A Gis-based traffic infrastructure management system for pavement markers and markings

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A GIS-BASED TRAFFIC INFRASTRUCTURE MANAGEMENT SYSTEM FOR PAVEMENT MARKERS AND MARKINGS

by

Kaizad Jehangir Yazdani

Bachelor of Science
University of Nevada, Las Vegas
1995

A thesis submitted in partial fulfillment of the requirements for the

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Howard R. Hughes College of Engineering

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A GIS-Based Traffic Infrastructure Management System for Pavement Markers and Markings

is approved in partial fulfillment of the requirements for the degree of

Master of Science in Civil Engineering

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Public infrastructure management is the management of all public assets to maximize public benefit. The management of such assets are complex as they are diverse and distributed throughout the region. Pavement markings and marker materials are used to delineate travel lanes on roads and at intersections, and they are a key component of the roadway system. They play a vital role in facilitating safe traffic operations on roadways. The management of markings and markers is critical to public agencies responsible for roadway operations and traffic safety. However, few agencies have automated or computerized systems to maintain these inventories and to assist them in planning and managing their resources in this regard. Geographic Information Systems (GIS) technology, provides an important step for automating and better managing the pavement markings of the roadway infrastructure.

The GIS-based system described in this thesis facilitates developing and maintaining
an inventory of pavement markings and markers for individual links of a road network, and performing various queries and analyses using this information. It is based on a set of standard cross-sectional lane design configurations for links. Quantities of materials required for each design category and unit installed costs of the materials are maintained in a master spreadsheet that is linked to the GIS program. Information, such as link length are maintained in the GIS environment, so that the user input is kept to a minimum. Each link is assigned a unique identification number and is coded based on the type of materials used and the type of cross-sectional lane design. The GIS program is linked to a series of spreadsheets that are used to calculate the quantities of materials used and their costs. The system provides invaluable capabilities to managers and policy makers regarding the evaluation of safety, operations, fiscal planning, and allocation of resources.
# TABLE OF CONTENTS

ABSTRACT ....................................................................................................................................... iii

TABLE OF CONTENTS ......................................................................................................................... v

LIST OF FIGURES ............................................................................................................................... vii

ACKNOWLEDGMENTS ......................................................................................................................... viii

CHAPTER 1 INTRODUCTION ................................................................................................................ 1

CHAPTER 2 BACKGROUND .................................................................................................................. 4
  2.1 Roadway Infrastructure Elements ............................................................................................... 4
  2.2 Review of Management Practices ............................................................................................... 7
  2.3 Review of the Literature .............................................................................................................. 9
    2.3.1 Review of Practices at Clark County, Nevada ................................................................. 15
  2.4 Goals and Objectives .................................................................................................................. 18

CHAPTER 3 METHODOLOGY .............................................................................................................. 20
  3.1 Pavement Marking Inventory Information .................................................................................. 20
    3.1.1 Pavement Markers .............................................................................................................. 21
    3.1.2 Pavement Markings ............................................................................................................ 21
  3.2 Basis for Inventory ....................................................................................................................... 23
  3.3 Database Setup ............................................................................................................................ 43
    3.3.1 Creating the Decision Support Tool (DST) in Excel ..................................................... 43
    3.3.2 Linking GIS to Excel ........................................................................................................... 51

