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ZONING OF NATURAL AND MAN-MADE DISASTERS FOR RELIEF AND RESCUE CENTERS SITE SELECTION USING THE MODEL LOGIC (CASE STUDY: GUILAN RURAL AREA)

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ABSTRACT

Guilan Province with vast forest resources and abundant rainfall which sometimes causes flooding, fires, road accidents and earthquakes, besides its tourist attraction, high population density and dispersion of rural areas has faced with the problems that necessitate emergency response centers against unexpected disaster with a balanced and equitable access. In order to select stationary and mobile station sites the potential risks were identified at first and then danger zones were determined. Nine major risks including floods, earthquakes, mass movements, fires, road accidents, snow and blizzards, marine incidents, avalanches and war were paired compared using Analytical Hierarchy Process (AHP). Then proper sites were determined based on required standards for establishing relief and rescue centers using the model LOGIC. Finally, 49 and 34 points were proposed for establishing stationary and mobile centers, respectively. Also the radius of effective range for each center was calculated based on a maximum response time to the incident.

Keywords: Site selection, Stationary and mobile stations, Relief and rescue, Disasters, Zoning, Analytical hierarchy process.

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Contribution/ Originality

This study is one of very few studies which can be used as a template to optimal site selection for relief and rescue centers in rural areas of the Province.

1. INTRODUCTION

Today, one of the obstacles to sustainable development of communities is natural disasters and crises which impose heavy losses and damages on communities due to the lack of study and planning as well as the lack of proper preparation and deal with these problems [1]. The statistics show that Iran has higher rank in terms of the crisis than other countries, for example in terms of death toll caused by the earthquake in the twentieth century, Iran ranked fourth after China, Japan and Italy [2].

In Guilan Province which has vast forest resources, abundant rainfall that sometimes causes flooding, fires, road accidents and earthquakes, as well as tourist attraction and high population density the emergency response centers against unexpected disasters with a balanced and equitable access is inevitable. It requires more attention when according to the reports of Disaster Management Organization fires, floods and road accidents are among common events in Guilan Province, especially in rural areas, roads and forests and impose significant losses to the national and human capital, every year. While, it seems on the other hand that the current distribution of relief and rescue centers including firefighting stations and equipped health and emergency centers is not optimized and with equal access, particularly in rural areas of the province, thus, it is essential to establish stationary stations in some

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populated villages with wide sphere of influence and mobile stations in some areas with seasonal attraction for tourists and with seasonal events of precipitation and fires caused by seasonal winds, while evaluating available facilities systematically and comparative, in addition, necessary measures should be applied to establish relief and rescue and emergency response infrastructure with balanced distribution across the Province. Site selection for such infrastructure requires a lot of spatial data that must be analyzed logically; unfortunately, the previous site selections were not carried out systematically and data collection for the creation of existing infrastructure was sometimes conducted through a questionnaire only in some specific demographic landmarks, and the relationship between intended centers and the surrounding villages and their sphere of influence, stations quality and slope are not much considered. In addition, the high volume of data and variety of items involved in site selection process require the use of mathematical models and site selection software or risk of error would otherwise very high.

Data such as distance to the vegetation and forest resources (especially coniferous and risky forests), surface water resources available for use in emergencies including natural ponds and rivers, slope and impassable areas, access and road networks to station location, the human and building density, factories and industries, distance from cities and urban stations, compatibility with different rural land use, spatial priorities and the risk of accident in terms of the type of structure, importance, texture, alleys, the equipment required to respond to the needs of station's coverage area in terms of number and type of equipment, vehicles, personnel etc. are such items that are effective in stations' site selection and should be considered; each of these items has standards in terms of distance from the proposed location of the station and station quality, and it is not possible to select these sites in a balanced form and equitable access without the use of information and spatial layers' overlapping and calculating the priorities. Selecting an appropriate location for establishment of relief and rescue centers requires a comprehensive study, because establishing these centers in proper location increases their efficiency and productivity in order to achieve the desired objectives in critical situations. Also, since risk zoning in previous studies was mainly performed in urban areas and considering only some parts of the natural disasters, in the current research it is tried to study a set of natural disasters and man-made hazards in rural areas of Guilan Province, simultaneously, and finally a pattern for optimal site selection for stationary and mobile relief and rescue centers in these areas is proposed using accurate and convenient tools.

