"Establishment of Management System for Maintenance Activities in Urban Road Network" Case study in Benghazi – Libya

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ABSTRACT

The City of Benghazi, like many cities throughout Libya, is facing a monumental challenge in dealing with aging infrastructure. For pavements in particular, it is observed that they have been deteriorated because of misuse, overuse and mismanagement. The current management system at the Municipality of Benghazi is not tracking down the damages that occur during the design life of the pavement, which makes the decision for the roads maintenance is late or perhaps entirely absent.
In many cases in Benghazi, maintenance needs and priorities have not been determined and maintenance has been inadequate which led to minor and major deterioration to many roads which now need minor and sometimes major reconstruction rather than ordinary maintenance operations. Moreover, maintenance activities were performed as a result of user complaints and usually in a random way without planning or management. This type of maintenance practice leads to inefficient spending to maintenance budgets. In conclusion, there is no defined system in implementing maintenance strategies.
Therefore, This study aims to initiate a Pavement Maintenance Management System computer program (PMMS) for the city of Benghazi through which it provides a systematic process of maintaining, upgrading and operating the city pavement network and tools to facilitate a more flexible approach that can enable the management team to perform tasks in better, more economically, effectively and of higher quality manner. A computer program has been presented to facilitate the decision making process for the city of Benghazi pavements.
A pavement maintenance management system program has been designed within the framework of this study to be applied in the city of Benghazi. This program can be used to provide a very accurate data about the current situation of the roads network, maintenance required and maintenance cost. The budget needed would be then allocated in a proper and precise way. The program was also tested by a data collected on a number of arterial roads in the city network with road sections of about (27.53) km length. This data was entered into a computer program which analyzed the overall situation and give different analytical results such as the type of maintenance required, the cost, and the priority of maintenance per different sections.

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1. BACKGROUND

Roads are among the most important public assets in many countries. The quality of life, the health of the social system and the continuity of economic and business activities depend to a large extent on the quality and efficiency of roads.
Traditionally, the core of engineering activity in the roads sub-sector has consisted of the design and construction of new roads. Increasingly, however, road networks have been substantially completed in many countries. the focus of attention is moving away from building new roads to maintaining the existing roads. However, road maintenance is a fundamentally different process from that of building a new road. Construction activity usually involves projects with a defined start and finish; conversely, maintenance is continuous. Whereas design and construction are dominated by engineering issues, maintenance is essentially a management problem. Pavement maintenance programs can reduce the rate of deterioration, prolong life of pavements, reduce vehicle operating cost and ensure safety to road users. Generally, pavement treatment strategies can be ranged from: sealing, routine patching, overlaying, to reconstruction as a last option.
Recently, the concern of highway agencies has shifted from focusing on methods and techniques of performing maintenance to managing maintenance activities. Studies indicated that 60% of a highway network would reach the stage of functional failure unless Pavement Maintenance Management Systems (PMMS) are implemented (1). For that reason, many highway agencies developed their own PMMS to improve the efficiency of decision making, provide feedback on the consequences of decisions, control the rate of deterioration, and limit maintenance costs.

2. THE CITY OF BENGHAZI

Benghazi roads network played an important function in activating the development of new areas. Huge achievements in the road infrastructure have been done during the past Thirty years in Benghazi city. The city of Benghazi is considered the capital of the north east of Libya and the second largest city in the country with a population approaching 1,166,992 people in the year 2006 (2). Benghazi is a vital city which represents major economic centre of different commercial and industrial activities. There are more than 1,500 kilometers of paved roads in addition to unpaved roads. Road construction in the city since 1974 has been

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carried out by specialized international foreign contractors, using local materials in pavement construction and imported materials for other works. Although, Benghazi's highway network was constructed at a very high standard, but, road authority has not been interested to preserve these investments. Benghazi city is suffering from difficulties in developing an adequate maintenance management system for its existing roads network. Insufficient funds, shortages of skilled and experienced staff or lack of regular training to update the staff leads to difficulties in carrying out planning and management of the maintenance requirements of the city highway network. Because the highway agencies in Benghazi do not use computerized systems, it is necessary to start with a simple system of maintenance decisions that suits the essential current needs of these agencies. This study provides a simplified PMMS computer program that can be considered the first one that can be implemented in Benghazi City as well as in other cities in Libya. This programmed will store and analysie data, provide accurate information about the existing situation of the network, identify maintenance needs and cost, and allocate optimal budget.

2.1. Hierarchy of the City Road Network

The highway network in the city of Benghazi has been classified into four main categories according to: road location, traffic volume, and the road layout, by experts in roads and transportation, who were appointed by the Municipality of Benghazi to study the traffic and transportation characteristics of the city. Figure (1) and Table (I) present the Benghazi highway network and the different road categories.

2.2. Existing Road Condition in Benghazi

The roads in general are in bad condition and need immediate solution to be restored to their serviceable condition. The major problem within the highway network is water, leaking from sewers or through unsealed cracks, and weakening the ground underneath. The roads can be classified into four existing conditions:

- Roads in good condition
- Roads in acceptable condition
- Roads in bad condition
- Roads in failed condition

