Managing Evacuation Process in Urban Areas using a GIS System: A Case Study on Mansoura City

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ABSTRACT

Urban areas are prone to natural or man-made disasters and in the event of a disaster, population in these areas will be in danger and need to be evacuated from the threatened place to a safer place in order to protect their lives. This paper discusses a GIS system for evacuation planning; the system combines geometric information with non-geometric information in order to fulfill evacuation planning process's requirements like: selecting safe areas to which evacuees should be transferred, determine evacuation routes from the incident place to the safe areas, and minimize the overall time required for the evacuation process to complete. A case study on Mansoura city in Egypt is implemented using ArcInfo software.

Keywords
Geographical Information Systems (GIS), Evacuation Planning.

1. INTRODUCTION

Urban areas are prone to natural or man-made disasters such as earthquakes, fires, floods, and road accidents. These disasters always threat society; they happen suddenly and cause significant losses which result in a crisis, so that every country should have a crises management strategy includes the development of plans to reduce the risk of a crisis occurring and to deal with any crises that do arise, and the implementation of these plans so as to minimize the impact of crises and assist the organization to recover from them.

Evacuation planning is one of crisis management activities, which means the transfer of people at the site of the incident from the danger place to another safe place. This process is a very complex process, besides needing to be accurate and carful; it must be done very quickly. In the recent years, many studies have been made in the field of evacuation planning examining different methods from different perspectives such as evacuees' behaviors, traffic control, safety areas selection, and route finding for evacuation. Basically, Evacuation planning should involve several aspects such as the position of the safe areas to which evacuees should be displaced, the locations of the hospitals to which injuries should be transferred, routes from the incident place to safe areas should be determined, and the ability to minimize overall time required for the evacuation process to complete.

Due to the geographical nature of the evacuation process, GIS has been widely used in the field of evacuation planning. GIS can get space-related data collection, management, operations, analysis, simulation, display, and then analyze these data by using geographic model with the support of computer hardware and software, and timely affords various dynamic geographic information of space to build computer systems for geographic research and decision-making services [1]. In addition, GIS is attractive to most people who encounter it because it is both intuitive and cognitive. It combines a powerful visualization environment with a strong analytic and modeling framework that is rooted in the science of geography [7].

The data involved in the evacuation planning process has an obvious geographical data, it consists of: spatial data which describes data that has a geographical reference to the earth such as coordinates and features' positions, and attribute data that describes the geographical features such as roads, safe areas, and hospitals attributes. Spatial data are described as point, line, and polygon features in the GIS software, and stored with its geometric information. Where attribute data is stored and managed by a Data Base Management System (DBMS). By integrating road information, traffic information, safe areas information, and the related geographical data, the system can provide decision makers with the relevant information needed to make a decision in the evacuation planning process. See Figure 1.
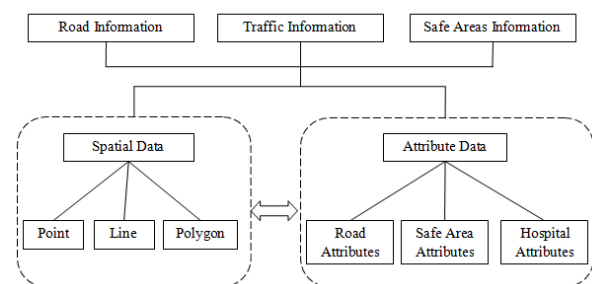

Fig 1: Evacuation system's structure

2. RELATED STUDIES

In the recent years, there were many studies in the evacuation planning field examining different perspectives. For example, *Mohammad Saadatseresht et al* [2] has proposes a three step method for an optimized evacuation planning algorithm to be used to evacuate individuals to safety places in case of crisis. Two objective functions were defined, and then the spatial MOP was solved using the NSGA-II algorithm in a GIS environment.
Yang Bo et al [3] presents an evacuation system based on Multi-Agent system that Simulate individual movement by a

modified Particle Swarm Optimization (LWDPSO) and Modeling the evacuation environment by a GIS platform.

