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Urban Risk Assessment Using Geographic Information System: Amritsar City

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ABSTRACT

In the framework of the Academic Thesis on *"Mitigation Measures for urban risk in Amritsar city"* a case study was carried out on urban risk assessment of the city of Amritsar, located in the north-west part of the Punjab. The city with a population of 11, 32,383people (M.C) are located in an area, which is affected by different Natural and Anthropogenic risks. In order to know the level of different types of risk in city, the secondary sources were carried out in the development of a Geographic Information System (GIS) –based system for risk assessment and management.

The work was made using satellite imagery as basis, on which all buildings, land parcels and roads, within the city and its direct surroundings were digitized, resulting in a digital parcel map, for which a number of hazard and vulnerability attributes were collected in the field. Based on secondary sources information a GIS database was generated, which was used to generate different risk zone maps for different types of risk such as Liquefied Petroleum Gas (LPG)Godown and Petrol Pumps risk. For determining the hazard a modified version of the Radius approach was used and the anthropogenic hazard was determined based on the secondary information inventory and a number of factor maps, using a statistical approach.

The present paper emphasized on the role of GIS in the determination of urban risk in the city. The resulting database can be a tool which determines the level of urban risk and effect of certain mitigation measures, for which ananalysis can be carried out. The database also serves as an important tool in the disaster preparedness phase of disaster management at the municipal level.

The present work describes the structure and characteristics of the Geographic Information System (GIS) developed for the urban risk study of the city of Amritsar, identifying the stages in which the use of this tool proved to be very beneficial for adopting informed decisions throughout the execution of the work. It also gives thedetail about the spatial analysis overlay regarding the risk assessment in the city which is based on the population distribution or density from which the affected area is determined and gives recommendations of it over a particular risk factor.

KEYWORDS: Urban risk assessment, Geographic Information System,Vulnerability, Amount of elements at risk.

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INTRODUCTION

The increased vulnerability of many urban areas, especially in developing countries is a major reason of concern[1]. Therefore emphasis should be given to the reduction of vulnerability in urban areas, which requires an analysis of potential losses in order to make recommendations for prevention, preparedness and response[2]. The survey of the expected damages for a potential disaster essentially consists of risk evaluation. Risk is defined as the expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to particular hazard for a given area and reference period. Based on mathematical calculations risk is the product of hazard, vulnerability and cost of the elements at risk[3].

Most of the data required for disaster management has a spatial component, and also changes over time. Therefore the use of Remote Sensing and Geographic Information Systems has become essential in urban disaster management.

The objectives of Present study is to know the role of GIS software with basic information required for disaster management at the Municipal level, through the development of a GIS database, containing the following types of information:

a. Hazard maps indicating the probability of occurrence of potentially damaging phenomena within a given time period. This was done by generating hazard maps for LPG Godowns, Petrol Pumps, earthquakes, flooding and landslides for different return periods.
b. A database of elements at risk, concentrating on the buildings and the infrastructure in the city.
c. Analysis of vulnerability of the elements at risk, taking into account the intensities of events as indicated in the hazard maps, combined with information from damage curves;
d. Loss estimation of the elements at risk, concentrating on the buildings and their contents;
e. Urban risk assessment.

The figure 1 shows the Schematic overview of the risk assessment procedure using GIS. The result of this study is based on a great set of variables that provide a comprehensive view of the urban risk, such as the damage distribution of buildings and dwellings of different typologies. In this, firstly data availability is must for the software which works on the process of the software and gives the intermediate result. The result shows the output regarding the level of work.

OBJECTIVES

The objective of this article is to show how a GIS can help to estimate and understand an urban risk study, in this case of the city of Amritsar. The objective of using a GIS in the study is to

facilitate the interpretation of the calculation variables and project results. Moreover, it is actively used as a calculation tool in some phases of the study, such as the geographical assignment of vulnerability. It also measures the urban risk regarding LPG Godowns and Petrol Pumps and its recommendations.