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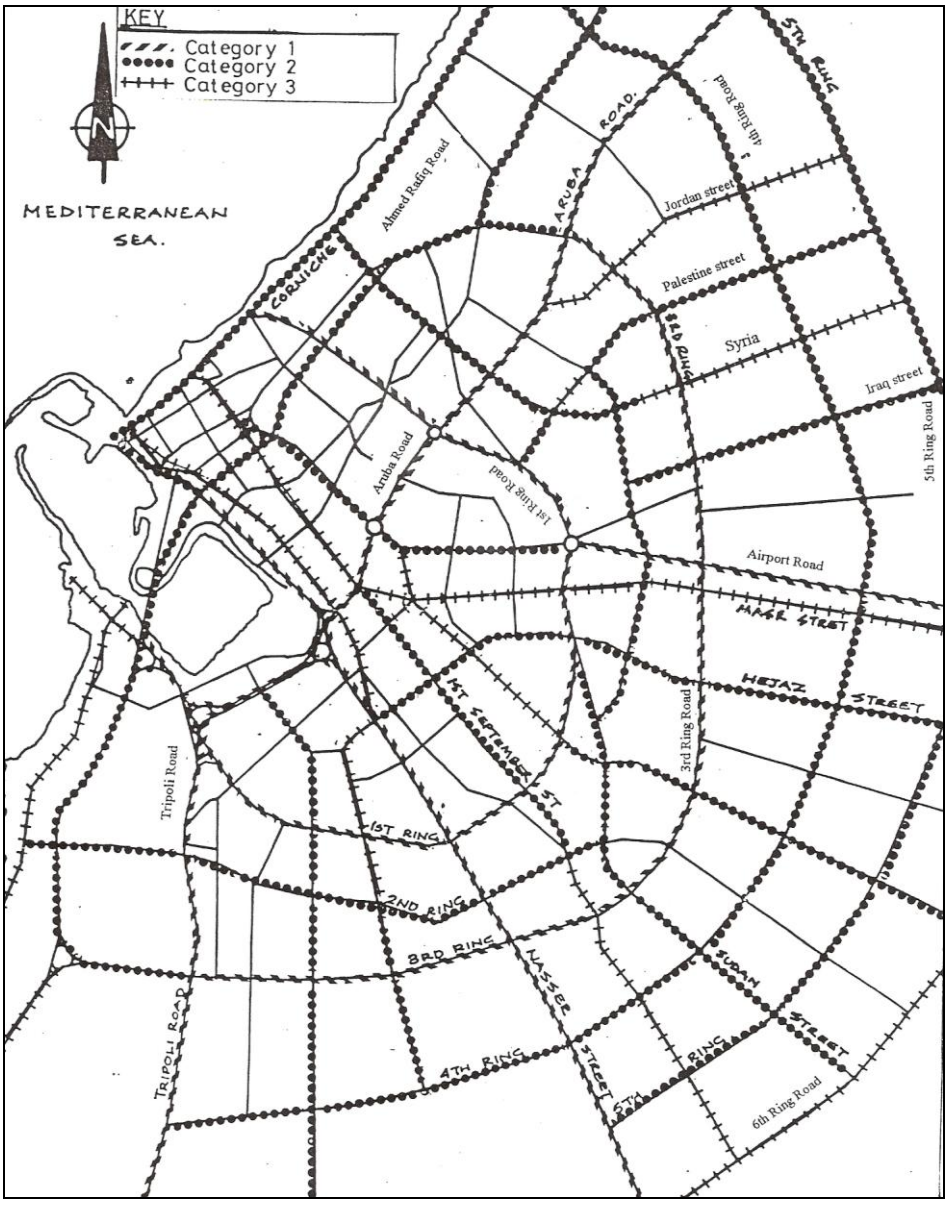

Figure 1 - Road hierarchy in Benghazi network

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Table I - The City of Benghazi network road hierarchy

Road category	Number of lanes per carriageway	Lane width (m)	Speed limits Km/hr	Median m	Side walk m
Category I roads	Two	7.65	80 km/hr	5.5	2.5
	Three	11.65		5.5	2.5
Category II roads	Two	7.65	60 km/hr	5.5	2.5
	Three	11.0		5.5	2.5
Category III roads	Two	7.0	50 km/hr	3.5	2.5
Category IV roads	One	2.5	40km/hr	N.A.	2.0

3. DEVELOPMENT OF PAVEMENT MAINTENANCE MANAGEMENT SYSTEM COMPUTER PROGRAM

The computer program has been rewritten in Visual Basic.net and uses Microsoft Access tables to store data, both in order to be compatible with current operating systems. The PMMS computer program can provide answers to questions related to each one of the following:

- Pavement Condition

Which sections are with failed, poor, good conditions, etc?

- Pavement Maintenance

Which sections require localized maintenance, global maintenance, overlaying or reconstruction?

- Treatment Cost

What are the treatment cost of each section, each road or overall?

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3.1. Proposed Benghazi PMMS Computer Program Components

Generally, a PMMS consists mainly of two major components:

- An information system to collect, store and manage data and information.
- Decision support system to process and analyze these data for decision making.

The proposed PMMS components depend mainly on the following two management softwares:

- Microsoft Access

It is used as a management tool to store the inventory information, distress data, treatment and cost data, and Pavement Condition Index (PCI) values. It also allows retrieving, displaying, and updating data.

- Visual Basic. Net

It is used as a modeling tool to help in evaluating the city pavements condition and to provide information and decisions about the city maintenance needs, costs, and priorities. However, the proposed PMM computer program uses the Access database format and consequently, the information system is contained while it also has the capability to perform complete analysis. Therefore, the decision support system is also included within this system.

3.2. PMMS Computer Program Organization

The main features of the program are accessible from six buttons arrayed across the top of the computer program Desktop. The buttons have been arranged to reflect the logical sequence of pavement maintenance management. Moreover, clicking one of the buttons, user launches one of six principal program components. These components are:

- Inventory Data Screen (Basic Operations) :- Inventory data entry (see Figure 2).

- Work Information Screen (Additional Field Data):- Work required and work history (see Figure 3).

- PCI Inspections Screen (Basic Operations):- Field inspection data entry (see Figure4).

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- Maintenance & Repair needs and costs Screen:-Maintenance and repair needs reports (see Figure 5).
- Priorities Screen:- Priorities report (see Figure 6).
- Reports Screen:- Program reports and summary chart (see Figure 7).