Bo Huang and Xiaohong Pan [4] presents a novel approach for dispatching response units, which incorporates an optimization process for multiple incident response management. An incident response management toll (IRMT) has been developed by integrating GIS with traffic simulation and optimization engines.

Tang Fangqin and Zhanng Xin [5] presents a simulation model AutoEscape to study building evacuation problems. AutoEscape abstracts the key features and variables in evacuation scenarios and design levels of geometry and occupants.

Thirumalaivasan and Guruswamy [8] use the ROUTE Module available in ArcInfo, which is a path finding program used to model the movement of resources between two or more points. The optimal path is determined by finding the path with the lowest total for the arc directional impedance and the turn impedance. A case study was applied to Chennai City, India.

Mina Khalesian et al [6] has proposed and implemented an approach to measure each urban intersection degree of importance, considering the impact of other network intersections using GIS capabilities, dynamic traffic modeling, and space syntax theory.

3. METHODOLOGY

Evacuation situation is a critical-time process, so dealing with this situation must be done quickly and accurately. To achieve this goal the evacuation methodology should consider some factors such as: (1) Selecting safe areas that the evacuees will be placed to, (2) Selecting hospitals locations that the injuries will be carried to, (3) Determining evacuation routes from the incident place to the selected safe areas, and (4) Reduce the overall time required for the evacuation process to complete. Based on this methodology this paper introduces a proposed GIS system to manage the evacuation process in the event of a crisis, and apply the methodology on Mansoura city as a case study. Figure 2 shows the flowchart of the methodology.

The first step was collecting data required for the system. These data are the spatial data and the attribute data. The spatial data is data that has a geographical reference to the earth such as coordinate points and features' positions; these data need to be geo-referenced to its real location on the earth through a process called "Geo-referencing". In this paper: roads, safe areas, and hospitals locations are considered spatial data.
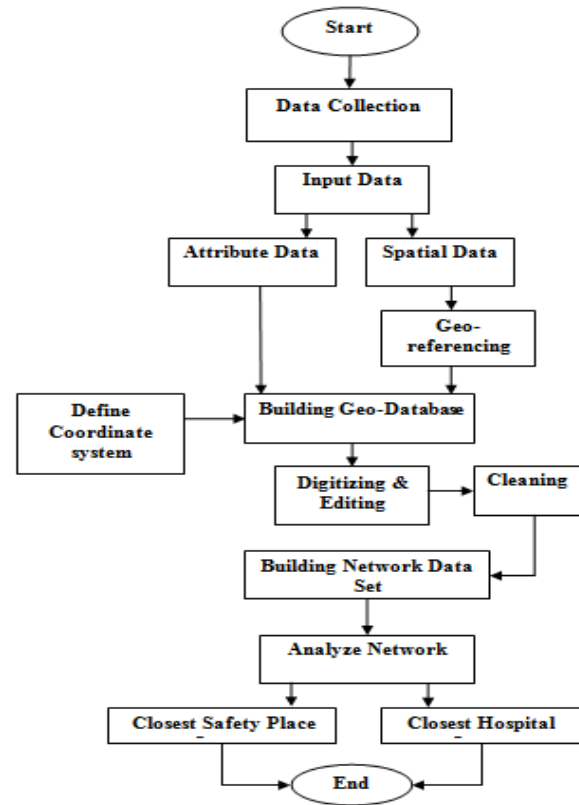

Fig 2: Flowchart of the methodology

The next step was building the Geo-Database in which spatial data are combined with attribute data; data that describe the spatial features. In this step three feature classes has been created named: Safety Places, Hospitals, and Roads, Figures 3, 4, 5 show snapshots of the feature classes and their attributes. The Safety Places feature classes is considered to store the location of safe areas to which the evacuees should be displaced, a safe area should be an open and large location where basic life facilities is available. According to Mansoura geographical nature, parks and schools are the best places that can be considered as safe areas. The Roads feature class has a "Minutes" attribute which stores travel time for each road considering the vehicle speed is 90 kph.

