

# Designing a Spatial Database to Facilitate Road Maintenance Tasks

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**Key words:** Database, GIS, Management, Road Maintenance, VB.NET Programming

## SUMMARY

This study represented one of the projects that achieved the tendencies of the Ministry of Works (**MOW**) in using all available techniques, tools and technologies to organize the processes of roads maintenance section (**RMS**) in a manner that can increase the quality and quantity of the **MOW** products (services).

This study has designed a Relational Database (**RDB**) to manage and organize the road maintenance tasks. This database has the ability to connect the **RMS** data (non-spatial data) with their location (spatial data) using the techniques of Geographical Information Systems (**GIS**), which will facilitate the **RMS** tasks and increase the productivity and the accuracy of the section.

The methodology adopted was divided into three main practical stages; collecting of all required information to design the database; designing the **RDB**, adding data to **RDB** in the **MS-Access**, and Building the Graphical User Interfaces (**GUI's**) using the Visual Basic (**VB.NET**); Connecting the locations in the designed **RDB** with their real locations on the map using a selected GIS environment (MapWindow – Open Source), which was connected with the **RDB** in **VB.Net**.

The final product of this study is a standalone application that can facilitate the reinstatement tasks, and can increase the productivity by three times compared to the current situation.

Finally, the study highlights some recommendations such as:

- Adopting the **RDB** design by the **MOW** and generalize the spatial database to the entire Kingdom of Bahrain.
- Using the results of this project into consideration in the new strategies of **MOW** e.g. to get the International Organization for Standardization Certificate (**ISO- 9001**).

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## 1. INTRODUCTION

The office automation management strategies and techniques for the organization represent the scaling for success and development of the organization. Therefore, the organizations are competed together by using the newest technologies and techniques to achieve the highest scale of organization, such as using of the database management systems (DBMS) in their office automation processes. The ministry of works (MOW) in the Kingdom of Bahrain is one of the pioneer organizations in the management and electronic services fields. The ministry has got the (ISO-9001: 2008) certificate in October 2010, and it tries to enhance the quality and quantity of the provided services to the customers, which means the ability to increase the productivity of the ministry staff, with a challenge of limited and restricted financial resources. Therefore, this study uses the GIS techniques to enhance one of the road maintenance tasks, as a pilot project that can applied later to achieve the main goal of the ministry, by designing a spatial database for the Road Maintenance Section (the reinstatements tasks only).

The reinstatement tasks deal with the fixation of all types of damage on the paved roads as shown in the example in the Figure (1), which may be caused by a settle down in the paving material (such as asphalt or interlock), leakage in the underground services, or by other factors like the rain. Where, the consumed time to finish the office work for each reinstatement task is approximately 3 working days as mentioned by the RMS technical staff.



Figure (1) Roads Defect need maintenance (Cracks on the asphalt)

The first day for preparing the location plan and calculating the cost, the second day is for issuing the Contractor Order (TCO), and the third day is for finalizing the job and preparing the final bill. The delay in road maintenance tasks has two effect, the direct impact due to the current situation of the job, and indirect (expected) impact due to delay in the maintenance action that lead to bigger problem, e.g. the solution of the case shown in Figure (1) can be constructing a patch for small area but if that delayed for a long time, the problem will be increased and may be the whole road need reconstruction.

To mitigate the negative impacts of delaying the reinstatement and maintenance tasks of the road work, this research intend to build a spatial database to enhance and accelerate this process by automating all the steps needed to finalize the work in less time compared to the current situation, which will increase the productivity and enhance the quality of the job (by organizing the data manipulation), in the same time it will reduce the consuming of paper works.

Also due to the availability of the spatial data the study was applied on the area of Isa Town in the middle of Bahrain. Figure (2) shows the location of the study (The kingdom of Bahrain), and Figure (3) shows the location of the case study (Isa Town).



Figure (2) Area of study: Kingdom of Bahrain (Extracted from Google Earth website)

