

DEVELOPMENT OF A PAVEMENT MAINTENANCE MANAGEMENT SYSTEM (PMMS) FOR GAZA CITY

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(PMMS)

(Micro PAVER)

(GeoMedia)

(GIS)

PMMS

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Abstract Gaza City, like many cities throughout Palestine, 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 reveals that the system used is not flexible enough to reflect changing conditions and is poor to assist in decision making during the design life of pavements.

This study aims to initiate a Pavement Maintenance Management System (PMMS) for Gaza City in which it provides a systematic process of maintaining, upgrading and operating the City pavements and tools to facilitate a more flexible approach that can enable to perform tasks better, more economically, effectively and of higher quality.

A system has been presented to facilitate the decision making process for Gaza City pavements. It is based mainly on the direct integration between Micro PAVER as a pavement software and GeoMedia Professional as Geographic

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Information System (GIS) software in order to fully exploit the capabilities of each individual package. Also, a simple Graphical User Interface (GUI) has been developed in which it contains user-friendly menus that can help in presenting PMMS results and consequently, to justify the decisions made.

A case study zone of about 20 km length of roads was inspected to analyze the proposed PMMS. Condition analysis and decisions were performed to determine maintenance needs, budgets, priorities, etc.

Key Words: Gaza City, PMMS, GIS, Micro PAVER, GeoMedia Pro.

1. Introduction

There is no doubt that the quality and efficiency of roads affect the quality of life, the health of the social system and the continuity of economic and business activities. Deterioration and catastrophic failure of these roads may occur because of aging, overuse, misuse and/or mismanagement. Timely 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.

PMMS can be defined as a scientific tool for managing the pavements so as to make the best possible use of resources available or to maximize the benefit for society. Therefore, PMMS can be used in directing and controlling maintenance resources for optimum benefits [1].

In most countries, the pavement network constitutes one of the largest community assets and is predominately government-owned. A PMMS provides means to manage pavement maintenance expenditure more economically and efficiently. Nowadays, Pavement Maintenance Management Systems are becoming more widespread throughout the world, not only in highway applications but also airport applications [2, 3, 4]. A strong need to gradually introduce new technologies like Geographic Information System (GIS), Global Positioning System (GPS), work scheduling, reports and inventory management will enable the highway agencies to perform tasks better and of higher quality [1].

In Gaza City, good efforts under the supervision of the author were performed for evaluating individual sections of pavement network through graduate projects conducted in the Islamic University of Gaza. Because of non existence of previous studies to initiate a PMMS in Palestine, it is necessary to introduce a PMMS that takes into account the technologies used in developed countries. This paper provides a simplified PMMS that can be considered the first one that can be implemented in Gaza City as well as in other cities in Palestine.

1.1 Current Management

The Department of Road Maintenance in Gaza Municipality is responsible for performing routine and periodic maintenance activities for the City pavements. The available resources at the Department in terms of its technical skills, human resources and the quantity and condition of equipment should form the backbone for its capability to carry out the road maintenance and rehabilitation programs. It is observed that the current resources (personnel and equipment) at the Department need to be updated and can not efficiently help in performing maintenance activities. The Department considerably suffers from budgeting constraints since its financial resources are based mainly on external funds. These funds are generally presented in terms of materials and equipments. The Department policy depends on the application of minimal maintenance to await total road deterioration before new construction is required. This policy requires a larger amount of budget but at fewer intervals. Experience shows that the policy of application of periodic maintenance at specified condition levels is more profitable for society and easier to manage although it requires a larger budget but at less often intervals.

1.2 Study Problem

Gaza City has a great importance for its historical, political, and economical role. In Gaza City, there are several universities, ministries, international organizations and other institutions. Consequently, it attracts heavy traffic volumes as well as different types of transportation means. Gaza City is also facing a great challenge in dealing with an aging infrastructure. For pavements in particular, it is sought that many streets were built 20 or 30 years ago and they are near the end of their economic life. As a developing city, Gaza City pavements have the following current threats:

- Increase rate of deterioration. (pavements deteriorate fast)
- Overloading of vehicles. (no commitment with the legal loading)
- Rapid traffic growth. (high increase of vehicle ownership)
- Poor maintenance. (improper materials, wrong implementation, etc)
- Improper design and implementation.
- Israeli occupation (direct and indirect effects)
- Limited resources (geometry, funds, equipment, materials, etc)
- Insufficient information for decision-making.
- Inefficient current traditional management system.

In addition, a future challenge will face the pavements in the city. Construction of Gaza Sea Port requires a good maintained road network for rapid, safe and comfort movements of people and goods. It is expected that

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heavy axle loading generation will increase causing more deterioration of Gaza pavements. The traditional maintenance system that is currently in use in Gaza Municipality reveals that:

- There is a lack of documentation.
- There is no use of database programs in storing and processing the system data in the Road Maintenance Department.
- The system is not flexible enough to adjust work plans and schedules to reflect changing conditions.
- The system is poor to assist in making decisions.