THE RISK ASSESSMENT THROUGH GIS TECHNIQUES

The development of a risk study is a multidisciplinary task that counts on the participation of urban planner, engineers and architects. Hence, it requires the integration of a large set of heterogeneous information: data of different nature with varying size and formats. The GIS plays a fundamental role as a common storage space that allows the consistent homogenization of all these data and spatial distribution of it. Hence, the use of a GIS facilitates the joint analysis of all the involved and guides the decisions adopted in the execution of this study. Additionally, the GIS facilities for the cartographic representation of the variables and results of the study are especially efficient for the monitoring and interpretation of all the stages of the risk analysis, particularly for end users such as emergency managers, etc[4].

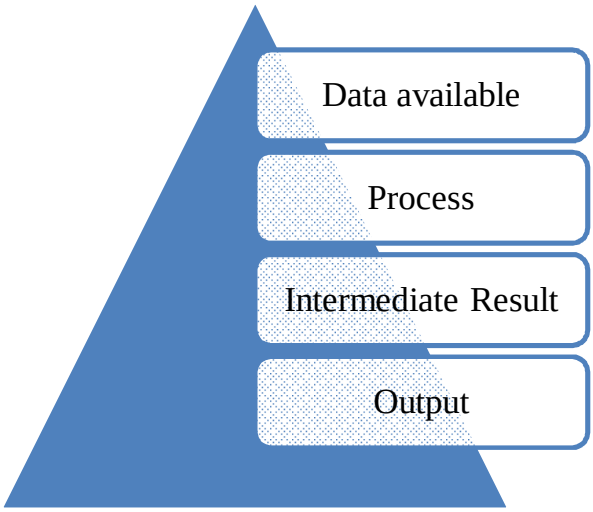

Figure 1: Schematic overview of the risk assessment procedure using GIS

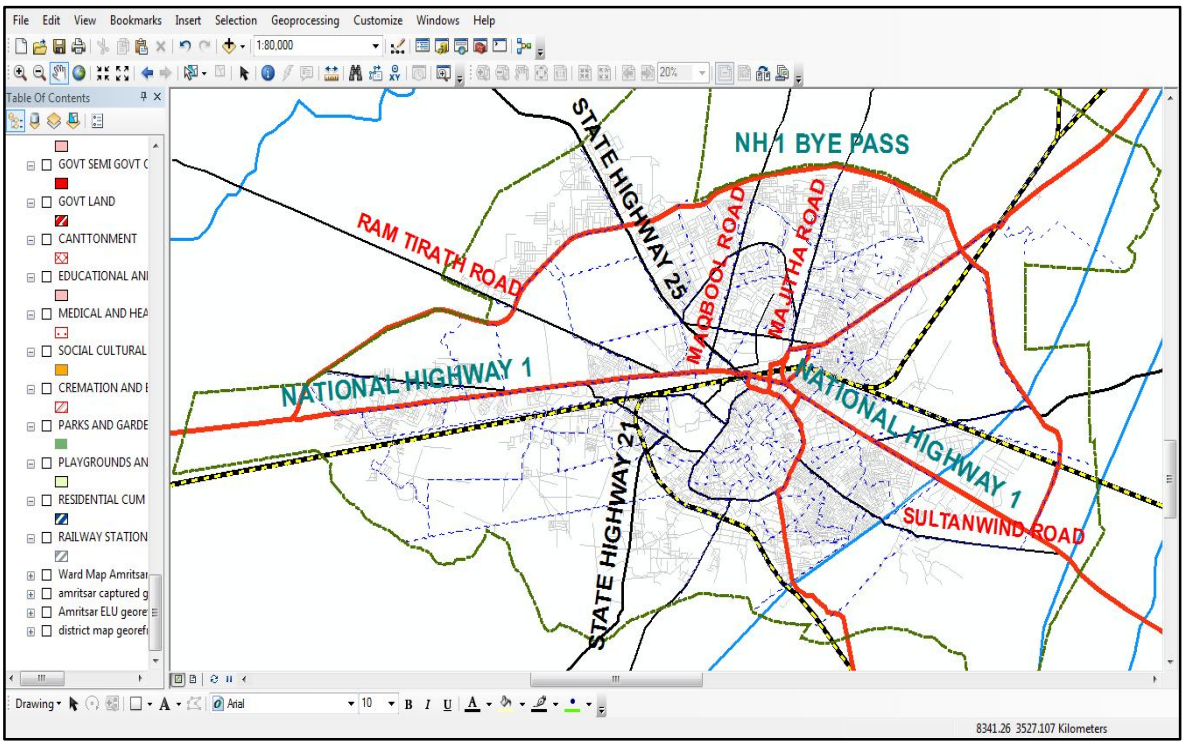

Figure 2: An Arc GIS visualizer showing the working units

GIS characteristics and Working tool

The main characteristics of the GIS used in the development of the urban risk analysis of Amritsar are described in this section. The software used for the creation of the Geographic Information System was ArcGIS v9.3 since it allows carrying out all the processes of the Geographic Information System within the same space, from the capture, data editing and analysis of variables.

Working unit

