

# Using GIS data and satellite images to manage hazard zone in earthquake

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## Abstract

One of the quickest and most efficient methods to study urbanism conditions and determine critical conditions of regions and rate of losses after earthquake is the use of aerial photos. The critical conditions are more severe in cities and mountainous regions due to the steep slope of traffic routes, snow and frosting, and use of aggregates. Using satellite images and GIS maps different regions were classified into three categories. The zoning was based on the route, slope, materials, construction, and population density, as well as the map of facilities, power lines, water and wastewater networks, and gas pipes. The critical conditions for each region were defined numerically and the resulting figures were summed up based on the maps of different zones. However, each figure was assigned to a certain portion of the map. With an increase in the number of maps with different zonings, the critical areas and figures changed.

**Keywords:** *satellite images, GIS maps, hazard zone, earthquake management, Urbanism System.*

## 1. Introduction

Crisis management and prediction of critical conditions at the time of earthquake in mountainous regions highly depends on the climatic, urbanism, and structural conditions and residential buildings of the regions. When the mountainous regions are located on faults, it is necessary to conduct a study before an accident. Studying any region, controlling structures of each building, ground conditions and old urbanism maps are among the factors that should be checked for data collection.

One of the quickest and most efficient methods to study urbanism conditions and determine critical conditions of regions and rate of losses after earthquake is the use of aerial photos. This is performed very conveniently using satellite images these days. Appropriate software (such as GIS) allows us to determine number of residential units, their access conditions and position, and population density. Some countries have estimated losses after earthquake with a high accuracy using 3D images.

Research and activities of Japan and America are among them.

Mekni [1] proposed a novel approach to building informed virtual environment using data which provided by Geographic Information Systems (GIS). The model illustrated automatically standard data from GIS files and navigated information. Informed boundaries are difficult to exploit by the model specially to check a position inside a building. The algorithm built groups of cells which verify a geometric criterion in urban areas. The cells correspond to a node in the topological graph which represented triangles generated the decomposition techniques. Pollino et al. [2] used geospatial methodology for mapping and predicting the vulnerability to seismic hazard. Spatial data and thematic maps had been used for analysis tasks carried out through the GIS system which is devoted to the geodatabase. The model was categorized six different levels of damage for buildings. These six levels used factor of damages for coloring satellite images for disaster management or other impediments in the tools and services. Fatwa Ramdani [3] monitored urban tree heights by using hyperspectral image and LiDAR data. In fact, this research shows ability of google street view and local images in cooperation. This semi-automatics technique gives an efficient framework to mapping cities and trees heights. For the urban modeling, Tasoulas et al [4] developed GIS application for urban forestry management. Indeed, helping managers for providing better living conditions for urban population was the results. The urban satellite maps were detected for trees and polygons of forest and parks. Furthermore, these methods can use for inserting or editing buildings and streets. Building detection and specifying streets boundaries can be the other application of this method.

Othman et al. [5] used GIS and multi-criteria decision making (MCDM) to map the landside hazard zones. Ten landslide inducing parameters were considered by using two different models which had on landslides history.



Predicting landslide, earthquake, flood and other natural hazard are difficult. GIS is a powerful tools which can be applied to predict and manage hazard zone before disaster happening can be another application. Javadian et al. [6] studied environmental dimension of sustainable urban development and suitability analysis of educational land use in Tehran by GIS and analytical hierarchy process. They used analytical function of GIS for overlaying the indicators. The factors in finding suitable location for educational land use are slope of area, chronological and destinations factors, population density and physical properties. Furthermore, these factors are important for hazard zone too and this study used them for investigation area conditions. Many researchers worked to modeling the earthquake effects and building damage by GIS. Irwansyah and Sri [7] developed an integrated system that implements FNN and GIS to evaluate building damage caused by earthquake. Two types of data were used (lithology, topographic zone and the building inventory data in Banda Aceh). Building damage hazard data classes were obtained by the integration of the building inventory and hazard zone. The result showed that over 97% of the building functions were in the low building damage hazard area when earthquake occurs. GIS technology has been developing fast and traditional GIS deals with two-dimensional information. Luo e al. [8] researched of the 3D-GIS for earthquake engineering. The 3D graphics library was produced by open graphics library. The method divided into three steps (terrain modeling, texture reflection and terrain roaming). Mignard and Nicolle [9] presented a research work for reduced the gap of heterogeneity between GIS and building information models. They developed a semantic extension to the urban information modeling. A new approach for managing urban facility defined which including modeling and exploitation of building information and urban elements. Life cycle of the urban environment form design to the recycling of the buildings was managed on the existing platform. The base of this modeling can be use on prospecting and managing earthquake effects on urban elements.