CHAPTER 4 ANALYSIS ......................................................................................................................... 54
  4.1 System Requirements and Installation ....................................................................................... 54
    4.1.1 Hardware Requirements ..................................................................................................... 54
    4.1.2 Software Requirements ....................................................................................................... 55
    4.1.3 Data Needs .......................................................................................................................... 56
    4.1.4 Installing the Program ......................................................................................................... 57
  4.2 Program Startup ............................................................................................................................ 59
  4.3 Data Integration ............................................................................................................................ 60
  4.4 Example Application .................................................................................................................... 65
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 3.1</td>
<td>Center Line and Lane line Types</td>
<td>25</td>
</tr>
<tr>
<td>Figure 3.2</td>
<td>Design Categories (2010, 2021, 2032)</td>
<td>29</td>
</tr>
<tr>
<td>Figure 3.3</td>
<td>Design Categories (3010, 3020)</td>
<td>30</td>
</tr>
<tr>
<td>Figure 3.4</td>
<td>Design Categories (3031, 3042)</td>
<td>31</td>
</tr>
<tr>
<td>Figure 3.5</td>
<td>Design Categories (4010)</td>
<td>32</td>
</tr>
<tr>
<td>Figure 3.6</td>
<td>Design Categories (4022)</td>
<td>33</td>
</tr>
<tr>
<td>Figure 3.7</td>
<td>Design Categories (5010)</td>
<td>34</td>
</tr>
<tr>
<td>Figure 3.8</td>
<td>Design Categories (5022)</td>
<td>35</td>
</tr>
<tr>
<td>Figure 3.9</td>
<td>Design Categories (6010)</td>
<td>36</td>
</tr>
<tr>
<td>Figure 3.10</td>
<td>Design Categories (6022)</td>
<td>37</td>
</tr>
<tr>
<td>Figure 3.11</td>
<td>Design Categories (7010)</td>
<td>38</td>
</tr>
<tr>
<td>Figure 3.12</td>
<td>Design Categories (7022)</td>
<td>39</td>
</tr>
<tr>
<td>Figure 3.13</td>
<td>Design Categories (8010)</td>
<td>40</td>
</tr>
<tr>
<td>Figure 3.14</td>
<td>Design Categories (8022)</td>
<td>41</td>
</tr>
<tr>
<td>Figure 3.15</td>
<td>Design Categories (9012)</td>
<td>42</td>
</tr>
<tr>
<td>Figure 3.16</td>
<td>Design Categories</td>
<td>44</td>
</tr>
<tr>
<td>Figure 3.17</td>
<td>Marker Design Types</td>
<td>45</td>
</tr>
<tr>
<td>Figure 3.18</td>
<td>Marking Design Types</td>
<td>46</td>
</tr>
<tr>
<td>Figure 3.19</td>
<td>Quantities of Markers by Design Categories</td>
<td>48</td>
</tr>
<tr>
<td>Figure 3.20</td>
<td>Amount of Markings by Design Categories</td>
<td>49</td>
</tr>
<tr>
<td>Figure 3.21</td>
<td>TIMS Editing Form</td>
<td>52</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>Error Message Due to Incorrect Excel Path</td>
<td>58</td>
</tr>
<tr>
<td>Figure 4.2</td>
<td>User Authentication</td>
<td>59</td>
</tr>
<tr>
<td>Figure 4.3</td>
<td>Microsoft Excel Startup Prompt</td>
<td>59</td>
</tr>
<tr>
<td>Figure 4.4</td>
<td>Prompt for Updating Microsoft Excel Links</td>
<td>60</td>
</tr>
<tr>
<td>Figure 4.5</td>
<td>View of the Street Network</td>
<td>62</td>
</tr>
<tr>
<td>Figure 4.6</td>
<td>View of a Single Link Selected</td>
<td>62</td>
</tr>
<tr>
<td>Figure 4.7</td>
<td>View of Multiple Links Selected</td>
<td>63</td>
</tr>
<tr>
<td>Figure 4.8</td>
<td>Red Diamond Shaped Icon</td>
<td>63</td>
</tr>
<tr>
<td>Figure 4.9</td>
<td>Data Recorded After Data Input</td>
<td>64</td>
</tr>
<tr>
<td>Figure 4.10</td>
<td>Data Input into TIMS</td>
<td>64</td>
</tr>
<tr>
<td>Figure 4.11</td>
<td>Pavement Marking Attributes in Spreadsheet “TIMS”</td>
<td>66</td>
</tr>
<tr>
<td>Figure 4.12</td>
<td>Query Based on Number of Lanes</td>
<td>67</td>
</tr>
<tr>
<td>Figure 4.13</td>
<td>Query Based on Type of Marking</td>
<td>68</td>
</tr>
<tr>
<td>Figure 4.14</td>
<td>Query Showing the Links Selected Based on User Name</td>
<td>69</td>
</tr>
</tbody>
</table>
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CHAPTER 1

INTRODUCTION

The Transportation Equity Act for the 21st Century (TEA-21) enacted by the U.S. Congress in 1998 builds on the initiatives established by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), which was the last major authorizing legislation for surface transportation. TEA-21, in continuation of the effective programs established through ISTEA, has included new programs such as Border Infrastructure, Transportation Infrastructure Finance and Innovations. This new act combines the continuation and improvement of current programs with new initiatives to meet the challenges of improving safety. In fulfilling the demands of the ISTEA, it is important for city, county, and state agencies to consider new means of gathering transportation information. Each agency is required to account for their infrastructure and develop a maintenance management system to support requests [U.S. D.O.T., 1998].

