Generating Thematic Displays for A Simplified Pavement Information and Management System for A Developing Country Using Matlab Application

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Abstract: The trend in the development of most sophisticated Pavement Information and Management Systems (PIMS) is to thematically display the results of the analyses in GIS environment. However, for a developing country such as Nigeria, there is always the challenge of lack of mastery and skill necessary to develop and maintain a PIMS based on GIS. The thrust of the research work was to develop thematic displays for a simplified PIMS, based partly on ArcGIS, and MATLAB. Paper map of the federal road network for Nigeria was digitized in ArcGIS environment and transferred to MATLAB environment. The resulting database (of the digitized road map) was merged with the parent database of the PIMS in Microsoft Access, such that, the results of all the various analyses performed within the MATLAB environment are also displayed thematically in MATLAB.

Key Words: PIMS, thematic display, GIS, MATLAB, referencing systems

INTRODUCTION

The road transport infrastructure in Nigeria consists of 34,340.95 km of federal highways including seven major bridges across the Niger and Benue Rivers, the Lagos ring road and the third mainland axial bridge (FMWH, 1999).

Currently, there is no comprehensive management system for inspecting, recording, analyzing, prioritizing and programming highway maintenance works. The ability to integrate data from a variety of sources and provide summarized, strategic information in an easily understandable format for decision makers is also lacking.

In order to obviate the above mentioned challenge, a computerized but simplified PIMS was constructed and validated. The rating system adopted is the Pavement Condition Index (PCI) method.

For the thematic display of the results of the PIMS, an interface was constructed within Matlab environment. This interface is capable of displaying pavement management activities and provides information in thematic maps, charts and graphs.

Generating Digital Road Network Maps: Usually, the first aspect of digital management of infrastructure such as road network starts with the production of existing paper road network map in digital format. Many methods have been variously adopted over the years including conversion of hard copy maps (produced with manual cartographic techniques and updated using orthophotography) into digital format (Higgins, 1996). Existing paper maps have also been converted using large format table digitizers, personal computer and software such as Arc/Info software. There is also a record of Global Positioning System (GPS) and video being used to obtain centre line survey of 28,000km long national road network in the Philippines (Lagunzad, et al., 2003). In this work, the most-updated paper maps of the federal roads network of Nigeria were obtained and digitized within ArcGIS/ArcInfo environment.

Concept of Referencing Systems: The primary purpose of the referencing system is to accurately define and identify the road network. The reference or indexing system used by a PIMS affects the utility of the system. The data used for PIMS are located and stored according to two main methods:

- Using management units (e.g., link/node) or
- Based on a location referencing system.

Traditionally, PIMS data collection has used linear location referencing methods, such as route name and mile-post/logpoint (AASHTO, 2001). In the route name and milepost referencing method, each roadway is given a unique name and number and the distance along the route from a specific origin is used to locate points along the route. The distance units are usually marked with signs placed along the route (e.g., mileposts) to determine the position of linear or point events or data collection points in the field. One of the problems associated with this method is that the locations of the signs do not always agree with the actual location of the mile referenced when measuring using a DMI.

However, because of the increased use of GIS, automated data collection equipment and Global Positioning System (GPS), coordinate-based referencing methods are becoming popular. The most common
coordinate systems are the longitude and latitude, state plane coordinate system and universal transverse Mercator. Although many agencies use linear referencing system for their PMS data collection and storage (NCHR, 2004), coordinate-based systems are also becoming popular.

The use of GPS has many advantages in terms of location accuracy and data integration potential; however, it also creates a significant challenge regarding compatibility with historical data and interoperability with existing systems.

**MATERIALS AND METHODS**

The developed PIMS is customized computer software that incorporates knowledge-based Visual Basic Windows® and MATLAB applications. The computational aspects of the system are implemented using the MATLAB programming language with jet engine-based access to database files in Microsoft Access (mdb) format. The results and generated reports are displayed in Visual Basic Interface. The system is a completely interactive menu-driven application.

The PIMS system is designed to operate with manual visual condition survey of the pavements. Collated field distress data are entered in and the system automatically carries out PCI procedure and generates PCI condition rating for the particular road section. The system thereafter recommends suggested appropriate maintenance and rehabilitation strategies.

