Geographical Information System for Pavement Management System

Abstract

Pavement management systems (PMS) are useful tools for highway agencies in quantifying the overall maintenance needs of pavements and presenting the alternative maintenance strategies under budget constraints. The most important aspect of development of a PMS is to collect, manage and analyse the pavement condition data in a considerably detailed format. Since geographical information systems (GIS), with their spatial analysis capabilities, match the geographical nature of the road networks, they are considered to be the most appropriate tools to enhance pavement management operations, with features such as graphical display of pavement condition. An attempt has been made in this paper to enhance the PMS process with GIS for GIS in PMS, pavement management system and an identified highway network.

Introduction

A pavement management system encompasses a wide spectrum of activities including the planning and programming of investments, design, construction, maintenance and the periodic evaluation of performance. The function of management at all levels involves comparing alternatives, coordinating activities, making decisions and seeing that they are implemented in an efficient and economical manner. The minimum requirements of such a system would include adaptability, efficient operation, practicality, quantitatively based engineering decision support, and good feedback information. A proper maintenance management system, which could optimize the distribution of available funds over the road network is, therefore, required essentially and has been emphasized world over.

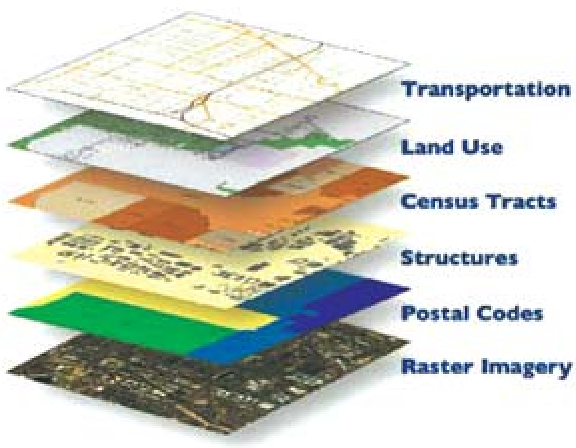
A GIS add tremendous functionality to a pavement management program not only in graphical output but also in data collection, analysis, planning, reporting and other areas. GIS procedure provides a coordinated methodology for drawing together a wide variety of information sources under a single, visually oriented umbrella to make them available to a diverse user audience. The data points which we get from GIS technologies will eventually allow for building reliable baseline reference maps to locate pavement sections and to inventories roadside features with sub meter accuracy. The road inventory data such as number of lanes, surface type, historical data of existing pavement and pavement condition data such as pothole, cracking, patching, rutting, edge breaking data which we collect using GIS Palmtop is helpful to find out the decision support system for PMS. The resulting system, GIS and GPS-PMS, represents a significant enhancement of all aspects of the PMS as well as pavement maintenance process.

GIS & PMS systems integration offers the following abilities:

- Digitizing detailed highway network map.
- Attaching the data referencing information to the graphic elements.
- Accessing the pavement sectional data through the graphical map interface.
- Visual display of the results of database queries and pavement management analyses on the map of road network.
- Retrieval of attribute data from the pavement database and automatically generate custom maps to meet specific needs, such as identifying the maintenance location

What Is GIS?

GIS is computer software that links geographic information (where things are) with descriptive information (what things are). Unlike a flat paper map, where "what you see is what you get," a GIS can present many layers of different information.



To use a paper map, all you do is unfold it. Spread out before you is a representation of cities and roads, mountains and rivers, railroads, and political boundaries. The cities are represented by little dots or circles, the roads by black lines, the mountain peaks by tiny triangles, and the lakes by small blue areas similar to the real lakes.

A digital map is not much more difficult to use than a paper map. As on the paper map, there are dots or points that represent features on the map such as cities, lines that represent features such as roads, and small areas that represent features such as lakes.

All this information—where the point is located, how long the road is, and even how many square miles a lake occupies—is stored as layers in digital format as a pattern of ones and zeros in a computer. Think of this geographic data as layers of information underneath the computer screen. Each layer represents a particular theme or feature of the map. One theme could be made up of all the roads in an area. Another theme could represent all the lakes in the same area. Yet another could represent all the cities.

These themes can be laid on top of one another, creating a stack of information about the same geographic area. Each layer can be turned off and on, as if you were peeling a layer off the stack or placing it back on. You control the amount of information about an area that you want to see, at any time, on any specific map.

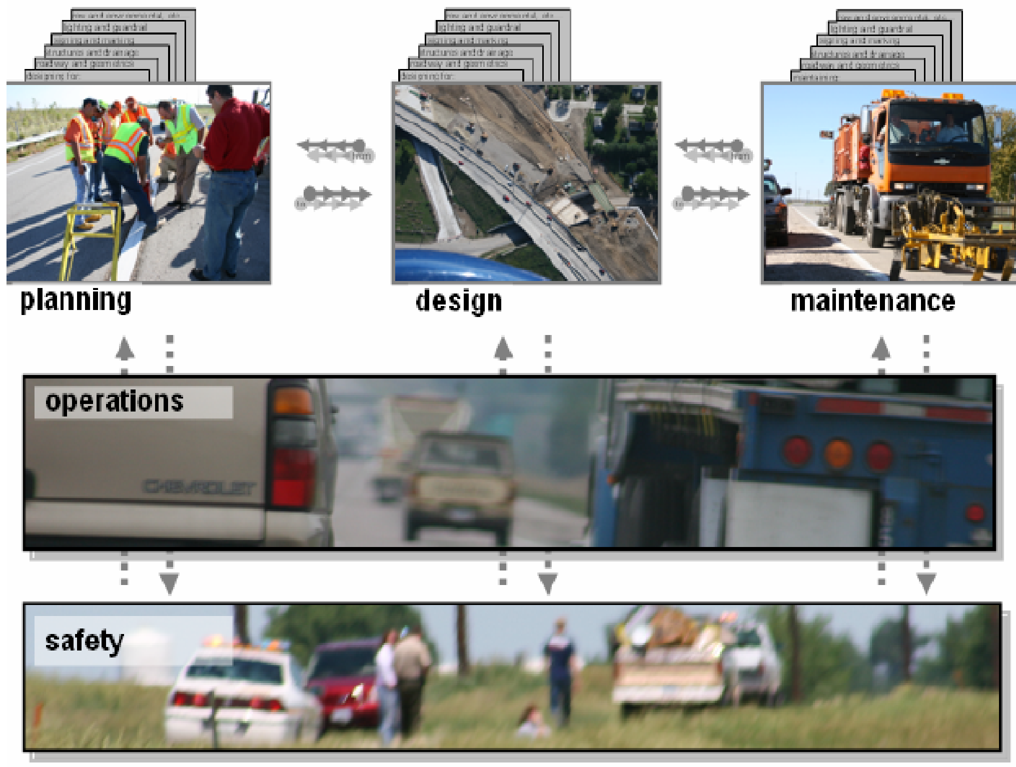


Figure 1. Relationship between Operations and Planning, Design, Maintenance, and Safety

Pavement management system

"Pavement Management System" (PMS) represents a significant tool for Financial Managers, Asset Managers and for Road Maintenance Engineers. The System offers asset valuations and depreciation schedules, road inventory management, optimised pavement condition management and maintenance works scheduling.

The PMS has been developed to used for predicting pavement deterioration and road user costs under different maintenance scenarios. The System provides the tools necessary for Road Asset Managers to:

- analyse, optimise, prioritise and schedule road maintenance and rehabilitation programs, ensuring a rational approach to maintenance and rehabilitation of the road network
- provide detailed recommendations for the most cost effective maintenance treatments.
- optimise benefits to the users of the road network.
- provide a guide to long term financial planning, and assess the implications of alternative funding levels.
- facilitate planning, and implementing of the maintenance and rehabilitation program, and monitors its effectiveness.
- minimise costs to the agency responsible for the road network.

In short, **it is a way of getting the right money to the right place in the right time.**

Road asset management systems that do not have the ability to model and optimise the benefits of whole of life savings associated with treatment options will often revert to treating the worst roads first. It can easily be

demonstrated that this approach may cost a road authority millions of dollars.

The PMS/PMMS System is capable of providing the following optimum solutions:

- project level optimisation and network level optimisation based on whole of life analysis
- optimisation to determine best network condition achievable under predefined yearly budget constraints or optimisation to determine the funding requirements necessary to achieve defined target network condition goals
- Yearly program of works to achieve optimisation goals
- optimisation parameters can include recurrent maintenance costs, user costs, asset depreciation, condition of both surface and pavement layers as well as combinations of optimisation parameters.
- This innovative, state-of-the-art system:
- eliminates the need for expensive annual pavement condition surveys, by the use of a deterioration prediction model
- is applicable to all pavement types including rigid pavements, asphaltic concrete, chip seal pavements and unsealed roads
- incorporates local policies and experience, together with theoretical life-cycle analysis to optimise maintenance treatments
- displays graphical representation of the street, street condition, and inventory items.