1.1. Background of Study

Rashidi, et al. [3] in their study examined the factors involved in site selection for temporary housing centers. The results of this study showed that the existing access criteria and the spatial characteristics are of high importance among other criteria and standards for selecting the proper sites for sufferers' temporary housing Rashidi, et al. [3]. Philippe, et al. [4] evaluated the potential of firefighting stations to respond to fires using Spatial Decision Support System (SDSS) and parameters such as distance and population density and 8-minutes performance radius and 90 percent coverage of accidents. The results showed that 60 firefighting stations in the country with the standard performance cover 67 percent of possible events Philippe, et al. [4]. Hosseini, et al. [5] used multi-criteria decision-making model for site selection of temporary housing areas in Rasht. In this study, they analyzed site selection criteria in 4 groups, natural criteria, the road conditions, access to crisis management centers, and being away from risk centers Hosseini, et al. [5]. Murray [6] in an investigation considered time standard for fire response as 9 minutes. He used strategic planning for new firefighting stations' site selection and examined the proper distribution of new stations using the buffer tools Murray [6]. Nouri, et al. [7] in their study with the aim of zoning the areas vulnerable to natural disasters, identified rural zones with very low, medium, and high risk and concluded that it is inevitable to establish guards and fences and dams as well as to modify the natural course of the river through increased its recharging capacity or dredging in order to prevent overflow of the river and severe storms Nouri, et al. [7]. Palash [8] in a study assumed natural disasters as a cause of slow development process in a given period and considered all disasters dependent on each other, and then examined the intensity and weakness of the impact of these factors in relation to each other and provided suggestions for overcoming the current situation [8].

Above studies have been done mainly in urban areas and in terms of one or more natural disasters, while this study has carried out risk zoning in order to site selection for relief and rescue centers in rural areas considering a set of natural disasters, forest fires, floods and snow, mass movements, earthquakes and avalanches, as well as man-made hazards such as fires in residential areas, road accidents, marine events and war. Since depending on the scope of rural or urban areas studied, the affecting factors can be different, in this study, it is tried to formulate a full framework of natural and human hazards affecting the rural areas and to study their current status.

In addition, since a special survey which was specifically focused on site selection of inter-cities and inter-villages relief and rescue centers didn't conducted in Guilan Province yet, the results of this study can be used as a template to optimal site selection for relief and rescue centers in rural areas of the Province.

2. STUDY AREA

Guilan Province is one of the northern provinces of Iran locating in the geographical coordinates 34° 36 ′ to 27° 38′ N and 27° 48′ to 50° 53′ E and extends along the northwest-southeast (Figure 1).

In general, the topography of Guilan Province consists of two parts, lowland and flat plain and high and steep mountain.

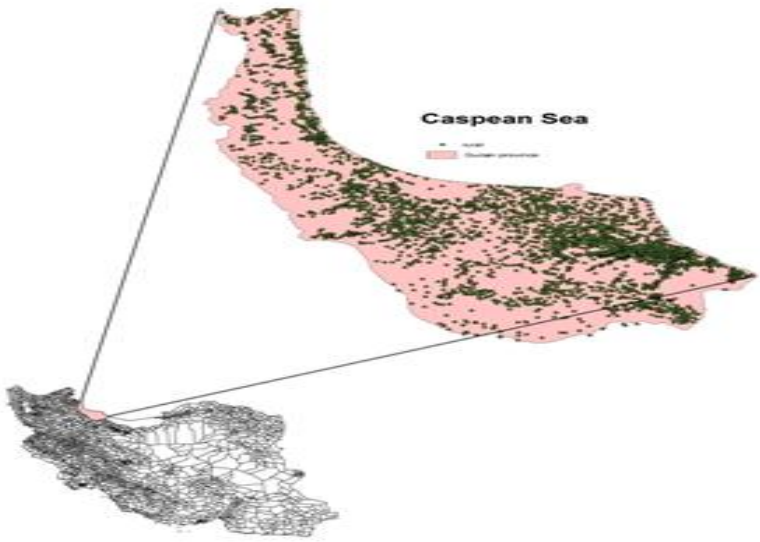

Figure-1. Location of Guilan Province in the country and the distribution of its villages
Source: Passega

3. METHODOLOGY

In this study, different valued layers were overlapped in GIS environment to suggest proper sites for establishing new centers while studying existing centers in order to cover whole study area in a balanced form and with equitable access of human, environmental and industrial resources to relief and rescue centers. The Analytic Hierarchy Process (AHP) model was used to prioritize risky areas. In addition, threat scenarios for demand centers (rural areas of Guilan) were predicted for zoning the risk priority areas. In fact, the possible future threats to rural areas of Guilan were identified; in this regard by using library studies, interviewing with experts and reviewing the records, the significant threats to the rural areas of Guilan was categorized including natural and anthropogenic such as: 1earthquakes, 2-snow, 3- flood, 4-fire, 5-war, 6-road accidents, 7-marine accidents, 8-drift and landslides (mass movements), 9-avalanche. Then, depending on the kind of threats, risks across the rural areas of Guilan and the radius of destruction, the severity of the impact, importance and priority, studied areas were valued using opinions of experts and scholars and using hierarchical tree structure (Figure 2) in Software EC.

