DEVELOPING A TRANSPORTATION PLAN FOR EVACUATION OF BUILDUP AREAS IN CASE OF EARTHQUAKE "CASE STUDY"

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ABSTRACT:

The Palestinian territories in general and more specifically the West Bank area are considered an earthquake risk zone. Palestinian urban areas are considered highly dense populated areas with limited roadway network to service the community. In addition, the Palestinian areas lack the legislative laws to enforce a building code that would reduce the extent of damage and number of casualties.

One of the basic issues of concern is the availability of an evacuation plan of injured and homeless people in case of an earthquake, in such conditions that would close part or most of the roadway network. The objective of this research work is to set the bases and methodology for an evacuation plan and provide a mechanism for emergency vehicles to maneuver within the devastated area. Nablus city was considered as a case study for developing such an evacuation plan. The GIS was used as a tool to create a database for the capacity of the roadway network in addition to the basic scenarios of road closures for different levels of earthquakes. Analysis of this database gave the different scenarios of evacuation which include access plans for each geographical area within the urban setting, recommended health and other emergency services centers for each zone, proposed storage buildings for emergency equipments, and work plans for emergency teams.

KEYWORDS: Earthquake, evacuation plan, emergency services, transportation network, databases, GIS.

1. INTRODUCTION

Highway network plays a crucial role in the development and economic well being of the urban areas. Several studies focused on the importance of developing highway networks considering economic, social, political, and military aspects to reflect the level of development in the urban setting. Planning the expansion and development of roadway network considers mainly the population growth and physical setting with minor consideration for incident management. Any disruption of the operation on the network at one location will create a domino effect on the system as a whole. Incident management studies lately are considered one of the elements that are considered in the design and planning process.

Several areas of the world are located on critical seismic zones requiring special consideration for rescue management plans. Emergency relief work depends mainly on the mobility and accessibility of emergency vehicles to devastated sites within the urban area. Developments of scenarios of emergency routes based on network characteristics and setting is an essential part of developing access to devastated areas and emergency relief locations like hospitals, medical centers, shelters, warehouses, and fire stations.

2. STUDY OBJECTIVES

The objective of this study is to develop a traffic management and evacuation plans to reduce the destruction in the devastated areas as a result of an earthquake. Those plans are developed based on the current earthquake maps and scenarios for the designated urban area and existing roadway network considering both static and dynamic characteristics. The proposed plan should meet the requirements of moving people under panic conditions and more importantly serve movement of emergency vehicles to key relief centers. This will make an assessment of the readiness of the network to handle such a condition as well as preparedness of the different departments and agencies of concern to carry their tasks. A case study will be considered for developing the outcomes of the proposed plan. The city of Nablus Palestine will be considered for that purpose.

3. LITERATURE REVIEW

Experience showed that the effect of earthquake damage to the roadway network goes way beyond life safety risks and direct and direct cost. The real problem are created by the extent of damage caused by lack of mobility and accessibility to devastated areas which will affect post earthquake emergency response causing further loss of life and disruption of traffic within the urban network creating more panic and kayos. This will initiate a domino effect with regard to the economic and social impact making the recovery even more difficult.

Readiness programs as it relates to urban roadway network are vital in preparing the system to consider the shape and configuration of the networks for post-earthquake condition of rerouting traffic to operate in a reasonable manner. This will require a thorough analysis of the capacity of the different components of the network and the potential level of service (LOS) right after the earthquake and during the recovery period. This analysis will help in identifying the critical components of the existing network and in turn help in the short and long term planning in the development of the urban network.

Werner, S. (2003) developed a risk-based methodology for assessing the seismic performance of highway systems by which it utilizes models of seismology and geology engineering (structural, geotechnical, and transportation), repair, and construction, system analysis, and economics to estimate system-wide direct losses and indirect losses due to reduced traffic flows and increase travel time caused by earthquake damage to the highway system. Results from this methodology also show how this damage can affect access to facilities critical to emergency response and recovery (1).