* OBJECTID	* SHAPE	Name	Area	Type
5	Point	Safe_Area1	16423.86	Park
14	Point	Astad Al Jameaa	15234.69	Park
16	Point	School 1	7470.02	School
17	Point	School_Group	14836.766	School

Fig 3: Safety places feature class

* OBJECTID	* SHAPE	Name	Area	Type
1	Point	El-Twaee	4251	General
2	Point	Al-Atffal	5470.7	Kids
4	Point	El-Kila	9390	Kidney

Fig 4: Hospitals feature class

ID	Name	Region	Minutes	Width	OneWay	SHAPE_Length	Type	Meters	Name_Arabic
1	Mokhtar ElMasry	East Mansoura	0.374106	20		374.105751	Main	374.105751	مختار المصري
2	Saad Saghloul	East Mansoura	1.198712	10	FT	1198.712231	Main	1198.712231	سعد زغلول
2	Saad Saghloul	East Mansoura	0.23921	10	TF	239.209512	Main	239.209512	سعد زغلول
3	Abd ElSalam Aref	East Mansoura	0.345772	10	FT	345.771993	Main	345.771993	عبد السلام عارف
3	Abd ElSalam Aref	West Mansoura	0.024646	10	FT	24.645867	Main	24.645867	عبد السلام عارف
3	Abd ElSalam Aref	West Mansoura	0.170818	10		170.818367	Main	170.818367	عبد السلام عارف
3	Abd ElSalam Aref	East Mansoura	0.232391	20	TF	232.390741	Main	232.390741	عبد السلام عارف
3	Abd ElSalam Aref	East Mansoura	0.462779	10		462.779008	Main	462.779008	عبد السلام عارف
4	Port Said	West Mansoura	0.149027	10	TF	149.027323	Main	149.027323	بورسعيد
5	Al Mashia ElOloia	West Mansoura	0.849249	10	TF	849.248906	Main	849.248906	المشاية العلوية
6	Al Bahr	East Mansoura	0.598185	10		598.184843	Main	598.184843	البحر

Fig 5: Roads feature class

After building the geo-database, the digitizing process begins to extract the spatial features from the map and save it with its attribute data in the corresponding feature classes, see Figure 6. Finally, a network data set is built and a two closest facility layers are created over it. One of them used to find the closest hospital from the incident place, and the other used to find the closest safety place. After selecting the appropriate destination, the system draws the fastest evacuation route from incident to destination.
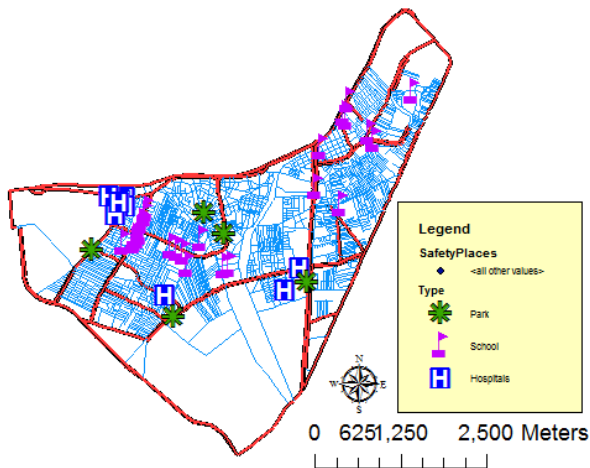

Fig 6: Digitized map for Mansoura city

4. ANALYSIS RESULTS

GIS analysis is the process of manipulating geographic features in order to find answers to common queries. The GIS evacuation system in Mansoura city is built using ArcInfo software. The system manipulates the road network with the geo-database in order to choose the needed safe areas for evacuees or hospitals for injuries, and to find best route to it. The following lines represent some of the functions that the system can provide and examples of it:

- **Find a place:** as shown in Figure 7, this function used to locate the incident place on the map giving the road name. Figure 8 shows the incident location on the map as a small square.
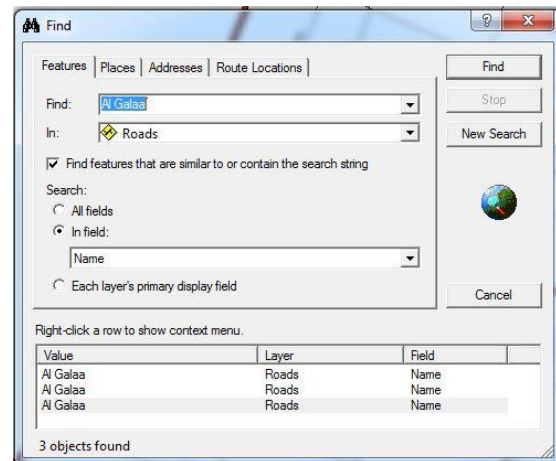

Fig 7: Finding "Al Galaa" street

Fig 8: Location of the incident point

- **Find closest safe area:** this function uses the Closest Safety Place Layer to find route to the closest safety place from the incident location, e.g. with the lowest travel time. Figure 9 shows that the chosen safe area was "Al Shahid Mahmoud Ali Saied" primary school.
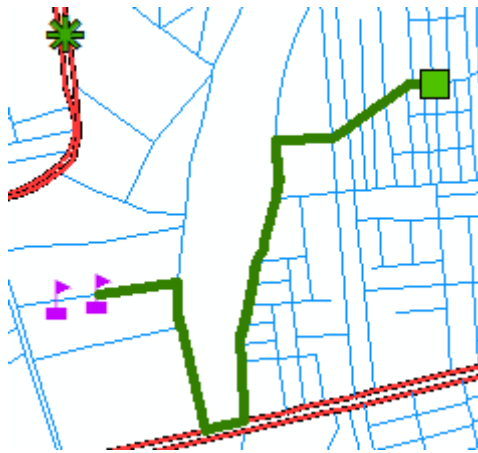
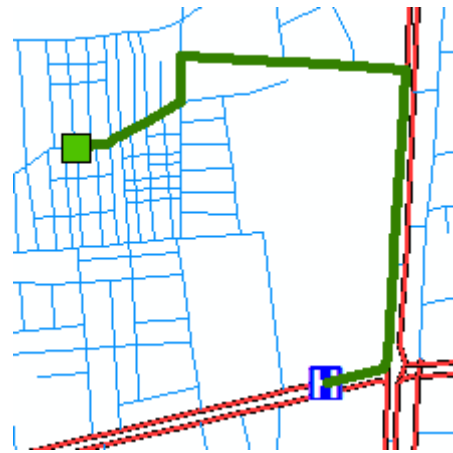**Fig 9: Find closest safe area**

Fig 10: Find closest hospital

- **Find the closest hospital:** this function uses the Closest Hospital Layer to determine the place of the incident and to find the route to the closest hospital, e.g. with the lowest travel time, from it in the case of injuries. Figure 10 shows the closest hospital from the incident point.