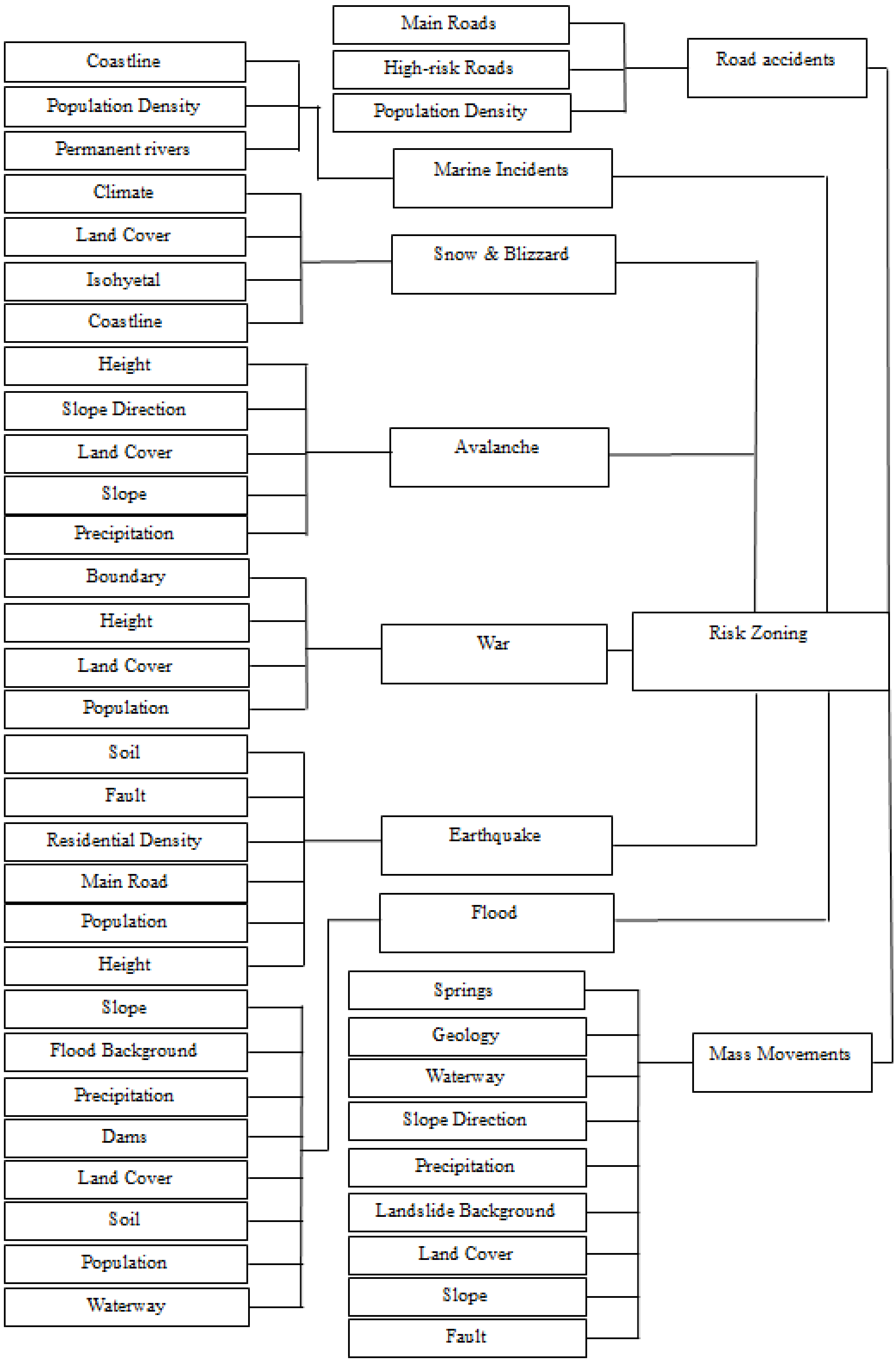

Figure-2. Analytical Hierarchy Process (AHP) tree diagram of risk zoning

3.1. Analytical Hierarchy Process (AHP) Model and integration into Geographic Information System (GIS)

Analytical Hierarchy is a decision-making technique that can be used for analyzing and supporting the decisions which have multiple and reciprocal purposes [9]. This method is one of the suitable techniques for weighting, which is designed to solve complex multi-criteria problems. This is a powerful and flexible tool to evaluate multi-criteria problems quantitatively and qualitatively and is characterized by pairwise comparisons [10]. Implementing this idea requires identification of compatible alternatives and an alternative grading and scoring approach based on their degree of attractiveness. Using this method in the field of Geographic Information System contributes user to improve decision-making processes [11]. Since the 1960s, integrating multi-criteria decision-making into GIS to solve spatial planning problems has received a great deal of attention of urban planners followed by developing the GIS-based Multi-Criteria Decision-Making approach to solve planning problems involving with multiple conflicting objectives, such as land-use allocation problems. This approach is so simple and flexible that a large number of criteria and indicators can be used in it Phua and Minowa [12].