Mang et al. [10] modeled hazard zone in earthquake by using contributing weight model based on GIS. Structures can be retrofit and new construction building according to the level of hazard by developing landslide hazard maps. The model provided the basis for risk management in the landslide zone. The analysis was carried out on several steps (rock type, slope gradient, ratio between weight factors...). The results provided a hazard map and seismic-landslide illustrated which high and low hazard areas specified. Sevtap et al. [11] presented software based on GIS for lifeline reliability in hazard area. Transportation systems and pipelines are lifelines' examples. The combination of techniques from seismic hazard analysis, capacity determination, network reliability and GIS were

used. Seismic hazard map inputted to the flow chart of the developed software. Life line layers were drew by software over the satellite image. Outcomes of this software used for managing risks before and after disasters and improved for design new lifeline networks. Yishao et al. [12] proposed a new method for evaluating urban population carrying capacity based on spatial analysis with GIS carrying capacity focused on four aspects in the urban conditions. Biological population, elements of transportation, urban agglomerations and equilibrium in supply-requirements were the factors of categorizing urban areas. Agricultural production, urban construction, industrial and ecological protection subspace controlled by the GIS maps. Estimating population and carrying capacity happened by controlling these four factors in the GIS map. Fecht et al. [13] simulated a model for urban environmental health analysis. The model involved identifying and quantifying fundamental processes in urban areas. Environmental health studies in urban stings included pedestrian flow, air pollution, population movements and transport network and etc. which base analyzed by GIS. The model gave the user full control over the simulation environment but the results were not universal and directly representative of every real-world setting.

Hassanzadeh et al. [14] modeled earthquake based on GIS by characterizing magnitude, depth, distance, time and date of KARMAN earthquake. The model gives urban planners to design and redevelop. Several modeling tools were developed for hazards' conditions and earthquake effects on building, facility, transportation and lifelines. The data of these models were the different layers of GIS (geological and geotechnical, population and building, cities and villages, roads and topographic). Death and injuries in different ways from an earthquake increases with increases population in large cities such as Tabriz [15]. Risetto and Landun [16] used GIS to measure social integration across urban landscapes. Land shapes before and after hazard is the data base for identifying land scape. Speed, volume and direction of movement were controlled by GIS data. Managing the lifeline and finding access way to reducing damages were the results of GIS monitoring. Ping and Xiabin [17] presented a method to generating the isoseismic lines for reduction earthquake damage evaluation based on GIS. Earthquake parameters and remote sensing were input data of the flowchart method. The earthquake parameters were pointed to the damage and economic evaluation module and scenario earthquake model which they improved final isoseismic lines for emergency response model. The presented method examined on BACHU earthquake (case study).

Of course, these tools have also some limitations in identification. This research studied the critical regions of the old and mountainous cities. The regions have specific conditions. The region is mountainous and often located

close to faults. It encompasses the old texture of the city with high population density and houses with masonry structure. Access routes were not designed for service machineries and residential renewal of the regions is very costly. Of course, satellite images may be very useful for reconstruction and determination of the area of routes and houses after devastation. This section mainly aims to identify critical parts and to find suitable solutions before accidents.

## 2. Traditional System for Urbanism and Layout of Houses

There was not an urban comprehensive system for urbanism and determining house layout, rate of population density, and modern housing methods in a traditional method. In a traditional system, most buildings are built in a masonry manner and their major materials include stones, wood, and mud. Lifetime of the most buildings exceeded 50 years and they were one or two-story buildings. In past, urbanism and layout of houses were determined with respect to ground conditions and its terrain.

### 2.1 Traditional System for Urbanism (Concentric Circles)

This form of layout mostly occurs on hilly areas with one peak. In fact, some part of the urban area where housing was developed was constructed traditionally without layer removing and leveling. In this type of housing, buildings are placed beside each other on a circular route with heights similar to the peak. They then form the main roads with an accessibility that is more suitable. Satellite images show that there are also some routes tracing directly from peak downward. The routes are highly steep with low widths (Fig1).