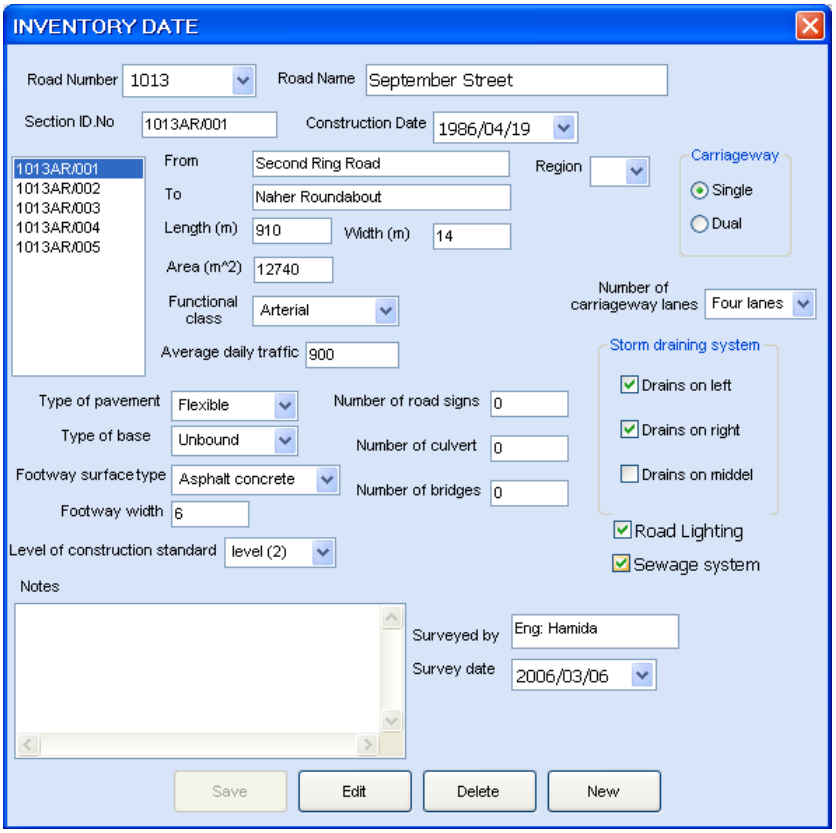

Figure 2 - The inventory data inter screen

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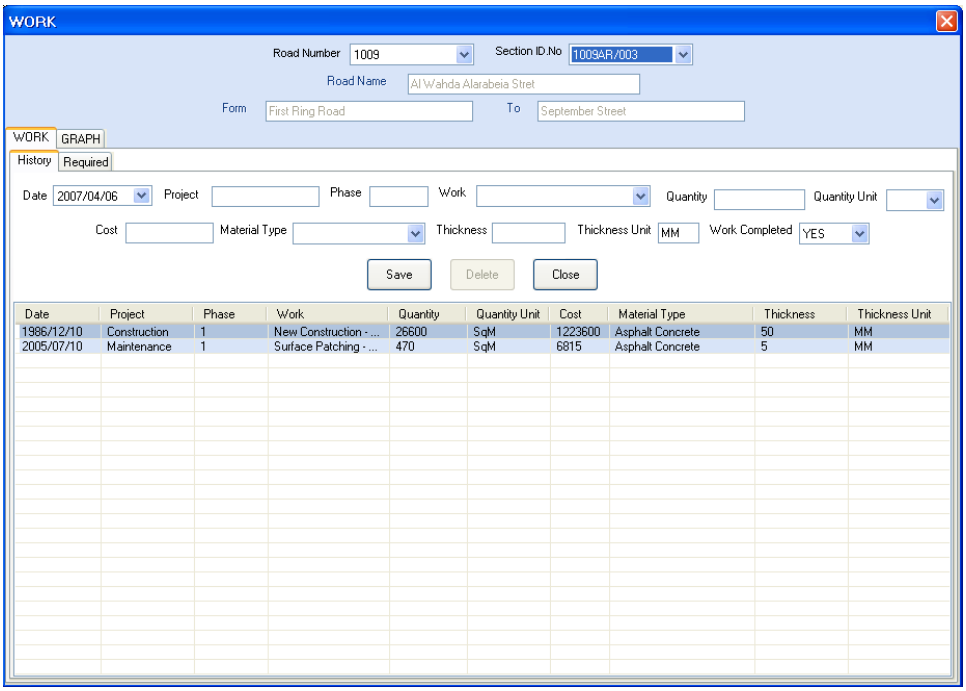