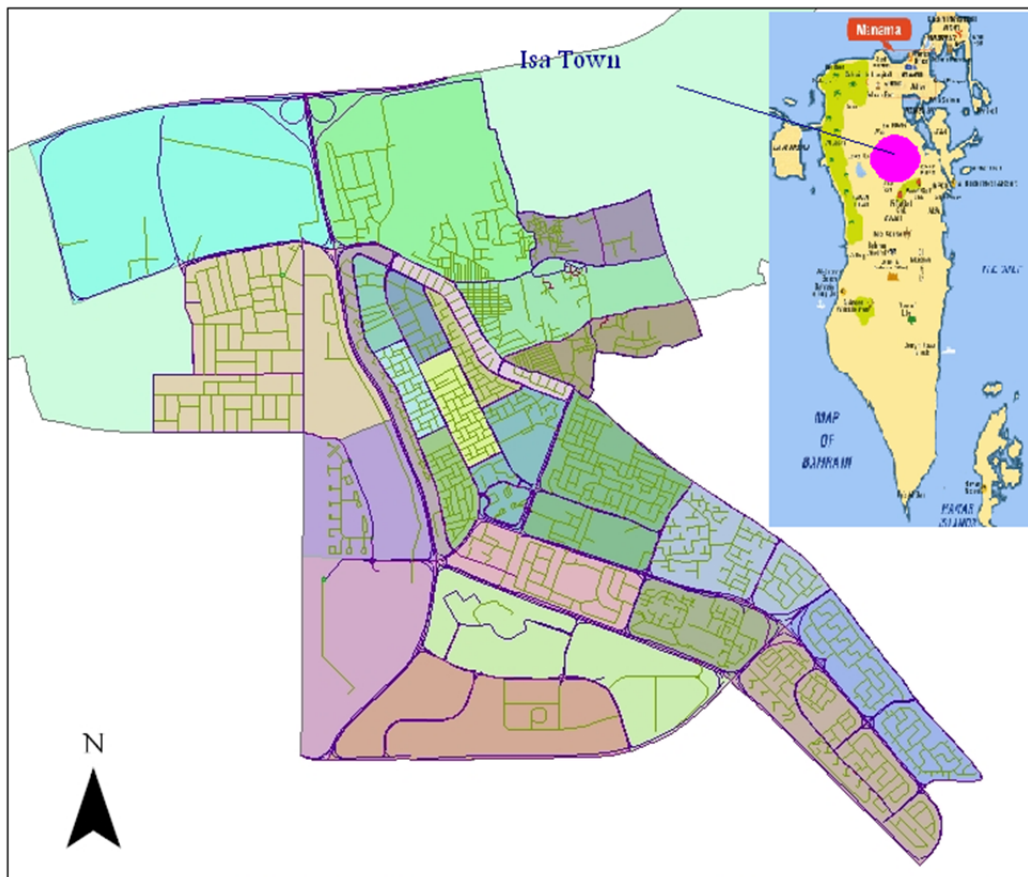


Figure (3) Case Study Location: Isa Town

## 2. DESIGNING THE RELATIONAL DATABASE FOR REINSTATEMENT TASKS

The section shows how the current situation for manipulating the reinstatement tasks inside RMS, illustrates the design of the required RDB for these tasks, discusses the content of the final design, and presents the Designed GUI's, their uses along with their snapshots. The RDB design was developed using the MS Access, and the GUI's was built using the VB.Net 2005.

### 2.1 Description Of The Current Situation

The Figure (4) illustrates the organization chart of the RMS work flow. The chart shows that there are several resources and outputs related to the section, which give a good indicator about the size of the job in the section, and means that there is a great amount of work. Therefore, there is a need to reorganize the workflow and to use different technologies to manage and control the work, which can be done by designing a spatial database, which will constitute the core of the enterprise GIS solution.

The procedure for doing a reinstatement task is described in the following steps:

1. Receiving complains for the damage in the road surface.
2. Preparing a preliminarily site plan (sketch) for the complain area.

