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DEVELOPMENT OF ROAD SAFETY ASSESSMENT SOFTWARE

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Abstract

The purposes of this work are creation database about the physical conditions of some Egyptian highways and developing software to implement the database for road safety, analysis and maintenance. Roads physical conditions are examined and each condition's percentage impact on road safety is allocated. Applications of Real Time Kinematic Global Positioning System technique for collecting the field data of the road physical conditions and constitution of the database are explained. The development and capabilities of the Road Safety Assessment (RSA) software are presented. The results of case study show that the software provides great deal of flexibility in generating essential data in the form of digital maps and reports for road safety and maintenance studies. RSA Software is a powerful tool for transportation and tourist companies and provides an affordable tool to researchers in universities and academic centers. To increase the efficiency of the developed software, three methodologies are suggested.

Keywords: highway safety, RTK GPS, road physical properties, road safety factors, GIS

1. Introduction

Roads are perhaps the one main foundation that helps individuals' monetary and social exercises, associating urban communities with urban communities, among metropolitan and rustic regions, and between towns. Likewise, roads can further develop admittance to expected regions (the travel industry, industry, agribusiness, fisheries and yields), open up distant regions and back advancement in line regions.

Over the last few years, there has been a gradual decline in serious and fatal accidents. In addition, there appears to be an increasing traffic flow, at least on highways, possibly due to the economic upturn [1] .

Traffic safety is a fundamental part of transportation management. Numerous endeavors have been made by the management administrators to add to a reliable decrease of mishap chances. As a matter of fact, car crashes are one of the main sources of death and injury around the world, bringing about critical individual misfortunes and huge social and financial costs such as valuable lives, clinical consideration, protection, and loss of public and confidential property. All around the world, the number of individuals killed in auto collisions every year is assessed at practically

1.19 million, while the number of harmed could be more than 10 million [2].

Each individual who utilizes the road network is worried about safety, particularly government authorities and other local area pioneers.

Highway safety emphasizes driver conduct, vehicle safety and roadway safety. Roadway safety is fundamental for overall highway safety permanently set up by the physical properties of the road, for example, operating conditions, roadside objects like poles, signs, trees, and guardrails, bridges, intersections, and all parts of the road design [3].

Highway crashes have severe personal and financial consequences for our citizens and communities. A few things to keep in mind are [4,5]:

(1) The level of deaths connected with crashes with side-of-the-road risks has expanded throughout recent many years.

(2) The financial expenses for society in clinical express, specialist misfortunes, property harm, and crisis administrations compound the individual misfortunes coming about because of highway crashes.

Safety specialists name the accompanying roadway conditions that, paying little heed to the area, are considered possibly perilous [3,6-10]. Furthermore, driving at an excessive rate of speed, making mistakes as a driver, and adverse weather can all be contributing factors that cannot be ignored.

Road traffic Volume: Road traffic volume is considered to expand the likelihood of occurrences on narrow roads because of diminishing the accessible passing space for approaching vehicles.

Road width: Carriageway width is significant because a wide road with space for two approaching vehicles to pass is more secure than a limited road where just a single vehicle should yield. Carriageway width is taken as the width of the road surface disregarding any pathway or edge.

Quality and perceivability of street signage/carriageway: Sufficient road signage/markings are considered to contribute towards showing drivers that a risk exists (blind highest point, curvature, road limits, and so forth).

Intersections: Drivers have encountered perilous intersections with befuddling turn paths, vulnerable sides, or absence of proper or insufficient signage or traffic lights. A driver's view of traffic control devices like signs, signals, and vegetation can be obstructed by obstructions like these.

Railroad crossings: Trains are not able to stop rapidly or steer far removed and a train going at 60 km/h needs more than 2 km to stop. Obviously, railroad convergences are of a fundamental concern, and they can be remarkably hazardous.

Road surface conditions: Variations in the road surface, for example, asphalt edge drop-offs,

potholes and decreases in surface rubbing because old enough, wear and deficient seepage during precipitation storms clearly impede vehicle halting and moving abilities.