From the above mentioned points, there is a strong need for a comprehensive PMMS that involves:

- *Databases*: facilitate the physical data of the system to be managed and allow data storing, retrieving, displaying, updating and getting queries.
- *GIS Capabilities*: allow representing the inventory data and reporting in a geographic format.
- *Evaluation System*: assists in making timely cost effective decisions related to the maintenance and rehabilitation of pavements.
- *Modeling System*: provides information about maintenance needs, costs, priorities, etc.

1.3 Study Objectives

While developing a PMMS for Gaza City, the following objectives are to be determined:

- Constructing a suitable database for the maintenance works of Gaza City pavements.
- Selecting an evaluation system for these pavements.
- Integrating Micro PAVER with GeoMedia professional software to review, interpret and evaluate data for supporting decision made.
- Developing software for facilitating the management process of Gaza pavements.

2. Proposed Gaza PMMS Components

Generally, a PMMS consists mainly of two major components [5]:

- 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 three management software:

1. Micro PAVER

It is used as a pavement management tool to store the inventory information, distress data and Pavement Condition Index (*PCI*) values. It helps in evaluating the city pavements. Condition assessment can be performed easily and rapidly by using this software.

2. GeoMedia Professional

It is used as a GIS tool that offers complete set of spatial analysis and provides a high-performance decision support.

3. Visual C++

It is used as a modeling tool and to provide a simplified Graphical User Interface (GUI) that presents information and decisions about the city maintenance needs, queries, treatments, budgets, etc.

Clearly, the above components use the Access database format and consequently the information system is contained while they also have the capability to perform complete analysis. Therefore, the decision support system is also included within this system.

3. Gaza PMMS Architecture

Gaza PMMS constitutes a computer environment in which Micro PAVER, GeoMedia Professional and GUI has been integrated for supporting:

- Maintenance works performing.
- Management of maintenance operations.

Each one of Gaza PMMS software components provides functionalities for supporting the concrete tasks of the PMMS process. The overall system architecture is presented in Figure (1).

Gaza PMMS depends on the direct integration between Micro PAVER and GeoMedia Professional programs. Inspection data is entered and processed by Micro PAVER to assess pavement network. Results are saved in the PAVER database and then connected into GeoMedia through the Warehouse Connection Wizard. Join of PAVER and GeoMedia databases is established based on the similar section ID in both. This will enable data and condition results after each periodic inspection to be updated into the GeoMedia database. A simple GUI, named PMMS, has been developed to help in presenting the PMMS results and to justify the decisions made, Figure (2). This GUI contains user-friendly menus that can call Micro PAVER and GeoMedia files. It also has capabilities to execute rapid queries and perform different types of reporting. In addition, reports can be exported in different types of document format (PDF, Excel, Word, etc). With this tool, the GUI can provide answers to questions related to each one of the following:

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1. Pavement Type
Which sections are paved, unpaved or closed?
2. Pavement Condition
Which sections or branches are with failed, poor, excellent conditions, etc?
3. Pavement Maintenance
Which sections require routine maintenance, overlaying or reconstruction?
4. Treatment Cost
What are the treatment cost of each section, each branch or overall?

The PMMS interface inputs data from both GeoMedia and Micro PAVER. Its basic principle of analysis is based on knowing the PCI value, area, functional classification and other information for each section of Gaza pavement network. The condition class and treatment type required can then be determined. PMMS also allows unit cost of each treatment type to be entered and this will be helpful in determining maintenance cost for each section.

4. Gaza PMMS Process

The implementation of PMMS to Gaza pavement network is completed with a systematic procedure that involves the following tasks on a periodic basis[3]:

1. Defining the Gaza roadway network by breaking it into management segments and creating an inventory for each segment.
2. Gathering and inspecting the pavement condition and maintenance data of each segment.
3. Calculating the pavement condition assessment by selecting an evaluation criterion.
4. Determining the treatment strategy and cost for each segment based on pavement condition.
5. Developing a method of prioritizing segments when funding constraints exists in a pavement maintenance program.
6. Documenting and reporting results.

These tasks are illustrated in the chart shown in Figure (3) and discussed briefly below:

4.1 Gaza Roadway Network Definition

Actually, Gaza Municipality has already established a street coding for its roads and buildings to help in field surveys and in order to improve the quality of services offered to citizens. In this study, it is better to make use of this road coding but with some modifications in sectioning to suit with pavement maintenance requirements.

Gaza roads are classified functionally into the following three categories:

1- Major Roads

Those roads that pass through the whole city and they hold numbers taking the Identification (ID) form (X00), where X is between 1 and 9.