The working unit is the geographical entity in which the calculations will be computed, hereby controlling the geographical resolution of the study. The definition of the working unit depends strongly on two factors: the geographical unit in which the original data are expressed and the scale of the study. In the present urban-scale urban risk study, a squared grid was considered appropriate to cover the entire city of Amritsar (Fig. 2), totaling an amount of different equal cells or working units. This size of the working unit is compatible with the size in which the original data are provided – small enough to detect lateral variations of the outputs and big enough to save computation time.

Role of the GIS in the phases of the risk assessment study

An urban risk study comprises several phases: definition of the action, assessment of vulnerability distribution, expected damage estimation and calculation of human and economic losses. The GIS plays a role as a useful tool in this scheme, as shown in the following section.

THE STUDY AREA

The city of Amritsar lies at 31^0 07' and 32^0 03' North latitude and 74^0 29' and 75^0 23' East longitude on the Grand Trunk Road, only 27 Kilometers from the Indo-Pak International Border. It lies in a depression in the middle of the Bari Doab, occupying 139 sq. Kilometers with a population of 11,32,383 persons (Census, 2011). It had been served by a Class I Municipality since 1868, but converted into Municipal Corporation in 1977. It is also a district headquarter of the Punjab state and second largest city in Punjab, after Ludhiana[5].