Road design limitations: Many municipal roads were designed to handle fewer cars traveling at slower speeds, hence their safety is limited. Many of these highways are now high-speed commuter corridors due to the significant increase in vehicle miles driven over the last 40 years. Hazards include abrupt slopes and horizontal curves, shoddy signage and markings, and a deficiency of medians to divide oncoming vehicles all endanger their safety [11].

Roadway departure hazards: Roads crashes occur on both straight and curved portions of the road and much of the time incorporate either rollover of a vehicle or contacts with fixed things like trees and utility shafts. Slopes, seepage ditches, steep sides, and limited shoulders that aren't sufficiently large to fit a vehicle in a difficult situation are another side-of-the-road risks.

Work zones: Work zones, characterized as development, upkeep, and utility regions, make conditions that can be perilous to drivers and expressway laborers. Changes in traffic patterns, lowered speed limits, congestion, and an increase in the number of construction workers and equipment on the road are all possible outcomes of work zones, which are a necessary part of life in our communities. Work zones may be inadequately checked, and cautioning signs are difficult to see, particularly around evening time. It is possible that traffic control devices and warning signs are not accurately depict actual hazards in the work zone or related to actual work in progress. Drivers accordingly ignore these admonition signs with possibly grievous outcomes. Work zones only have an effect for as long as it takes to accomplish their intended aim(s).

For road safety improvements, the following elements or features must be considered [3,12,13]:

(1) The lifecycle maintenance of roads.

(2) Extra directional and instructive signs.

(3) Improving the visibility on highways, i.e. the greatest distance under given weather conditions to which it is possible to see, especially at night through a variety of means such as retroreflectivity, roadway lighting and automobile headlights.

Unfortunately, roads construction, reconstruction and lifecycle maintenance are governmental jobs that may have the following limitations:

(1) A lack of the required funds.

(2) Time consuming.

Moreover, there is a need to develop a database for the highway network [13,14] in Egypt to achieve the following tasks:

Providing a choice of safety routes from origin to a destination city.

Identification of major problems of highways such as dangerous horizontal and vertical road alignments, narrow carriageway width, intersections, etc.

Helping as an information source for planners and engineers.

Identification of highway(s) requiring major upgrading/improvements.

To achieve some of the above mentioned tasks, RSA software has been developed. RSA is an acronym that the author has coined to specify the Road Safety Assessment for some highways in Egypt.

2. Research Methodology

2.1. Assignment of the Percentages for Highway Safety Factors

The safety value that each component of a road contributes to a single road weight is not the same. The weight of each element is organized by the greatness of the significance of safety to the component, in view of the assessments of the skilled gatherings who truly ace, impact the decision-making or truly know the needed data. Because there is no weighting for each of the road components until now, the importance of damage to road components is used to determine the weighting.

To make sure all relevant factors were taken into account, a series of meetings involving heavy truck drivers and highway and transportation engineers resulted in the development of the road safety assessment.

The percentage of safety of each factor was assigned (optional) according to the specifications of oil companies in Egypt [15] and tabulated in Table 1.

For example, the computation of the percentage of safety for the second factor, horizontal curves with obstacles, is proposed to be as follows:

$$F_2 = \frac{\sum_{i=1}^{3} n_{2i} F_{2i}}{\sum_{i=1}^{3} n_{2i}} \quad (1)$$

where F_2 is the percentage of safety for the second factor, n_{2i} is the number of simple, satisfactory or dangerous horizontal curves with obstacles on the road, or on a specified road zone and F_{2i} is the percentage of safety for each case i.e. 12, 8 or 5%.