2- Main Roads

They are the roads that have large lengths and widths and they are considered as main roads. They are given the ID form (XX0).

3- Local Access Roads

The roads that have small lengths and widths and they are numbered in the ID form (XXX).

Two major roads are selected as reference roads: Omar Al-Mukhtar and Al Rasheed Streets. The first extends longitudinally from west to east and given road ID 200. The other extends transversely parallel to the sea shore from north to south and given road ID 100.

For Gaza pavement network system to be efficiently managed, it is broken down into small units, *branches*, where they are taken as the city streets. Because a branch 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 *sections* (segments). To identify these sections, they must be measured from one reference point to another. The boundary between two sections of a branch in Gaza network is defined according to one of the following factors:

- A change in the number of traffic lanes.
- A change in pavement or surface type.
- A change in pavement width.
- Roadway major intersections.
- Gaza City limits.
- Recommended length (every one km, one mile or others).
- Pavement condition.

4.2 Network Data Collection

Once the network is in manageable sections, all the data associated with each section needs to be collected. The network data collection is the foundation of any pavement management system. The intent of gathering data is to collect enough detailed information about the network to relate it to pavement condition, traffic, cost and funding. One of the most required data is the *inventory data*. The basic purpose of this inventory is to provide information describing the pavement physical features. Generally, the inventory is recorded once and will not be updated unless physical characteristics change. It is important to realize that the PMMS is only as

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good as the data stored in a database. The minimum required data for each street section in Gaza pavement network includes:

- Data entry date or construction year (last surface).
- Street name, number and section designation.
- Beginning and ending location of the section.
- Functional classification.
- Number of lanes.
- Pavement type, thickness, length, width and area of the segment.
- Average Daily Traffic (ADT) and traffic composition.

Another type of required data that need to be calculated is the *institutional data*. The institutional data will include administration goals, policies, standards, resources, budget details and annual constraints.

After the pavement management inventory and institutional information have been created and all the data has been collected, pavement *condition data* survey can begin. Regularly scheduled pavement condition inspection is one of the most important steps in implementing a comprehensive PMMS. The purpose in performing pavement condition surveys is to document the progressive deterioration of each network section. A recommended pavement condition inspection policy minimizes the overall inspection effort of the city. A 2-3 year inspection interval at maximum is recommended [3].

4.3 Condition Assessment and Prediction

After inspecting the pavement network, the condition assessment of each section is performed by using Micro PAVER. The PCI value for each section or branch can then be determined and consequently the current condition can be identified. Over time, the Gaza PMMS database will contain a great amount of historical pavement condition data about the network. This information can be used to develop pavement performance curves (models) that predict how a certain type of pavement will perform based on how it has performed in the past.

4.4 Maintenance Strategy and Cost

After having determined a PCI score for each branch section of the network, calculating a range that the score falls within will be needed to assist in selecting a possible treatment. For example, if a section is in good condition with a PCI of 84, it would receive a different treatment than a section in poor condition rated as 35. Pavement treatment of a section can be selected according to the range that the PCI of this section belongs to.

One of the key activities in Gaza pavement management is budgeting since funding needs are always much lower than available funding. After all

needed pavement information has been collected into the database; methods to analyze that information are needed to make budget decisions at network and project levels.

4.5 Maintenance Prioritization

After the condition of all network sections have been calculated and the treatment and cost determined, the application of a method for choosing a logical order to address the section is needed. There are different methods which can be developed for establishing priorities [3, 4]. Prioritization can be as simple as a "best section first" or "worst section first". Any prioritization method should be selected carefully to suit the circumstances of Gaza as a developing city. The ranking index formula which was developed by Khoury and et al [6] considers a combination of section condition, functional classification and traffic exposure.

$$PI = \left(\frac{1}{PCI}\right) \times TF \times FC \times MF \times SR$$

Where:

PI = Priority Index.

TF = Traffic Exposure Factor.

FC = Road Classification Factor.

MF = Maintenance History Factor.

SR = Special Factor to emphasize Priority of Specially Designated Routs.

This formula can be the basis to determine priorities for Gaza City pavement sections. A section that has higher priority index is ranked first.

4.6 Documenting and Reporting

Once a prioritization list of roadways is developed, they should be formulated into a budget document and reported to the decision makers. Due to the technical nature of the data and the analysis, it is desirable to translate the findings from the PMMS into clear terms that are understandable to decision makers. In presenting the PMMS findings, it is important to be brief point of key facts to enable them to make better decisions.