As well as being used to manage **the maintenance of the road pavements, the system can also be used to record and monitor information concerning bridge structures and roadside inventory such as signs, traffic lights, culverts, road verges, etc. The system has been designed for both rural and urban environments and is currently installed throughout Australia, and in a number of different countries.**

GIS and other computer integrated with PMS models can be calibrated on observation of field condition surveys and based on local knowledge of road pavement behaviour to provides:

- optimisation analysis to analyse and optimise road maintenance and rehabilitation (or other improvements) with options to determine short and long term works programs based on either budget constraints or target network condition levels.
- Integrated GIS interface which allows users to access the database by clicking on a road section, footpath or individual defect displayed on the map view of the road network. Data can also be displayed thematically on the map giving a clear indication of the network status.
- Standard financial reporting meeting the requirements for reporting replacement costs, written down value and annual depreciation either based on straight line depreciation or condition assessment.
- Integrated footpath management module aimed at managing governments risk liabilities through rigorous management of hazard defects through surveys and planned maintenance programs.

ROLE OF SPATIALLY INTEGRATED DATA IN PMS

Comprehensive pavement management models require a diverse collection of highway-related data including pavement condition surveys, skid resistance measurements, traffic counts, bridge inspections, sign inventories, photo logging, accident investigation, construction and maintenance records and inventories of signs and roadside obstacles. Although these data may be available in digital format, they are typically unrelated to each other, duplicative and inconsistent. The various files may have been created independently of one another, using different referencing systems or computer formats. Popular referencing systems include milepost, reference post, paper document methods, state plane and latitude longitude. In the worst case, some of the data required for analysis may not be spatially referenced at all. As a result, they are difficult to use in a consistent and efficient manner as inputs to a PMS. GIS technology is proposed as a framework for data integration because it provides a means of relating data collected under various referencing systems.

GIS – PMS INTEGRATION FRAMEWORK

As with any management process, pavement management needs a decision support system to be effective. The decision support system functions range from information retrieval and display, filtering and pattern recognition, extrapolation, inference and logical comparison, to complex modeling. A GIS can be a very important decision support system element by facilitating the preparation, analysis, display, and management of geographical data. In a PMS, a GIS can greatly enhance the analysis and presentation of information. Figure 1 shows the typical PMS structure for a local situation. The

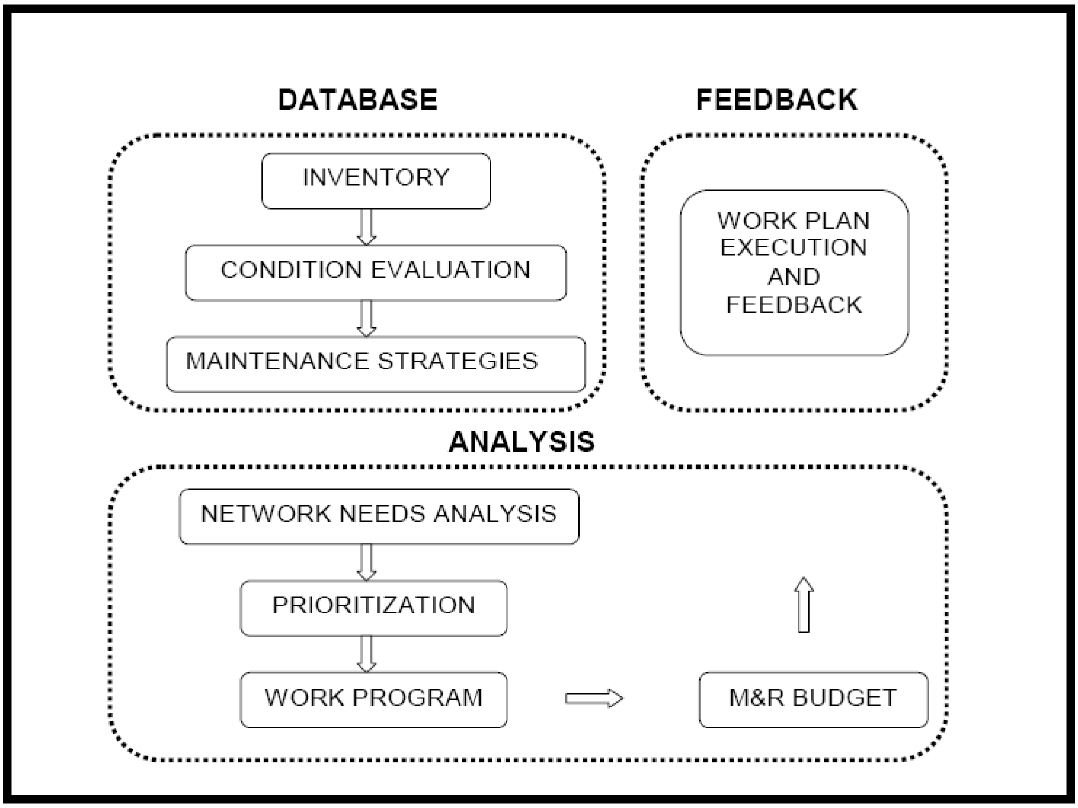
database is the first building block of any asset management system, and it must include, at a minimum, the following information's :

- Inventory – basic physical attributes of the road network being managed
- Pavement Condition – periodic functional and structural evaluations to assess the level of
- service being provided to the user, and

- Maintenance and Rehabilitation strategies – strategies the agency uses to correct the
- problems. These are determined using the periodic condition surveys.
- The database information is then analyzed to produce a multiyear maintenance and rehabilitation
- work program and budget, as follows:
- Network needs – the system will first assign all the maintenance and rehabilitation
- strategies for each road section in the inventory and narrowed down to the best strategy
- Prioritization – since the resources available are usually less than what the system needs,
- the resulting projects are ranked based on criteria consistent with agency objectives;
- Work program – using the list of prioritized projects, a multiyear maintenance and
- rehabilitation program is prepared; and
- Budget – the annual financial needs for executing the projects included in the work
- program are defined.

The last step entails the work plan and providing the necessary feedback process, that is,

comparing the pavement and treatment performance with that predicted by the PMS, is crucial for improving the system's reliability.



Determination of Strategies and Assignment of Resources

The determination of strategies could imply a series of decision rules based on economic analysis that match deficiency ratings with appropriate actions. Well-designed GIS/PMS should have direct links to decision modules so that the strategies can be readily determined. The strategy module should have direct access to the GIS/PMS database, and the model results should be entered directly into the database.

A GIS would enrich the decision-making process by incorporating other types of data that could not easily be brought into the process without the ability to relate data spatially. One of the example is accident analysis requires the correlation of a number of explanatory roadway and environmental variables such as roadway geometrics, weather conditions, traffic volumes, signage, signalization, lighting, and pavement condition. A GIS can serve as the integrator of all transportation activities (e.g., pavement management, accident analysis, sign and signal inventories and planning), as well as the link to other agencies with overlapping data needs (e.g., planning environmental resources, utilities).

ESSENTIAL COMPONENTS OF GIS/PMS

A number of essential analytical capabilities that should be included in comprehensive GIS/PMS have
been identified:

- data base editor for storing and editing pavement condition data and other data to be used in the analysis;
- Formula editing of data base fields that facilitates the computation of new relationships such as an overall condition rating;
- Unvaried statistics (min, max, sum, mean and standard deviation), e.g., to compute the total lane miles with a deficiency rating greater than 90; multiple regression to compute deterioration equations; correlation to compute dependence between possible explanatory variables such as truck volumes, weather, and soil conditions and pavement Charting (e.g., pie charts and bar

charts) to enhance the understandability of the data and make it easier to communicate results to decision makers, politicians, and citizen groups; Matrix tools for creating and manipulating origin-destination tables, travel time matrices, and other one and two-dimensional matrices used in transportation models for shortest path detour determination and traffic assignment;

- A set of useful transportation models and algorithms including shortest path, traffic assignment, vehicle routing (for efficient reallocation of trucks and equipment), and traveling salesman (for the delivery of materials to several construction sites); and
- Links to external procedures such as life cycle costing, decision analysis, shortest path, and traffic assignment.
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GIS TECHNOLOGY AND BENEFITS

A GIS is a computerized data base management system for accumulating, storage, retrieval, analysis and display of spatial (i.e. location defined) data. A GIS contains two broad classifications of

Information, geo coded spatial data and attribute data.