Data collection and management are essential for any management system. The difficulties in roadway system asset management are being aware of the condition of the facilities, being able to observe and account for the lane miles of roadway, and for any given asset of the infrastructure. This research effort is focused at developing an application
software that will aid public works or transportation agencies in populating and maintaining an inventory of pavement markings within their jurisdictions and to serve as a decision support system. This is accomplished by populating the inventory database with the necessary information for pavement markings management and then linking it to a GIS database. This makes it possible to spatially quantify existing markings, project future marking requirements, estimate cost of markings, and develop maintenance/replacement schedules for markings.

This thesis includes information on some relevant software programs, technologies, and approaches that can aid in populating, maintaining, and querying the pavement markings inventory database. There are many firms with software programs that aid in tracking the condition of the pavement, but there have been very limited attempts at developing a software program that can inventory the lane miles of pavement markings or the number of raised pavement markers for a segment of roadway.

In order to develop a Traffic Infrastructure Management System (TIMS) for a Public Works agency, it is necessary that the application support the desired analyses. Existing software applications were researched as they can be integrated to create a tool that can provide the same results as a customized software package. This thesis document the various software applications that were reviewed for the integration, namely:

- Geographic Information Systems (GIS ArcView)
- Maintenance and Repair System (MARS 2.0)
- Applied Management Engineering
- Condition Assessment Survey System (CAS)
Data collection are a critical aspect of the infrastructure management system. Accuracy of the data is directly proportional to the overall performance of the infrastructure management system. Several technologies exist which can assist in populating the pavement inventory database. These technologies are:

- Global Positioning Systems (GPS)
- Voice recognition
- Pen-based Computers
- Wireless Data Collection
- Contact Memory Buttons

This thesis describes the development of an application that will automate the inventory of pavement markings and pavement markers on roadways, and also provide a decision support tool for management of the pavement markings and markers. It is important to establish an automated means of capturing pavement marking data. This research involved the following steps: a) research for applications capable of automated data capture, b) Identification of Clark County requirements for the developed applications, c) development of the data inventory application, and d) a demonstration of the developed application. The application of the system developed is demonstrated using a portion of the road network under the jurisdiction of Department of Public Works, Clark County, Nevada.

An evaluation of the current Infrastructure Management practices and software applications is presented in Chapter 2. The methodology for the Infrastructure Management System is discussed in Chapter 3. The system requirements and application implementation are discussed in Chapter 4. Chapter 5 discusses conclusions and recommendations.
CHAPTER 2

BACKGROUND

The background information relevant to this thesis is categorized into four subsections. First is a review of elements of the roadway infrastructure and the attribute information generally collected. Second is a review of typical management practices. Third is a review of literature material related to software applications and data collection techniques available for roadway network asset management. Fourth is an outline of the goals and objectives for this thesis. These are based on the needs and requests of Clark County Department of Public Works.

2.1 Roadway Infrastructure Elements

Infrastructure of a region comprises of many assets. Applied to public works infrastructure, asset management is the process of keeping track of and deploying the public's capital. The focus of public works assets management is necessary on making decisions about development, use, maintenance, repair, and retirement or replacement of sewers, highways and other infrastructure [Lemer, 1997]. This section describes the different assets that make up a typical roadway infrastructure system and the attributes for inventory:
Bicycle Lanes: A bicycle lane is that part of the street specifically reserved for the exclusive use of bicycle riders. The number of lane miles of bicycle lanes, location, and number of lanes are some attributes for which data needs to be collected [Garber 1988].

Bicycle Paths: Bicycle paths are separated by some physical barrier from automobile traffic. The number of lane miles of bicycle paths, location, and number of lanes are some attributes for which data needs to be collected [Garber 1988].