Table 1 Percentage of safety for each road factor

Number	Road Factor	Percentage of Safety	
1	Curves roughness • Horizontal curves • Vertical Curves • Horizontal turning into vertical curves	Not Exist	**14**
		Simple	12
		Satisfactory	8
		Dangerous	5
2	Horizontal curves with visual obstacles	Not Exist	**14**
		Simple	12
		Satisfactory	8
		Dangerous	5
3	Road surface conditions and artificial obstacles	Good	**10**
		Satisfactory	7
		Poor	5
4	Frequency of curves	Simple	**10**
		Satisfactory	7
		Dangerous	5
5	Intersections design and control	Good	**10**
		Satisfactory	7
		Poor	5
6	Road slopes and road bridges	Not Exist	**10**
		Simple	8
		Satisfactory	5
		Dangerous	2
7	Road width	>7.0m	**7**
		6.25<>7m	4
		<5.5m	0
8	Road type	Single road	**7**
		Dual carriageway	3
9	Road signage		**7**
10	Traffic volume and intensity	Light	**7**
		Satisfactory	5
		Dense	3

11	Nearby area description		**2**
12	Road service		**2**
Total			**100**

The overall road safety is obtained by adding the percentages of safety for the 12 factors together. This gives a wide range of safety values.

2.2. Field Data Acquisition of Highways

Field data includes geometric data and traffic operational data [16]. Geometric data is related to the physical characteristics of the roadway facility. Below is a list of general geometric data that may be needed to perform road safety analyses. This is not an exhaustive list.

(1) Geodetic coordinates (e.g., WGS84)
(2) Number of lanes
(3) Lane assignment
(4) Lane, shoulder, and crosswalk widths
(5) Type of lane (e.g., general purpose, managed lanes, bus-only lane, bike lane)
(6) The presence of sidewalks and pedestrian Elements
(7) Length of turn lanes or bays
(8) Ramp spacing
(9) Clear zone
(10) The curvature of roadway (i.e., centerline alignment)
(11) Grade
(12) Median width
(13) Median type (e.g., divided, undivided barrier)
(14) Right of way
(15) Driveway entries and location
(16) Location of railroad crossings

Traffic operational data includes:

(1) Speed limits, operating speeds, and/or design speeds
(2) Lane utilization
(3) Area type (e.g., rural, urban, suburban)
(4) Lane utilization
(5) School zones
(6) Railroad preemption
(7) Signage types and locations (e.g., regulatory, warning, guidance signs).

Global Positioning System (GPS) is considered recently the standard tool for surveying roads and railways, and their related features [17-22] .

In this research, the field data of the roads was obtained along with many other data in a short period using Real Time Kinematic (RTK) GPS, which is rather good in its accuracy [20-22]. The

equipment used for measurement was a Trimble 4600LS, and accuracy was horizontally 1 cm+ 1 ppm, and vertically 2cm+lppm in RTK Survey Mode.

A reference receiver was installed at the survey fields, and a rover receiver did the role of obtaining 3-dimensional coordinates at each measuring point for the features and facilities of each road. To obtain the coordinates of points for the alignment and grade of the center line of an existing road, surveying with a car equipped with a rover receiver was used.

Furthermore, the field study program contained a visual investigation of the current conditions of road surface, traffic signal gadgets and signs, road lighting, road marking, side of the road safety components and road kilometer marks. The rover receiver was used to locate the position of the existing conditions..

2.3. Constitution of the Database for Physical Conditions of Highways

The acquired data was downloaded every day, and post-processed to get the X,Y &Z coordinates of the road features.

Many softwares have been developed to perform the necessary computations to obtain the required results. Some of these softwares are related to the determination of horizontal curve beginning point, radius, the speed corresponding to the radius, slope, width, and other road geometry features. These results were analyzed and compared with those for road design and planning [23] to classify these features as safe, satisfactory, or dangerous and to calculate the advisory speed.

To help the drivers, the obtained X&Y coordinates of the road features were reduced to road chainage distance according to the road kilometer marks.

A database has been designed using MS Access to hold all of the extensive data collected during the fieldwork. This contains in excess of 100 fields that database describe highways physical conditions, names, lengths, etc. Moreover, additional data collected in the field could be readily added to the database.
The constituted database provides all information for 8,000 kilometers of highways in Egypt.

2.4. An Overview of RSA Software

The configuration of RSA is realized by the software structure depicted in Fig. 1. The structure of RSA operations is modular. The main software RSA initializes and terminates the operations of three main modules namely Technical Data of Roads, Reports for Drivers and Updating Databases.