Geo-coded spatial data define objects that have an orientation and relationship in two or three-dimensional space. Attributes associated with a street segment might include its width, number of lanes, construction history, and pavement condition and traffic volumes. An accident record could contain fields for vehicle type, weather conditions, contributing circumstances and injuries. This attribute data is associated with a topologic object (Point, line or polygon) that has a position somewhere on the surface of the earth.

A well-designed GIS permits the integration of these data. The sophisticated database in a GIS has the ability to associate and manipulate diverse sets of spatially referenced data that have been geo-coded to a common referencing system. The software can transform state plane coordinates and mile point data to Latitude-longitude data and vice versa.

A GIS can expand the decision-making on repair strategies and project scheduling by incorporating such diverse data as accident histories, economic needs hazardous materials shipment and vehicle volumes. A GIS can perform geographic queries in a straightforward, intuitive fashion rather than being limited to textual queries; A GIS/PMS can used to build projects through spatial selection, Can compute traffic impacts of various PMS plans and can incorporate the results of life cycle Forecasts into measurements of future mobility.

2.1 Data Collection

In pavement management, process first step is to collect and record the condition of the roadway segments. A series of computer displays showing the segments color-coded by the various attributes would greatly facilitate the process of data entry and editing. Omissions in the data collection effort would be immediately apparent from segments in the roadway showing no data. Errors in measurement or coding would also be readily apparent.

In electronic data collection, equipment makes it feasible to scan a roadway from a moving vehicle and automatically record pavement distresses on a microcomputer. If the data were to have entered directly into a GIS database, this procedure could produce an instant map display of the road condition.

2.2 Preliminary Analysis and Interpretation

In the traditional PMS, the highway engineer transfers some of this tabular information to a base map by hand as a step in understanding the data. For example, he might construct a map showing the severity of rutting or block cracking or create a

map indicating the overall performance index. A GIS that integrates the database attributes describing the pavement condition with a cartographic display of the road network can be used to create any number of illustrative visual displays of the status of the road system.

2.3 Determination of Strategies and Assignment of Resources

The determination of strategies could imply a series of decision rules based on economic analysis that match deficiency ratings with appropriate actions. Well-designed GIS/PMS should have direct links to decision modules so that the strategies can be readily determined. The strategy module should have direct access to the GIS/PMS database, and the model results should be entered directly into the database.

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ESSENTIAL COMPONENTS OF GIS/PMS

A number of essential analytical capabilities that should be included in comprehensive GIS/PMS have identified as:

- **data base editor for storing and editing pavement condition data and other data to be used in the analysis;**
- **Formula editing of data base fields that facilitates the computation of new relationships such as an overall condition rating;**

- **University statistics (min, max, sum, mean and standard deviation), e.g., to compute the total lane miles with a deficiency rating greater than 90; multiple regression to compute deterioration equations; correlation to compute dependence between possible explanatory variables such as truck volumes, weather, and soil conditions and pavement condition;**
- **Charting (e.g., pie charts and bar charts) to enhance the understandability of the data and make it easier to**

- **communicate results to decision makers, politicians, and citizen groups;**
- **Matrix tools for creating and manipulating origin-destination tables, travel time matrices, and other one and two-dimensional matrices used in transportation models for shortest path detour determination and traffic assignment;**
    - **A set of useful transportation models and algorithms including shortest path, traffic assignment, vehicle routing (for efficient reallocation of trucks and equipment), and traveling salesman (for the delivery of materials to several construction sites); and**
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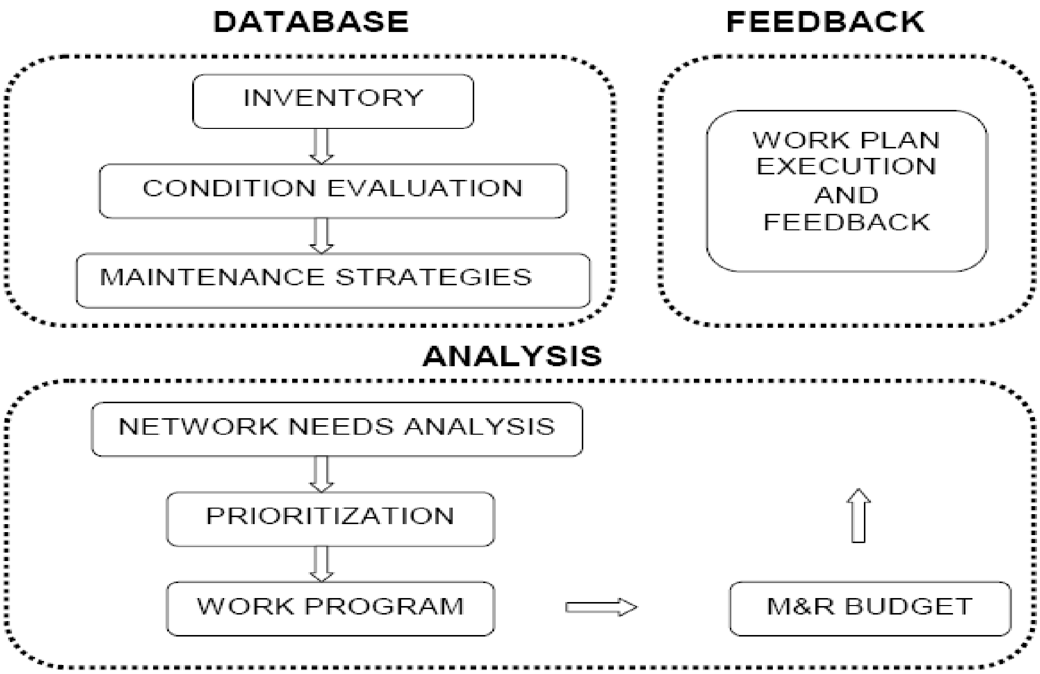


Figure 1 PMS Structure

3. ROAD MAINTENANCE

Roadway maintenance takes the load of several entities activities beside the traveling public. The condition of the roadway network and its features are severely affected by utility maintenance and upgrades, urban developments and many other social and economical facilities and activities. Treating the symptoms alone of degradation resultingfrom such activities had been historically proven to be inadequate (Haas et al., 1994).

Most of the developing countries due to lack of sources and budgets don't use such systems for road maintenance management. The result was an endless chain of problematic issues, some of which were deemed almost impossible to resolve. A Maintenance Information / Decision Making Mechanism that integrates and "thinks" other affecting bodies within its structure, is definitely desired. Integration between the roadway maintenance system and other entities such as utility department, traffic control, urban planning, etc will ensure the systematic well organized operations for both current maintenance measures and future development projects. An approach would ensure that

the working version will be able to communicate with other existing systems in the manner that would provide users in both sides with the appropriate output needed for coordination between decision making mechanisms (Sharaf, and Abo-Hashema, 2004).

2. Overview of PMMS

A Pavement Maintenance Management System should not be confused with a Pavement Management System (PMS). A PMMS is a part of a PMS program, i.e. they overlay rather than replace one to another. Figure 1 shows PMMS versus PMS and the concept of the overlay between them [Abo-Hashema, 2004; Sharaf et. al, 2003].

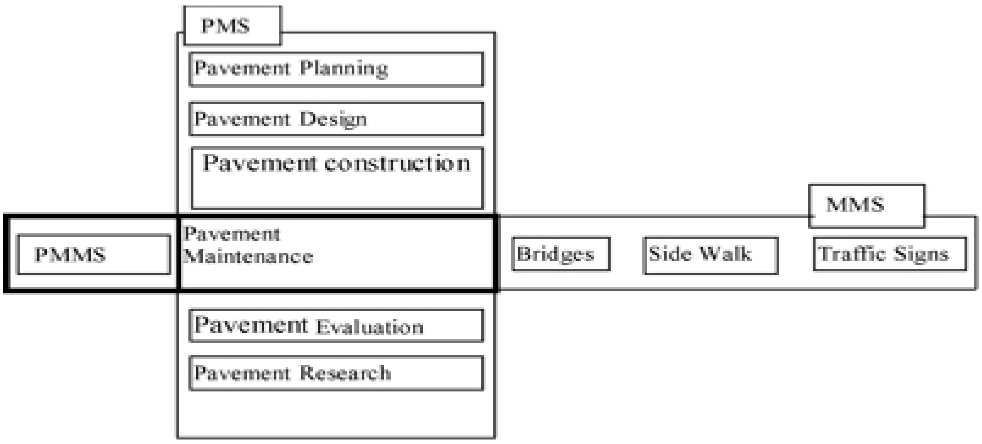


Figure 1 Pavement Maintenance Management System (PMMS) Versus Pavement Management System (PMS)

Pavement maintenance is the preserving and keeping of the pavement structure as possible as in its original condition as constructed or as subsequently improved, and such additional work as is necessary to keep traffic moving safely. This involves routine maintenance works (patching, filling ruts, removing surface corrugation, pouring cracks, bleeding surfaces, etc.) and major maintenance activities such as resurfacing, rehabilitation, overlays, etc. [AASHTO, 1986]

Pavement maintenance is not an exact science. The same type of

road in different locations requires different maintenance operations. Consequently, repair methods, which give good results at one location, may not be the proper methods at another location. Thus it can be quickly seen that experienced personnel with good judgment are the key to proper maintenance [Haas and Hudson, 1978].