Studying local areas and visiting specified regions specified that such urban texture, which include older parts of cities were situated in the central and populous areas of cities. Accessibility was convenient, it is possible to use fire and health services to the foothills, and there is no direct path for vehicles to access every house. Studying local areas better specifies condition of local available buildings as far as structure and engineering is concerned. More than 90% of the buildings had stone substructures and they were constructed as masonry structures. Most of them were one-story. They were built as a two-story and stepped building on mountain in some cases (high steep foothill). The land was made of stones and no excavation operation was performed due to the high cost.

### 2.2 Traditional Urbanism (Root-shaped)

This layout mostly occurs by putting buildings together on mountainous hills with a stretched and semi-cylindrical mode. In fact, the hill on which the buildings are situated has more than one peak, a route forms between two peaks, and a shape is created that resembles roots of plants in satellite images. The images of the cities built in mountainous regions showed that most of the old textures of the city have taken on a similar shape. Complex and indirect routes fork a main route in different angles (uneven alleys).

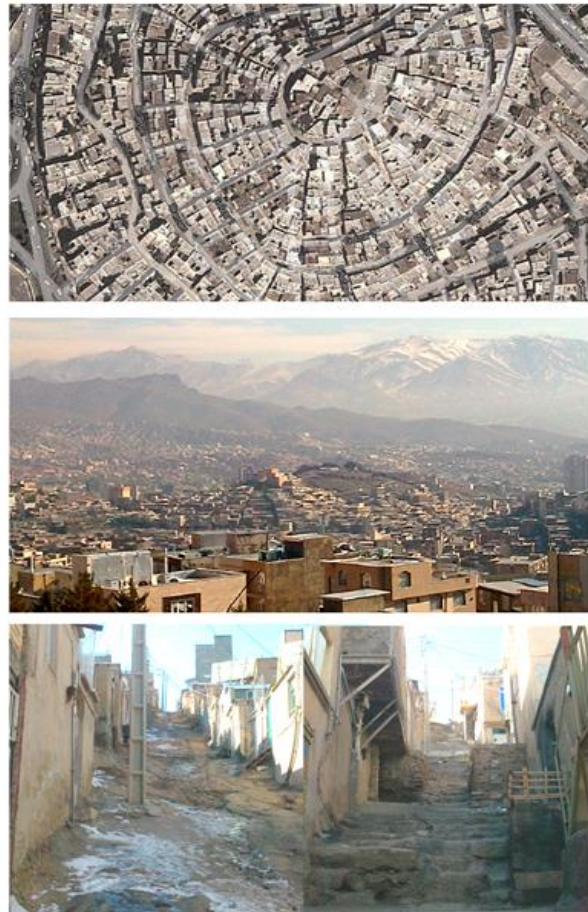


Fig. 1 Concentric circles system

The main route and/or the same middle route are also seen in the valley areas between two mountains and/or the route between two peaks with different heights of a hill (Fig2). Local studies show that the access routes had different slopes in these areas. It was due to non-sphericality of the hill on which the buildings were built. It is also possible to construct two-story buildings with suitable heights in foothill areas. It is more probable to reconstruct and improve in such form of the inter-urban routes. The regions with lower slopes have better access. Of course, texture of these regions is old and more than 60% of the buildings in these regions are of masonry type.