The Technical Data of Roads module reads the stored data in the RSA database and provides the transportation and highway, engineer(s) with the technical data for the roads, routes, etc. Reports for Drivers module selects the best and auxiliary routes between the departure and arrival cities and generates a report supported with map(s) for the main and auxiliary, if any, route(s).

Updating the Databases module enables the engineers to modify, add or remove the stored data in RSA database.

For automatic processing and presenting the data and results, RSA makes use of effective techniques like Data Structuring [24], Random File Access, and Dynamic Memory Allocations [25]. Furthermore, the window-driven user interfaces that the system employs [26] facilitate the user's execution. The user interface and its input and output data are developed in Arabic to improve the software's efficiency and practice.

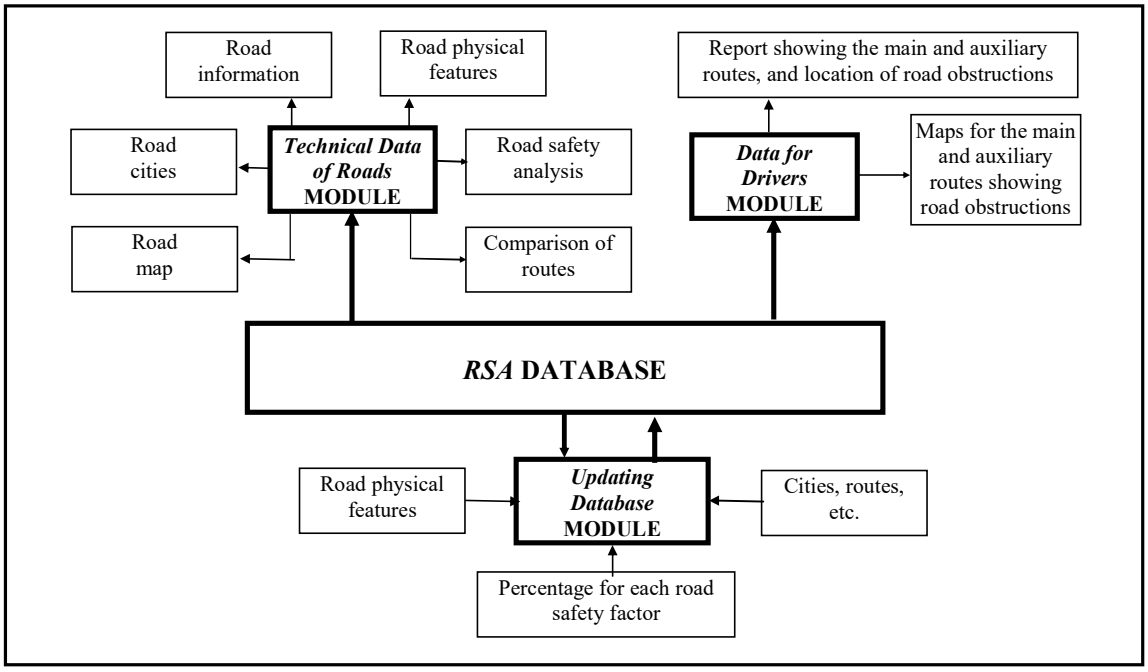

Fig. 1 Structure of the developed software (RSA software)

Technical Data of Roads Module is designed to provide transportation and highway engineers with the available technical data of highways. The module has Road Studies and Route Determination menus.

(1) Road Studies Menu: This menu allows the selection of the road from a list of road names. The user can scroll through this list and select a road. When selecting the road, the program displays different windows to perform the following tasks:

- Displaying the general road information such as road length, width, lanes, etc.
- Displaying the road cities and their kilometer marks.
- Generating a map, in digital form, for the road showing the kilometer marks and located cities.
- Evaluation of road safety: To perform this task, the user has to select the road zone either by total road, or zone between specified two-kilometer marks or two cities. After the road zone is

selected, the program starts the computation of the road safety factor for the specified zone. This capability enables the user to compute the road safety for a constant interval, e.g. each 1 km, to determine the critical section(s) of the road.