Figure 3 - The work information screen

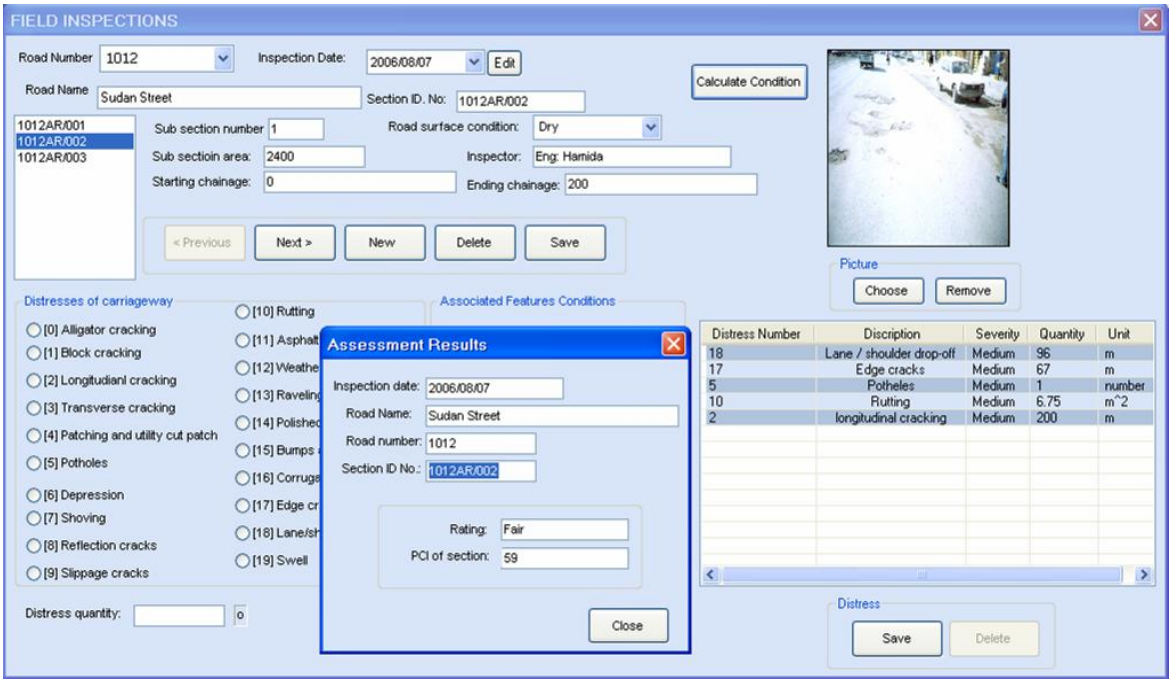

Figure 4 - The inspection data screen

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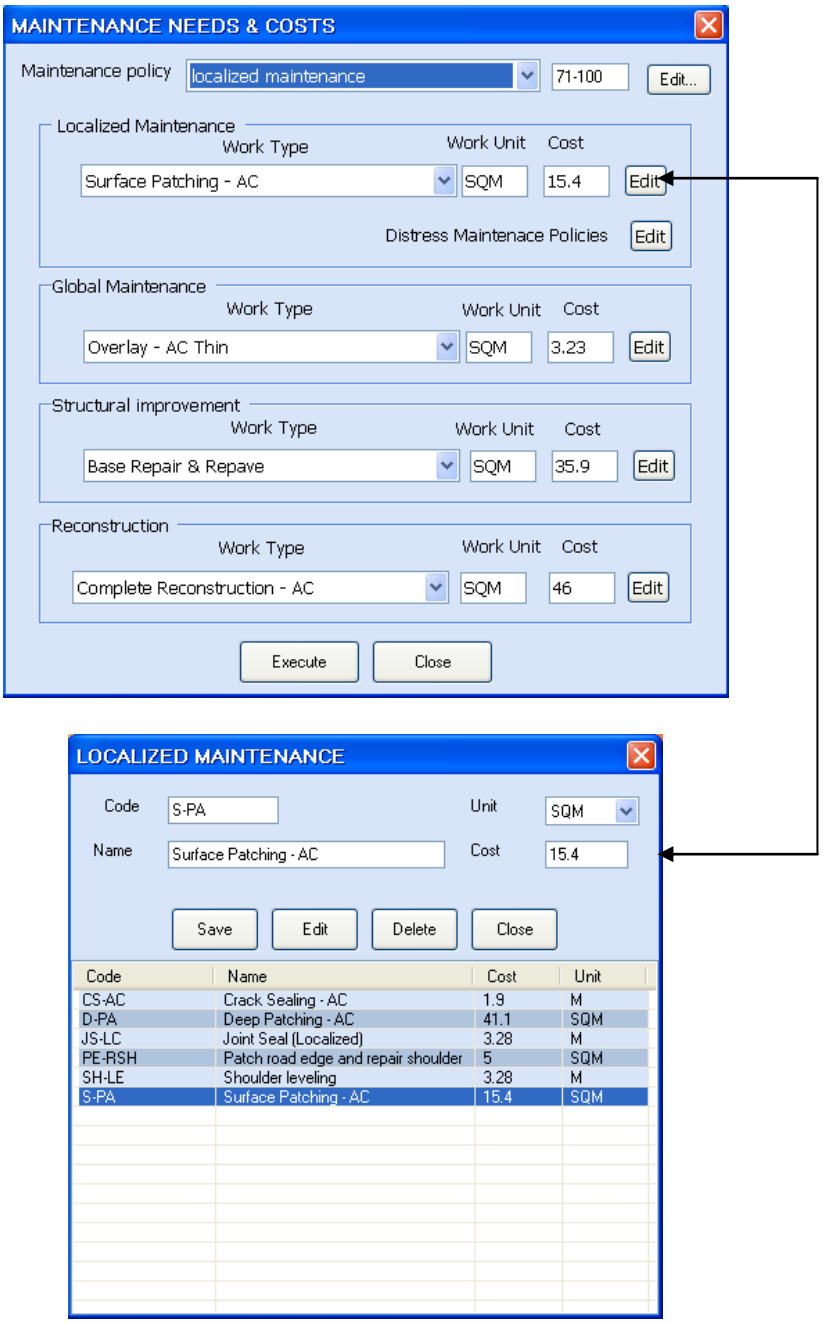

Figure 5 - The maintenance and repair needs and costs screen

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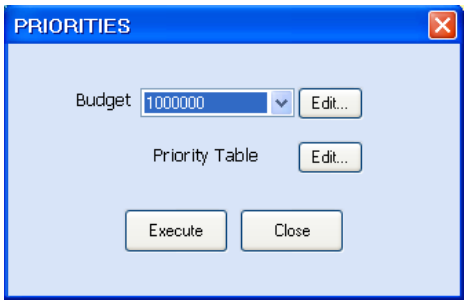

Figure 6 - The Priority screen

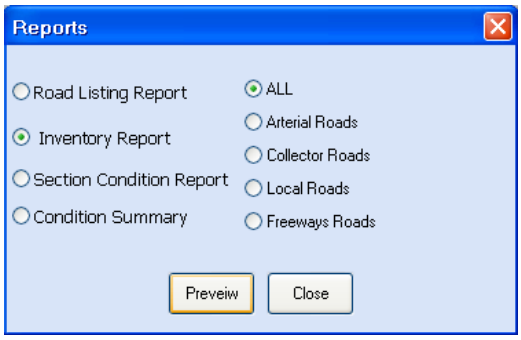

Figure 7 - The Program reports screen

3.3. Analytic Tools of Program

While the database is the "heart" of PMMS, data are not useful unless they are presented in a meaningful way. It is the role of analysis procedures to transform the raw collected data into products such as graphs, and reports that are helpful to decision makers. Analytic procedures in the proposed program are:

3.3.1. Calculating the pavement condition assessment

A fundamental component of any pavement maintenance management system is the ability to track pavement condition. PMMS program offers procedures that take the physical distresses data for a section of pavement and combined them into an overall pavement condition score. To assess pavement condition of each section, program uses the pavement condition index (PCI) as its primary standard. PCI provides a rating of the surface condition of pavement on scale from 0 to 100 (4).

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3.3.2. Determining the treatment strategy and cost

One of the most important benefits of the PMMS program is the ability to make a correlation between the network condition and its maintenance and repair needs. After having determined a PCI score for each section of the road, calculating a range that the score falls within will be needed to assist in selection a possible treatment.
Pavement treatment of section can be selected according to the range that the PCI of this section belongs to. The program allows the user to customize the PCI ranges. PMMS program also allows unit cost of each treatment type to be entered and this will be helpful in determining maintenance cost for each section.

3.3.3. Determining maintenance prioritization

After the condition of all network sections has been calculated and the treatment and cost determined, the application of a method for choosing a logical order to address the section is needed. The method of setting priorities which was suggested from TRRL Overseas Road Note 1 (3) considers a combination of section condition, functional classification, importance of the maintenance activity and traffic volume. This method can be the basis to determine priorities for Benghazi city pavement sections. A section that has lower number is ranked first.

4. APPLICATION OF THE PROPOSED PACKAGE IN SOME REAL LIFE CASES

The proposed program will be tested through field inspection of a number of road sections and consequently, get the results (reports) needed to define the maintenance needs, costs and priorities for these sections.
These results may help highway engineers in Benghazi in making proper decisions and will show them how consider the results as a methodology to divide funds efficiently.

4.1. Case Study

To analyze PMMS computer program, a necessary data collection was conducted to a part of Arterial roads of the city network that has been illustrated in Figure (1). The selected Arterial roads have approximately (27.5376) km of length. The total number of the sections

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is (31) sections. Arterial roads of the city network have been selected to be used as a case study for the following reasons:-

1. These roads have an economic and strategic importance because of the places they link.
2. Arterial roads are most liable to deteriorate rapidly because they carry out the heaviest traffic loads.
3. Sections of arterial roads covered different condition categories from good to failed.

4.1.1. Benghazi Highway Network Definition

For Benghazi pavement network system to be efficiently managed, it is broken down into small units, which are considered as the city streets and roads. Because a road does not always have consistent characteristics and thereby does not require the same maintenance and rehabilitation treatment throughout its entire length, therefore, it is divided into smaller manageable units (sections). Each section has been given a unique reference code using a combination of numbers and letters. The boundary between the two sections of a road in Benghazi network is defined according to one of the following factors:

1. A change in the number of traffic lanes.
2. A change in pavement or surface type.
3. A change in pavement width.
4. Roadway major intersections.
5. A change in traffic volume.

4.1.2. Network Data Collection

The data collection stage is considered one of the stages that need organization and good identification to achieve the objective of the program.
An inventory has been assigned to each road section consisting of its main characteristics.
The required inventory data which are collected for each street section includes:

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1. construction year (last surface).
2. Street name, and number.
3. Beginning and ending of the section.
4. Functional classification.
5. Number of lanes.
6. Pavement type.
7. length, width and area of the section.
8. Average Daily Traffic (ADT).