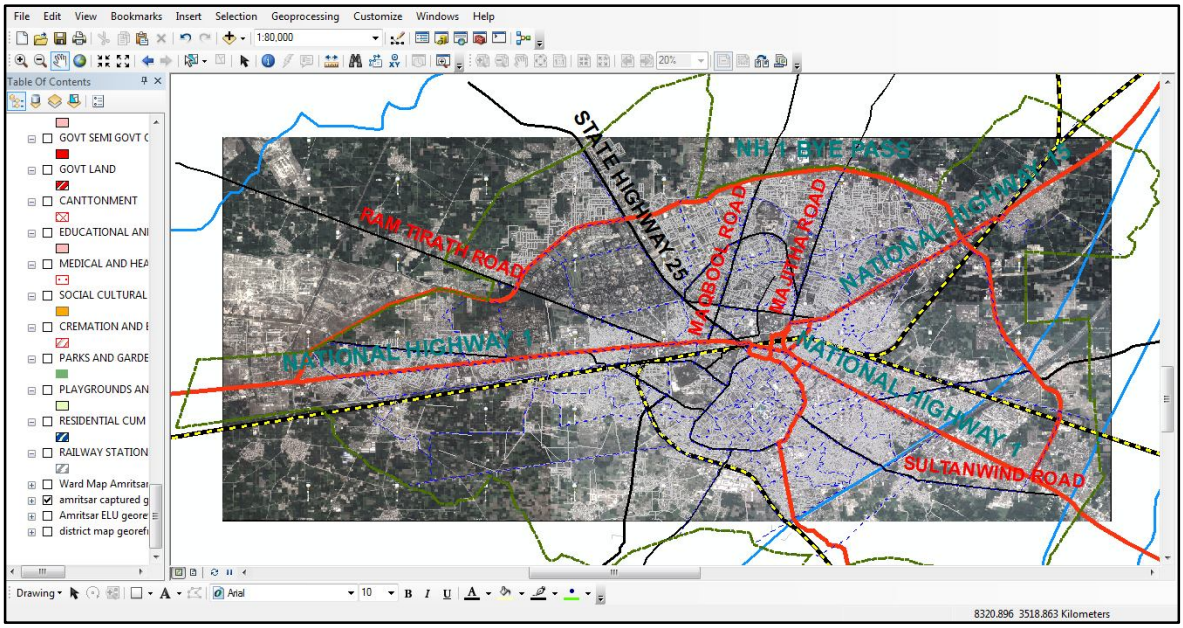

Figure 3: An Arc GIS showing the Amritsar City as Satellite Imagery

The city is affected by different Natural and Anthropogenic risks. In order to know the level of different types of risk in city, the secondary sources were carried out in the development of a GIS –based system for risk assessment and management.

Natural Risks	Anthropogenic Risks	
• Earthquake- Seismic Zone • Environment- Industrial pollution • Air and water pollution.	• Urban Fire • LPG Stores • Slum Risk • Unsafe Buildings	• Landfill Risk • Petrol Pumps • Water Logging areas • High tension line areas

Mapping building units using screen digitizing

For the calculation of risk there are using the basic formula:

Risk = Hazard * Vulnerability * Amount of elements at risk

In this part of the exercise we will concentrate first on the last part of the formula: getting information on the elements at risk. See below

Elements at risk may be listed as follows

- **Physical**
  - Infrastructure
    - ✓ Roads
    - ✓ Railway
    - ✓ Bridges
    - ✓ Harbour
    - ✓ Airport
  - Critical Facilities
    - ✓ Emergency Shelter
    - ✓ Schools
    - ✓ Hospitals and Nursing Homes
    - ✓ Fire Brigades
    - ✓ Police
    - ✓ Utilities
      - Power Supply
      - Water Supply
    - ✓ Transport
    - ✓ Communication
    - ✓ Government Services
- **Economic**
  - Business and Trade Activities
  - Access to Work
  - Impact on Work Force
  - Opportunity Cost
- **Societal**
  - Vulnerable Age Categories
  - Low Income Group People
  - Gender
- **Environmental**
  - Loss of Biodiversity
  - Damaged Landscape
  - Physical and Chemical Changes in the Surroundings

In this case study, its only take into account two types of elements at risk: buildings and population. Building information could be obtained from existing cadastral databases, and population data from census database. However, in many cities in developing countries such data are not available, or are restricted, or are not in a digital format. When these data are not available they should be collected in to digital format. However, the generation of a building database in GIS is a very time-consuming procedure. When high-resolution data sets are available, such as in this

exercise, it may use them for interpretation, and the basic mapping units can be digitized on the screen[6].

Risk assessment could be done on a building-by-building level. However, in most cases this level of information is in too detailed, thus it is very difficult and time consuming to evaluate vulnerability of individual buildings. Therefore, it bases the risk study on similar land use pattern than building level. In exercise it is concentrate on the mapping of the basic units for the urban risk assessment. There are two files in the dataset that are most important for that:

- *Unit Boundaries:* This contains the boundary lines of the mapping units that will be used as basic units for the elements at risk. It has been made through screen digitizing on the high-resolution image.
- *Mapping Units:* These polygons represent the mapping units used for elements at risk mapping, but now as polygons. Each of the mapping units has a unique identifier, so that in the accompanying table information can be stored for each unit. The units may be individual large building or plots with a specific land use, although they are mostly grouping a number of buildings.