5. Case Study

To analyze Gaza PMMS, a detailed visual inspection survey was conducted to a case study zone illustrated in Figure (4). This zone has approximately 20 km of roads length. A pavement condition inspection form was prepared for this purpose. This form, for example, containing the condition data of Jammet Al-Doual Alarabia Street is shown in Figure (5). In addition, pavements of the case study zone sections are also video taped with digital

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cameras, Figure (6). The inspection data is first analyzed by Micro PAVER to determine the PCI value for each section of the case study zone. Micro PAVER results are automatically updated into the GeoMedia Professional database. Information about any pavement section can be easily obtained by clicking this section on the pavement network map of GeoMedia. A video file for any section can be also shown to indicate its current condition.

6. Gaza PMMS Outputs

Gaza PMMS provides variable outputs that can help in reducing the time allocated to the maintenance activity and facilitating the decision making process. The following are examples of these outputs:

1. Reports

Different types of reports can be provided including branch condition, section condition, surface type, required treatment and maintenance budgeting reports, etc. Figures (7, 8, 9)

2. Thematic Maps

Several thematic maps can also be presented based on surface type, pavement condition (by branch or section), functional classification, etc. Figures (10)

3. Charts

Charts and figures can be obtained in different formats (Bar, Pie, XY charts, etc) and illustrating condition analysis, predictions, pavement types and other needed relationships.

4. Queries

Different information can be performed about Gaza pavement network through the developed Graphical User Interface, PAVER and GeoMedia packages.

5. Decisions

Gaza PMMS can assist in decision supporting process about the actions that should be taken and related to the maintenance needs, required budgeting, section treatment priorities, etc.

7. Conclusions and Recommendations

1. This study shows that a PMMS which is based on the direct integration between Micro PAVER and GeoMedia Professional can be used to facilitate the decision making process for managing Gaza City pavements.
2. A simple Graphical Interface which contains user-friendly menus can be developed to present PMMS results to justify the decisions made.
3. A centralized PMMS should be initiated to involve all cities in Gaza Strip.

4. Future developments should be made to ensure full integration between Micro PAVER and GeoMedia.
5. Future developments including other elements of a highway maintenance management system should be considered.
6. There is a great need of long-term commitment of officials, pavement managers, public and road users towards the conservation and protection of Gaza pavement assets.

8. References

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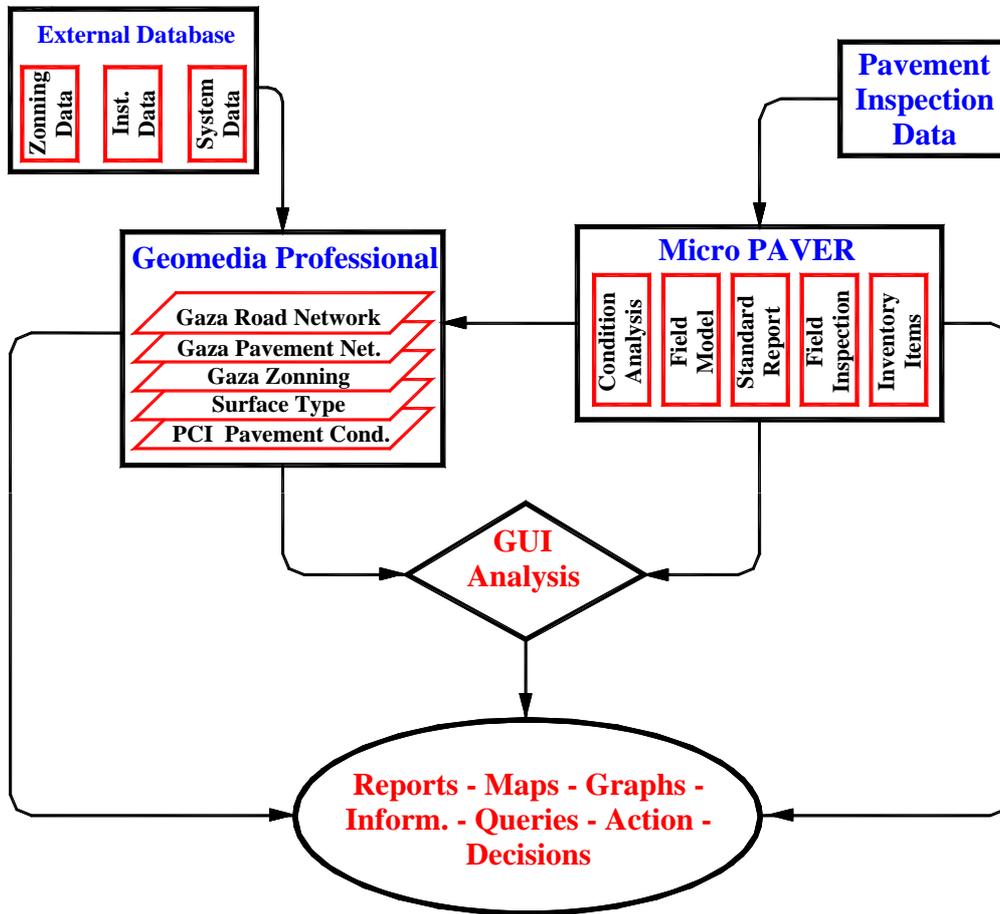


Fig. (1): Gaza PMMS Architecture.