- Locating the physical conditions of the road: The user has to specify the road zone as explained earlier. The module generates a report containing the locations of all physical conditions for the specified zone. Moreover, the module has different menus to enable the user to select the required physical condition(s) to be reported only for example the location of the curve roughness. This function is necessary for road maintenance or reconstruction determination.

(2) Route Determination Menu: This menu enables the user to select the departure and arrival cities from a list of city names. After selecting the two cities, the module determines the best main and auxiliary routes between the two given cities. It can be performed using two modes: Automatic and Manual modes. For Automatic mode , the software searches in its database for the available route(s) between the two given cities. The Manual mode enables the user to specify the route(s) by himself. This is necessary in case of temporary closing of roads for work zones as explained earlier. After selecting the routes, either automatically or manually, the assessment method generates, for each route, an overall "score" of safety which can be used to compare between routes. The main and auxiliary routes may be chosen based on the computed scores of safety or the lengths of routes (optional). Data structure techniques [24,25] are widely used in this module for reducing the CPU time of searching for specific data in the RSA database.

Data For Drivers Module allows the selection of the departure and arrival cities from a list of city names. The user can scroll through this list, which contains hundreds of city names, and select the two cities. After the departure and arrival cities are selected, the program displays two menus: the Best Route Selection and Driver Report. Best Route Selection menu enables the user to select the best route based on either route safety factor or route length. Driver Report menu helps the user to select the desired route obstructions i.e. dangerous slopes, dangerous horizontal curves, cracks, etc. to be printed in a report which will be given to the driver.

After the above-mentioned options are selected, The module becomes ready to search in the databases for the available route(s) between the departure and arrival cities, compute the factor of safety and length of each route, select the best and auxiliary routes, and display the following:

(1) Report: which includes, for the best and auxiliary routes, road(s) and cities names, and location of obstructions.

(2) Maps: which show, for the main and auxiliary routes, the located cities and obstructions (if any). These maps are used as a warning tool for the location of obstructions. The software generates the maps in Windows Bit map and DXF file formats. The Map scale is set to fit A4 paper size to be easily handled and readable by the driver during the driving session.

Updating Database Module controls the stored data in the system database. The module enables the specialist engineers to modify, add and delete the stored data in the database. The updated data may be for roads, cities, routes between cities, percentage of each road safety factor (Table 1).

Because any error in the entered data will have an effect on the behavior of the software and may give inaccurate results, each menu of the module is supported by security measures taken to prevent the access of non-specialist users to the database. To update the database, a user must have a password with acceptable confirmation.

3. Demonstrating some Applications of RSA, Results and Discussion

Some of the above mentioned capabilities of RSA software have been demonstrated in the following taking the Cairo-Suez road as case study.

(Note: The all texts are translated from Arabic to English and maps are for demonstration only and not drawn to scale).

The output products of Technical Data of Roads module for the case study road are shown in Figures 2 through 5. Safety Evaluation of Cairo-Suez Road is depicted in Fig. 2. Fig. 3 shows the location of the physical features of Cairo-Suez Road. Fig. 4 illustrates the location of some required physical features such as dangerous curves.

Comparison of the routes connecting between Cairo and Port Said cities to find the main and auxiliary routes is shown in Fig. 5.

In addition, the results of Data For Drivers Module are shown in Figures 6 and 7. The report which includes, for the best and auxiliary routes, road(s) and cities names, and location of obstructions as shown in Fig. 6. Fig. 7 shows a map for the road, the located cities and obstructions.

Road Safety Evaluation Road Name: **Cairo-Suez Road**			
Number	**Road Factor**	**Proposed Safety (%)**	**Actual Safety (%)**
1	Curves roughness	**14**	**10**
2	Horizontal curves with visual obstacles	**14**	**14**
3	Road surface condition and artificial obstacles	**10**	**10**
4	Frequency of curves	**10**	**10**

5	Intersections design and control	**10**	**4**
6	Road slopes and road bridges	**10**	**7**
7	Road width	**7**	**7**
8	Road type	**7**	**7**
9	Road signage	**7**	**7**
10	Traffic volume and intensity	**7**	**7**
11	Nearby area description	**2**	**0**
12	Road service	**2**	**2**
Total		100	**85**
Road Safety		Excellent	