The present study is focusing on the two risks such as Liquefied Petroleum Gas (LPG) store and Petrol Pumps risk. These risks are based on the radius parameter of the location which shows the affected area. This affected area is shown by the different commands in the Arc GIS tool as proximity analysis such as Buffer command. Therefore, Liquefied Petroleum Gas (LPG) store and Petrol Pumps risk aspects is selected to determine the spatial analysis overlay regarding the risk assessment in the city which is based on the population distribution or density from which the affected area is determined and gives recommendations of it over a particular risk factor. Therefore, it may be the good factors to measure the scale of vulnerability in the particular area because it is directly related with population distribution or spatial parameters.

Liquefied Petroleum Gas (LPG) Stores

The Explosive Act 1884 under section (18) has mentioned the rule for gas cylinder store or godown. According to this rule the location of LPG godownshould not in the residential area andshould be located within 15 Km of city limit. There should be minimum 30 Meter buffer of no development should be kept around the LPG godown according to the quantity of the storage of gas cylinder. At present, There is six LPG godown is situated in residential areas of Amritsar which is not according to the rule. The gas godown of Khandwala, WadaliRoad, Rani ka Bagh, Police Line, ChhabalRoad and LohgarhGate are having residential area within 30 meter buffer this is a threat to human habitation as shown in figure 4.

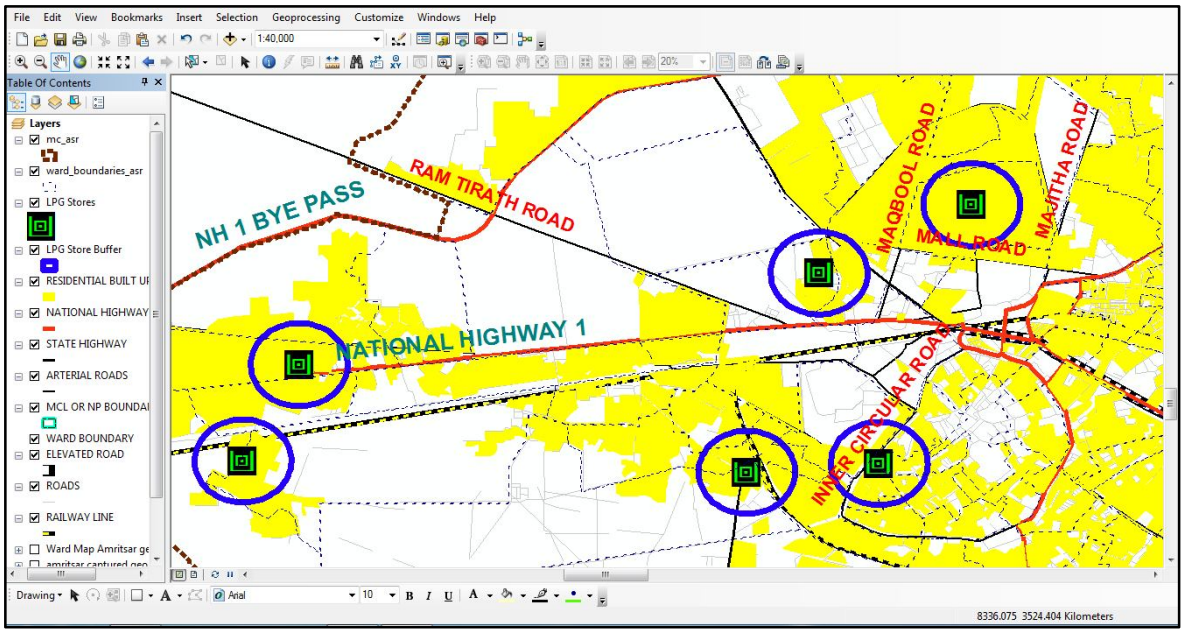

Figure 4: An Arc GIS showing buffer along the LPG stores

The 30 m buffer is encroaching by unauthorized development and the total population living in the threat zone is near about 30,000 persons. The figure 5 shows that the percentage of effected population is 2.5 percent which are affected by it.