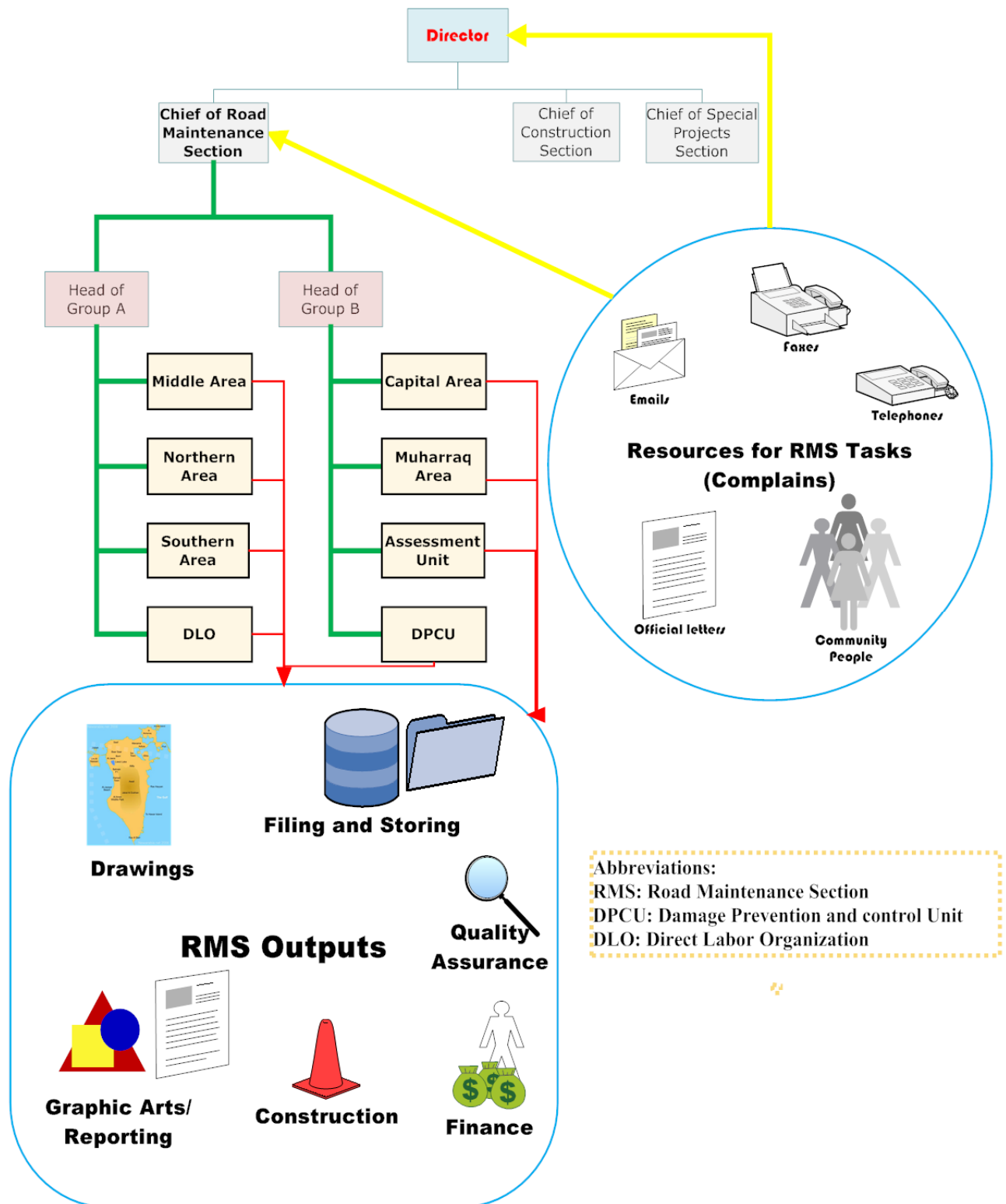


Figure (0) The flowchart of Roads Maintenance Section

3. Taking the measurements at site and determine the proposed job (length, wide, and height)



- and thickness), and take some photographs for documentation.
- The office work consists of doing all needed calculations to determine the approximate cost and prepare a site plan for the required job, as in Figure (5).