An example of recent experience in disaster management which raises the importance of roadway network management is the earthquake of 1999 of Marmora Region of Turkey in which major loss of life and property were inflected creating an even bigger threat for neighboring city of Istanbul with population exceeding ten million. The city is preparing for the urban disaster through a new urban mitigation project. As part of an overall emergency management model, an urban disaster mitigation model is prepared to focus on response phase of emergency management categories which include coordination, incident command system, proper resources management and training. This model calls for the coordination of all concerned parties amongst which is the directory of Road maintenance (2).

Road networks are the lifelines for community and are essential for the economic and social well being. Earthquake and other natural hazard events cause extensive damage to transportation network leading to significant repair cost, emergency access constraints and distribution to road users and the community. Risk management approaches, such as in California for example, have primarily considered one element of the roadway network in their risk management actions (Bridge system in the case of California). They have placed considerable effort on the seismic screening of bridges, prioritization of mitigation and implementation of retrofit works to improve the resistance of bridges to earthquakes. They do not appear to have considered the road networks as a whole. While recent US research has considered the effect on road networks, they have primarily considered only bridges in the network (3).

Many urban areas worldwide developed management emergency programs for evacuation, damage assessments, incident management plans, etc (4, 5, 6, 7). A comprehensive plan for disaster management should be considered on organizational and preparedness levels as well as for the short and long term planning of roadway network configuration and characteristics.

4. METHODOLOGY

The methodology can be carried out for several earthquake scenarios and roadway networks. Characteristics of the roadway play an important role in the output. Figure 1 gives a schematic diagram of the preparation of the evacuation plan of typical urban setting.

4.1 Earthquake Module

A database is build for the urban setting considering the history of previous earthquakes and the consequences on the roadway network, infrastructure, and building structures. In addition, it includes updates of the current critical elements of the roadway network like bridges, roads with critical embankment structures, and other static characteristics of the network, more importantly roadway width, length, grade, …etc. In this module, a thorough evaluation was done for the critical structures adjacent to arterial and major collector roads followed by the evaluation of the schemes of collapse of those structures relative to roadway width to determine the status of accessibility of the road itself. Two cases were considered, total collapse causing full closure and partial collapse causing partial closure of the road. In the second case there will be some accessibility for emergency vehicles but drastic reduction in mobility. All data above are built in the Geographic Information System (GIS) database having the potential to get the following outcomes:

A. Designate all road closures as a result of building or embankment or retaining wall collapse and /or closure caused by falling rocks.
B. Designation of roadway closure as a result of broken sewage or water line.
C. Designate the type of closure condition as full or partial.
D. Display the network closure condition for several scenarios of earthquake severity.

4.2 Emergency Centers Module

In this module a database is created for all key emergency services like fire departments, hospitals, civil defense centers, clinics, emergency warehouses, etc. Those centers and their locations are considered critical for emergency relief for regional pockets isolate as a result of an earthquake. The data are built to a GIS database to analyze the different regional pockets isolated and link it to the emergency services within the pocket itself. It will serve as a viable outcome for planning to situate the basic service as well as emergency warehouses and emergency relief centers. This database is created with aid of local inventory of those places, aerial photographs, and maps to designate the location on the GIS database.