Drainage Systems:

- Curb and Gutter: Curb and gutters prevent automobiles from encroaching pedestrians on the sidewalks and help contain and direct surface flows into drop inlets.
- Drop Inlets: Drop inlets are a part of the storm drain system, located at low points to capture ponding water and redirect it to a channel or to the main storm drain system.
- Flood Channels: These are facilities designed to contain flood waters and minimize flood impacts to an area.
- Culverts: Culverts are openings that allow water to flow through. Two types of culverts are typically used, box culverts and metal pipe culverts.

In general, the data that must be captured for drainage systems include the following location: of the drop inlets, flood channels, culverts; size: of the culvert, flood channel, drop inlet; type: of culvert, and flood channel; capacity: of the drop inlets, flood channel, and culverts.
Parking Facilities/Garages: Areas specifically designed to facilitate parking for automobiles. The location, capacity, ownership and the fees are some attributes that need data collection for a parking facility.

Roadway Lights: roadway lights are another asset of the infrastructure that need to be accounted for in the database and constantly maintained and upgraded. The street light database populated must include information such as the type, material, condition, lamp type, type of arm, location, type of circuit, and maintenance fields for all street lights.

Roadway Pavements: Roadway surfaces can be paved or unpaved. Paved road surfaces are divided into two categories; rigid and flexible. The top most surface of the roadway is termed the wearing surface. The wearing surface of a rigid pavement is usually constructed of Portland cement concrete and the wearing surface of a flexible pavement is usually constructed of bituminous materials such that it remains in contact with the underlying materials. Flexible pavements usually consists of multiple layer below the wearing coarse. Flexible pavement is further subdivided into a) Subgrade: subgrade is the natural material located along the horizontal alignment of the pavement and serves as the foundation of the pavement structure, b) Subbase Course: the subbase component is located above the subgrade and consists of superior materials, c) Base Course: this course is placed above the subbase. The type of materials used consist of crushed stone, crushed gravel, and sand [Garber 1988]. Attributes to collect for roadways include paved and unpaved roads for the network of roads, classifications for roads, and maintenance history of
the paving for each roadway segment.

Traffic Safety Systems: Traffic signs, signals, and pavement markings are traffic safety systems aiding the drivers in traffic conflicts situations. Providing traffic safety devices is a very important task for users of the roadway system. Traffic safety systems are subdivided into a) Traffic signals: signals are placed to control conflicting flow of traffic on the roadways. Signals have proved to be an effective way of controlling traffic and improving safety, b) Traffic signs: signs are placed to regulate, warn and guide traffic on all streets and highways. Sign information such as the code, description, legend, sign direction, support type, number of supports, retro reflectivity and inventory date are important when populating the signs database. c) Pavement markings: markings are used to provide assistance to drivers on the roads helping them keep safe distance from other automobiles traveling along side them and prevent any crashes. The required attributes for pavement markings will be discussed later in the report.

2.2 Review of Management Practices

The management of various assets of the infrastructure by public agencies is a challenging task. Fully operational and functional infrastructure systems must have tools that help provide adequate and accurate information for decision makers. Achieving a fully integrated and functional system requires adequate and accurate data collection, decision support tools for data analysis, and compatibility with other applications such that the data populated in one applications can be retrieved in another application. Effective management
of the infrastructure system requires three components [Martin 1986]:

A. Data Management

B. Technology Management

C. Applications Management

A. Data Management:

Data are the key component of any management system. The data management aspect of the system requires effective management to ensure access, compatibility, integrity, and storage. Roles which perform these functions have been defined as Data Strategists (planning and co-ordination), Data Administrator (data analysis, definition of views and schemas, data modeling, validity, consistency, and accuracy of data), Database Designer (physically structuring data and planning access methods, database backup and recovery, physical schemas, database performance, security, searching techniques), and Data Operations Supervisor (data errors, system restarts, and recovery, audit trails, computer scheduling, file transfer for export) [Martin 1986]. The system component of the database management is not entirely performed by the data management component.

B. Applications Management:

Applications management consists of the hardware, and software systems providing services to the user. Applications management involves the operation, maintenance, and redevelopment of computer systems. Applications management is responsible for all the input/output functions of the system. Applications management is more concerned with “how” while Data management is focused on
the "what" [Martin 1986].