Collecting pavement condition information for the selected sections is the next step in the process of data collection. Due to the fact that there is no automated equipment for collecting data, a visual distress survey has been carried out for the defined sections. Each distress type, severity, and quantity has been recorded to be entered in a computer program for computing the PCI value.

4.1.3. PMMS Computer Program Outputs

After data collecting and storing, the data analysis operation started through the program. The various reports generated by the program are used to present the condition of the road sections, show what sections need maintenance, rehabilitation, and reconstruction and also show section treatment priority. The use of each report is outlined below.

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1. Condition summary report:- this report provides the user with an indication of network condition based on PCI scale (Figure 8).

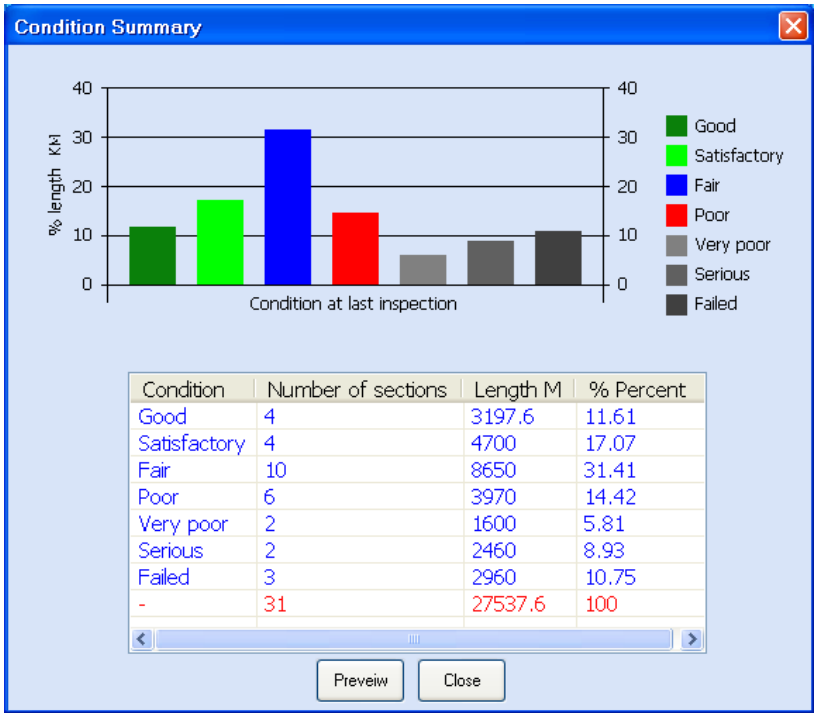

Figure 8 - Current Condition Summary Report

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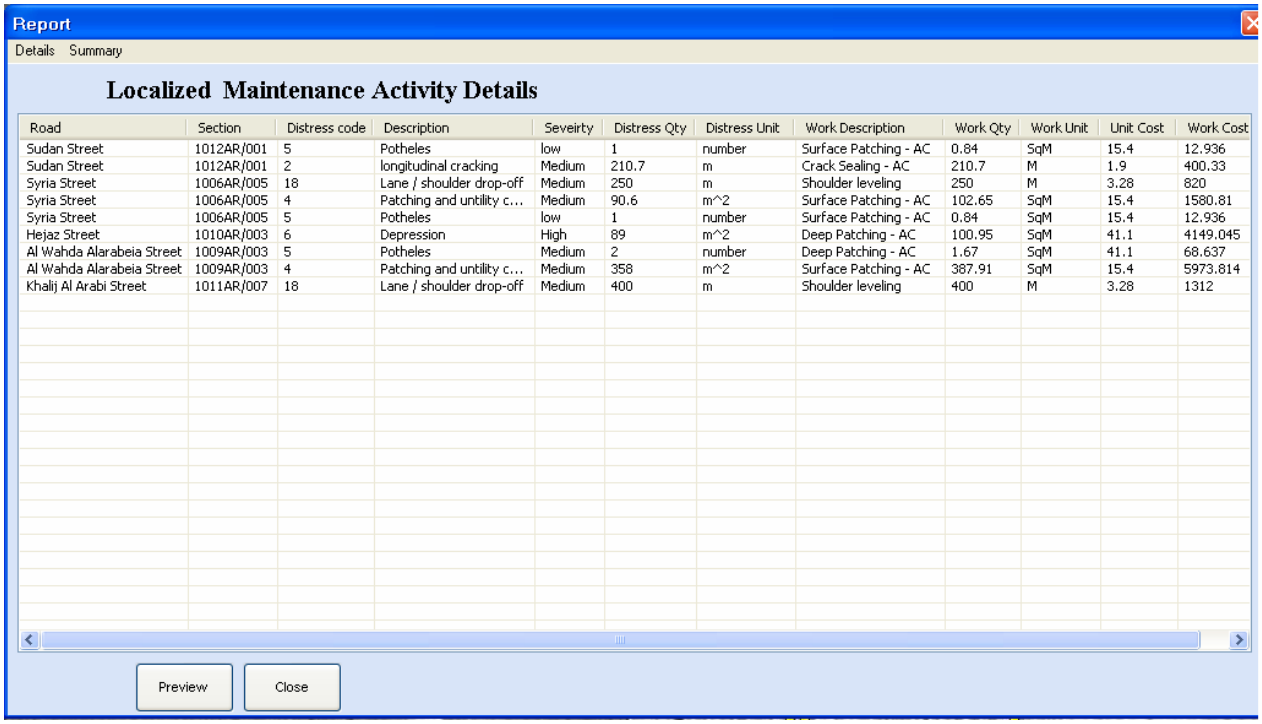
2. Localized maintenance activity details report:- This report can be used to estimate both the type of work needed, and the cost involved for the development of an annual work plan. This report uses the maintenance policy which is stored in the database and applies it to the distresses identified in the latest inspection (Figure 9).