Fig. 2 Safety evaluation of Cairo-Suez road

Road Risk Studying Road Name: **Cairo-Suez Road**			
Item	**From Kilometer**	**To Kilometer**	**Remark(s)**
Curves roughness	128.86	128.68	Horizontal curves-Satisfactory
Road slopes	127.76	127.39	Raising slope-Satisfactory
Road signage	125.39	125.39	Traffic signs
Road signage	121.23	121.23	Painting planning
Intersections	102.67	102.67	U.T.
.	.	.	.
.	.	.	.
.	.	.	.
Road service	23.58	23.58	Parking Zone

Artificial obstacles	12.93	12.93	Natural bump
Intersections	3.03	3.03	Triple intersection

Fig. 3 Location of the physical features of Cairo-Suez road

Road Risk Studying Road Name: **Cairo-Suez Road**			
Item	**From Kilometer**	**To Kilometer**	**Remark(s)**
Curves roughness	101.97	101.23	Horizontal curves-Dangerous
Curves roughness	98.75	98.43	Horizontal curves-Dangerous
Curves roughness	92.42	92.06	Horizontal curves-Dangerous
Curves roughness	91.96	91.69	Horizontal curves-Dangerous
Curves roughness	87.83	87.47	Horizontal curves-Dangerous

Fig. 4 Location of the dangerous horizontal curves of Cairo-Suez road

Comparing the Routes Between Cities From City: **Cairo** To City: **Port Said**					
Route Number	**Road Name**	**From City**	**To City**	**Safety (%)**	**Length (km)**
1	Cairo-Suez Suez-Ismailia Ismailia-Port Said	Cairo Suez Ismailia	Suez Ismailia Port Said	82.28	291
2	Cairo-Ismailia Ismailia-Port Said	Cairo Ismailia	Ismailia Port Said	80.27	196
3	Cairo-Alexandria Tanta-Mahla Mahla-Mansoura Mansoura-Damietta Damietta-Port Said	Cairo Tanta Mahla Mansoura Damietta	Tanta Mahla Mansoura Damietta Port Said	78.29	366
Best Route **Auxiliary Route**			Route No. 1 Route No. 2		

Fig. 5 Main and auxiliary routes between Cairo and Port Said

Road Risk Studying
General instructions for the driver 1 - Ensure that the car is in good condition according to the car inspection form 2- It is necessary to wear a seat belt. 3- The speed should not exceed 70 km/hour on highways. 4 - The speed does not exceed 60 km/hour on the agricultural road. 5 - Go on curves slowly and carefully, according to the speeds indicated for each curve. 6- Stand to rest when feeling tired or exhausted. 7- Stop to rest every 5 hours while driving long distances. 8 - The necessity of adhering to the mentioned itinerary.

9 - Immediately inform the warehouse of any obstacles or changes in the route.				
Departure City: **Cairo** Arrival City: **Port Said**				
Main Route				
Road Name: **Cairo-Suez Road** From City: **Cairo** To City: **Port Said**				
Item	**From Kilometer**	**To Kilometer**	**Remark(s)**	**instructions**
Road slopes	115.83	115.37	Raising slope-Dangerous	Slow down - be careful
Curves roughness	101.97	101.23	Horizontal curves-Dangerous	Speed does not exceed 30 km/h
.	.	.	.	.
Road Name**: Suez-Ismailia Road** From City: **Suez** To City: **Ismailia**				
.	.	.	.	.
.	.	.	.	.
Road Name**: Ismailia-Port Said Road** From City: **Ismailia** To City: **Port Said**				
.	.	.	.	.
.	.	.	.	.
Auxiliary Route				
Road Name: **Cairo- Ismailia Road** From City: **Cairo** To City: **Ismailia**				
.	.	.	.	.
.	.	.	.	.
Road Name: **Ismailia-Port Said Road** From City: **Ismailia** To City: **Port Said**				
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Fig. 6 Driver report