A PMMS provides the framework for decision making in pavement maintenance based upon an objective approach. The complexity of highway maintenance cannot be reduced to a series of mathematical expressions; its management should be subjected to a rigorous systems approach to ensure that policies are developed on a basis of need that performance is monitored and proper financial control is exercised. The overall systems concept of maintenance management system is shown in Figure 2 [Sharaf et. al, 2003; Pinard, 1987].

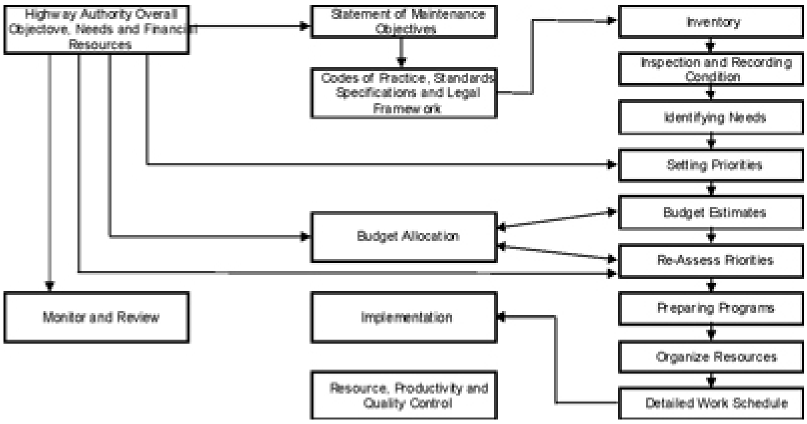


Figure 2 Maintenance Management System, an Overview

4. PMMS AND GIS

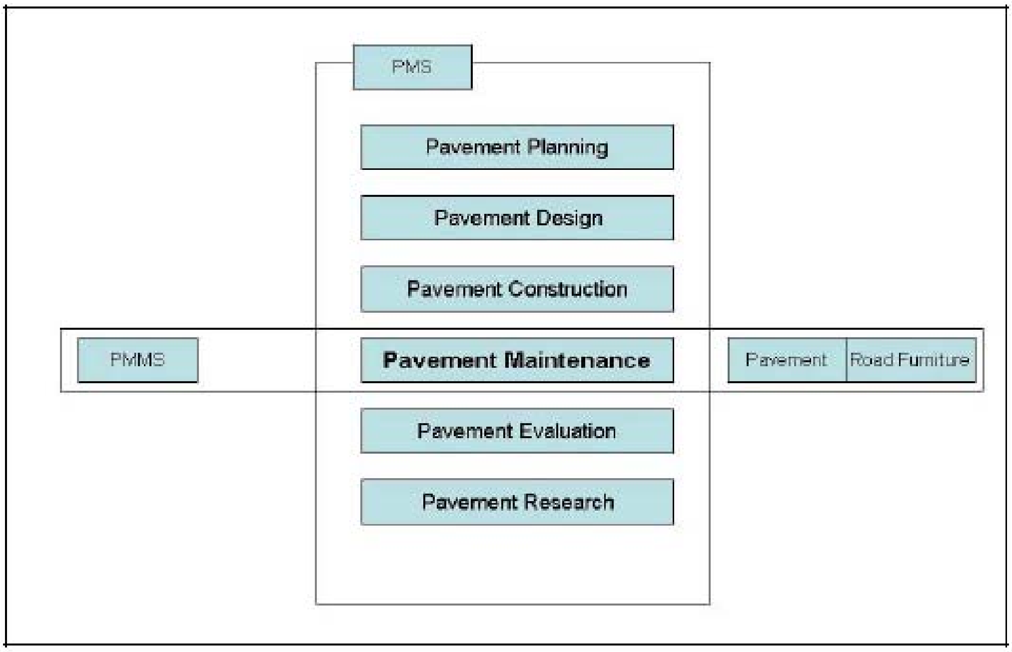
4.1 PMMS Components

Pavement Management System (PMS) should not be confused with PMMS. PMMS is considered one part of PMS out of six parts. Figure 2 shows the six parts of the PMS,

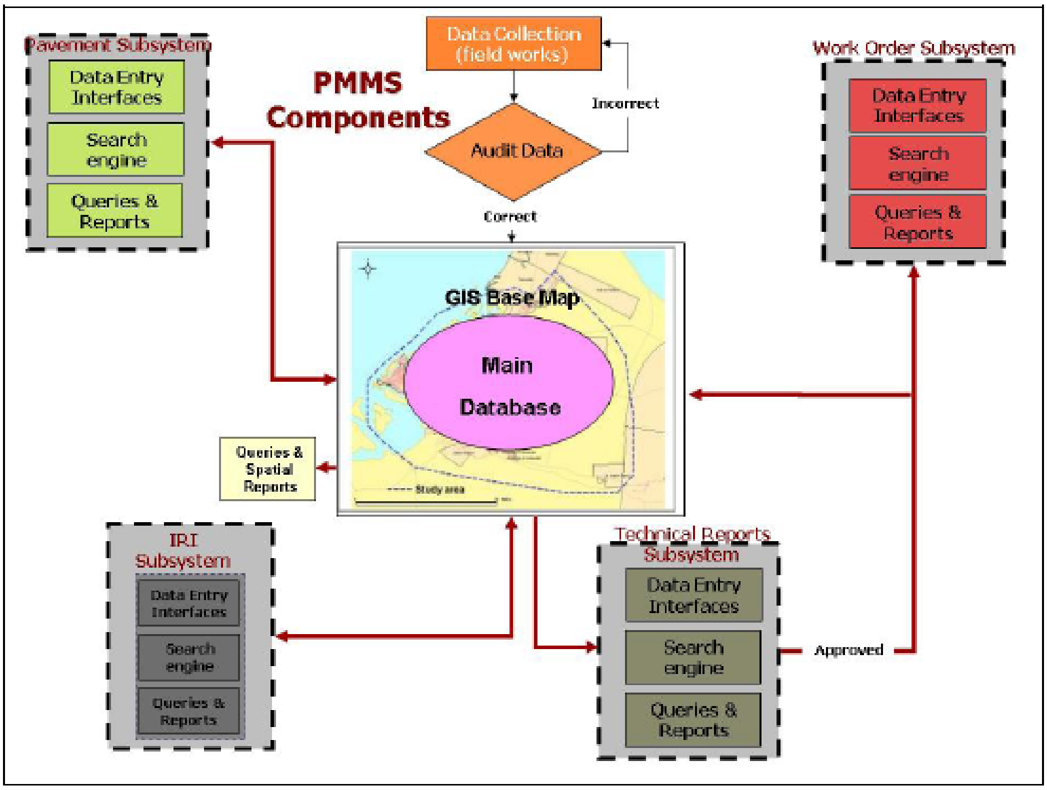
which are listed as follow:

- **Pavement Planning**
- **Pavement Design**
- **Pavement Construction**
- **Pavement Maintenance**
- **Pavement Evaluation**
- **Pavement Research**

This research project covers the Pavement Maintenance Management System. Figure 3 illustrates the overall system structural framework of PMMS



PMS
Pavement Planning
Pavement Design
Pavement Construction
PMMS
Pavement Maintenance
Pavement
Road Furniture
Pavement Evaluation
Pavement Research



Pavement Subsystem
Data Entry Interfaces
Search engine
Queries & Reports
PMMS Components
Data Collection (field works)
Incorrect
Audit Data
Correct
Work Order Subsystem
Data Entry Interfaces
Search engine
Queries & Reports
GIS Base Map
Main Database
Queries & Spatial Reports
IRI Subsystem
Data Entry Interfaces
Search engine
Queries & Reports
Technical Reports Subsystem
Data Entry Interfaces
Search engine
Queries & Reports
Approved

As shown in Figure 3, data is the backbone of any management system especially when

such management scheme is built on a database system where the accuracy of data collected and entered becomes critical. Data is typically collected for a specific purpose in the pavement maintenance management system (Corazzola, 2003). The PMMS database is developed in a GIS environment to facilitate data integration and to supporteasier access and use of information. The PMMS database integrates all of the data and creates an environment by which the users can make knowledgeable decisions regarding their pavement maintenance, rehabilitation, or reconstruction (Prasada et al., 2006). The database includes the entire inventory, history, and condition information referenced to a graphical interface, which allows the user to obtain data for any road, street segment or sector.