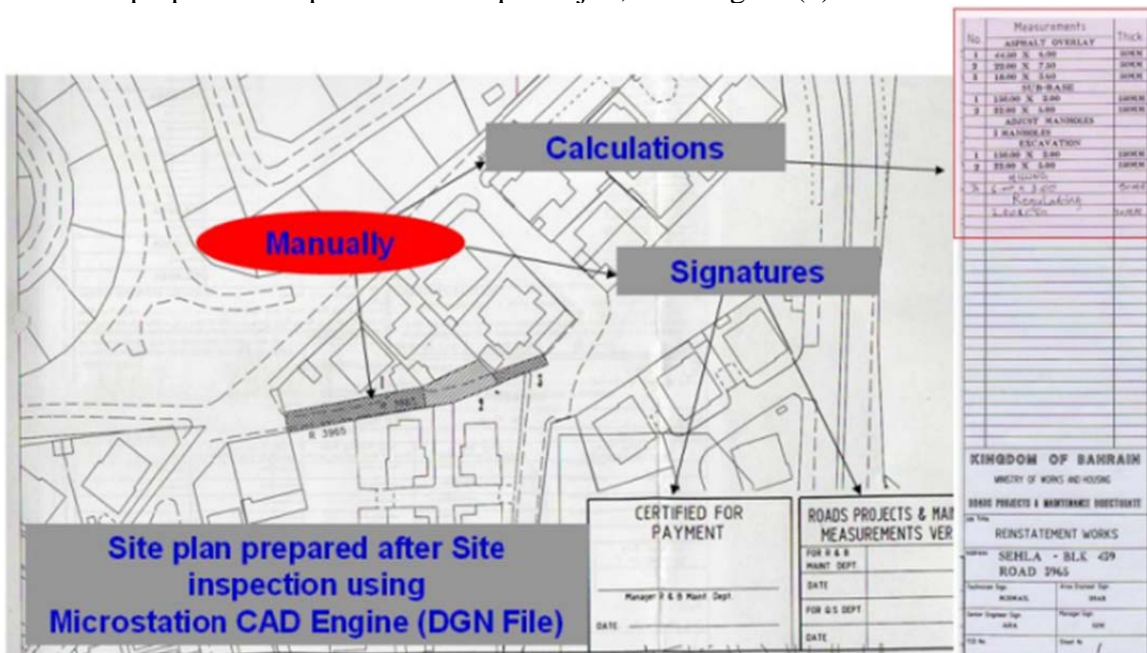


Figure (5) Example of drawings done by RMS technician after site visit

- After the approval of the job, and desalinate the contractor of the job by the top management of RMS, then the employee will issue the Job Statement which is called a TCO (Term Contract Order: it's a contract signed with different contractors with fixed prices for all items) to the contractor to execute the job), as shown in Figure (6).

TERM CONTRACT ORDER BILL OF QUANTITIES ASPHALT WORKS					
SCHEM	TITLE: SEHLA - BLK 439 - ROAD 3965				
ITEM	DESCRIPTION	QTY	UNIT	RATE BD	AMOUNT BD
CLASS E : EARTHWORKS					
E220	Material other than topsoil, rock or artificial hard material.	183.86	cu.m	0.750	137.895
E522	EXCAVATION ANCILLARIES				
	Preparation of excavated surfaces; material other than	595	sq.m	0.130	77.350
E532	Disposal of excavated material; material other than	183.86	cu.m	0.500	91.930
CLASS R: ROADS AND PAVINGS					
SUB-BASES					
R114	Granular material type A; depth 150mm	262.4	sq.m	0.850	223.040
Y722.1	raised or lower n.e. 150mm	3	nr	46.537	139.611
BILL TOTAL					669.826
Contingencies Percentage as Per Ministers Instruction					133.965
Grand Total of Estimate					803.791
Prepared by: M.ISMAIL 19-08-2006					

Say -BD 820.0

Figure (6) Example of a TCO prepared by civil engineering technician

- The employee must visit the site before and during the job execution process and take the

measurements of the job, and decide if any Site Instruction (order given to the contractor if additional tasks added to the job or if the specification was changed) need to be issued or not.

7. Taking the final measurements by the Joint measurement committee (it's a committee from several sections with the contractor, which go to the site after the completion of the job). The committee has to visit the site and take the measurements of the job to make sure that the job has been done correctly, and to issue the final bill to the contractor.

Briefly, by reviewing the previous steps it can be noticed that the majority of the works are in paper form. Also the retrieving for any job in the future requires knowing the year of the job implantation and the number of the block (that contain the task). Where, the querying about the total of tasks in some location or some dates is not so easy, because it's a time consuming process.

## 2.2 Relational Database Design

By using the data and results from the current situation, besides the notes and comments of the RMS staff about the required database the study designed the relational data model RDM for the pilot project as shown in Figure (7) according the international standards for database design (e.g. the conceptual, logical and physical design, applying the normalization forms, and etc...).