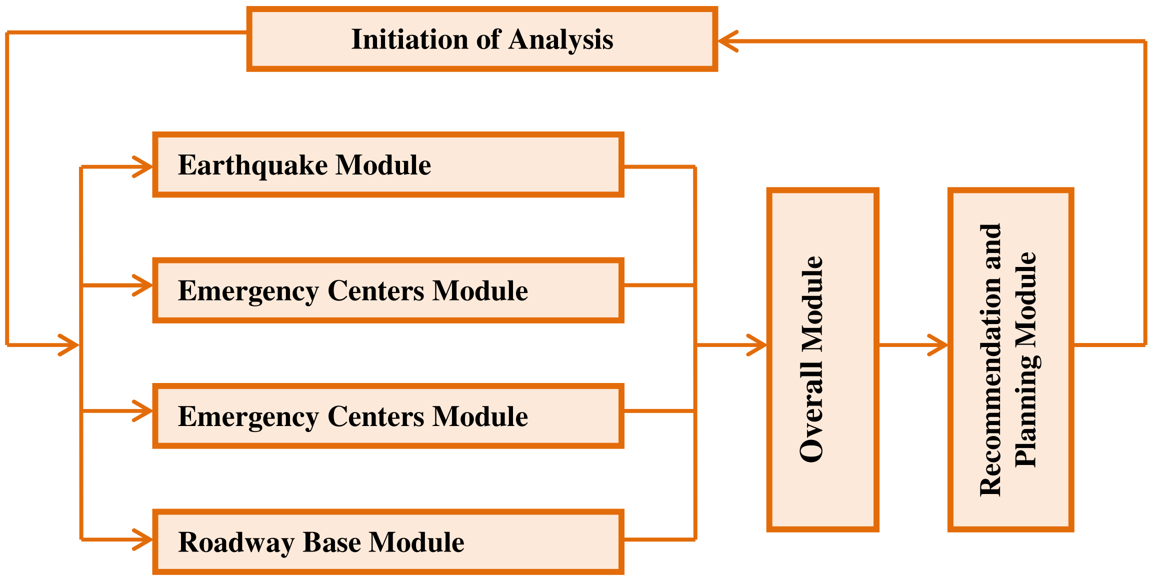

Figure 1: Schematic diagram of the preparation of the evacuation plan of typical urban setting.

In this module a database is built for the static and dynamic characteristics of the roadway network. The database of the network is designated based on a grid pattern having links and nodes by which links represent road sections and nodes represent roadway intersection. Characteristics are built in such as link width, length, average daily traffic (ADT), average speed, level of service (LOS), etc. The purpose of this database is to analyze the conditions of mobility on the network as a result of a closure initiated from the outcomes of the earthquake module. This will help in defining the congested sections within the network and plan a traffic mitigation plan to countermeasure the movement of emergency vehicles within each regional closure. To consider the growth of traffic in the network, two scenarios were developed for five and ten year’s analysis period respectively.

4.4 Overall Module

In this module integration is done of the three above modules to generate four types of roadway network maps, namely, base map, earthquake map, emergency services map, and LOS map. The GIS is utilized to integrate the databases and generate the maps. The output of this module will designate the roadway closures, type of closure, congestion points, proposed routes of emergency vehicles, regional pockets as a result of closures, the closest emergency centers, warehouses and shelters for each regional pocket, and built an emergency evacuation plan based on those outcomes.

4.5 *Recommendation and Planning Module*

In this module recommendations are generated for concerned agencies like municipalities, Department of Transportation (DOT), and planners for future emergency services were it should be situated in addition to future maintenance and construction projects. Based on those outcomes, awareness programs are set for the public and private sectors.

5. Case Study

The methodology above is tested and implemented using the City of Nablus, Palestine as a case study. The City of Nablus is considered a linear city situated between two mountain ranges limiting the residential, commercial, and industrial development in a narrow strip of land with some of those activities build on the lower mountain side. Most of the city is built on solid to fractures solid rock layer. The city is located 60 Kilometers of the holy city of Jerusalem at an altitude between 600 to 800 meters above sea level. The city has more than 240 thousand inhabitants is considered a center for commercial and educational activities. The city had two major earthquakes in 1837 and 1927 with the later causing heavy damage in the city, the magnitude of the 1927 earthquake was 6.25 on the Richter scale with epicenter near the Damiye Bridge on the river Jordan in the Jordan Valley (8). All predictions regarding the next earthquake shows a severity of 6-7 points on the Richter scale expected with sizable damage to old buildings and high rise buildings. The predictions shows that the collapse of those buildings will cause total and partial closures of the roadways especially in the mountainous regions which is in most cases has narrow roads running a long side the mountains. In addition, several landslides and collapse of retaining walls will occur if the earthquake hits during the winter rainy season (9).

In the analysis of this case, three cases of earthquake severity are considered. Figure 2 shows the impact of earthquake having up to 5 points on the Richter scale on the closure situation in the city, out of the 2287 links defines and analyzed using the methodology stated in this study, practically no closure were reported for this case.