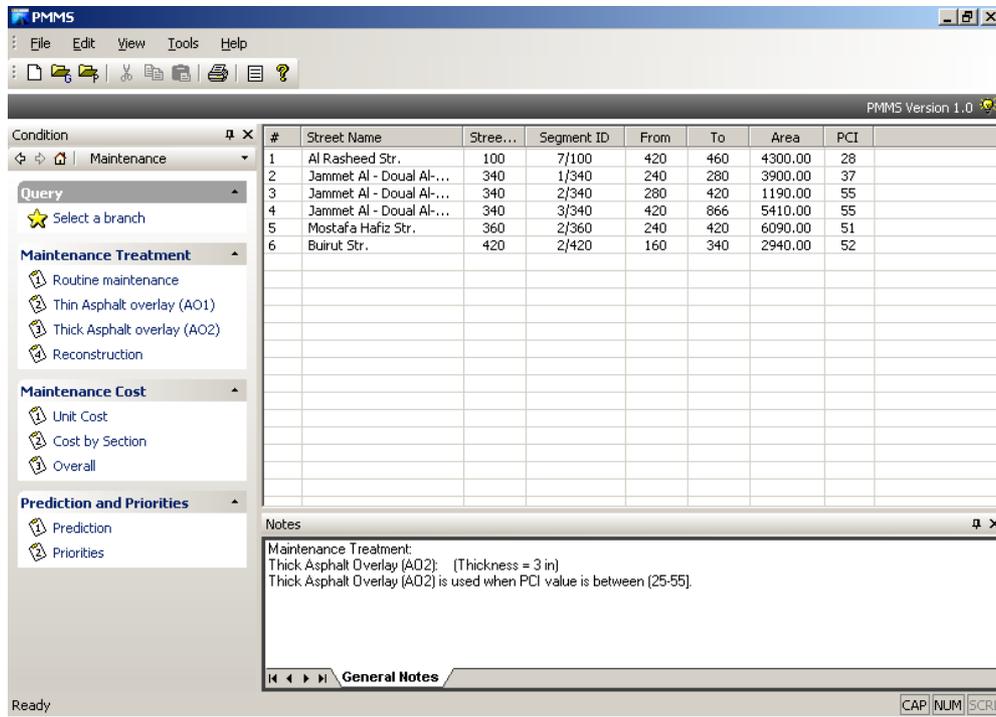


Fig. (2): Gaza PMMS Interface.

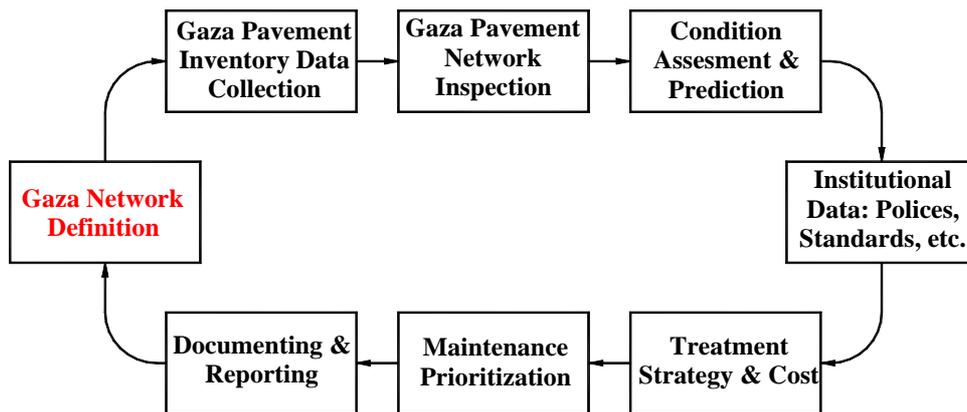


Fig. (3): Gaza PMMS Process.