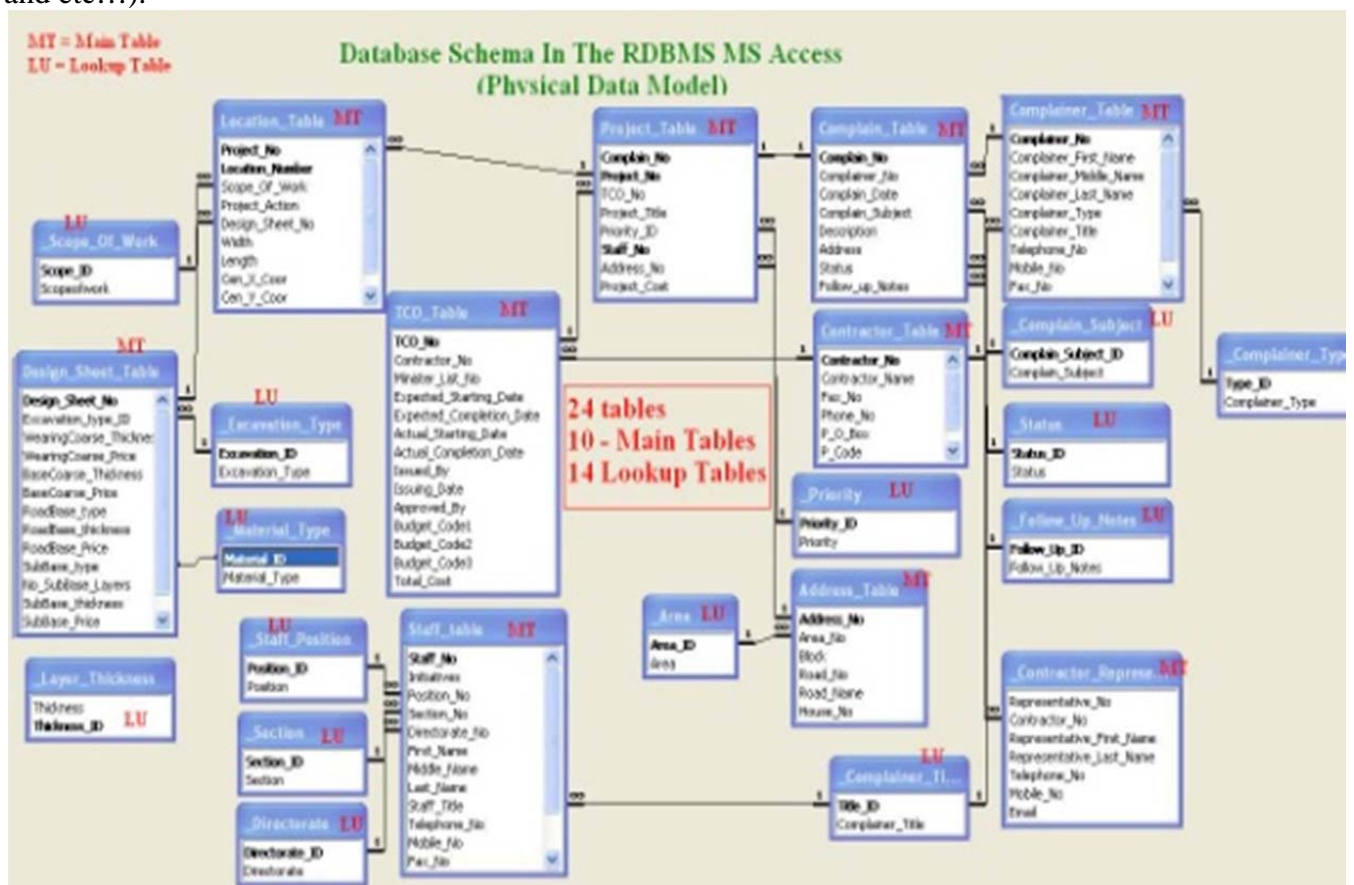


Figure (7) the Final Relational data model for Reinstatement tasks in RMS

### **2.3 Building The Graphical User Interfaces**

The study designed some graphical user interfaces to do the manipulation processes on the RDM, to check the validity of the design, and to ask some queries about the data. The designed GUI's was classified in two categories depending to their uses; the GUI's for adding new information, and the GUI's for searching, updating and reporting existing information.

The design didn't answer all queries on the designed Database, but showed a sample for the most requested query in RMS, which is: how many locations in a specific Block. This type of question usually is answered by list and map, therefore, this question represents the link to the next part of the study.

### **3. THE SPATIAL DATABASE**

This section represents the core of the study because it connects the non-spatial data discussed in the previous section with the spatial data using the base map of Bahrain. This connection was done by adding some maps to the previous design and updating them again to answer the spatial queries like where is a specific job, how many jobs in a specific location, what are the jobs that are related to specific location, and etc...

The building of the spatial database in this project was done according to the following steps:

- a. Delineating what the spatial database will do; which is to answer the question that link the database records by their location on the site, also it has the ability to answer the query in two directions (read and write to the map), firstly by showing the results of the query about non-spatial data on a map, or by showing the non-spatial data about specific position on the map. Besides the ability to reports the results and outputs of the query by several ways (e.g. reporting, table, or printing).
- b. Choosing the GIS Environment; the choosing of the GIS environment depends on the availability, usefulness, operating and maintenance costs, and the compatibility with the project objectives. Therefore the MapWindow open source environment was chosen to design the spatial database. Because it's available, easy for programming, no additional costs required for operating, generalization, and maintenance, and in the same time achieving the objectives of the study.
- c. Connecting the spatial data to relational database; some of the designed GUI's in the RDB designed were updated to show records locations on a map, as illustrated bellow.
- d. Checking and enhancing.