Road	Section	Distress code	Description	Seveirty	Distress Qty	Distress Unit	Work Description	Work Qty	Work Unit	Unit Cost	Work Cost
Sudan Street	1012AR/001	5	Potheles	low	1	number	Surface Patching - AC	0.84	SqM	15.4	12.936
Sudan Street	1012AR/001	2	longitudinal cracking	Medium	210.7	m	Crack Sealing - AC	210.7	M	1.9	400.33
Syria Street	1006AR/005	18	Lane / shoulder drop-off	Medium	250	m	Shoulder leveling	250	M	3.28	820
Syria Street	1006AR/005	4	Patching and untility c...	Medium	90.6	m^2	Surface Patching - AC	102.65	SqM	15.4	1580.81
Syria Street	1006AR/005	5	Potheles	low	1	number	Surface Patching - AC	0.84	SqM	15.4	12.936
Hejaz Street	1010AR/003	6	Depression	High	89	m^2	Deep Patching - AC	100.95	SqM	41.1	4149.045
Al Wahda Alarabeia Street	1009AR/003	5	Potheles	Medium	2	number	Deep Patching - AC	1.67	SqM	41.1	68.637
Al Wahda Alarabeia Street	1009AR/003	4	Patching and untility c...	Medium	358	m^2	Surface Patching - AC	387.91	SqM	15.4	5973.814
Khalij Al Arabi Street	1011AR/007	18	Lane / shoulder drop-off	Medium	400	m	Shoulder leveling	400	M	3.28	1312

Figure 9 - Localized Maintenance Activity Details Report

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3. Maintenance and repair by section reports:- Figures (10,11,12,13) respectively, present the number of sections that need to be localized maintenance, global maintenance, structural improvement and reconstruction , they also show the area, the condition index, and the cost of section.

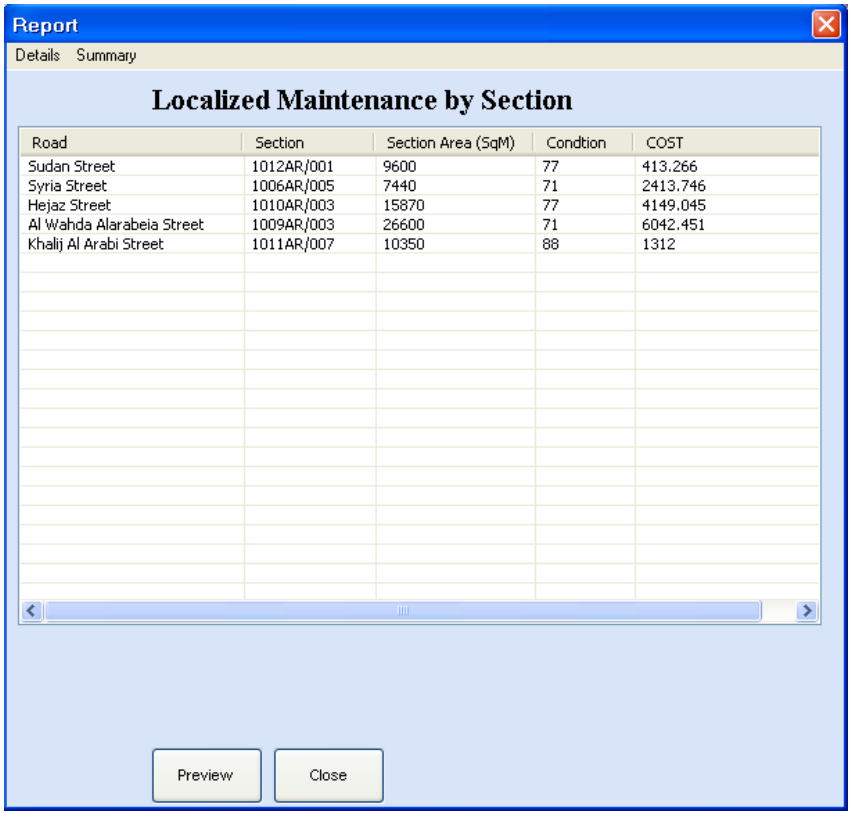

Figure 10 - Localized Maintenance by Section Report

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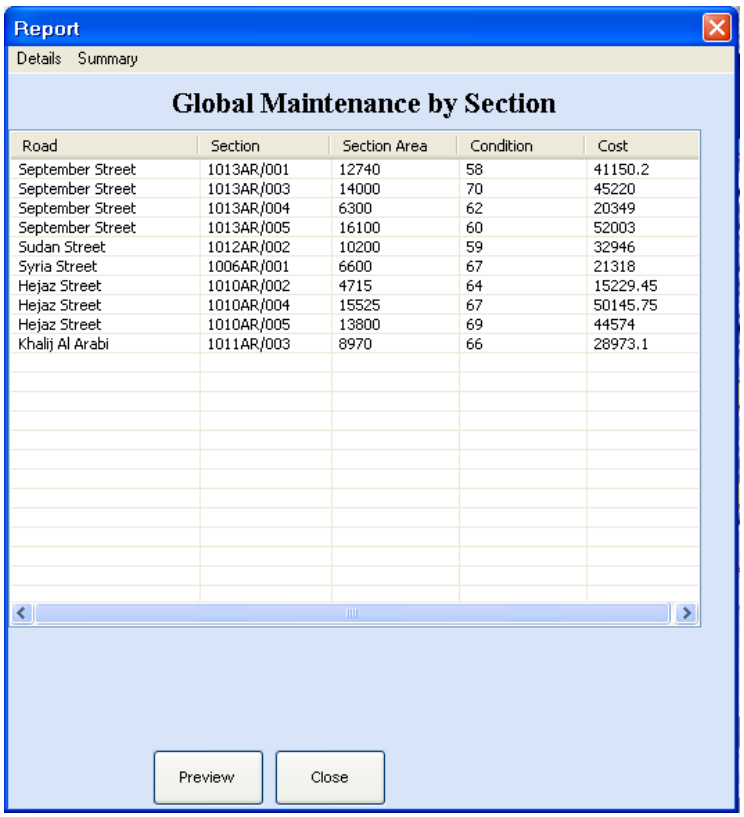

Figure 11 - Global Maintenance by Section Report

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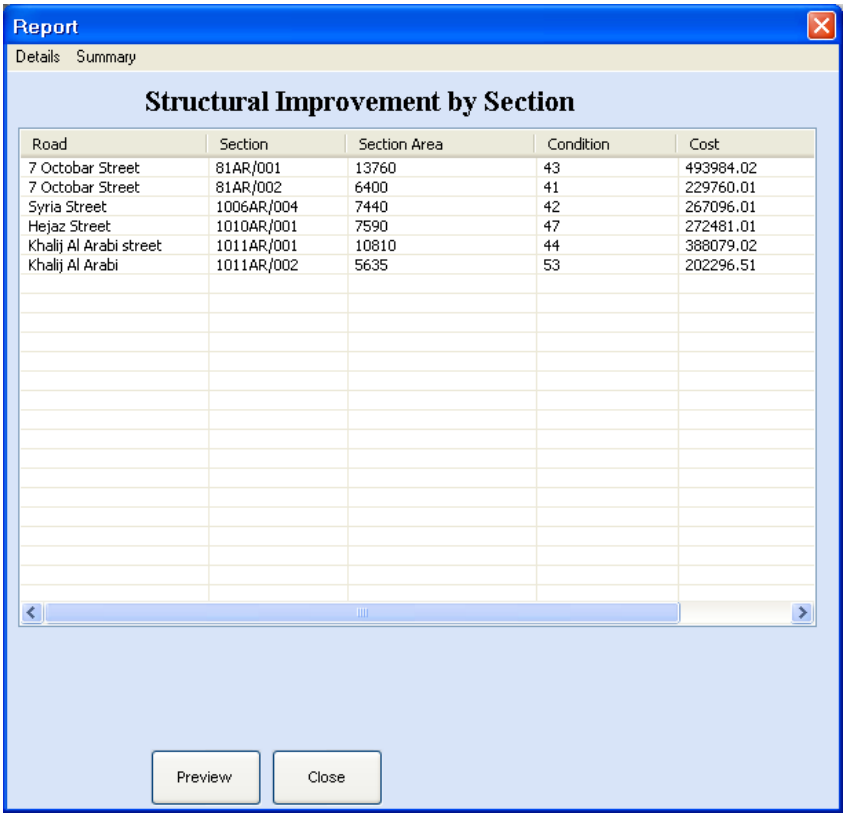