3.2. Creating the Crisis Map and Site Selection

In the valuation process, since it is necessary to identify high-risk areas using AHP model at first, places that have poor and limited access to relief and rescue facilities receive higher values and thereby risk range is achieved (lowest risk, medium risk, highest risk). Then, to determine the location of the centers in high-risk areas, the places with more facilities are selected using the model LOGIC. Such a site selection may cover deficiencies, while ignores some other areas, in these cases we may cover the holes created by mobile stations to achieve balance access and comprehensive distribution. Due to the extent of the subject in this study, two collecting methods were used including field collection and library study. Research process is summarized in Figure 3.

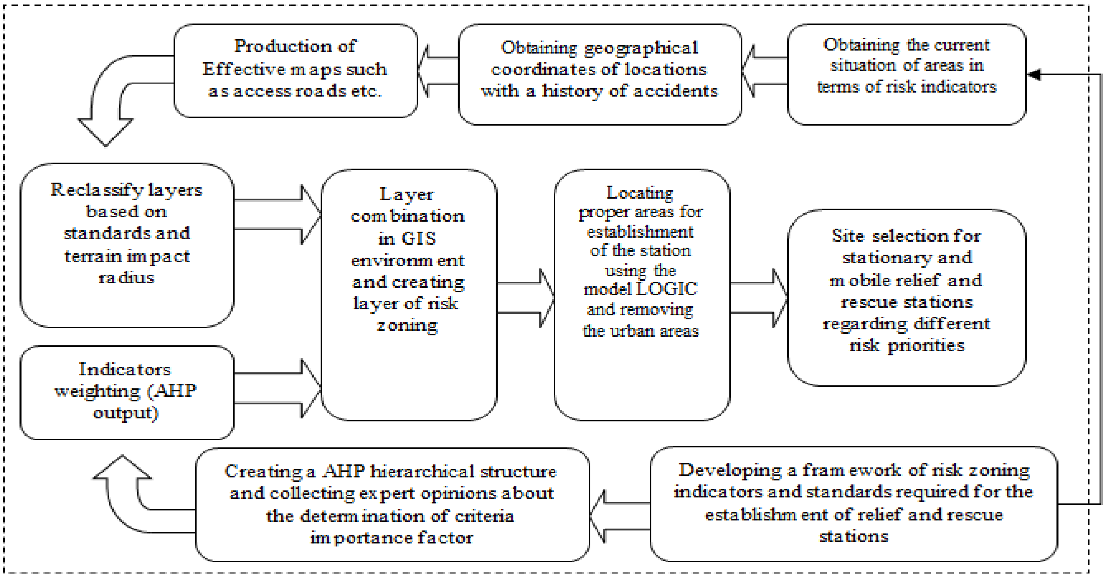

Figure-3. The research process

4. DISCUSSION AND CONCLUSION

4.1. Risk Zoning

After reclassifying the sub-criteria layers of each criterion effective in the crisis, risk zoning map for each crisis was created by multiplying the weights obtained from the AHP model, and then the ultimate risk zoning map was achieved by overlapping the nine-crises risk zoning maps (Figure 4).

Then, the risk zoning map for each crisis was reclassified by Natural Breaks method into 5 classes, very risky, high risk, medium risk, low risk and very low risk, and finally all nine risk zoning maps were overlapping together and were reclassified into three categories, low risk (No. 1 in green), medium risk (No. 2 in yellow) and high risk (number 3 in red) (Figure 5).

4.2. Site Selection Using Logic Model

Logic function is a cumulative function and all the variables are overlapped in it with certain circumstances. Only phenomena involved in site selection that their class, range, and threshold are clear. For this purpose, relief and rescue site selection guidelines developed in responsible organizations and theoretical foundations were extracted from previous studies (Figure 6).