Case study 1

Pavement maintenance management practices and gis in al ain

Abstract:

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. 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. Adding a technological element to PMMS has been a vital step in supporting and improving decision-making. Geographic Information Systems (GIS) were found to be powerful tool in providing such exertion. The implicit goal of using GIS is presenting new techniques for proper collection, archiving, and analyzing of pavement maintenance

data. Accordingly, Al Ain Municipality, UAE, decided to implement a GIS-Based PMMS through the current project "Maintenance of Roads and Bridges in Al Ain Region". Two Levels of PMMS data are collected in this project: Network-Level and Project-Level. The network-level is an overview of the condition of a network of roads. Minimum amount of data was collected at the network-level that is needed to support the analysis of overall condition of the network and determine which streets require repairs. In project-level, more detailed information is needed to finalize the list of projects and to provide a detailed scope-of-work for each individual project. The framework of the project includes a systematic, consistent approach to gathering and analyzing data and generating recommendations and reports. This paper presents the effort made so far in integrating the technological concept of GIS and PMMS activities through the current maintenance project of Al Ain City.

GIS datasets include tabular attributes that describe geographic objects. Multiple tables can be linked to the geographic objects by a common thread of fields (often called keys). These tabular information sets and their relationships give GIS users the data management power typically associated with relational database applications [ArcGIS, 2004]. Roads, utilities, and linear GFs are often represented as lines in a network with multiple connections, and intersections. With the interactive intelligence introduced by GIS; Engineers can handle tasks on both network and GF scopes easily, and timely, as shown in Figure 4. Intelligence (Topology) is the method used for defining different GF boundaries and interconnected relations.

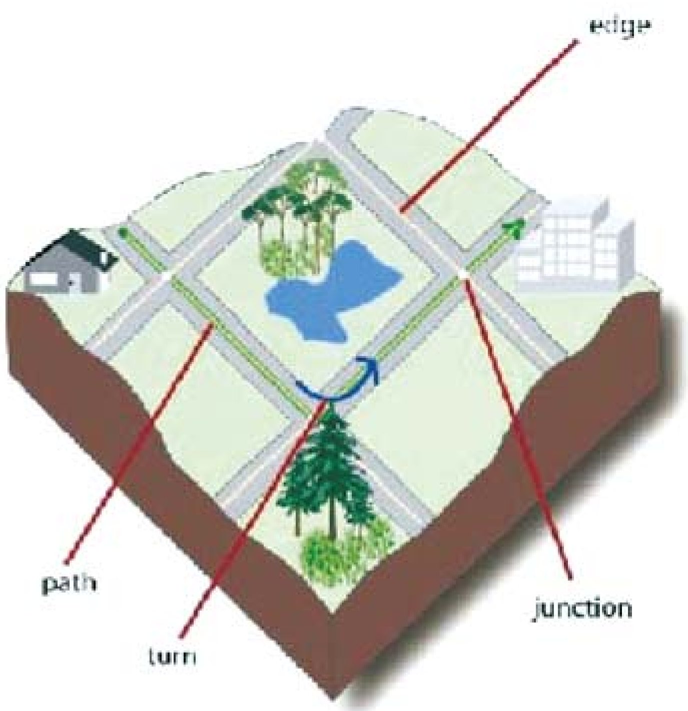


Figure 4 Roads Network Representation in Intelligent Environment

4. Integrating PMMS and GIS

Figure 5 shows a schematic representation of the integration between PMMS and GIS. PMMS starts with network identification and go through data collection, data analysis, maintenance priorities, maintenance decisions; and ends with supervision and follow-up. GIS starts with data entry and manipulation, thematic mapping, and ends with tailoring and decision support. GIS acts as the core for the integration process, through managing the different corresponding activities interaction. The integration interface is a transition level that exists to ensure adequate compatibility of integration requirements.

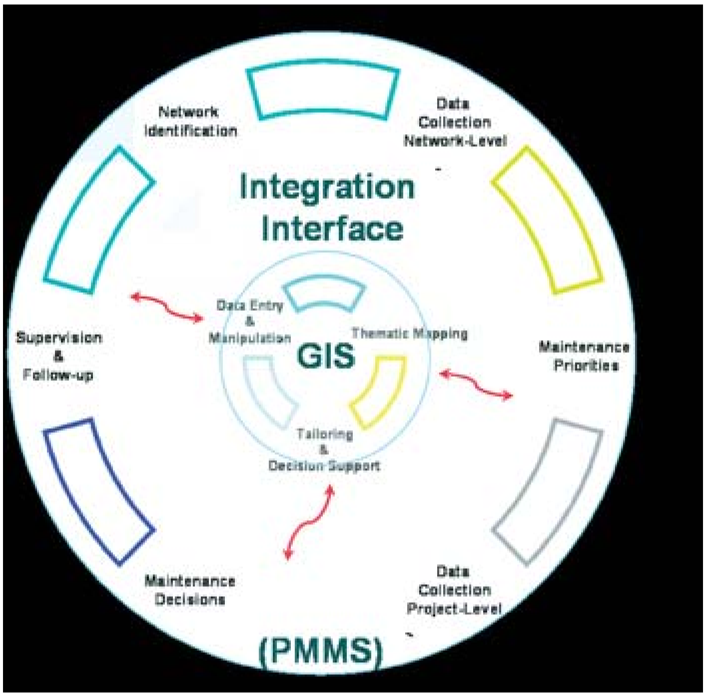


Figure 5 Integrating PMMS and GIS

5. General Framework of the Project

The general framework of the project can be outlined by the PMMS activities workflow, as shown in Figure 6. However, it can be noticed the chained link to the GIS workflow, which is presented in Figure 7. The framework starts from the network identification and ends with work orders and investigation reports with a comprehensive connection to the corresponding GIS activities. The following titles will describe some items in the framework.

6. Network Identification (Referencing)

6.1 General

The first step in the development of a PMMS is to identify the roads network. The development of the referencing system should start with a review of the current practices of the agency. Each of the divisions responsible for collecting pavement data, or associated data should be identified and reviewed.