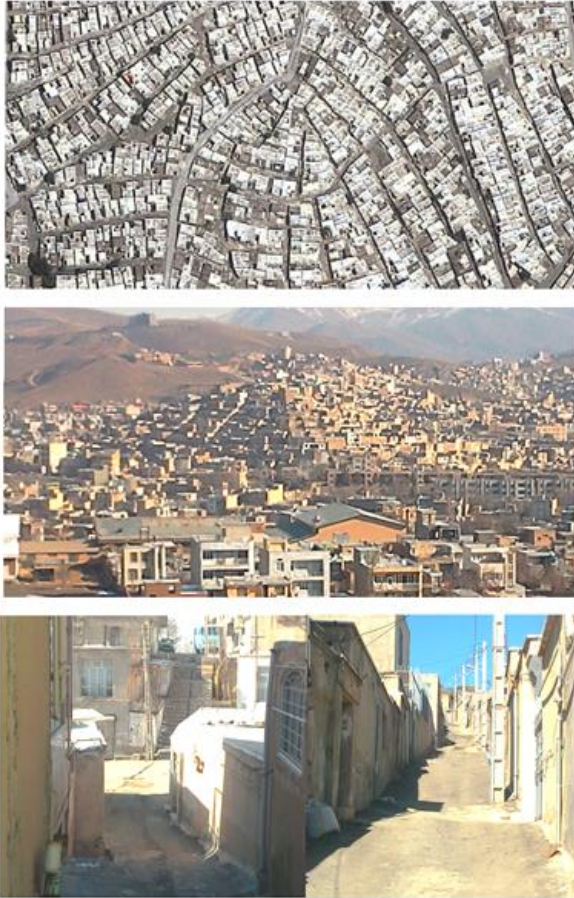


Fig. 2 Root-shaped system

### 2.3 Traditional Urbanism System (Root-shaped and Circular)

Most of the old cities built in foothill regions were extended over some parts of rivers margin and/or throughout flat lands. Some of these regions have small and low-height hills. Due to their rocky structure, they were indestructible and urbanism there is a combination of root and circular forms. The route between hills, which often takes a valley shape, forms the main route and minor routes lead to hill sections located along the main route. Access to the internal parts was simpler than the previous forms, as the regions' slope was lower than the earlier states. Moreover, reconstruction of the regions was cheaper and urban and structural texture of them enjoys further strength (Fig3).

### 2.4 Modern System for Urbanism and House Layout

Some regions are seen in the suburbs where urbanism was practiced by modern methods using satellite images. The

routes have appropriate slope and necessary excavations were performed in these regions. Access routes are often direct with suitable widths.

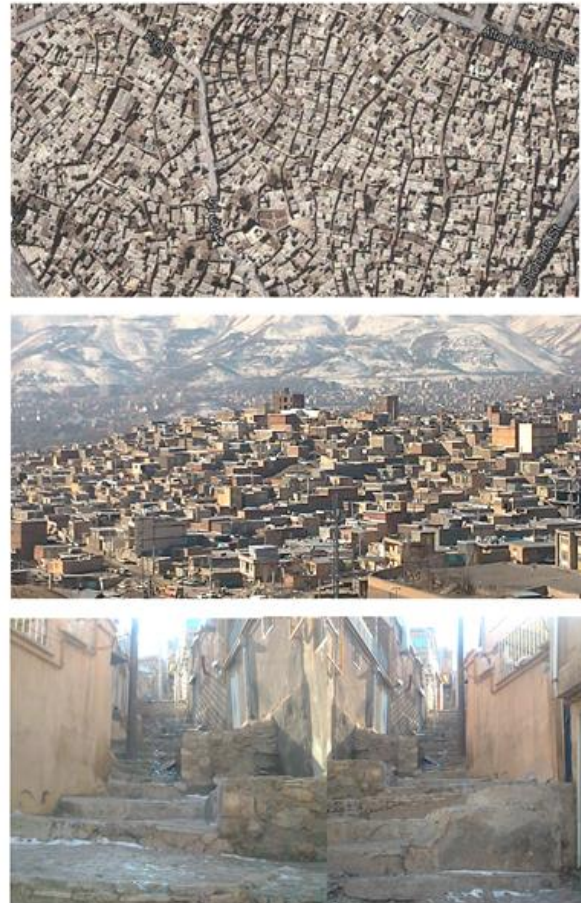


Fig. 3 Interference root-shaped and circular

The constructions have appropriate and modern structures. In fact, the obtained images determine limits of each house and specify rate of population density clearly. In these states of urbanism, most small routes are in a junction form and the junctions with more than four routes connecting to them were divided by creating a square in the center of the junction (Fig4).

### 3. Identification and classification of critical areas using GIS

With regard to urban conditions in mountainous areas and considering the same used materials and principles of urbanism, a classification can be provided for critical areas. In fact, earthquake-prone areas can be identified using the statistical data, the type of building structure, and population distribution and density. Access and outreach methods, determination of the extent of damage, and planning for crisis management, such as earthquakes,

hurricanes, etc. are some of the applications of such classification.

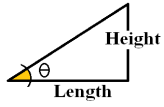





Fig. 4 Modern System

### 3.1 Access route

Access route to disaster area is major factor that can be considered to identify critical areas. These routes are classified depending on the route type, and the slope and width of route compared to the adjacent buildings (Table1).