C. Technology Management:

Applications are built on top of technology platforms. These are specific products and standards which can be used to create the applications which, ultimately, satisfy the user. Technology includes the computer systems, operating systems, input/output devices, communications networks, and software, which are generic in nature and which must be combined with context specific data to meet the needs of the system [Martin 1986]. Technology management involves the maintenance and upgrade of computer systems, hardware, software, networks, communications systems and implementation of new and reliable techniques.

2.3 Review of the Literature

The literature review is divided into two categories: a) Software applications, and b) Data capture technology.

A. Software Applications:


Geographic information system (GIS), is a complete sequence of components for acquiring, processing, storing, and managing spatial data (Star 1990). GIS is a key set of tools increasingly adopted by local and regional governments, represents an important step toward truly integrated infrastructure-asset management systems, but other tools are needed as well [Lemer 1997]. GIS facilitates the management of multiple sets of data, spatial and nonspatial linked
together in many ways.

2. **Maintenance and Repair System (MARS 3.0):**

   This is a windows based software that was created for large facilities that require detailed budget justification, real estate asset controllers, and accountability. This software is able to forecast maintenance and repair funding requirements for better management. The software contains the detailed labor and materials costs for 116 U.S. metropolitan areas, pre-defined building and facility templates, as well as life-cycle cost data for more than 350 components and a variety of useful cost indexes for economic comparisons. The official website for this company is [www.whitestonerresearch.com](http://www.whitestonerresearch.com).

3. **Applied Management Engineering:**

   There are three different application packages available. Facility Condition Information System (FCIS), Facility Equipment Maintenance System (FEMS) and Backlog and Funding Model. FCIS saves facility inventory data including photos and electronic plans, permits, ranks facilities and generates facility inspection reports. FEMS deals with facility equipment, including history inventory, preventive maintenance scheduling, and work order generation. Backlog and Funding Project Model helps plan capital renewal and maintains a count of backlog projects [Vanier, 1990].

4. **Condition Assessment Survey System (CAS):**

   CAS is a decision assistance tool that establishes the existing condition of the asset, and then produces a benchmark for comparison, not only with different assets,
but also with the same asset at different times. CAS is able to record the deficiencies in a system or component, the extent of the defect and urgency of repair work [NRC 1994].

Described below are a brief summary of the various applications available from the CarteGraph suites. The official website for this company is www.Cartegraph.com.

**Pavementview** - This application can be used to maintain a detailed inventory of the paved and unpaved roads, record road pavement types, and provides details of the roadway structure and geometry. This application lacks the capability for developing and maintaining pavement markers and markings inventories.

**Sewerview** - Sewerview manages both sanitary sewer and storm sewer. This application provides the user the capability to inventory, inspect, and manage the entire sewer network. Information such as the location of manholes, culverts, pipes channels, pump stations can be recorded, hydraulic data can be recorded and displayed graphically as well.

**Waterview** - This application in managing large or small water systems. Information such as hydrants, valves, mains, services, meters, pumps and blowoffs can be recorded and maintain inspection and inventory records.

**Bridgeview** - This tool is specifically designed to maintain an inventory of bridges and culverts. For all structure, inventory, inspection, appraisal, maintenance information can be maintained. A detailed inventory of the bridge including the elements, materials, structural details, easement data can be recorded.

**Workdirector** - This CarteGraph’s computerized version of the filing cabinet that are
used to keep records of the paper work orders. This application is a comprehensive tool for all the management of all work activities that occur within a public work department. The databases work together to help accurately record labor, equipment and material costs, relate work activities to specific work orders or projects.

B. Data Capture Technology:

1. Global Positioning System (GPS):

   GPS is a very powerful tool which provides, and will continue to provide, the location data for attributes in many Geographical Information Systems (GIS). GPS facilitates the rapid collection of spatial data. Manufacturers of GPS equipment have developed low cost, user-friendly receivers and software which are capable of providing position information with varying accuracy. The higher the accuracy the higher the GPS positioning cost.

   Differential GPS receivers are capable of receiving corrections derived from reference stations which are sent via dedicated data connections to a control center. At the control center the information is checked for the quality and performance before being processed and formatted into a stream of real time corrected messages. Real time DGPS allows for accurate coordinate positions and eliminates post processing of the data. There are two major modes of differential Global Positioning System (DGPS): LAN, and WAN. LAN employs a local base station to generate pseudo-range errors for each visible satellite. Real time corrections are transmitted in Radio Technical Commission for Maritime Services (RTCM) format. The post processing of data is done using the Receiver Independent Exchange (RINEX)
format. WAN employs a regional set of base stations, and other improved information, to build real time corrections for entire nations or hemisphere. The WAN corrections are then sent to the geo-stationary satellite relays.