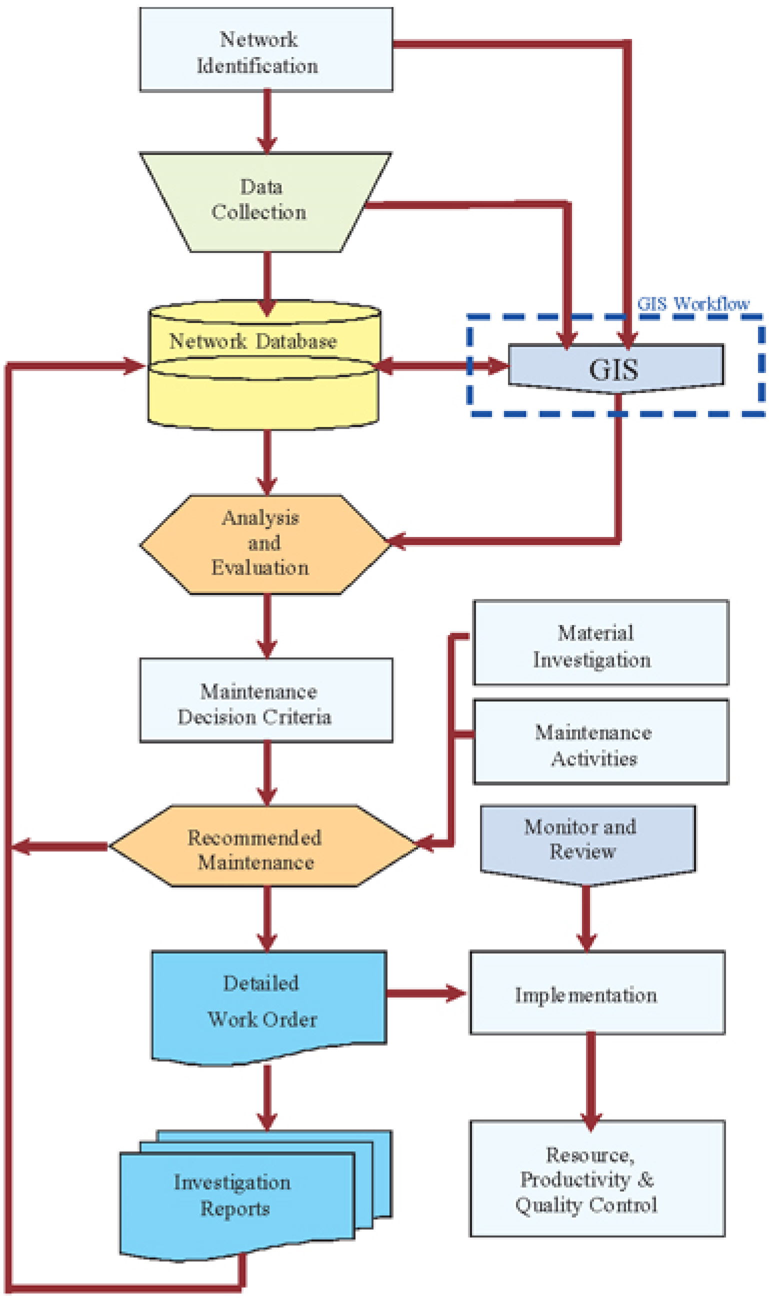


Figure 6 General Workflow of the Project for PMMS

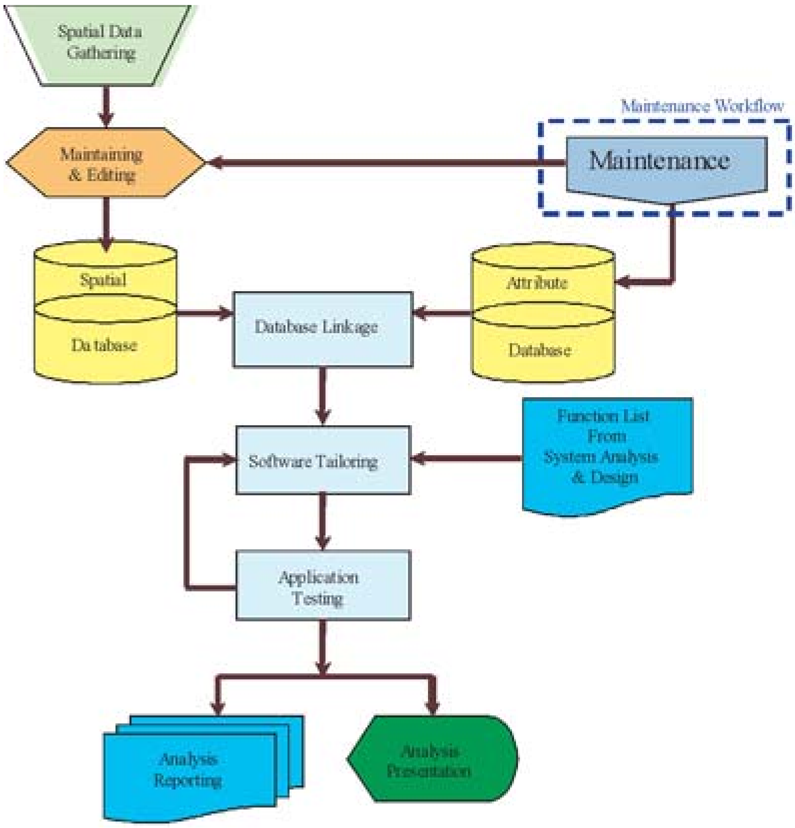


Figure 7 General Framework of the Project for GIS

For pavement management, one of the existing methods may be selected or a new method may be defined. In either case, plan should be made for coordinating the different referencing methods to permit a free interchange of data [Haas et. al, 1994]. There are three basic methods of referencing pavement sections:

Route milepost

Node - Link

Branch - Section

Once the referencing method is established, the specific pavement sections must be defined for use in the database. The methods used vary widely between agencies. Section can be defined to have either uniform characteristics or fixed length [Haas et. al, 1994].

6.2 AI Ain Network Classes

6.2.1 Main Roads

Main roads are defined as dual carriageways. There are 600 kilometers (Centerline) of paved main roads in Al Ain region. The Town Planning Department (TPD) in Al Ain city has assigned all the main roads with a unique number. It is noteworthy that ninety percent of the intersection points between the main roads are roundabouts and the others are signalized intersections. These intersection points are also defined by the TPD with a unique number.

6.2.2 Secondary Roads

Secondary roads are defined as single carriageways. All the secondary roads are located inside communities, which are located in Districts. There are 3000 kilometers of paved secondary roads located in more than 95 communities. Similar to the coding system of the main roads, secondary roads have a unique community internal coding assigned by the TPD.

6.3 Al Ain Network Encoding System

Although, there is a unique coding system used by the TPD, but there is no clear referencing system that can be used to apply the PMMS activities. Therefore, it is much wiser to extend this unique coding to formulate proper network identification.

6.3.1 Main Roads

The referencing or identification system that has been used in the main roads is Node-Link method. In the node-link method, key points in the network are defined as nodes and the sections between these nodes in each direction are defined as the links. Nodes are usually defined at intersections, boundaries, and point of change in the pavement characteristics, such as a change in surface type.

In this project, a defined section (link) in each direction consists of three traffic lanes excluding the node area. It starts at 50 meters away from each node area or intersection point. The total number of sections in Al Ain region fairly exceeds 500 sections with different lengths. Each inspected section was divided into sample units of 100 meters length per traffic lane through which data can be collected. The section code consists of 12 digits. The first four digits in the code starting from the left side represent the road code (TPD unique number), the next four digits represent starting node code (TPD unique number), and the last four digits represent ending node code. Lane code is represented by adding one more digit to the 12-digits of the section code. Furthermore, adding another three digits to the 13-digits of lane code represents 16-digits of sample code. Figure 8 and Figure 9 show an example of the coding system for Shakhboot Ibn Sultan Road between nodes 101 and 121.

On the other hand, nodes are defined at intersection points separately evaluated as a section. The node-section includes 50 meters towards each street or leg. The intersection points-TPD unique coding was used as the node code.

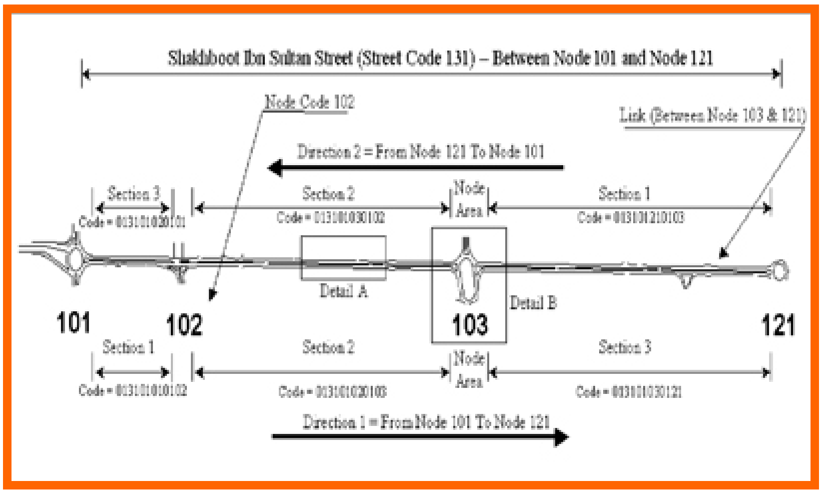


Figure 8 Network Identification for Main Roads

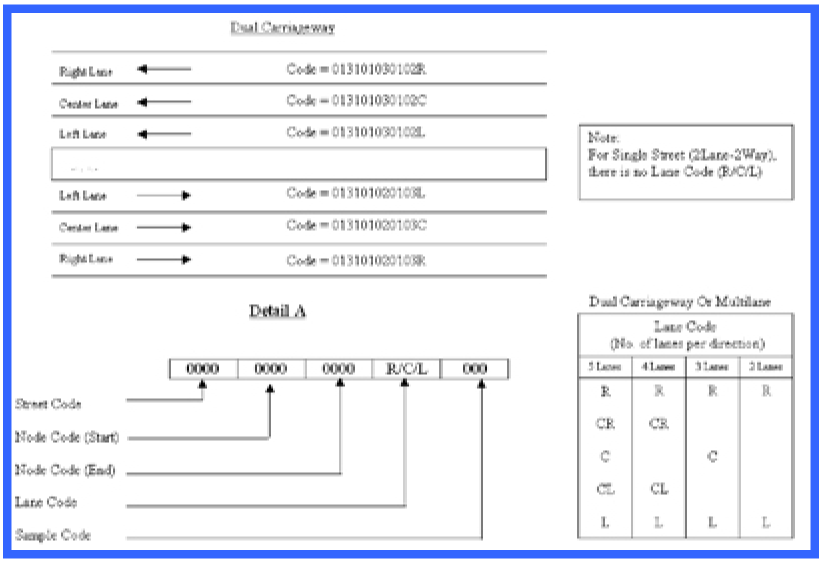


Figure 9 Coding System of Sections for Main Roads

Secondary Roads

The TPD code for districts, communities, and internal roads was extended to facilitate a unique code on a network scope. The referencing or identification system that has been used in the secondary roads is branch-section method.