Table 1: Routes classified

Title	Specification	Size	Shape
(A)	$\theta < 5^\circ$	1	
	$5^\circ < \theta < 15^\circ$	3	
	$15^\circ < \theta < 30^\circ$	5	
	$30^\circ < \theta < 45^\circ$	7	
	$45^\circ < \theta$	9	
(B)	Asphalt	1	
	Rocky road	2	
	Dirt road	3	
(C)	Flat	1	
	Corrugate	2	
	Stair	4	
(L)	Critical	$100 / (A*B*C) < L$	
	Limited	$L < 100 / (A*B*C)$	
Coefficient (T1)		$T1 = L*(A*B*C) / 100$	

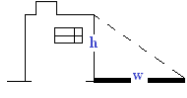
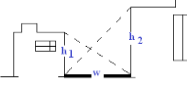
The one route, which is damaged considerably in times of crisis and cannot be operated by vehicles dispatched for providing aid, is the most critical route. The increase in the slope and roughness of the route worsen the conditions. Moreover, the materials used for construction of the route can be aggregates, earth materials, or asphalt. However, the height of buildings and type of structures are also other contributing factors. The classification assumes a state for

the route based on which determines the critical factor of the route.

### 3.2 Building Conditions

The age and conditions of buildings and structures are the main factors for determining the degree of criticality of a region during an earthquake. In fact, structures erected in a region can play a significant role in determining the criticality of the region and calculating the casualties and financial losses. The urban structure and building structures are usually compliant in every region. Old urban development models include masonry buildings as well as handmade stone buildings, which do not meet safety standards from the engineering point of view. In neighborhoods where measures have been taken to correct the existing old texture, the increase in building height has a slight effect on the reduction in the critical factor due to the growth of population density. Table 2 shows different divisions for critical regions based population density, building type and conditions, and the ratio of building height to the route width.

Table 2: Critical regions and building conditions

Title	Specification	Size
(Q)		H / W
		$(H1+H2)/W$
Earthquake Resistant standards by Richter (R)	$R < 3$	7
	$3 < R < 5$	5
	$5 < R < 6$	3
	$6 < R < 7$	2
Population density (D)	<b>D</b>	----
Coefficient (T2)	$T2 = (Q*R*D) / 100$	

### 3.3 Interference of Critical Conditions

In different urban areas, networks of urban facilities, water and wastewater, power and gas can be positioned next to each other. Therefore, with any possible damage to these sectors, the result of the shared damage leads to the development of critical conditions. The exhaustion of the texture of concern and utilization of its maximum capacity can intensify the critical conditions in the region. Another factor that leads to the interference of critical conditions is

the distance of the point of interest from the traffic route. In fact, with an increase in the distance from the street and the main road, access and provision of aid will be more difficult at the time of incident. The distance also includes the distance from the exit door of the building too. Table 3 shows the divisions based on infrastructural facilities and the distance from the main route. The factors for each part are also shown in this figure.

Table 3: Interference of critical conditions

Title	Specification	Size	
infrastructural Facilities	Electricity	F1=1	L <sub>f</sub> =F1+F2+F3+F4
	Gas	F2=1	
	Water pipe	F3=1	
	Sewerage	F4=1	
Critical area	$AC1 = \pi * (L_f / 4)^2$ ; $AC2 = \pi * (L_f / 2)^2$		
Coefficient (T3)	T3 =1 in AC1 ; T3 = 0.5 in AC2		

#### 4. Critical Regions on the GIS Map

GIS maps can be used to identify critical regions and determine the ratio of critical conditions in each region. Tables (1) to (3) present classifications that can be defined numerically and can be summed up. As the critical conditions of a region grow, the figure obtained for that region escalates. The scope of each figure is shown on satellite images. By putting the maps together the number of divisions and their precisions increase (Fig. 5). The figure associated with each table can be summed up with that of another table. Hence, the map resulted from satellite images includes smaller divisions and more numerical variations. By adding each map the data on critical conditions (such as earthquake) comes more into attention. These maps provide for management and planning in times of crisis.

A lot of the data required for the development of tables (1) to (3), which present the classification of critical conditions, can be obtained from GIS maps and satellite images. However, statistical data and local studies are also needed. It is also necessary to use plans of urban development and facilities to complete the investigations.

#### 5. Conclusions

In this research, satellite images and GIS maps of Sanandaj City were used along with additional urban development and facilities information to conduct a case study on the critical conditions of this city. The method and results of this research can be extended to old and mountainous cities with similar structures. In three zoning procedures, conditions of the main routes and roads, structures, buildings and urban facilities were studied based on the relevant probability of failure during earthquake. The aforementioned divisions were shown on

the satellite images of different areas and the criticality figure for each area was obtained based on the corresponding failure probability. Each region had a specific figure and each map was based on each of the zonings. By putting the maps of each specific area together the common effects of critical conditions were identified with more precision. Such maps provide for the management of the affected regions before and after incidence of crisis. Moreover, the method used for dividing facilities, rescuers, and repair and facility technicians and experts are also indicated. In the course of collecting the primary data, GIS maps are used to determine the location of buildings and main routes that can be used to provide aid. They are also used to determine the height of buildings, slope of routes and the type of the urban texture of concern. It is very important to present the results in the form of a single map. A unique color can also be assigned to each number (figure) to be able to determine the more critical regions based on color intensity variations.