2. Pen-base Computers:

Pen-base computers are handheld, portable data collection systems. These systems make use of the touch sensitive screen for data input. Pen-base computers are best used when paper-based forms are replaced with electronic forms. The portability of the system allows the user to be mobile while collection data. Typical applications include filling package delivery forms, field inspection and recording quality control information. An example of a widely used pen-base computer is the Fujitsu Stylistic 2300 [www.fujitsu.com].

3. Voice Recognition:

Voice recognition systems operate by digitizing a person’s vocal track or setting up a set of vocabulary. These systems are best employed for those applications where a user must have his or her hands or eyes free to perform some other task. An example of this application is the collection of street sign data while cycling on the road on a bicycle using the VoCartra system [www.datria.com].

4. Wireless Data Collection:

Wireless data collection is based on the radio frequency technology. Wireless data collection refers to systems that communicate data over radio links between a host computer and a data source such as keyboards, data terminals, bar codes, magnetic stripes, and radio frequency identification tags.
There are two major categories of wireless data collection technology currently in use. Radio Frequency Data Communications (RFDC) and Radio Frequency Identification (RFID). RFDC systems use portable interactive bar code readers. Once a scan is made on a bar code symbol, the information is sent back to a host computer via a radio signal. RFDC systems are often used in warehousing, shipping and retail industries. RFID systems use a radio signal to retrieve data stored in a small electronic device attached to the item being tracked. This technology is an alternative to systems such as bar codes which do not work properly in environments where labels may become dirty, painted, or damaged, when the distance prevents a proper reading [www.engrng.pitt.edu/adc/wless.html].

RFID have three main components: readers, antenna, and tags. The reader interrogates the tag by means of a radio wave signal sent by the antenna. The tag sends another signal with the information requested. The signal is captured by the antenna and read by the reader. The information stored in the tag may be an identification number, or other related information deemed necessary to track. Some RFID systems applications are tracking shipping containers, automobile parts, and in libraries.

5. **Contact Memory Buttons:**

Contact memory buttons are physical devices directly attached to an object. These devices are read by direct physical contact with a reading device. The buttons are small stainless steel containers, the size of a small button, with a memory chip sealed inside. The buttons have the ability to read and write through contact.
Contact memory buttons are sealed to resist moisture, temperature extremes, and radiation, thus making it suitable for use in harsh environments. Applications where contact memory buttons have been used are tracking assets such as fire extinguishers, gas cylinders, or access control [Morse 1997].

2.3.1 Review of Practices at Clark County, Nevada

The system used for pavement marking maintenance by the Clark County Department of Public Works (CCDPW) Traffic Division has been created using a Fox Pro database software. This database contains information for a select number of roadway links from the complete network of roads within the County. Only streets with painted lane lines are repainted by CCDPW’s Traffic Division, streets that have Raised Pavement Markers (RPM’s) as lane lines when required maintenance are contracted out. The database does not account for all the road links which use pavement markings for lane line delineations.

The database used by CCDPW’s Traffic Division contain many data elements of the roadways. The following is a list and explanation of the field as seen in the database:

a) Month: implies the month the roadway link was last maintained
b) Days: the total number of days before this roadway link needs maintenance again
c) Area: this indicates the area of the county the roadway is located
d) Order Done: the order in which the roadways are maintained
e) Street: the name of the roadway
f) From: the name of the cross street at the beginning of the link
g) To: the name of the cross street at the end of link
h) Miles: the approximate total distance in miles for the roadway link

i) One: this field of the database counts the amount of painted miles for Type I centerline as defined by the Clark County drawing standards

j) Two: amount of painted miles for Type II centerline

k) Three: amount of painted miles for Type III centerline

l) Four: amount of painted miles for Type IV centerline

m) Five: amount of painted miles for Type V centerline

n) Pmiles: The total amount of paints in miles in painting all the lanes for a given roadway segment

o) Complete: the date the painting for the road segment is complete

p) Workorder: a number tracing the information back to the paper work.