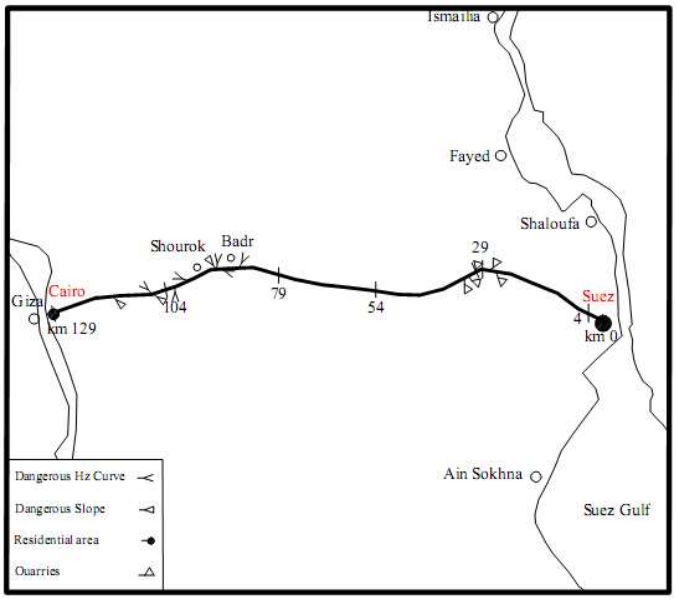

Fig. 7 Location of Obstructions on Cairo-Suez Road

In the literature, there are several studies for road safety but unfortunately they all posses some or all of the following limitations:

(1) Each study individually was developed for a specific task for example studying the factors affecting the road safety [3,4,6-8], surveying some physical features of roads [9], and constituting of data base for only pavement condition for a limited number of roads [13,14].

(2) No study for assignment of the percentages for highway safety factors or studying the effect of each factor on the whole safety of the road.

(3) No study for comparing the routes connecting cities to find the main and auxiliary routes based on the road safety percentage.

(4) No software for road safety assessment with the above mentioned capabilities of RSA is available in the literature or in the market.

The results of the case study and the above discussion make it abundantly clear that RSA software is able to effectively supply a system that is efficient, accurate, and cost-effective for road safety studies and numerous other potential applications. Additionally, RSA provides a window-driven system that, after a brief training period, can be utilized by non-technical users.

4. Conclusions

The present work has added the following new dimensions that had not been available:

(1) Developing software to provide the users in Egypt with:

- complete data to enhance roadway safety and maintenance, in corporation with academic centres of transportation, highway experts, highway safety organizations, and other safety and road design programs.

- best selection of the main and auxiliary routes between the departure and arrival cities that helps and warnings the truck drivers.

(2) Constituting a database for physical conditions of some highways (total of 8,000 km) in Egypt that may be essential for the Geographic Information System (GIS), transportation and highway communities.

(3) Developing window-driven software with Arabic interfacing language to facilitate its execution to non-technical users.

RSA Software is a powerful tool for minimizing the risk of accidental occurrence and assisting new truck drivers running on the roadway to recognize obstructions along the specified route.

The developed database is a helpful tool for current research and for future applications using GIS. Furthermore, the developed software provides an affordable tool to researchers in the universities and academic centers.

5. Recommendations

(1) This research work should be sponsored and supplemented by the mentioned official responsible organizations to provide training for truck drivers on the developed software.

(2) The conclusions of this work should be implemented and put through the documentation system of the official transportation organizations and conditional clauses should be applied to get driving licenses for heavy truck drivers.

(3) The developed software may not be flexible because its operations are limited to the pre-programmed functions that may be modified only by the developer of this software. Three methodologies are suggested to improve the overall efficiency of implementing the constituted database and widen the application fields of the proposed system:

- Developing a GIS-based system to improve the interaction between the user and the software, to make it easier to choose locations for cities and routes, and to provide additional geographic analysis of the route.
- Developing Expert system/knowledge-based system for diagnostic of roads, and suggestion of solution(s) and cost purposes.
- Interfacing the mobile track systems for real time helping and warning the drivers to increase the efficiency of these systems.

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