Figure 12 - Structural Improvement by Section Report

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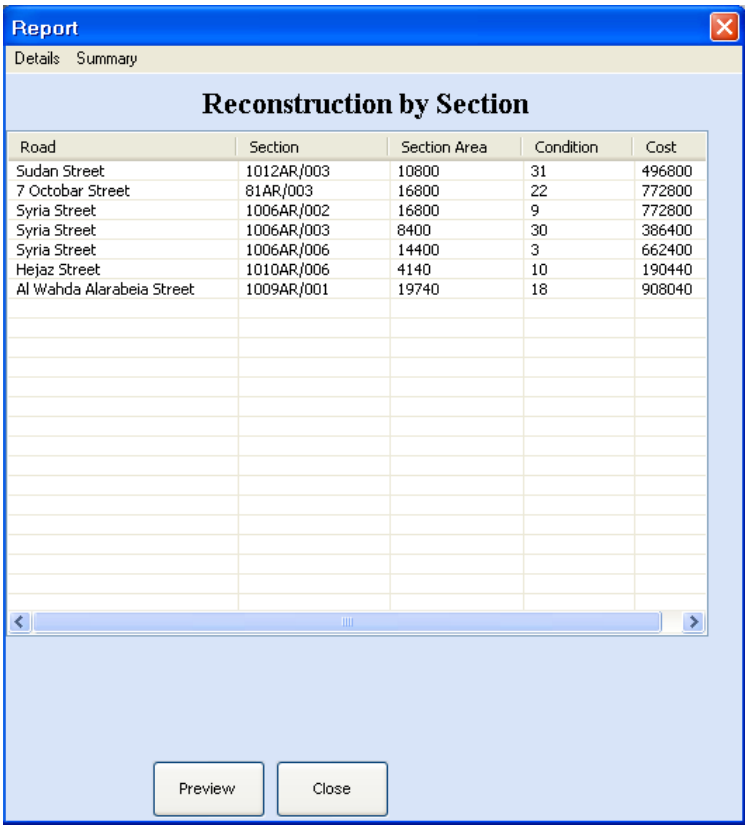

Figure 13 - Reconstruction by Section Report

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4. Work type Summary report:- This report shows the total quantity, and the total cost of each activity for entire sections which need the localized maintenance (Figure 14) .

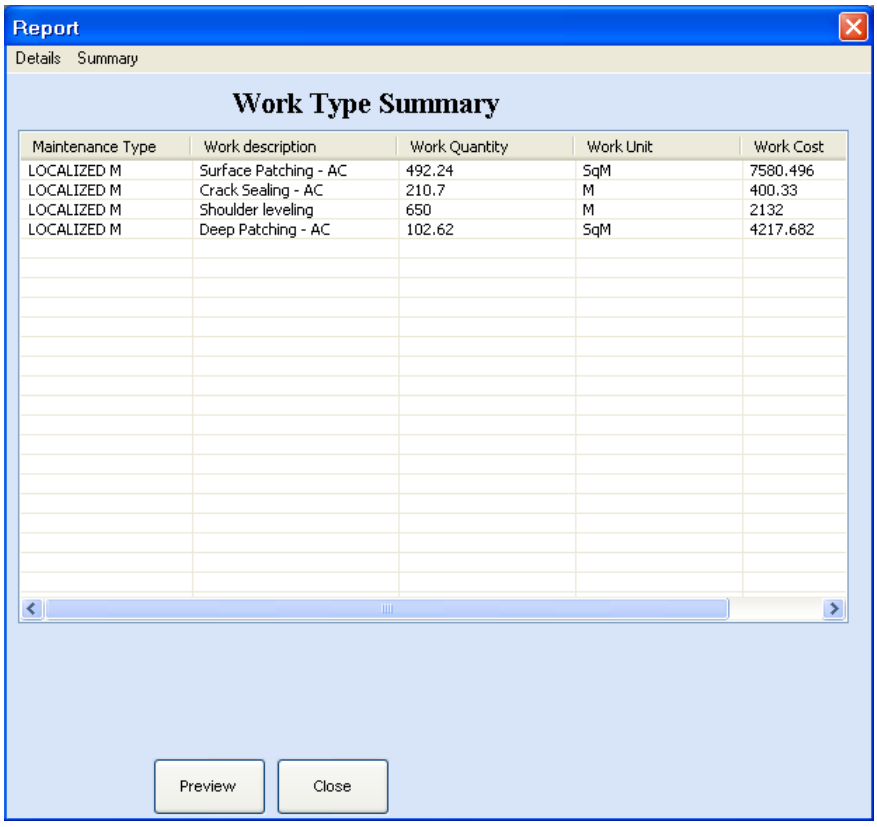

Figure 14 - Work Type Summary Report

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5. Total Funded report:- This report shows how much money should be spent in each maintenance and repair category and the total cost needed to completely maintain and repair the whole area (Figure 15).