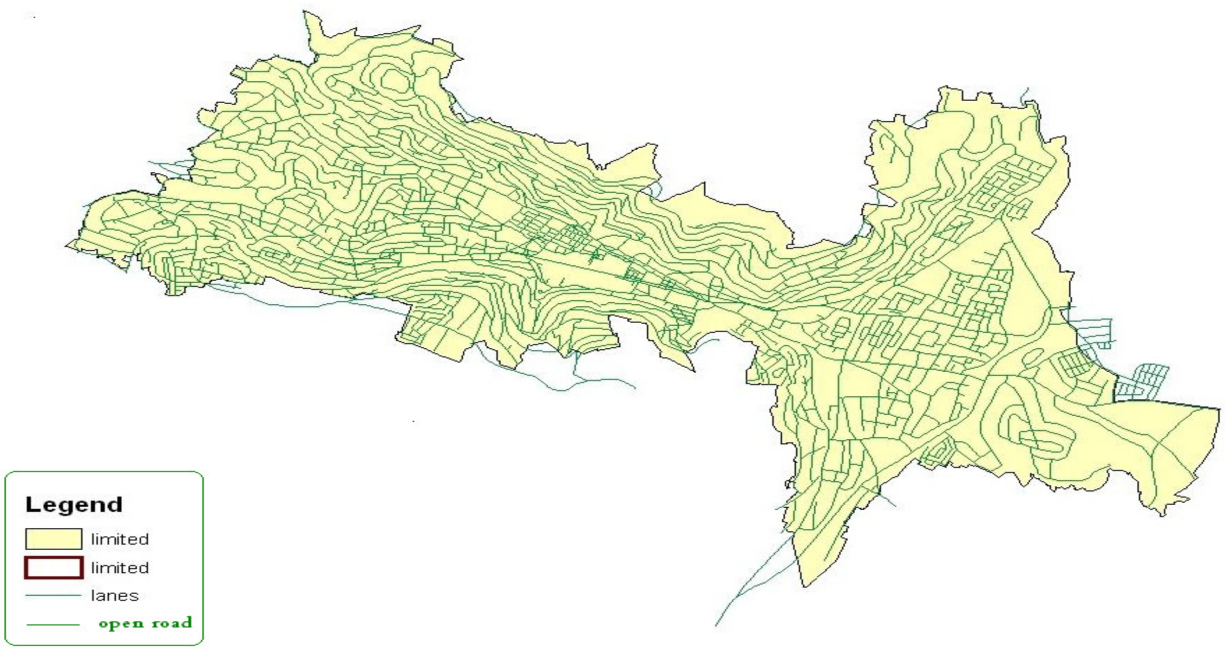

Figure 2: Closure due to earthquake severity of lower than five points.

For the second case of an earthquake between 5-6 point on the Richter scale as shown in Figure3, several roadway links on the southern and northern mountainous areas will be either totally or partially closed for traffic which amounts to 76.6 percent of the total links in the city. It should be pointed out that most roadways in the mountainous areas have no access to other parallel roads due to the steep grade, which means, the closure of one link might cause inaccessibility to other links within the same road. Most of the routes in the valley region will practically stay open for traffic with minor closures.

For the third case of earthquake severity larger than 6 points, most of the mountainous and lower mountainous regions suffer devastating destruction and additional destruction of roadway links of the already inaccessible routes shown in the second case above.