For this there should be recommendations which may the measure of risk factor such as according to Gas cylinder rule that LPG store are not allow in the residential area. But in case of Amritsar all the LPG store is located within the residential area. According to the rule there is buffer of no development 30 meter around the LPG store but in Amritsar there are development around the LPG stores in the range of 30 meter. So, all the LPG store should be reset at the open spaces where as is possible and there should be 30 meter buffer around the LPG store and no development in this 30 meter area is allow.

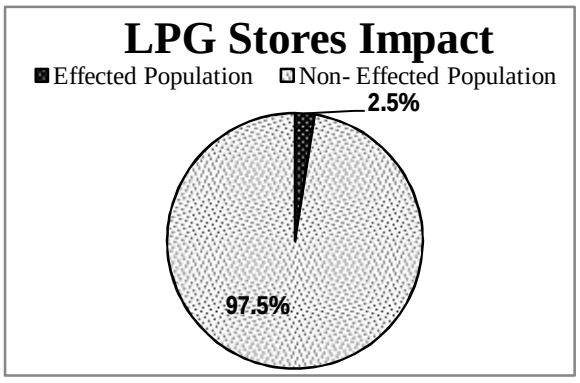

Figure 5: LPG Stores Impact

Therefore, there is proposal or relocation of the LPG store from the residential area to Non-Residential area. These are proposed on the basis of norms and standards with providing the appropriate buffer of no development along the LPG stores as shown in figure 8.

Petrol Pumps

In the Amritsar city there are 45 petrol pumps. According standards there is one petrol pump for the 150 hectare of gross residential area and one petrol pumps for the 40 hectare of gross industrial area but in Amritsar number of petrol pumps are more than standards parameters. These petrol pumps not under the 50-100 m buffer (category I) according to guidelines which is a threat to human habitation. The maximum threat around 600 meter (category II) from the point of source. These petrol filling stations is not fully according to the guidelines. Risk at the petrol pumps:

i. Fire hazard due to tanker failure, collision.
ii. Fire at the time of decantation of oil due to spillage or leakage from the pipe.
iii. Fire at the storage tank lid at the time of water content checking
iv. Fire at the filling points due to leakage or spillage from the worn and torn out pipes.
v. Mixing of oil vapor and air in the storage underground tank.
vi. Possible explosion from the above mention fires.

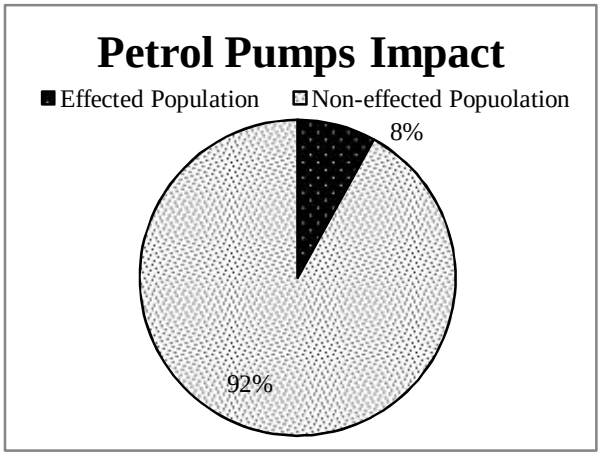

Figure 6: Petrol Pumps Impact

These petrol pumps not under the 50-100 m buffer according to guidelines which is a threat to human habitation. The 50-100 m buffer is encroaching by unauthorized development and the total population living in the threat zone is near about 90,000 persons. The figure 6 indicates that the percentage of effected population is 8% which are affected by it. The total built up area under the threat of possible explosion of fire from petrol filling station is 9.3 percent of the city as shown in figure 7. Therefore, the commercial and residential buildings and installations within the 600 meter should be cautions and well planned to avoid any untoward incident in the time of eventuality. There are 28 petrol pumps under high level risk and 17 are low level risk petrol pumps as shown in figure 7.