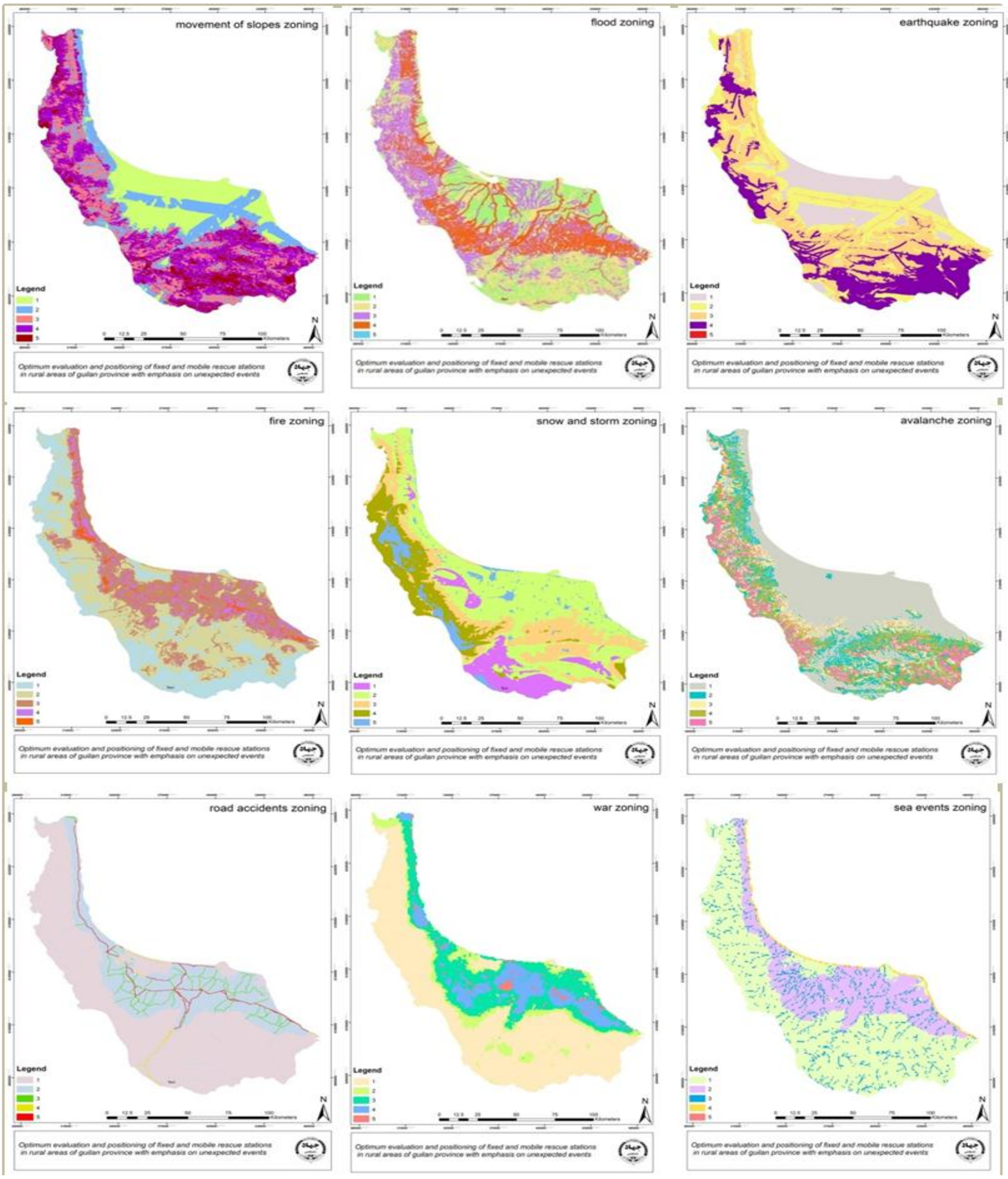

Figure-4. Risk zoning maps of nine-crises based on effective sub-risk criteria

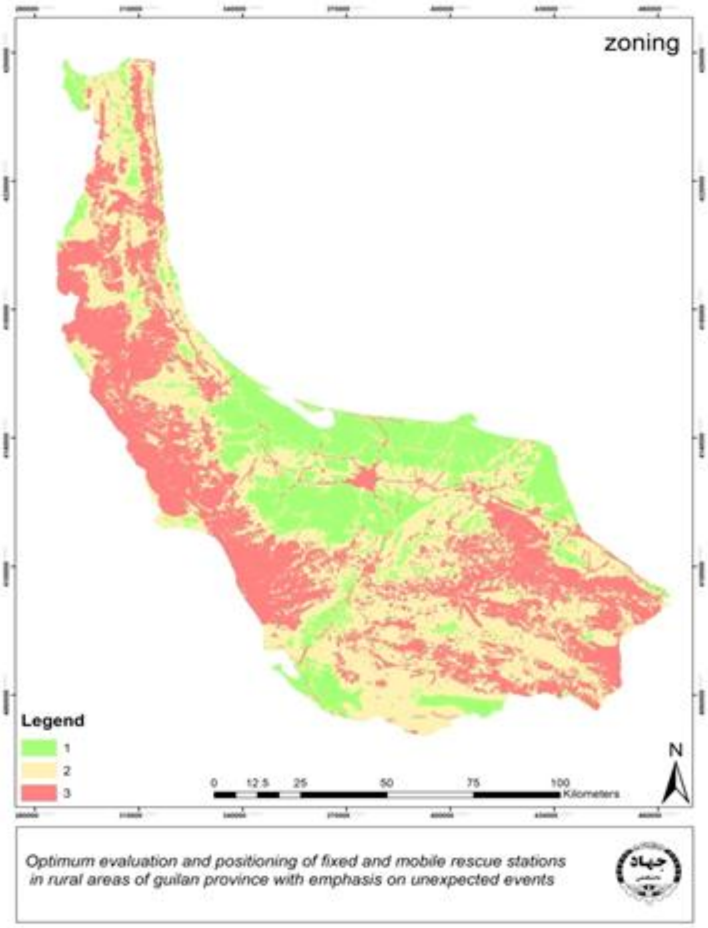

Figure-5. The final risk zoning map

0 Shows that all conditions for stationary stations are not available
101.111 Only the distance of 1000 meters from flood area condition is not met
111.110 Only population threshold condition is not met
111.111 All sextet conditions are met.

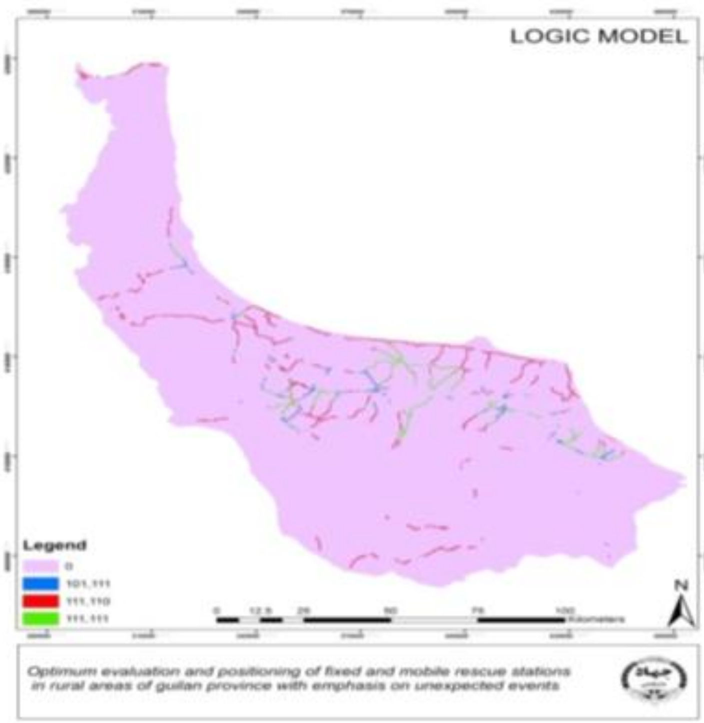

Figure-6. The logic map

4.3. Calculating the Radius of Effective Range of the Stations

In this study risk zoning has been done in rural areas assuming that any unexpected disaster can be covered in Guilan Province' rural areas and can be responded quickly and reasonably, and since some areas are of higher priority due to the potentials and dangerous terrains compared to other areas, and in order to optimal and functional site selection and avoid wasting investment in constructing the infrastructure and facilities, the radius of effective range of each station has been calculated in the triple risk priority (low risk, medium risk and high risk) (Table 1).

Table-1. The range radius based on the type of the risk

S/N	Risk type	Response timespan (min)	Mean speed (km/h)*	Effective range radius (m) **
1	High risk	4-6	40	2700
2	Medium risk	8-10	40	5400
3	Low risk	12-14	40	8000

*From comprehensive 5-year program instructions of relief and rescue organization, 2013.

** According to the formula X = V t, we obtain access radius which is multiplication of speed by time.

Effective range radius was achieved multiplying the minimum response time by average movement speed on main roads of Guilan Province; in this calculation the average speed was considered 40km/h 40. A few points were noticed in selection of the average speed:

1- Speed recommendation of relief and rescue organization
2- Steep slope of some mountain areas
3- Traffic and congestion in the flat areas
4- Traffic regulations

It is clear that the demand center (the accident location) and supply center (relief and rescue station) are not connected directly to each other and since the straight line was used to calculate the radius of the range, it was necessary to local roads, roads fault and road restrictions will also be included in this calculation.