### **4. CONNECTING THE SPATIAL DATA TO RELATIONAL DATABASE**

This section of the project shows how to achieve the core of the project by connecting the information about the roads maintenance task with their location on the site using the selected GIS environment by adding the ActiveX controls MapWinGIS from the [www.MapWindow.org](http://www.MapWindow.org) site to the designed RDBMS, so the final database is a spatial database. The final product of this stage is a pilot project that shows the solution for the delay in maintenance tasks, and if it is adopted by the Ministry of works, enhanced in a proper way, and then connected with the other existing systems, the product represents a full solution



(Fully Office Automation System).

In this stage the maps have been added to some GUI's. The connection of the data in the designed RDBMS with a map has been done by adding some programming codes for these GUI's (forms). These codes were designed to do the following:

- a. Firstly to read the shapefiles and their tables (\*.dbf) in a datasets or in separate tables, inside the RDBMS, so it can be used later on in searching and querying processes.
- b. Determine and select were the spatial data from these files are matching the user requirements.
- c. Show the results on table (Data Grid), textboxes, or on the map.
- d. Color the different results to be significant and clear.
- e. Export the results to new shapefiles and new layers. So they can be used for further manipulation in the designed RDBMS or using other GIS environments if necessary.

This project contains more than twenty forms, but the forms having maps are only 4 main forms (which are the Adding a new location - Figure (8), adding a new address – Figure (9), find and update the location Figure (10), and finding the addresses – Figure (11)), besides the location reporting form as shown on Figure (12). These figures show the significance of using the GIS in this project due to the ability to connect the maps to the designed RDBMS, e.g. in Figure (7) the process to add new address can be done in two ways even by filling the text boxes then showing the results on the map, or by selecting it from the map then fill in the text boxes and then can be saved. This process in the current situation is one of the most time consuming in work flow. At the same time, the address checking procedure in the adding and updating the job position (Location) guaranteed that the registered address for the job is in the correct location on the map. This facility represents one of the simplest functions that the GIS can do.

Finally the enhancing and improving of the project is a continuous procedure depending on the user needs. In other words; the work that has been done in this study is just a sample of what must be done in the future work to reach to full office automation.

**Add New Location**

Project No: 9      Location No: 29

Scope of work: Patch      Project action: In Queue

Length: 3      Action Date: 12/06/2010

Width: 4      Cen. X-Coord: 454,224.19

Design Sheet No: 4      Cen. Y-Coord: 2,896,271.86

Buttons: Check Address, Save Project, Cancel, Next Design, Add New Sheet

Map: ROAD 504

Diagram: R.B.R.C.W.C. (30mm, 60mm, 50mm)

Figure (8) Form for adding a new location

**Find Address**

Address Info

Address No:      Road Name: ROAD 504

Area:      Road No: 504

Block No: 805      House No: 181

Checkboxes:  By Block No,  By Road Name,  By Road No,  By House No

Buttons: Find Address from RMDB, Cancel, ChooseLocation from map, Blocks Legend Color, Select Address from map