A digitized federal road network map was generated using ArcInfo/Map software and displays in MATLAB interface. The approach adopted for PIMS-Thematic Map integration is the exportation of analysed results from the PIM S and subsequent display on the digitized federal road network map, through Microsoft Access. Spatial information on traffic, type of pavement rehabilitation and pavement condition can be presented for the highway system in the form of different themes. Temporal information can be displayed based on user selection of a particular year. The steps used in generating the thematic displays and the summarized source code are contained in the Appendices A and B.

**Appendix A: Map Display:** The map display was done using the mapping toolbox of MATLAB. The Mapping Toolbox is a collection of MATLAB functions, user interfaces, sample data sets and demos that read, write display and manipulate geospatial data. The toolbox supports standard analyses, such as line-of-sight calculations on terrain data or geographic computations that account for the curvature of the Earth's surface. It also supports key mapping and geospatial data analysis, manipulation and visualization tasks that are useful in applications such as earth and planetary scientific research, oil and gas exploration, environmental monitoring, highway management, insurance risk management, aerospace, defense and security.

The map display in PIMS is achieved with MATLAB mapping toolbox using the following steps:

The digitized map is read in MATLAB using the function `shaperead`:

From the result of the `shaperead` function, the attributes of the map available are Geometry, BoundingBox, X, Y, Id, Road_Type, Road_Name, DESCRIPTRN and Name.

An attribute that is common to both the base database and the digital map is selected.

The attribute used here is “Road_Name”.

From the result of the query to the PIMS database, the Road_Name in the various condition of selected option (ADT, M and R Action or PCI Category) with respect to the survey year are then mapped with different colours on the map using the function: `makesymbolspec(Line,Road_Name,color,LineWidth)`.

The map is then displayed on the specified axes on the Graphical User Interface(GUI) using the function: `mapshow()`.

**Appendix B: Sample Pims Code for Displaying the Map:**

```matlab
function showRoadMap(RoadNames,RoadColour)
    %RoadNames is an array of all roads that fall into the respective category
    %RoadColour is an array of colour legends for each road, respectively
    %Declaration
    global roads global roadSpec
    roads=shaperead('Final Road.shp');
    %reading the digital map into %memory
    l=length(RoadNames);
    %Length of roadNames vector
    RC={}; %pre allocating memory to variable RC - Road colour
    LW=[]; %pre allocating memory to variable LW - Line weight
    for j=1:l
        LW(j)=2;
        if RoadColour(j) == 1
            RC(j)={'y'}; %Yellow
        elseif RoadColour(j) == 2
            RC(j)={'r'}; %Red
        elseif RoadColour(j) == 3
            RC(j)={'g'}; %Green
        elseif RoadColour(j) == 4
            RC(j)={'b'}; %Blue
        elseif RoadColour(j) == 5
            RC(j)={'k'}; %Black
        end
    end
    AllRoads=RoadNames;
    %colour specification for each road
    roadSpec=makesymbolspec('Line',... 
    {'Road_Name',AllRoads(1),color, 
    RC(1); 'LineWidth',LW(1))}; ... 
    {'Road_Name',AllRoads(2),color, 
    RC(2), 'LineWidth',LW(2)}; ... 
    : ;
end
```

RESULTS AND DISCUSSION

Generating Thematic Reports: In addition to presentation of survey and analysis reports in tabular formats, the developed PIMS also has the capability of displaying reports for the entire roads network in thematic map formats. Towards this end, all the available federal road sections within the network were digitized using ArcMap-ArcView program (Fig. 1). Each digitized road section was assigned a unique name (same as the federal route number). Links were then established between the digitized road sections and those road sections listed in the PIMS database. As such, it is possible to attach survey and analysis results to specific road sections, which are then appropriately displayed in the road network map.

Adopted Referencing System for the Research Work:
The primary purpose of the adopted referencing system is to accurately define and identify the pavement sections within the digitized federal road network of Nigeria. This was accomplished by establishing a standard section and node system that could be utilized (in future) to store all linear data related to roadway characteristics, e.g., road width, number of lanes, pavement thickness, etc. The linear data stored, in this study, are basically the route number and description of all highways within the network. An established link with the MATLAB application enables the results of analyses to be extracted and displayed for each pavement section in the PIMS interface.