4.4. Stationary Station Site Selection

According to the criteria required for the creation of large-scale stationary stations based on LOGIC Model, eligible villages were selected and their radius of the effective range was determined based on population density considerations and congestion and quality of main roads (Figure 7). Small-scale site selection for each village depends on the factors such as land ownership, compatibility to adjacent land uses including residential, education and agriculture.

However, in site selection for the stationary stations the rural areas surrounding urban areas (which benefit from urban facilities in the event of disastres and are located in the direct influence of the urban area) were eliminated in order to optimize the regional facilities.

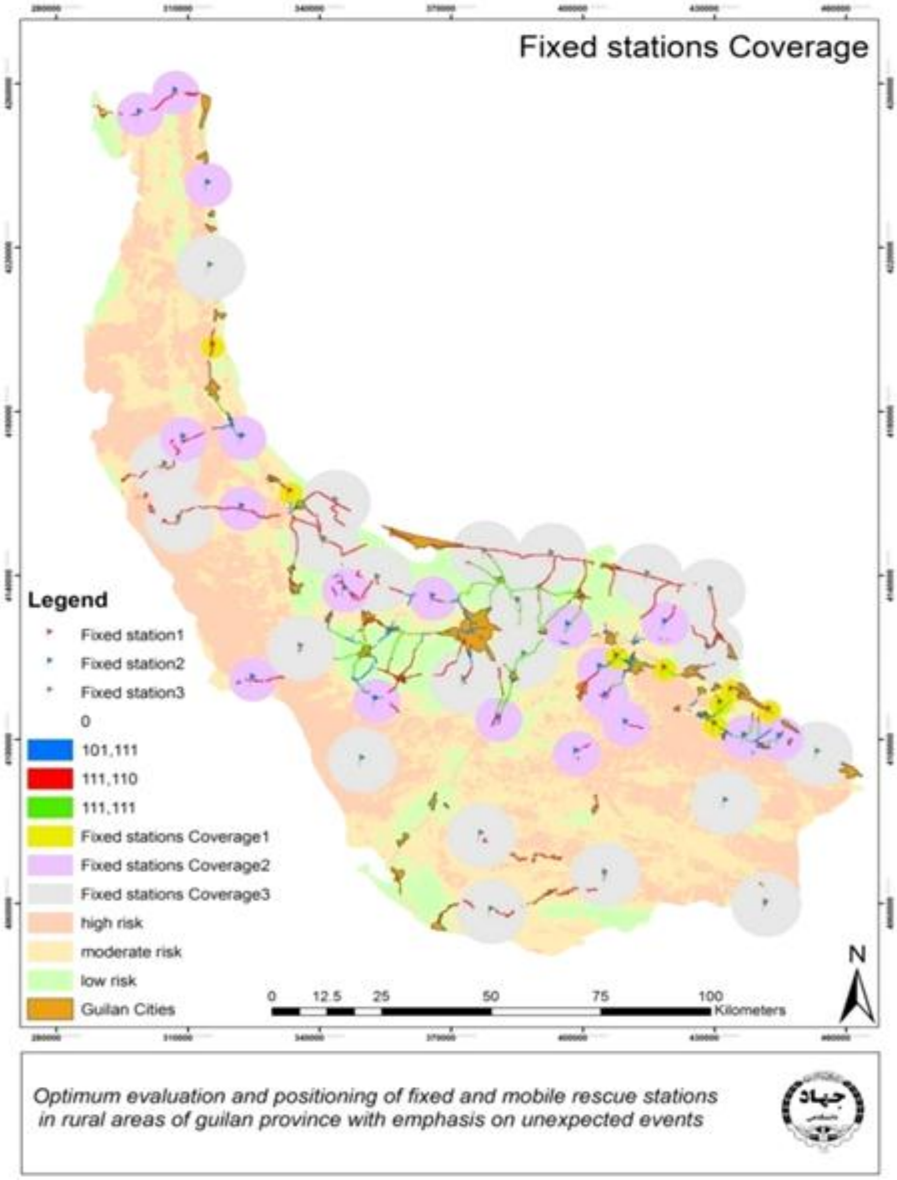

Figure-7. Determining the effective range radius of the stationary relief and rescue stations

4.5. Mobile Stations' Site Selection

A significant parts of the high risk priority ranges were not covered by stationary stations' performance covering because there was not required conditions for establishing the stationary station (such as minimum population threshold, proximity to the main road, appropriate slope, fault logical distance, flood and landslide zones), therefore, in order to cover the caused gaps establishing mobile (temporary) station was predicted in some parts (Figure 8). In site selection for mobile stations the factors such as forest areas coverage, impassable, road accident-prone and proximity to local roads cover were considered.