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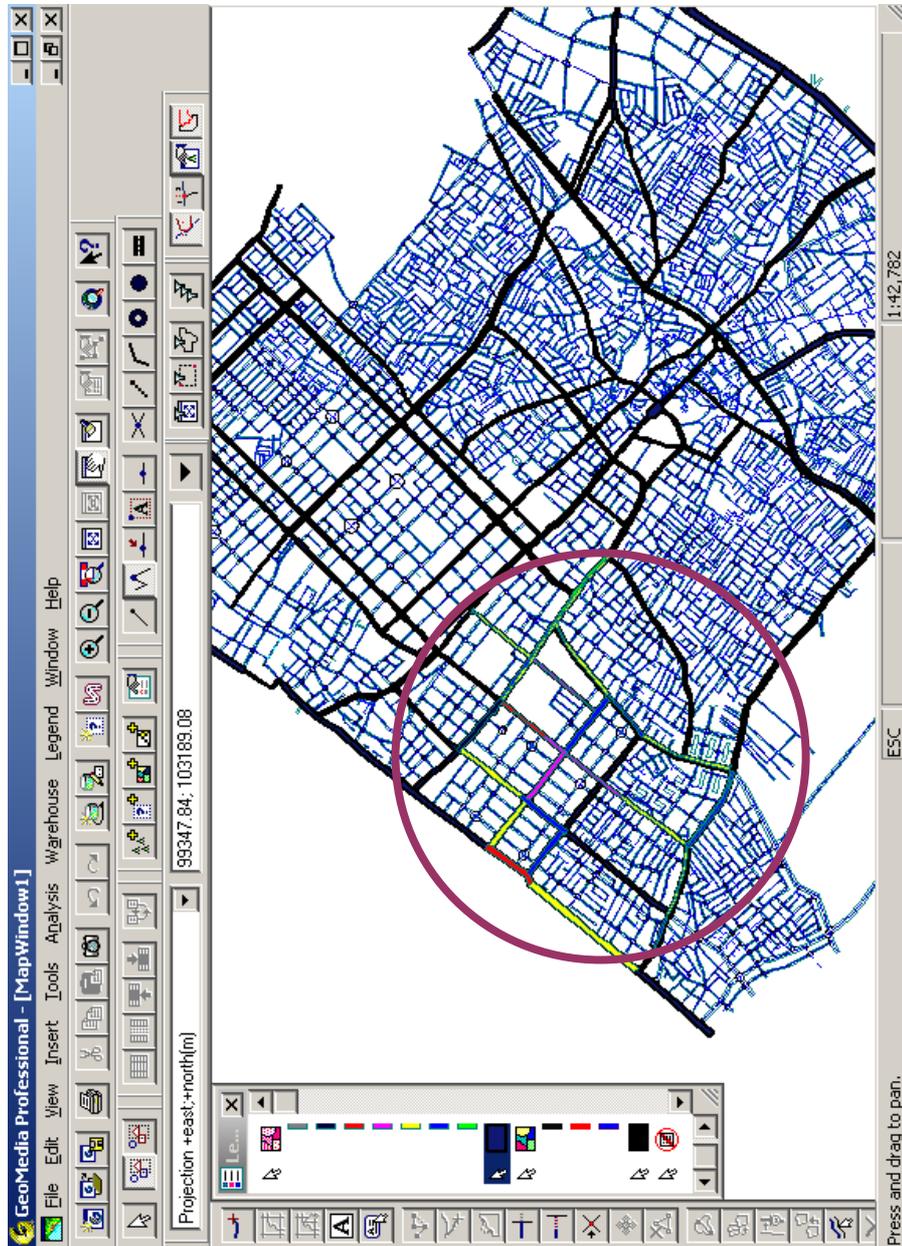


Fig. (4) Fig. (4): The Case Study Zone of Gaza City.

inventory information		Date: □/□/□ □ □ □							
Street name: 		Street ID: ◀ ▶ -	Functional Class: 						
Section ID: □/□/□ ▶ ▶ -		From: □ ▶ ▶ -	To: ▶ □ -						
Section length: □ ◀ - !	Section width: ◀ !	Number of lanes: □							
DISTRESS INFORMATION									
1. Alligator Cracking 2. Bleeding 3. Block Cracking 4. Bumps and Sags 5. Corrugation 6. Depression 7. Edge Cracking		8. Reflection Cracking 9. Lane/Shoulder Drop Off 10. Long. & Trans. 11. Patching & Util. Cut 12. Polished aggregate 13. Potholes 14. Railroad Crossing							
		15. Rutting 16. Shoving 17. Slippage Cracking 18. Swell 19. Weathering & Raveling							
Distress type		▲	▼	□ -		□ □	□ ▲	□ ◀	
		▶ ▶ - ▶ ▶ □ ▶ ▶ □	▲ ▲ ▲	◀ ◀ ◀	 	▶ ▶ - ▶ ▶ -	□ ▲ ▶ ▶ - ▶ ▶ -	▶ ▶ - ▶ ▶ -	▲ ▲
Total Severity	Low	□ ▼ □ ▶ ▶ -		□ ▲ ▶ ▶ -			▲ ▶ ▶ -	▶ ▶ -	▲ ▶ ▶ -
	Medium		▲ ▲	□ - ▶ ▶ -	□ - ▶ ▶ -	□ ▼ -			
	High		▲ ▲	◀ ◀					
Comments:									
Notes: 1. Distress (13) is counted as <i>number</i> of potholes. 2. Other distress types are measured in m^2 except (4 – 7 – 8 – 9 – 10) in <i>m</i> .									