Map: 181

Figure (9) Form for adding new address

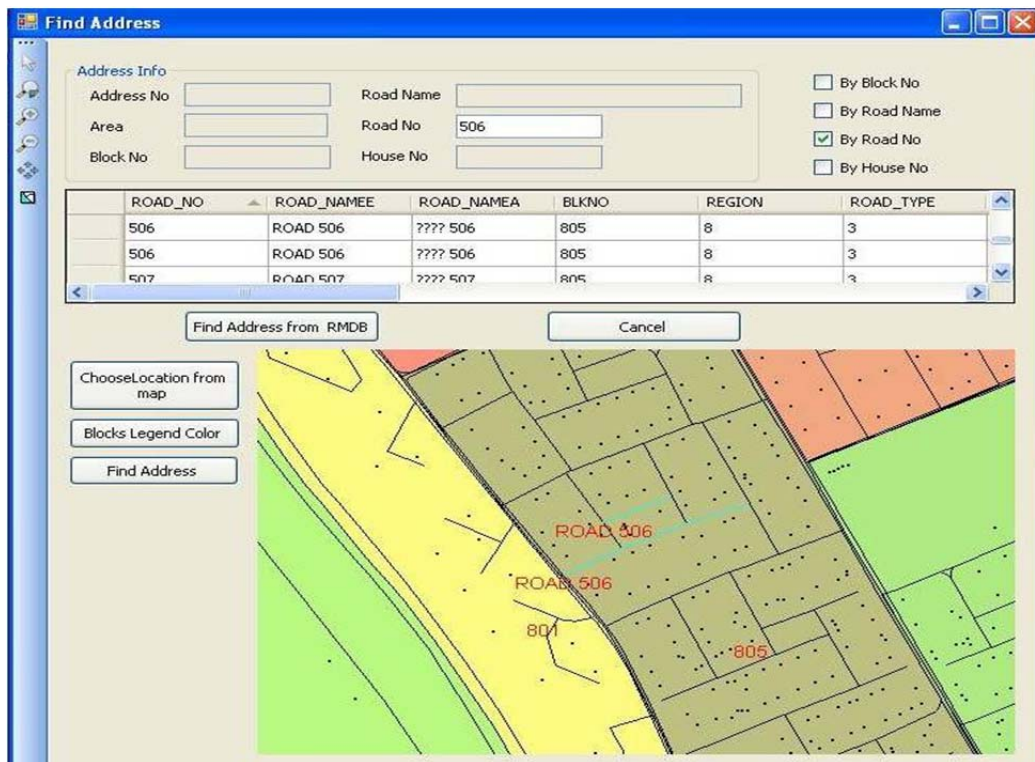


Figure (10) Find Address

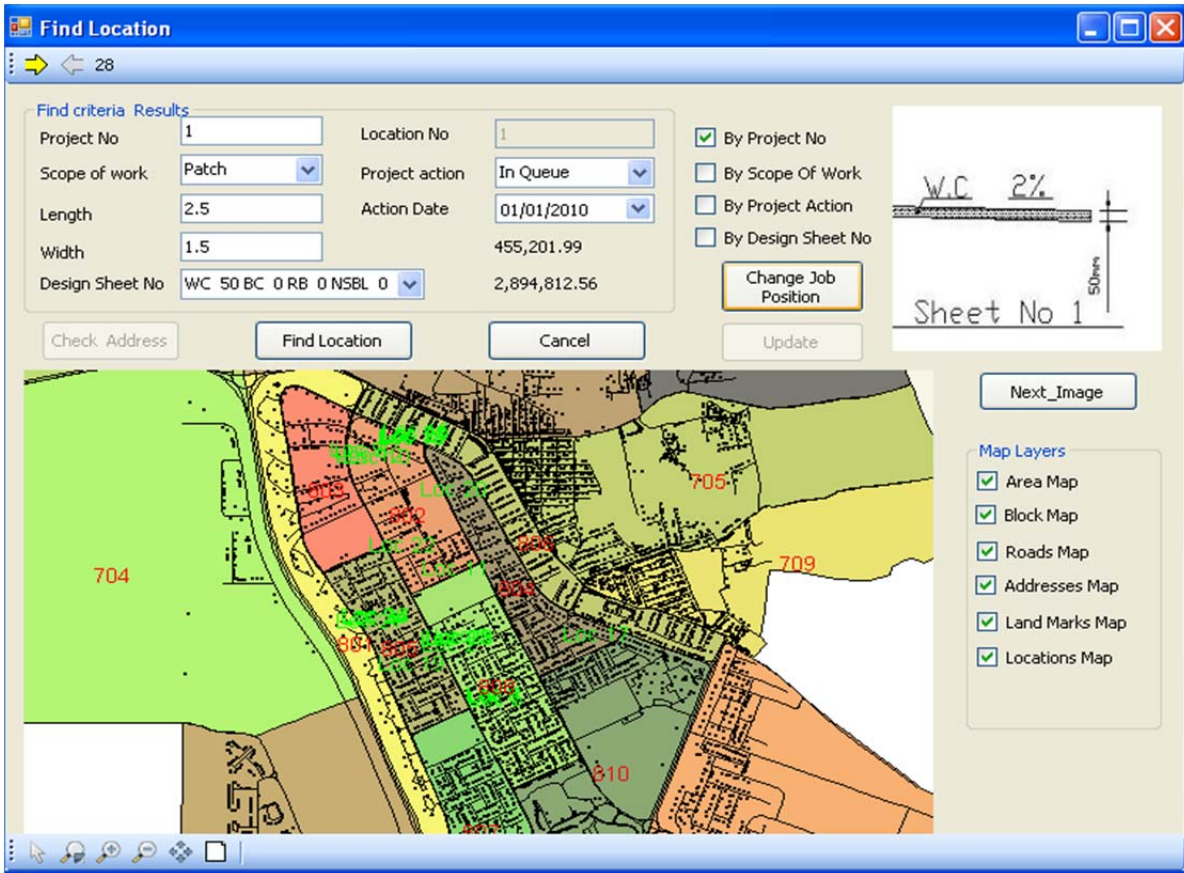


Figure (11) Find and Update Location.