A defined branch (District) consists of communities. A defined section (Community) consists of internal roads, which represent samples. The branch code consists of 3 digits (TPD-District unique number). Section code is represented by adding two more digits (TPD- Community unique number) to the 3-digits of the section code. Furthermore, adding another three digits (TPD- internal roads unique number) to the 5-digits of section code represents 8-digits of sample (road) code. Figure 10 shows an example of the network identification for secondary roads in Al Dhaher community.

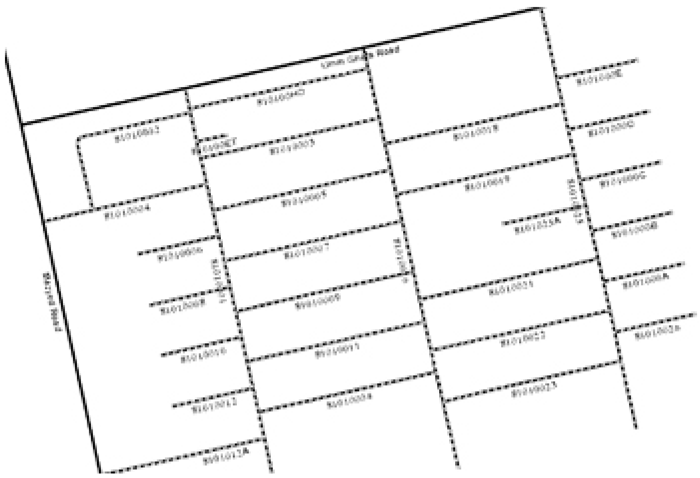


Figure 10 Network Identification for Secondary Roads

6.3.3 GIS Integration

The selection of the Node-Link and branch-section methods as referencing systems was implemented onto the base map of GPMA in the same order defined in previous sections. While the road GF was represented in a form of vector-Lines, round about was represented in a form of vector-point shape, and districts/communities were represented in a form of vector-polygon shape forming the system spatial data. This spatial data is considered the foundation for generating GIS abstract level "Archive".

The formulation of the secondary roads labels printed in Figure 10 consists of 8-digits code, as mentioned previously with the combination of district-community-internal road code.

7. Data Collection

7.1 General

A data bank is considered the main tool in which the results and the whole system will completely depend on. The data collection stage is considered one of the stages that need organization and good identification to achieve the objective of the program.

Field data collection was performed through two levels:

- **Network-Level**
- **Project-Level**

The network-level is an overview of the condition of a network of roads. Minimum amount of data was collected at the network level that is needed to support the analysis of overall condition of the network and determine which streets require repairs. In project-level, more detailed information is needed to finalize the list of projects and to provide a detailed scope-of-work for each individual project.

It is noteworthy that the database designed for GPMA relayed on the scopes portrayed previously and with respect to the needed analysis discussed later. Collected data was manipulated and properly edited forming GFs attributes, which was linked to the base map forming the "Archive".

7.2 Condition Survey for Network-Level

An overview of the condition of the network has been carried out covering the defined sections of the main and secondary roads. The purpose of this network condition survey is to come up with maintenance plan for the main and secondary roads. The collected data consists of sections definition, nodes definition, sections length, and general condition of sections.

CASE STUDY

Selected screenshots from the project Click on any thumbnail to view a high-res image

Case Study: Sonoma County's GIS Pavement Management System with Real-Time Scenario and Maintenance Analysis

Challenge

Sonoma County's Public Work's department is responsible for maintaining 1,387 miles of the County's 1,857 roads, a network of blacktop which is regularly traveled by hundreds of thousands of San Francisco Bay Area residents and visitors. To track and manage the condition of its road network the County uses StreetSaver 8.0, a Pavement Management System (PMS) application developed by the Metropolitan Transportation Commission (MTC), the Bay Area's regional transportation planning and financing agency, located in Oakland.

County engineers use StreetSaver and a Microsoft SQL Server database to store and analyze the condition of the County road network and to define and adjust maintenance treatments and costs. Engineering technicians enter information about specific stretches of roads into a StreetSaver form, allowing the software to calculate important measures of the street's pavement condition. These calculations are used to assess the quality of the County's streets and to allocate pavement maintenance budgets.

While StreetSaver is a powerful pavement management tool, its output is limited to forms and tabular reports. County Engineers recognized that presenting the results of their analyses on maps would be a much better way to visualize results, allowing both managers and technicians to see where maintenance efficiencies might be gained. Unfortunately, Streetsaver and the County's ESRI Geographic Information System (GIS) were not linked and contained different types of data. To display road condition information, County managers printed out hard copy maps from the GIS and then manually highlighted problem areas that were identified based upon Streetsaver database printouts.

Both MTC and the County realized that linking and dynamically integrating the GIS and StreetSaver would be necessary to create maps that could show both detailed street maps and pavement condition and maintenance information.

Solution

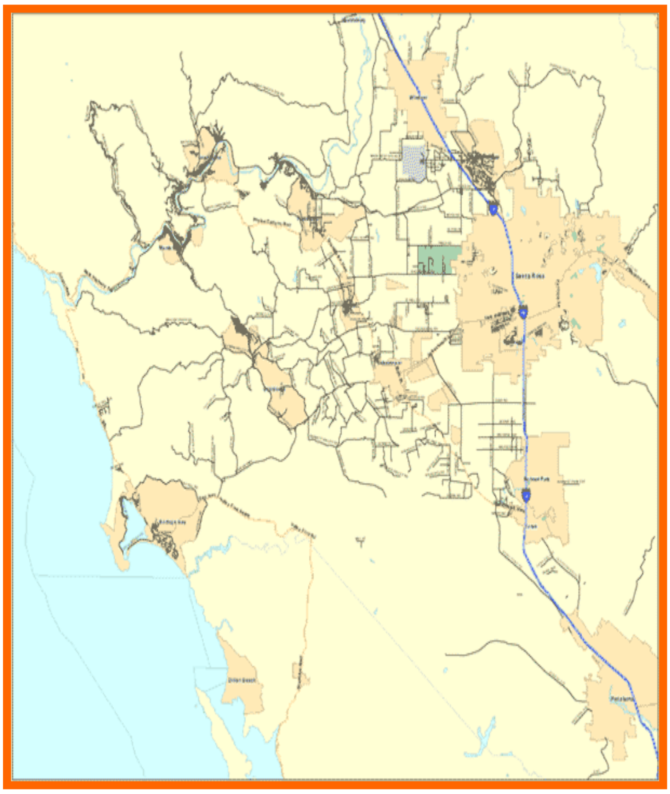
Farallon Geographics installed ESRI's ArcSDE with a Microsoft SQL server database. Through data modeling and testing, dynamic views were created that allowed the information in the GIS to be shared with the Streetsaver database. Tools in ESRI's ArcGIS were used to develop dynamic segmentation procedures to render Streetsaver information to the GIS. The segmentation of the streets into paving sections is done dynamically using the Streetsaver database post mile data at the time the user requests the information so that the two datasets never get out of sync.