A sample of the database is presented in Appendix A.

The current system has limited capabilities and accuracy. The lane miles maintained in this system are approximations of the true linear distances of each road segment, the street names and the segments are static, i.e. if there are new links added into the County roadway network system the database is unable to add update its records to show this addition of a new link. The road links are physically input into the database, and the other attributes of the link are estimated.

The Clark County Department of Public Works (CCDPW) Traffic Division as a part of an ongoing Integrated Infrastructure Management System (IIMS), has initiated the development of a Traffic Infrastructure Management System (TIMS). TIMS is intended to provide information consisting of traffic safety systems. The components of the TIMS are
sub-divided into:

1. Traffic Control Devices
   i.   Traffic signals and flashers
   ii.  Traffic signs
   iii. Pavement markings

2. Roadway Lights

CCDPW Traffic Division has selected CarteGraph as the software application for maintaining and collecting data. CarteGraph provides many applications for maintaining data for all the different components of the infrastructure. The following are some of the application in use by the CCDPW Traffic Division: a) Signview, b) Signalview, and C) Cartemaster.

Signview - Signview provides an efficient way to inventory, collect, maintain, and manage all sign attributes. The software provides the user with the ability of tracking attributes of the signs such as: MUTCD code, description, size, symbol, legend, shape, retro reflectivity, Currently CCPD W Traffic Division has a project to collect the location and various attributes of a sign for the entire County [www.cartegraph.com].

Signalview - Signalview provides the user with tools dedicated to collection, inventory, maintenance and management of all components for a signal. Signal information such as signal support, detector type, type of controller, maintenance history, and list a activities associated with a particular signal can be tracked easily [www.cartegraph.com]. CarteGraph provided the County with the locations and attributes for signals throughout the County. This was done to demonstrate the capabilities of Signalview. Since then Traffic Division has
kept maintained the database by adding new records when new signals are installed and updating the existing records for any maintenance activities associated with existing signals in the database.

Cartemaster - Cartemaster is a map viewing tool designed to work with all CarteGraph software modules. When used in conjunction with a CarteGraph software database, the links with these databases is "live". A wide variety of vector basemaps including .DGN, .DWG and .SHP files can be displayed. Raster images such as aerial images can displayed alongside the database [www.cartegraph.com].

2.4 Goals and Objectives

The specific GIS/application needs and management requirements for pavement inventory requires that the system developed meet the agencies asset management implementation needs. For example the needs for Clark County Department of Public Works Traffic Management Division are discussed in the Traffic Infrastructure Management System Design Report, October 1997 [Clark County, 1997] which provides a overview of one governmental agencies requirements in implementing the pavement marking inventory of the This report discusses a part of the Integrated Infrastructure Management System (IIMS) specifically the pavement marking inventory.

The GIS application requirements for pavement inventory system must address the following: a) quantify markers used on the roadways, b) describe characteristics (attributes) of existing markers, c) estimate quantities of markers needed in the future, d) estimate cost of maintenance and rehabilitation programs for pavement markings, e) be able to map the
data in GIS; facilitate spatial queries and analysis.

The developed application must be easy to operate, and address other issues such as ease of data capture/input, ease of data management, minimize computer hardware demands for computational storage and processing burdens.
CHAPTER 3

METHODOLOGY

Before any application is developed it is important that key elements of the application be identified, including hardware and software requirements. The Methodology chapter is divided into three sections. The first section discusses the types of pavement markings and markers materials to be inventoried. The second section discusses the basis for developing an inventory of pavement markings. The third section discusses the setup of the database in Excel, and linking Excel to GIS, including capture of data to complete the development of the inventory application.

3.1 Pavement Marking Inventory Information

Pavement markings are placed longitudinal and transversely on roadways. Longitudinal markings are placed on roadways to delineate the travel lanes on a multi lane road. Longitudinal markings are placed either solid or dashed as seen necessary. Transverse markings are placed at intersections, delineating the pedestrian cross walk, and also to indicate various advisory symbols on the roads. The materials used for longitudinal and transverse pavement markings are a) Pavement Markers, and b) Pavement Markings.
3.1.1 Pavement Markers

Pavement markers, also called Raised Pavement Markers (RPM) or buttons, are of two basic types: reflective and non-reflective. Pavement markers are made of various shapes, sizes and types. Generally, markers are square or circular in shape with an average width of 4 inches or diameter of 4 inches. Non-reflective markers are made of ceramic material with a glazed surface. Ceramic markers are preferred compared to plastic and other materials because they are resistant to scratching and to picking up road film and tire marks. Reflective marker types are made by encasing acrylic lenses, tempered-glass lenses, or glass bead lenses, mounted in either a plastic case or metal case.

