emergency responses. Such integration provides a unique opportunity to transfer knowledge and information to target groups and communities. Thus, game theories and especially scenario-based game-based GIS can be applied to improve people's knowledge to prevent and reduce the heavy losses of lives and properties caused by natural disasters.

By presenting a state-of-the-art approach, the results of this research can make a significant contribution to further the development of GIScience and its applications for disaster and risk management. We conclude that the results of this research are useful for understanding the capabilities of game-based GIS in crisis management and disaster simulation. In addition, the developed tool could be the basis for decision-making and educating people by simulating earthquake hazards and observing the functionality of rescue teams. The information provided by these maps could help citizens, planners, and engineers reduce losses caused by future hazards through prevention, mitigation, and avoidance. The results are also useful for explaining the effectiveness of rescue teams and crisis management facilities when supporting emergency response decisions and relief efforts to mitigate future hazards in Tabriz city, and other case studies might be examined by applying the developed tool.

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