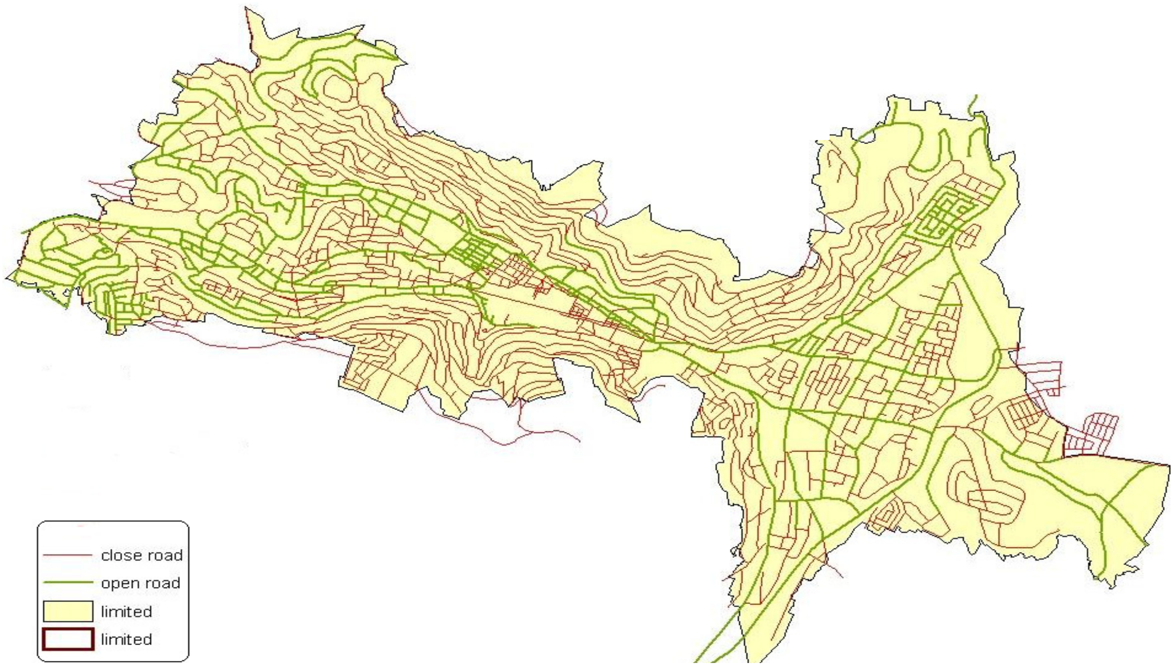

Figure 3: Closure due to earthquake severity of between five to six points.

For the purpose of determining the LOS of the different roadway routes, the city was divided into two regions, eastern and western regions to take into consideration the drastic growth of the western region relative to that of the eastern region and create several scenarios of traffic recovery in case of closure for the five, ten, and fifteen years planning periods. In addition, all routes in the planning and construction phases were considered. Capacity analysis of all links as well as the static and dynamic characteristics of the network were established for the city network for capacity, number of lanes, and running speed for the roadway links. Based on this database, the current LOS is establishes for the network. The figure shows that 75 percent of the city links have a LOS C, 17.8 percent LOS D, and 3.2 percent having LOS E and F. The rest of the links have LOS B or better. For consideration of the future LOS, a 3.5 percent traffic growth factor was considered as shown in Table 1. Figure 4 gives an example of the LOS for the year 2012.

Table: Change of Level of Service for the analysis period of fifteen years.

(L.O.S)	% for year 2007	% for year 2012	% for year 2017
A & B	2 %	1.5 %	1.1 %
C	75 %	74 %	72 %
D	17.8 %	18 %	19 %
E	3.2 %	4.0 %	3.5 %
F	2.0 %	2.5 %	4.4 %

For the consideration of closure relative to the current LOS analysis, it is important to note that the closure will depend on both severity of the earthquake and time of occurrence. Several scenarios can be developed based on physical closers caused by the drop in LOS as a result of time during the analysis period and diversion of traffic right after the earthquake. Table 2 shows some statistics relevant to those scenarios. Figure 5 gives an example of the integrated analysis of LOS and earthquake severity. For this case, about 74 percent of roadway network will be closed as a result of physical collapse and 3 percent as a result of lower LOS after the earthquake. It is clear that an earthquake with severity higher that 5.5 on the Richter scale as well as the time of occurrence of the earthquake during the 5-10 analysis period from the based year of 2007 will cause a significant increase in number of link closures. It is evident too that most routs in the mountainous region are inadequate in the case of an earthquake of five points on the Richter scale.