- **Display Directions:** this function opens directions window which helps to find out the directions of the result route and how to reach from the incident to the facility, also know how much time and distance required reaching the facility. Figure 11 shows driving directions from the incident point to the chosen safe area; the evacuation route takes about 79 seconds with a distance of 1316 meters.
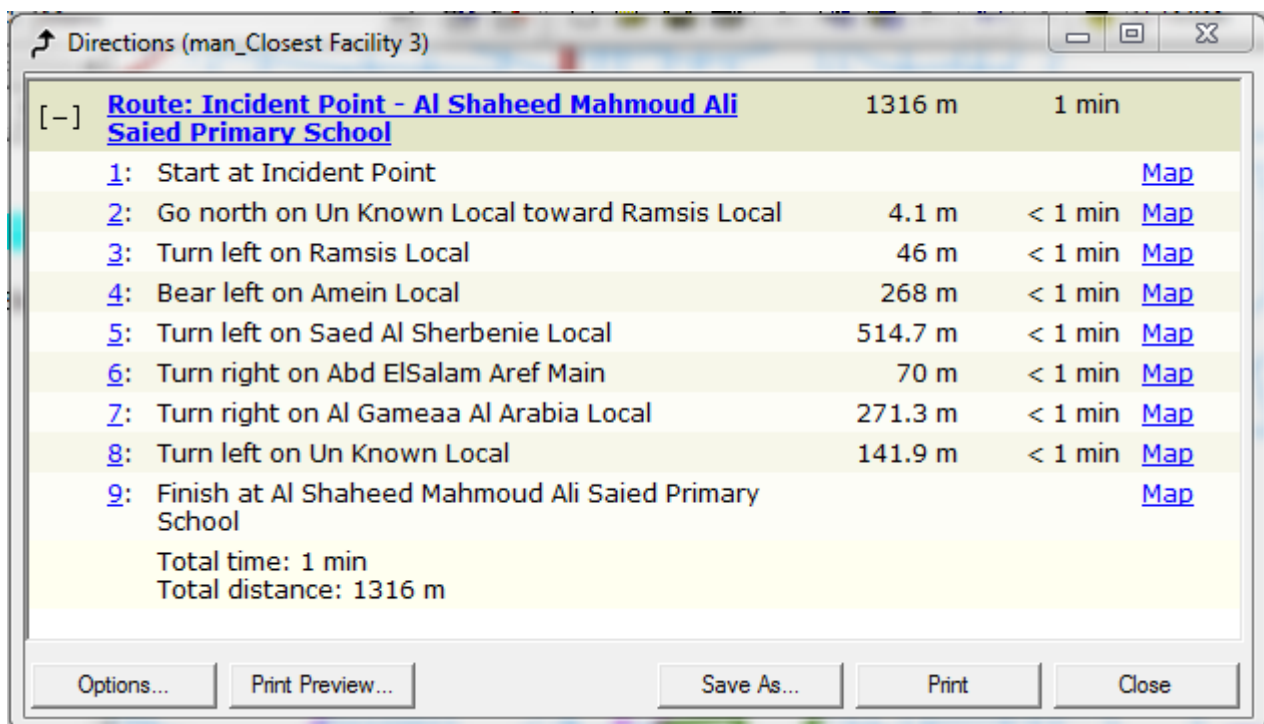

Fig 11: Displaying driving directions from the incident point to the chosen safe area

5. COMPARISON

According to Mansoura Crises Management Unit's shelter selection plan, the plan selects safe areas by traditional methods without using GIS and Mansoura city has only four shelters that can be used to house homeless people in case of a crisis and the shelter is selected depending on its nearness to the incident. These four shelters are: Mansoura sports club,

Omaal club (workers club), Al Saha Al Shaabia (the popular arena), and Al Magzr Al Aalie (the automated slaughterhouse). In our approach, we increase number of safe areas to 32 locations by considering schools as safe areas.

By applying Mansoura Emergency Unit's shelter selection approach, the approach selects the nearest shelter from the incident point that was "Mansoura Sports" club; the

evacuation route takes about 125 seconds with a distance of 2085 meters. A comparison between currently used plan and the proposed approach according to the case study incident point is presented in Table 1.

Table 1. Comparison between currently used plan and the proposed approach

	Current Plan	**Proposed Approach**
Using method	Traditional	GIS
No. of safe areas	4	32
Route distance	2085 m	1316 m
Route travel time	125 s	79 s

6. CONSLUSION AND FUTURE WORK

This paper introduces a GIS system for evacuation planning. The system combines attribute data and spatial data together to build a powerful geo-database that includes information about roads, safe areas, and hospitals ready to perform geo-processing on, then supply decision makers with relevant information about selecting the appropriate safe areas and how to evacuate people to it taking into account the overall time required for the process. The system has been implemented using ArcInfo software on Mansoura city in Egypt as a case study. The results of the geo-processing verify that the system can select the best safe areas for evacuees and closest hospitals with the lowest travel time based on time attribute of the evacuation routes.

This work need to be enhanced in the future to take the size of the safe areas into account while selecting the best safe area, also the nature of the incident place. These two factors can affect the results of the overall time for evacuation and the results of the best safe area chosen to displace evacuees into.

7. REFERENCES

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