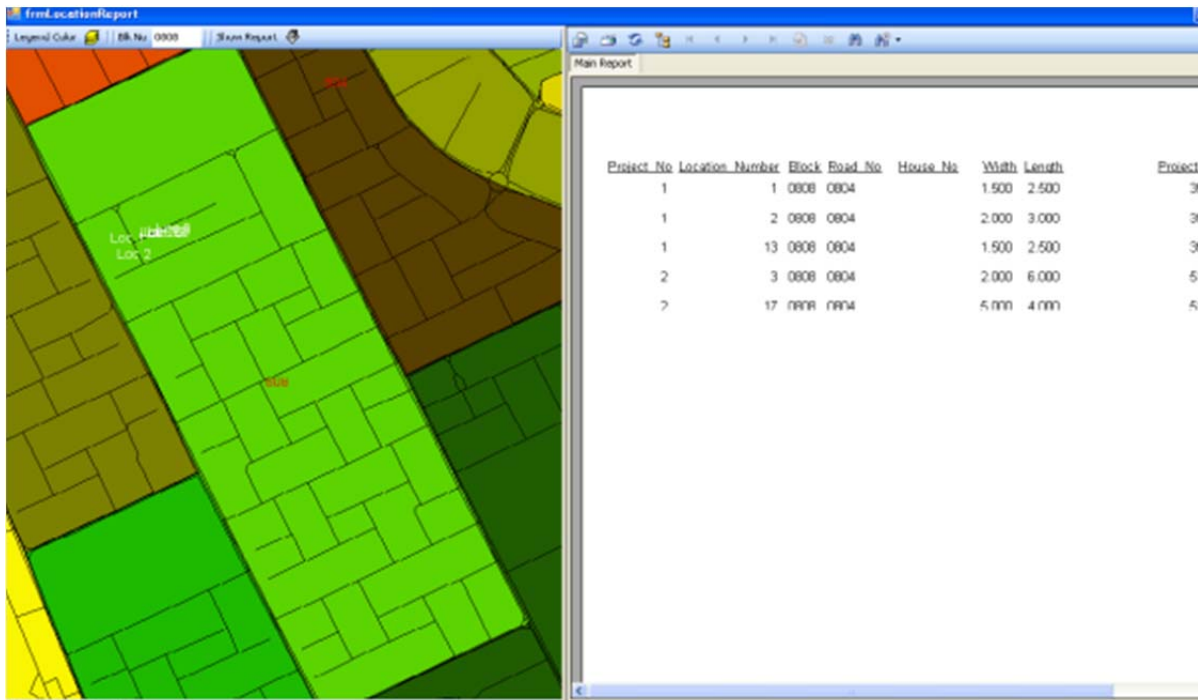


Figure (12) Report for query of jobs on specific address using the crystal report tools



## 5. CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

- The current situation of handling the Reinstatement task in **RMS** is time consuming, less productivity, and contains a lot of paper work.
- The deliverables of this study is a standalone application to facilitate the road reinstatement tasks for the road maintenance section, so it can save time effort, and cost of these tasks. This application represents a spatial database that has been built using the Visual Basic.Net.
- Using this application, the productivity of staff is increased because they will use only one application to do all their requirements, so the quality and quantity of the maintenance is increased three times compared with the current situation.
- The limitation of used **GIS** environment for dealing with only one type of the spatial data (the shapefiles), may require using another **GIS** environment on the enterprise project, asking the **GIS** service providers to solve it, or encouraging other researchers to work on the upgrading of this limitation, which can be less cost than purchasing a new **GIS** software and hardware.

### 5.2 Recommendations

To enhance the results of this project and ensure the validity and usability of its products the following recommendations must be taken into consideration:

- Adopting the results of this project by the **MOW** – represented by the **RMS**.
- Generalizing the project by replacing the existing sample base-map (Isa Town) with the completed one for the whole country.
- Enhance the Design to be able to follow up the correspondences related to this project, which will be one of the most important user requirements.
- Using the results of this research as a base for the Enterprise **GIS** System (or the Road Maintenance Management System) by
  - o Connecting the final Designed **RDBMS** with the other existing systems (the contract system).
  - o Doing further studies on enhancement of the other RMS tasks.
  - o Adding the security and integrity to the designed **RDBMS**, as been used at the **ITD** in **MOW**.
- Studying the ability of using the Location Based Services (**LBS**) in issuing the full solution package for this task and other tasks.

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