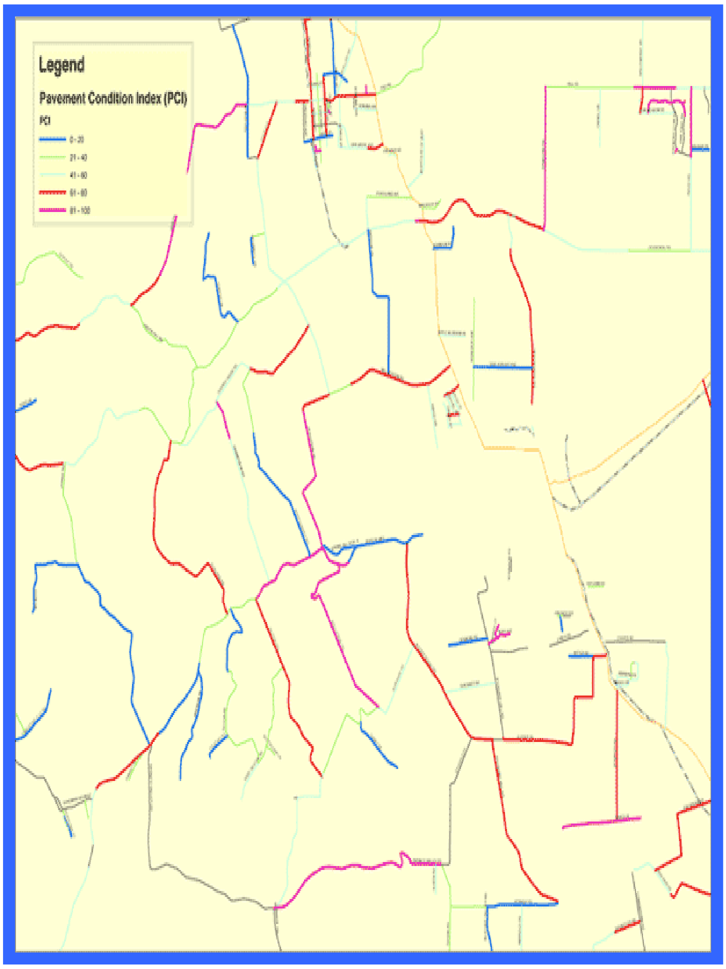
Dynamic segmentation also means that edits can be made to the Streetsaver data directly from the GIS by clicking on a segment and changing its criteria. This allows pavement managers to immediately see the results of these data changes on a map. Using Farallon's integrated GIS and PMS, County staff could quickly map Streetsaver information into the GIS and perform spatial analysis, allowing them to quickly create maps showing the extent of distressed streets.

"We already had spent the time and research to develop a route-based system," said Tom Nguyen, Senior Engineering Program Analyst with Sonoma County's Department of Transportation and Public Works. "Public Works staff could now use Farallon's GIS-PMS to quickly create and present maps showing the extent of distressed pavement, and the location and number of lanes and average daily traffic volume throughout the County."

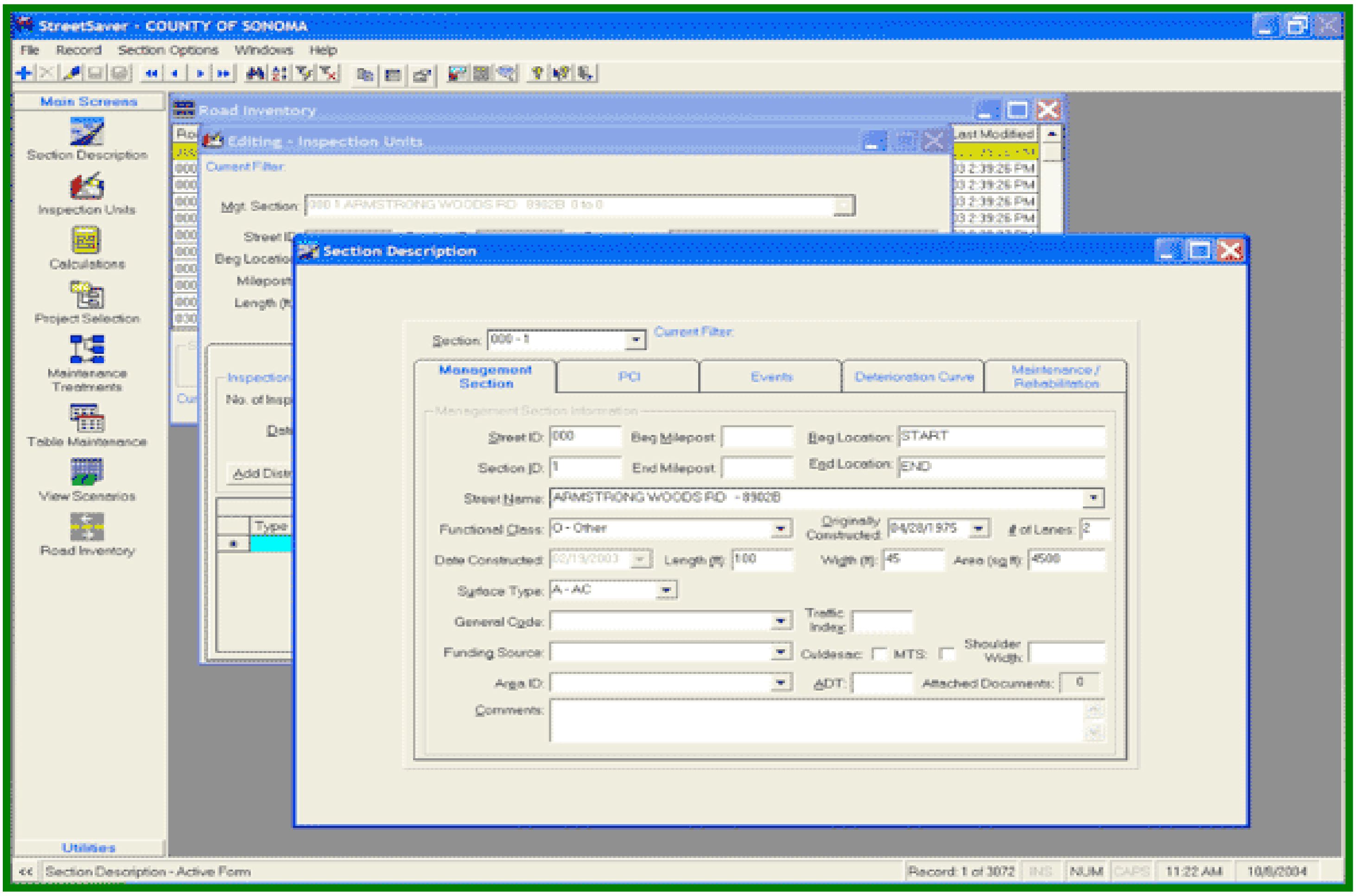
“We immediately recognized the usefulness of the maps. Because they were interactive, we can use them to show funding agencies our street maintenance responsibility,” said Mark Wein, Civil Engineer with Sonoma County’s Department of Transportation and Public Works.

“The Sonoma County implementation’s goal was the improvement of workflow and their effort and foresight to create a route-based GIS has made the County a model to other cities and counties. Ultimately, the team effort resulted in a solid return on investment through the real-time visualization of interactive maps,” said Dennis Wuthrich, CEO of Farallon Geographics.





Legend
Pavement Condition Index (PCI)
PCI



StreetSaver - COUNTY OF SONOMA
File
Record
Section Options
Windows
Help
Main Screens
Section Description
Inspection Units
Calculations
Project Selection
Maintenance Treatments
Table Maintenance
View Scenarios
Road Inventory
Utilities
Road Inventory
Editing - Inspection Units
Current Filter
Mgt. Section:
Last Modified
Section Description
Section: 000 - 1
Current Filter
Management Section
PCI
Events
Deterioration Curve
Maintenance / Rehabilitation
Street ID: 000
Beg Milepost:
Beg Location: START
Section ID: 1
End Milepost:
End Location: END
Street Name: ARMSTRONG WOODS RD - 8902B
Functional Class: O - Other
Originally Constructed: 04/28/1975
# of Lanes: 2
Date Constructed:
Length (ft): 100
Width (ft): 45
Area (sq ft): 4500
Surface Type: A - AC
General Code:
Traffic Index:
Funding Source:
Culdesac:
MTS:
Shoulder Width:
Area ID:
ADT:
Attached Documents: 0
Comments:
Section Description - Active Form
Record: 1 of 3072
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CONCLUSIONS:

The highway community is emphasizing on improved pavement management procedures and is exploring GIS technology at all sectors and research institutions. Efforts have been made to demonstrate the development and use of a PMS using a pavement attribute database in a GIS environment to support the pavement management decision using several applications. The coupling of appropriate GIS technology with a standalone PMS can result in an enriched PMS. The visual parameters such as cracking, rutting, raveling, potholes and the roughness and skid resistance values are collected using various field investigations and studies. This data is then stored in the GIS database. Different types of operations such as retrieval, insertion, updating and deletion of data can be done on this database. The data is used to perform calculations based on the functional and structural condition of pavements. Based on this an optimum maintenance and rehabilitation solution is suggested. The traditional strength of the GIS formulation are in mapping, display and digital processing and therefore a GIS based PMS requiring new data structures, data objects, interfaces and procedures will be of immense help to the highway community in fulfilling the effective decision making in PMS.

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