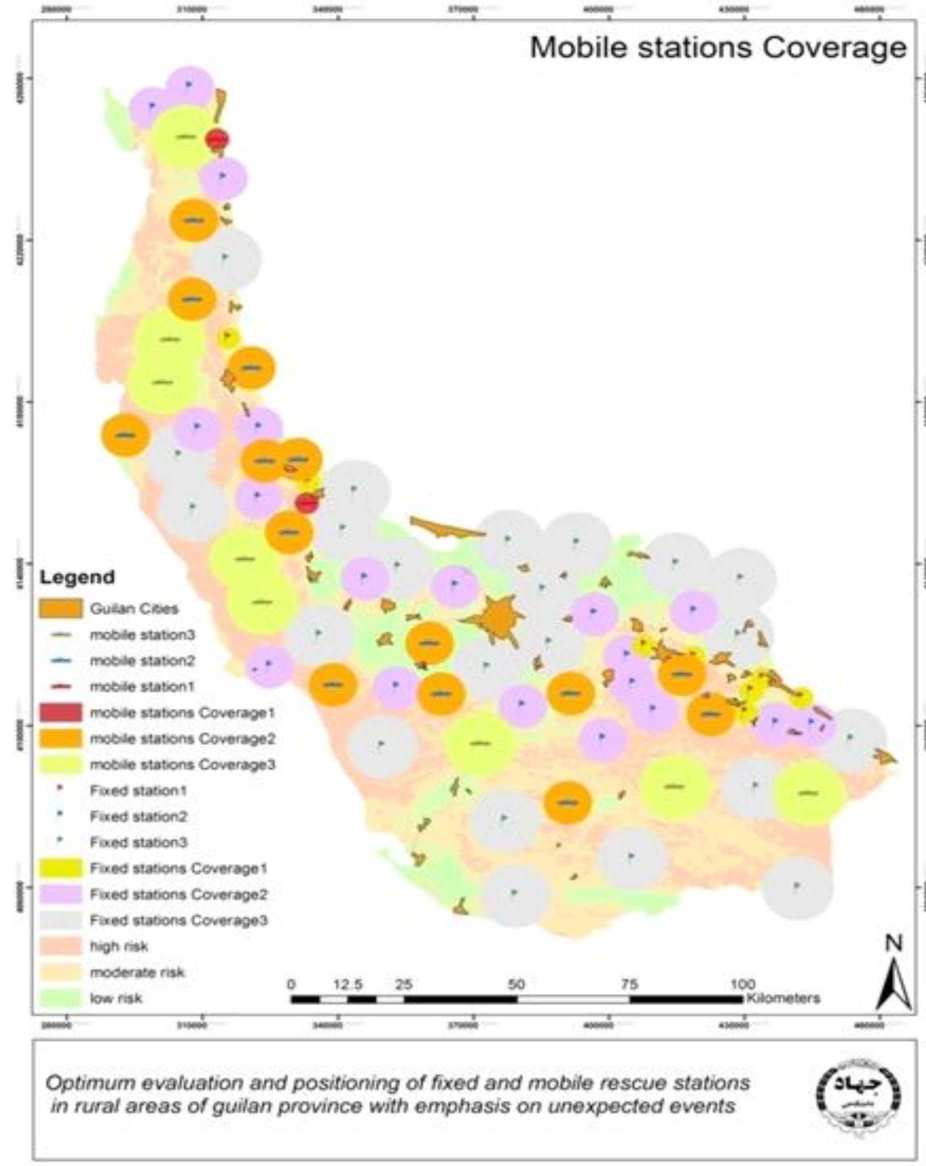

Figure-8. Determining the effective range radius of the mobile (temporary) relief and rescue stations

5. CONCLUSION

The rescue operation is one of the most important part of emergency response which should be began in a short time after the accident occurred and continue with proper speed to be applicable to help more people. This operation is usually time-consuming, boring and dangerous and should be taken during hard working conditions among various and sometimes dangerous problems. Authorities' confusion is inevitable during accident. For this reason, it is necessary to embed required facilities for these cases in certain centers and it might be possible to use them immediately after the crisis.

In this research, because the dispersion of relief and rescue centers was not done optimally and with balanced access particularly in rural areas, then, in villages where risk was predicted higher than other areas the stationary stations was suggested and their effective range radius was determined based on population density and main road activity and quality considerations. A significant proportion of areas with high risk priority were not covered by stationary stations since there were not the conditions required for establishing the stationary stations (such as minimum population threshold, proximity to the main road, proper slope, reasonable distance from the fault, flood zone and landslide zones), therefore, establishing the mobile station (temporary) was predicted in some parts to cover the gap created.

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