Fig. (5): Pavement Condition Inspection Form Example.

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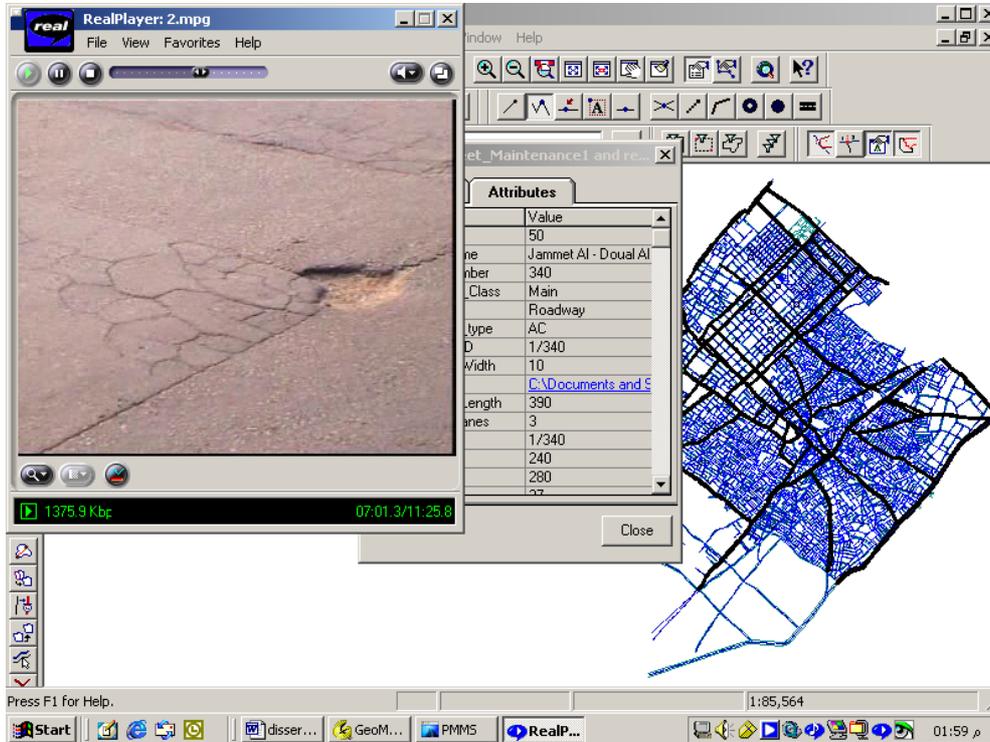


FIG (6): Video Taping of the Case Study Zone Sections (Section 1/340)

Printed Date: 06/01/2004	Last modified: 29/12/2003
Report Description:	
Condition: Fair	

Buirut Str.

Street Name	Street Number	Segment ID	From	To	Area	Condition
Buirut Str.	420	2/420	160	340	2,940.00	52

Jammet AI - Doual AI-Arabia

Street Name	Street Number	Segment ID	From	To	Area	Condition
Jammet AI - Doual AI-Ara	340	3/340	420	866	5,410.00	55
Jammet AI - Doual AI-Ara	340	2/340	280	420	1,190.00	55

Mostafa Hafiz Str.

Street Name	Street Number	Segment ID	From	To	Area	Condition
Mostafa Hafiz Str.	360	2/360	240	420	6,090.00	51

Printed Date: 06/01/2004	Last modified: 29/12/2003
Report Description:	
Condition: Poor	

AI Rasheed Str.

Street Name	Street Number	Segment ID	From	To	Area	Condition
AI Rasheed Str.	100	7/100	420	460	4,300.00	28

Jammet AI - Doual AI-Arabia

Street Name	Street Number	Segment ID	From	To	Area	Condition
Jammet AI - Doual AI-Ar	340	1/340	240	280	3,900.00	37

Printed Date: 06/01/2004	Last modified: 29/12/2003
Report Description:	
Condition: Very Poor	

Jammal Abdel-Nasser Str.

Street Name	Street Number	Segment ID	From	To	Area	Condition
Jammal Abdel-Nasser Str.	240	2/240	160	340	3,500.00	14

Fig. (7): Examples of Gaza PMMS Condition Reports.

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Printed Date: 06/01/2004	Last modified: 29/12/2003
Report Description:	
Maintenance Treatment: Thick Asphalt Overlay (A02)	

Al Rasheed Str.

Street Name	Street Number	Segment ID	From	To	Area	PCI
Al Rasheed Str.	100	7/100	420	460	4,300.00	28

Buirut Str.