Nodes and sections of pavements within the federal roads network map were identified according to FMW categorization as detailed in the Inventory of Federal Roads (FMWH, 1999). Nodes were defined as points in the road network and identified at road intersections or administrative/state boundaries.

State boundaries of roads were clearly identified and demarcated. A section represents the length of a road measured along the centerline between start and end nodes. The node that represents the end of a section defines the section’s limit and location. Fig. 2 shows the digitized vocational referencing of a section of the federal rural road network indicating nodes and sections.

Thematic Display Capabilities of the Developed Pims:
The developed PIMS is capable of reporting and displaying pavement and traffic information for the entire network of highways. The system is able to display information spatially as well as temporally. Spatial information on traffic (ADT), type of pavement rehabilitation (M and R Action) and pavement condition (PCI Category), can be presented for the highway system in the form of different themes. Temporal information can be displayed based on user-selection of a particular year. The flowchart for the thematic display is shown in Fig.3.

User interfaces are provided which facilitate easy selection of the different types of display of results from the analyses previously carried out in MATLAB environment. The user interfaces were developed and attached with label and tool buttons, lists and combination boxes. The user interfaces are used to display results for selected parameters such as ADT, M and R Action and PCI Category, for a particular year.

Thematic Displays of Historic PCI: The user selects ‘PCI Category’ as the desired parameter, selects the corresponding year for which information is required, selects the type of chart (pie or bar) and thereafter clicks on the EXECUTE button (Fig. 4, 5). The PIMS internally extracts and computes, from the database, the percent...
Fig. 3: PIMS Thematic Display Flow Chart

Fig. 4: Example of Thematic Map and Pie Chart of Historic PCI

Fig. 5: Example of Thematic Map and Bar Chart of Historic PCI

Fig. 6: Example of Thematic Map and Pie Chart of Historical M&R Actions

Fig. 7: Example of Thematic Map and Bar Chart of Historical M&R Actions

Fig. 8: Example of Thematic Map and Pie Chart of Historic ADT

values of pavement true areas falling within each PCI rating. The percent results are then automatically displayed for each PCI category and represented as pie / bar chart. The Show Map button is clicked to display the results in thematic map format.
Having first clicked on the radio button besides foregoing work, the following conclusions (coloured). Sections with gray colour indicate.

### Thematic Displays of Historic M and R Actions:

Figure 6 and 7 show examples of the system’s ability to display thematic map and charts for historic M&R activities. Having first clicked on the radio button besides the M and R Action, the user selects the desired year for which information is required and the chart type and then clicks the EXECUTE button. Based on the previously stored information (in the PIMS database), the system calculates percent area for the different M and R activities carried out on various road sections of the federal highway network. The results are presented for a particular year (Say, 2008) and displayed in different colours. The Show Map button is clicked to display the results in thematic map format.

### Thematic Map of Historic ADT:

In similar manner, historic ADT data for any particular year (for which data is available) can be displayed for the road sections within the federal rural highway network. Different colours of the map show different levels of ADT on the road sections. The different levels of ADT are shown in a legend and differentiated with colours on the charts and the map (Fig. 8 and 9).

### CONCLUSIONS

From the foregoing work, the following conclusions and recommendation are made, viz:

- For developing countries that obviously cannot successfully utilize sophisticated commercial PIMS software, a simpler but equally effective computerized more effective and attractive, graphical display PIMS has been developed.
- In order to make such developed PIMS much of analyzed result in the form of charts and thematic maps were incorporated. Though a digitized map of the federal roads was generated within ArcView environment, however the map is successfully incorporated to display results of analyses within MATLAB environment. Results are displayed in the form of thematic maps, charts and graphs.

### RECOMMENDATIONS

It was the challenges encountered in incorporating GIS with the developed simplified PIMS that led to the adoption of MATLAB programme for the thematic display purposes. However, GIS is a very powerful tool that could really boost the ability of developed PIMS to perform in-depth spatial queries and display. Further research should be geared towards the incorporation of GIS capabilities within locally developed PIMS.

Exploring the computational strength and mapping capability of MATLAB, a lot can be achieved ranging from geospatial data analysis, manipulation and visualization tasks that are useful in applications such as earth and planetary scientific research, oil and gas exploration, environmental monitoring, insurance risk management, aerospace, defence and security.

### REFERENCES


Fig. 9: Example of Thematic Map and Bar Chart of Historic ADT