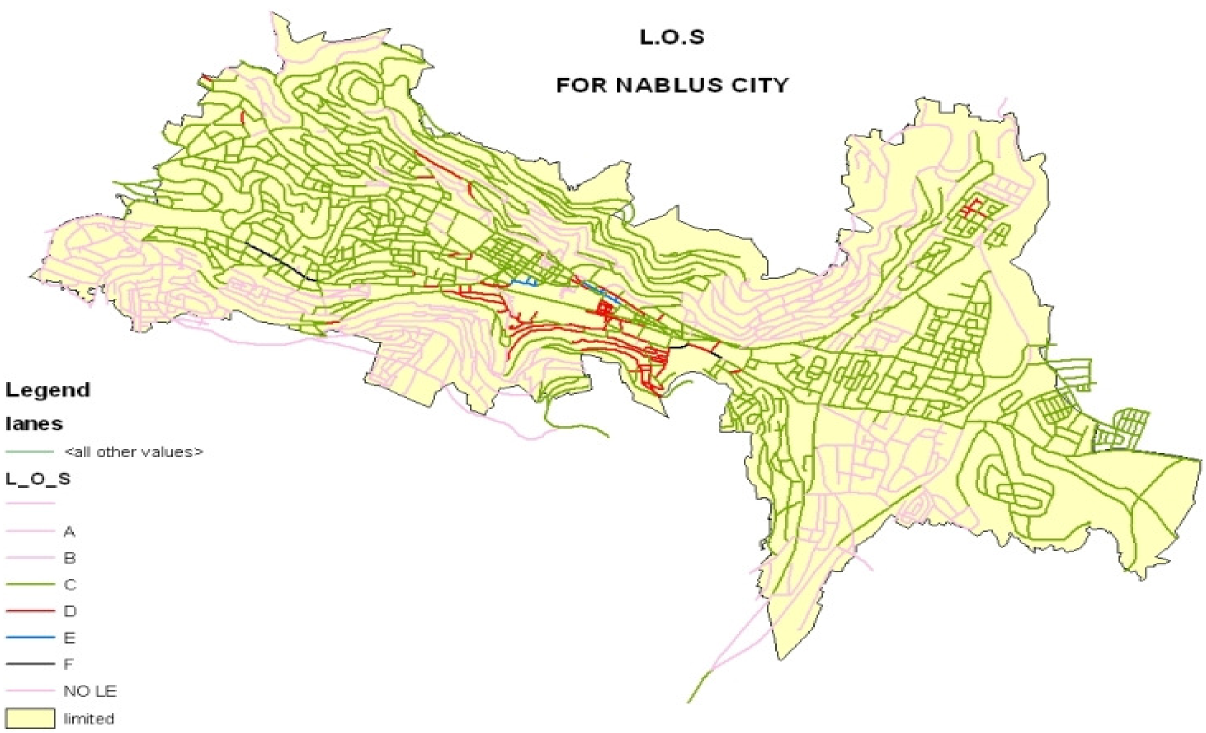

Figure 4: LOS in the City of Nablus roadway network for the year 2012.

Table 2: Percentage of roadway closure relative to earthquake severity and analysis period.

Analysis Year	Earthquake Severity	Percent Roadway Closure	Percent Open Roadways
2007	5.5-6	79.8	20.2
2007	More than 6	81.5	18.5
2012	5.5-6	80.6	19.4
2012	More than 6	82.3	17.7
2017	5.5-6	83.5	16.5
2017	More than 6	85.2	14.8