Street Name	Street Number	Segment ID	From	To	Area	PCI
Buirut Str.	420	2/420	160	340	2,940.00	52

Jammet Al - Doual Al-Arabia

Street Name	Street Number	Segment ID	From	To	Area	PCI
Jammet Al - Doual Al-Ar340		3/340	420	866	5,410.00	55
Jammet Al - Doual Al-Ar340		2/340	280	420	1,190.00	55
Jammet Al - Doual Al-Ar340		1/340	240	280	3,900.00	37

Mostafa Hafiz Str.

Street Name	Street Number	Segment ID	From	To	Area	PCI
Mostafa Hafiz Str.	360	2/360	240	420	6,090.00	51

Printed Date: 06/01/2004	Last modified: 29/12/2003
Report Description:	
Maintenance Treatment: Reconstruction	

Jammal Abdel-Nasser Str.

Street Name	Street Number	Segment ID	From	To	Area	PCI
Jammal Abdel-Nasser S240		2/240	160	340	3,500.00	14

Fig. (8): Examples of Gaza PMMS Treatment Reports.

Printed Date: 06/01/2004	Last modified: 29/12/2003
Report Description:	
Treatment cost by section	

Abu Bakr Str.

Street Name	Street No.	Segment ID	From	To	Area	PCI	Cost
Abu Bakr Str.	20,661	1/20661	700	900	9,800.00	100.00	0

Al Aqssa Str.

Street Name	Street No.	Segment ID	From	To	Area	PCI	Cost
Al Aqssa Str.	300	3R/300	460	800	4,830.00	66.00	48300
Al Aqssa Str.	300	2R/300	420	460	2,800.00	74.00	1400
Al Aqssa Str.	300	1R/300	240	420	4,410.00	69.00	44100

Al Basateen Str.

Street Name	Street No.	Segment ID	From	To	Area	PCI	Cost
Al Basateen Str.	422	1R/422	560	940	2,310.00	100.00	0
Al Basateen Str.	422	1L/422	560	940	2,310.00	100.00	0

Al Jalaa Str.

Street Name	Street No.	Segment ID	From	To	Area	PCI	Cost
Al Jalaa Str.	500	4R/500	600	490	3,360.00	100.00	0
Al Jalaa Str.	500	6R/500	690	830	5,100.00	100.00	0
Al Jalaa Str.	500	2R/500	230	611	3,710.00	100.00	0
Al Jalaa Str.	500	1L/500	200	230	2,700.00	100.00	0
Al Jalaa Str.	500	6L/500	690	830	5,100.00	100.00	0

Fig. (9): Example of Gaza PMMS Cost Reports.

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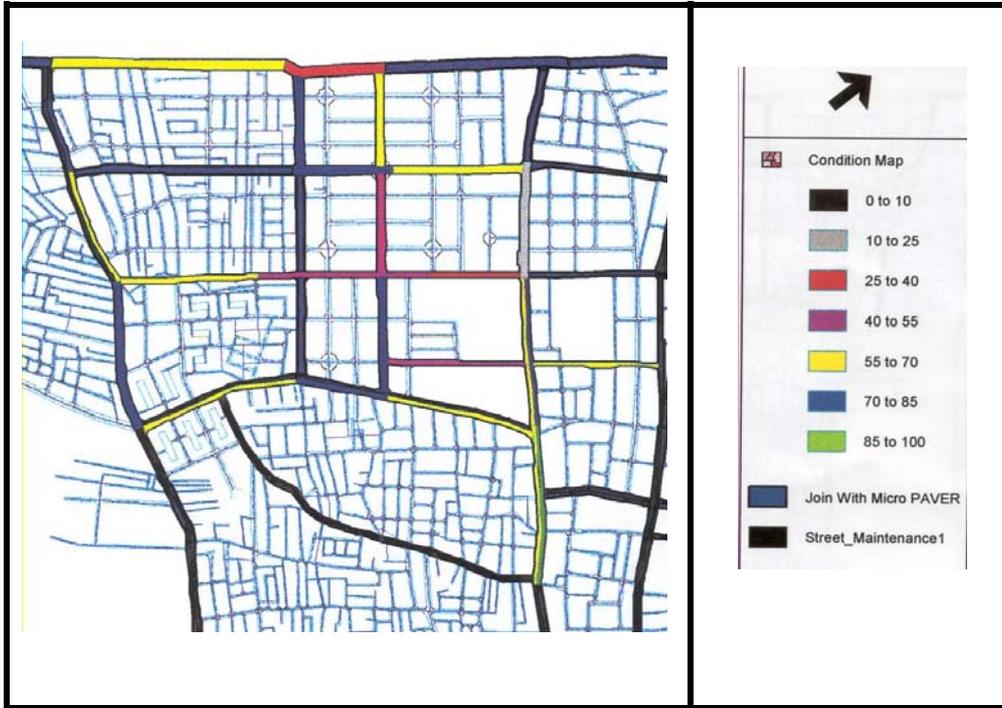


Fig. (10): Example of Gaza PMMS Thematic Maps.