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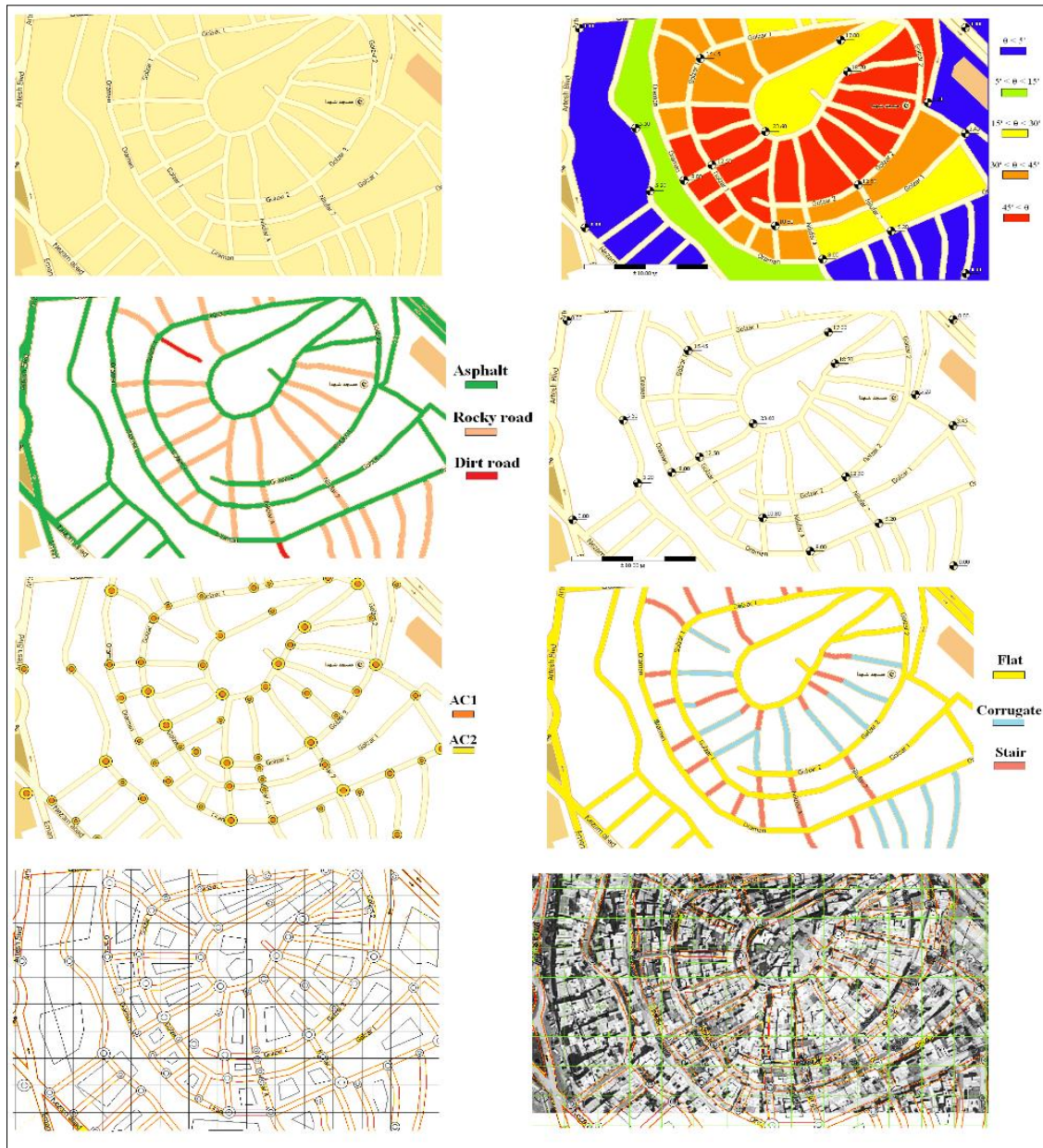


Fig. 5 Critical Regions on the GIS Map