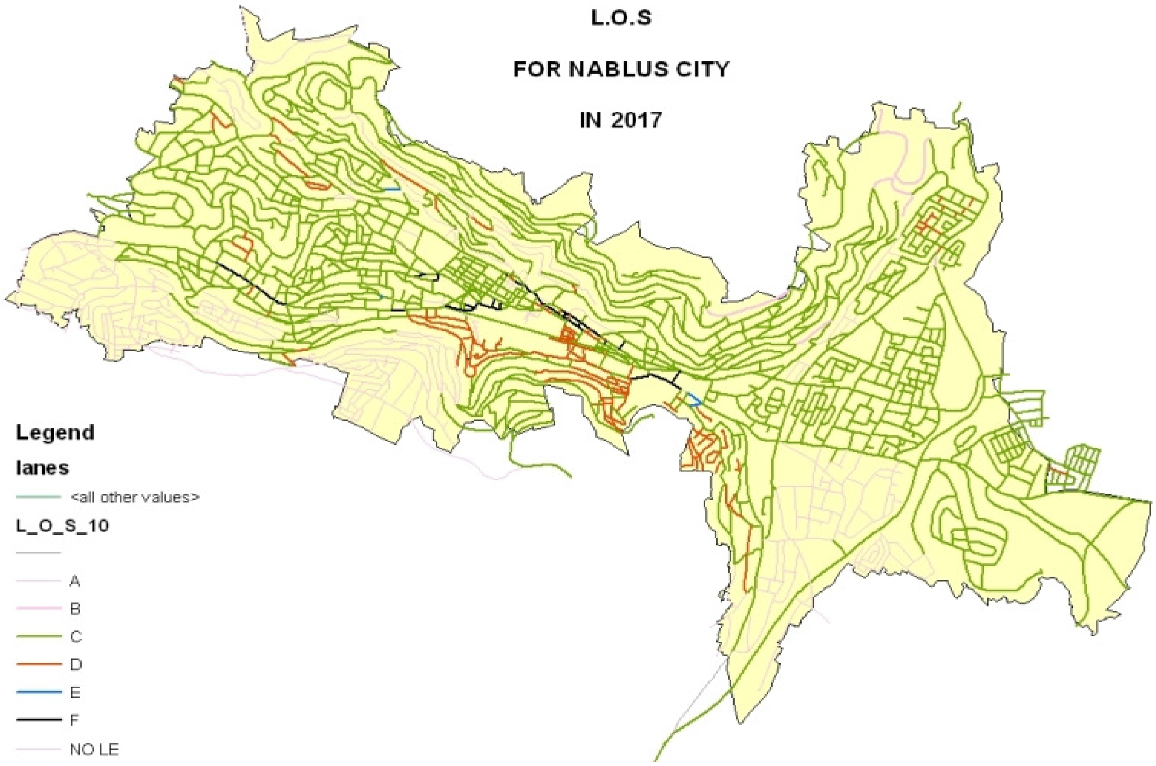

Figure 5: Future LOS in the City of Nablus roadway network for the year 2017.

To utilize this database for the effective and viable evacuation plan, the city of Nablus should be divided into six regions based on the closer situation, population density, and spatial distribution of services. The city of Nablus has distinct characteristics of the existence of the old city build over several times through the past four centauries and several highly populated refugee camps. For each of the regions, the following will be considered for link mobility:

1. Links already open
2. Links need to be open using heavy equipments for wreckage removal.
3. Links needs to be open with closure cased by lower LOS and congestion using rerouting and police control.
4. Links totally closed as a result of total collapse with no possibility to open the evacuation process.

Based LOS and earthquake modules, analysis of spatial connectivity to nearest emergency service within or outside the designated region is established. In addition, data regarding the emergency warehouses, departments of roadway maintenance, and availability of heavy machinery for wreckage removal are identified using the GIS database. The outcome are used to establish the evacuation plans and most importantly planning the future roadway section that needs to be developed as part of municipality master plan in preparation for the earthquake.

For the case under consideration the recommendations of the outcomes was delivered to the concerned agencies in the form of projects and strategies for the short and long term planning. In addition, guidelines for awareness programs to public were given for those agencies.

5. CONCLUSIONS

Based on the methodology developed as a part of this study, the following can be concluded:

1. Consideration of a comprehensive set of roadway and traffic elements will significantly improve the preparedness efforts for an earthquake.
2. Integration of traffic elements and earthquake database will further define evacuation and relief measures in case of an earthquake.
3. The model presented in this study can be utilized as an approach for planning of the urban roadway network.

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