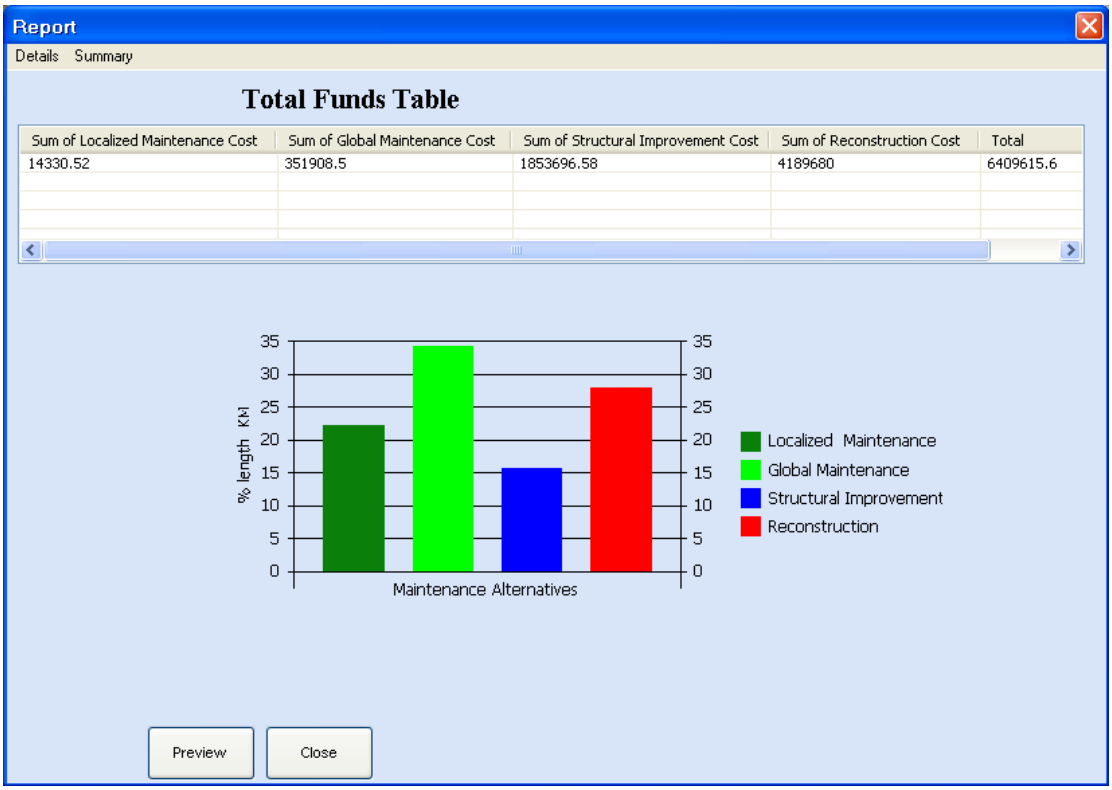

Figure 15 - Total Funded Report

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6. Priority report:- This report presents sections of roads in order of priority, the area and cost of each section. Priority is based on the estimated budgeting value introduced in the program (Figure 16).

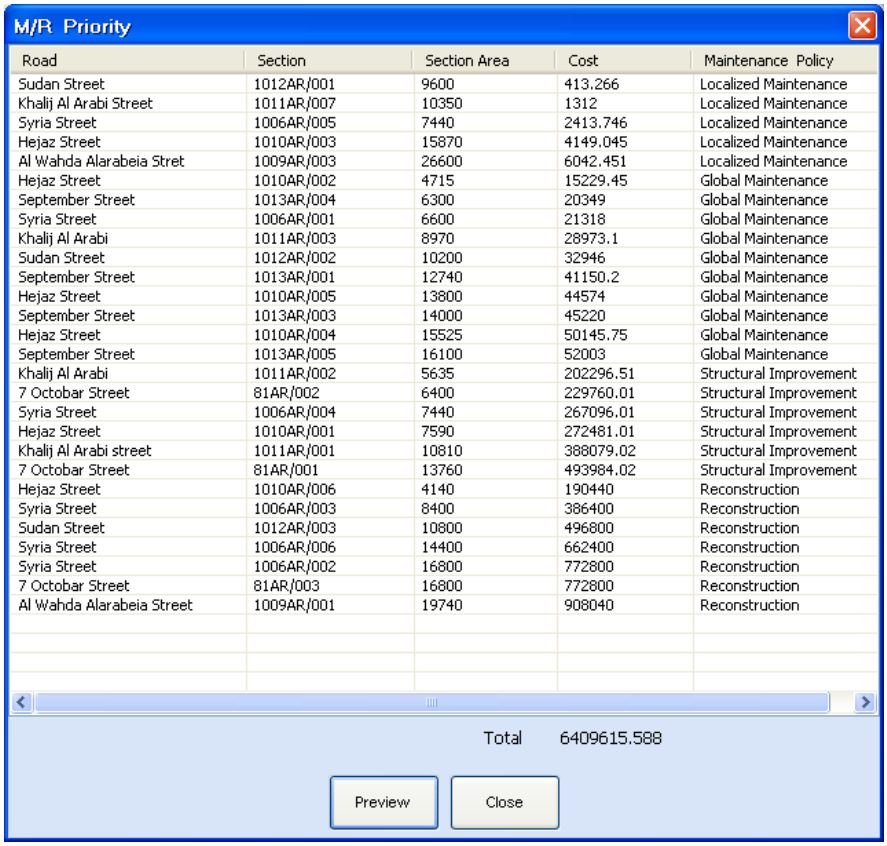

Figure 16 - Priority Report

5. A SUMMARY OF CONCLUSION

The principal objective of the study was to develop a pavement maintenance management computer program for Benghazi city in which it provides a systematic process of maintaining, upgrading and operating the city pavements and tools to facilitate the management process of Benghazi pavements.

The problems and obstacles that militate against establishing proper maintenance management system in Benghazi city are extensive. These problems are poor management,

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incorrect assessment in the budget and the priorities, lack of skilled and qualified people at all levels, inadequate assignment of responsibilities and duties, the conflict in the allocation of funds between maintenance and construction, absence of regular training programs, and reluctance of engineers and planners in adopting the computer technology .

Therefore, for the sake of preserving the highway network in an acceptable condition, efforts must be made in all aspects of road maintenance for the next few years using available resources. The computer program developed in this study can be used as a helpful and efficient tool for highway engineers in Benghazi city.

The input screen is set up to clearly guide the user on what information is required and how it is to be inserted into the database. The output from the program is designed to be clear and understandable to aid the engineer in making instant decisions.

The program provides database on selected roads. This database contains information relating to road inventory, pavement condition and works history. It shows current pavement condition ratings, estimates budget requirements, makes a recommended list of maintenance, rehabilitation and reconstruction projects, and suggests priorities for spending.

6. RECOMMENDATIONS

Listed below are general and specific recommendations, which the Benghazi Municipality could use to implement the maintenance management system:

1. The comprehensive highway maintenance management system must be established to protect the network from rapid deterioration.

2. The budget required for maintenance activities should be sufficient to cover all works.

3. The continuous monitoring for road network condition by sophisticated equipment are needed to make effective maintenance decision.

4. Establishing regular training programs to all levels to encourage engineers, planners and technicians to adopt and employ the high technology systems in maintenance management.

5. There is a great need of long-term commitment of officials, pavement managers, public and road users towards the conservation and protection of Benghazi pavement assets.

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6. Future developments including a simple performance model to predict pavement condition for Benghazi road network should be considered.

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