There are some recommendation which overcome the risk related to this factor such as according to planning criteria for the petrol filling station the petrol pumps are not allow in the residential area. But in case of Amritsar the most of petrol pumps is located within the residential area. According to rule there is buffer of 50-100 meter around the petrol pumps but in Amritsar there is no buffer of development around the petrol filling station. So, the commercial and residential buildings and installations within the 600 meter should be cautions and well planned to avoid any

untoward incident in the time of eventuality. All the unplanned development around the petrol pumps in the 600 m zone should be removed according to rules and regulations.

Therefore, the petrol pumps should be managed according to spatial parameters and mitigation measures as shown in figure 8. There should be provided buffer zone. These all recommendations will help to reduce the urban risk in Amritsar city with the help of GIS risk assessment as planning and risk management process[7].

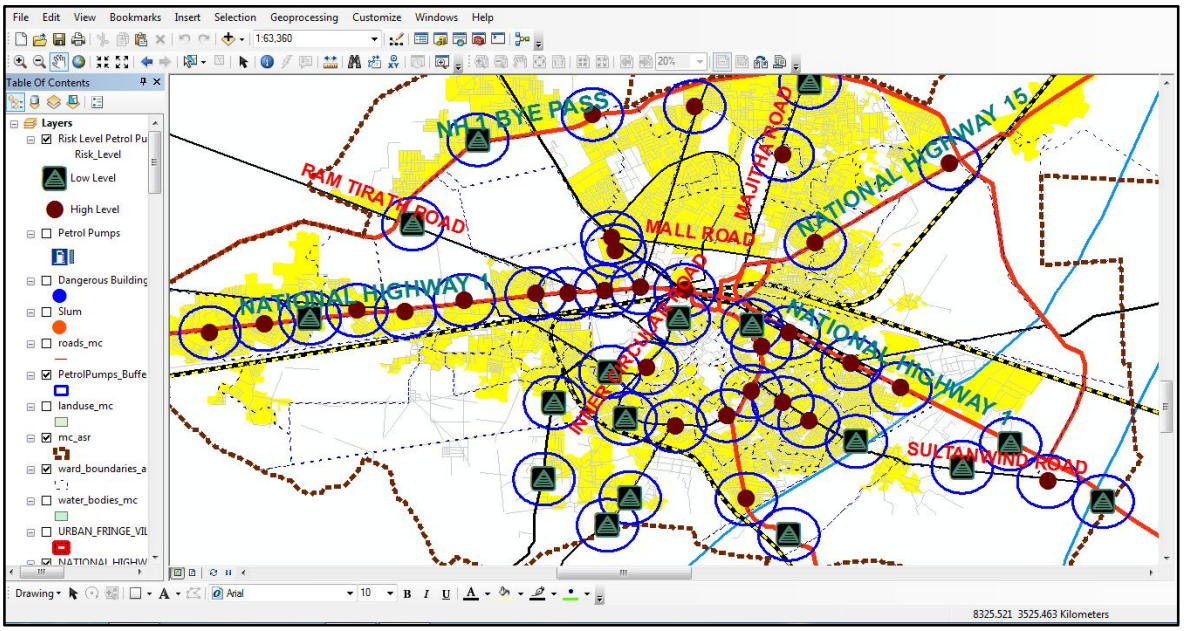

Figure 7: An Arc GIS showing buffer along the Petrol Pumps

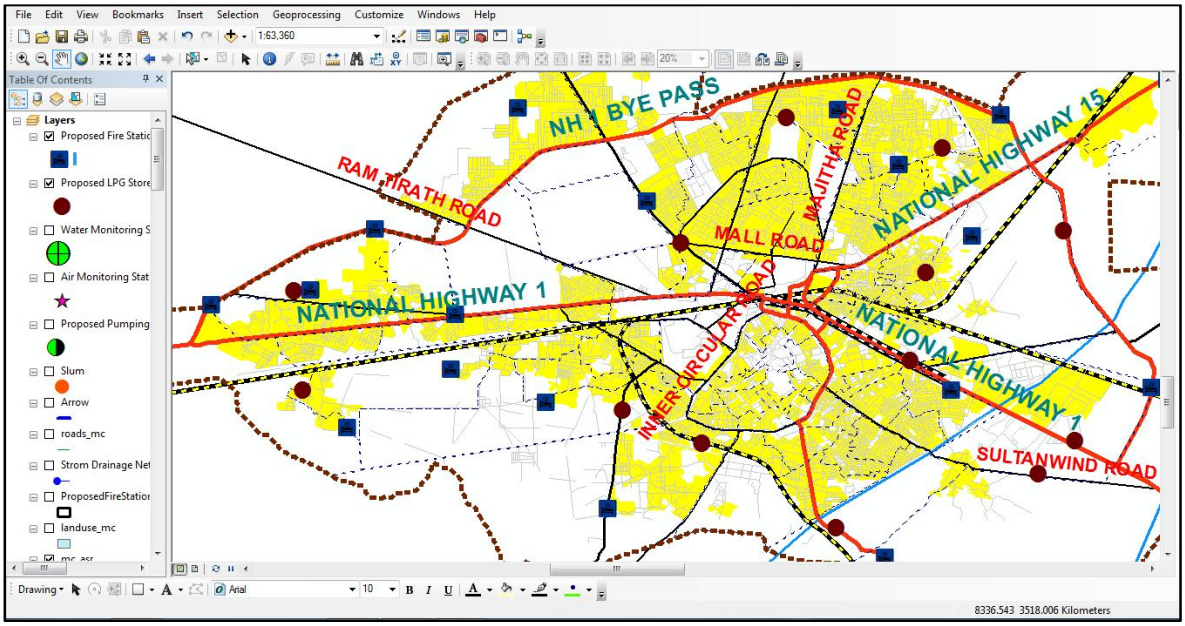

Figure 8: An Arc GIS showing Proposals for different Risk aspects

CONCLUSIONS

The GIS has remarkably contributed to the realization of the objectives of this study. In this respect, three main issues has been highlighted: Firstly, the capability of the GIS in assisting data compilation, organization in working units, georeferencing and display in a common environment; Secondly, the usefulness for making spatial analysis of input variables and results, which help to understand the relations between inputs and outputs of the study; Thirdly, the usefulness of developing a GIS-based web application which would facilitate the analysis of results by different end users, not necessarily specialized in risk calculations.

More specifically, other aspects in which the GIS led to a more insightful analysis includedas firstly, in decision making, when defining the risk scenarios associated with the controlling such as LPG stores, petrol pumps earthquakes and alike and the framework of the influence area. Secondly, using the spatial data into the database of the project and assigning vulnerability. Thirdly, in the integration of all the inputs of the study for the estimation of risk, such as hazard results, geotechnical characteristics of the ground, the vulnerability and the exposure of working units. Fourthly, in the interpretation of the studied variables, enabling the understanding of the influence and spatial distribution of each variable through the whole calculation process. Fifthly, in the analysis of the final results. Finally, in the dissemination of the results through a map visualiser, enabling anybody interested in the study to see the results remotely, without the need to rely on or know how to handle a specific GIS program me.

Therefore, GIS is helpful tool in urban planning for risk assessment as risk management process. It also makes the decision on the basis of spatial parameters which is provide the mitigation measures for its recommendations.

ACKNOWLEDGEMENTS

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