Non-reflective and reflective raised pavement markers are classified with alphabetical schedule. The lane marker schedule for raised pavement markers are as follows:

- Type A: Circular white ceramic marker
- Type B: Circular type yellow ceramic marker
- Type C: Two way yellow reflector
- Type D: One way yellow reflector, with yellow towards oncoming traffic
- Type E: One way white reflector, with white toward oncoming traffic
- Type F: Two way white and red reflector, with white toward oncoming traffic

Type A, and B are non-reflective markers while C, D, E, and F are reflective.

3.1.2 Pavement Markings

Pavement markings are used to stripe travel lane lines, cross-walks, and the edges of pavement. Generally, there are two colors used: yellow and white. There are five basic types
of materials used for pavement markings. Listed below are the materials:

a. **Paint**: Traffic marking paint is a special type of paint made with 25 percent pigment, extender, and filler, 25 percent binder package and 50 percent solvent. Traffic paint pigment used is generally Titanium dioxide for white, and lead chromate for yellow.

b. **Thermoplastics**: Thermoplastic materials change their physical state with the change in temperature. Thermoplastics are solid at ambient temperature and liquid at elevated temperature.

c. **Polyester**: Polyester markings are composed of two components. The first component contains 95 percent of polyester and consists of resin, styrene monomer, wetting agent, adhesion promotive, calcium carbonate, and pigment. The remaining 5 percent is methylethyl-Ketone peroxide, a catalyst which when mixed with the first component makes it a hard and durable substance.

d. **Epoxy**: Epoxy markings are made of two components. The first component contains epichlorohydrin-bisphenol, epoxy resin, the pigment, extender and filler. The second component contains a catalyst very often an amine.

e. **Tapes**: Tapes are rolls of fabricated sheets. They are manufactured using resin binders with pigment and fillers and come with a pre-applied adhesive with a protective paper backing. Tapes are easy to install and give a good appearance.
3.2 Basis for Inventory

In order to develop the decision support tool, it is necessary to design a database that would support the desired analyses. The design of the database takes into consideration a number of factors that relate to traffic engineering, operations, and roadway design. Some traffic engineering, operations, and roadway design factors that affect the design of the database include the following: while it is possible to inventory every single marker on the roadway network, it would require the capture of information, and the maintenance/update of the information in the database which is labor intensive. This would not be a meaningful use of resources. Therefore, it is more appropriate to describe the inventory in an aggregated manner.

In order to develop an inventory of the markings and markers for each link, the roadway design characteristics pertaining to the lane configurations for a link were identified. There are five possible types of longitudinal lane markings. First, the different lane line delineations for a longitudinal section of the roads were used in developing the design categories and developing the basis for quantifying the markers and markings. A Type 1 centerline is placed between opposing traffic for undivided roadways prohibiting crossing over. A Type 2 centerline is placed between opposing traffic for undivided roadways, permitting the driver in one direction to cross the centerline. A Type 3 centerline is placed between opposing traffic for undivided roadways permitting the drivers in both directions to cross the centerline. A Type 4 lane line is placed between adjacent travel lanes in the same direction to provide assistance to drivers in maintaining their vehicles within the designated travel lane. Also, the Type F
markers for the Type 4 lane line have the opposing side of the travel direction reflecting red, indicating to the driver that this is the wrong direction of travel. A Type 5 lane line is placed on undivided roadways with Type E markers for travel lanes in the same direction, to provide assistance to drivers in maintaining their vehicles within the designated travel lane. Figure 3.1 shows all the types of center line and lane lines mentioned above.

The roadways are classified based on the roadway lane configurations, using a four-digit numbering scheme such as (PQRS). The first digit in the numbering scheme (P) represents the number of travel lanes for a link in both directions. The second and third digit together, (Q and R) represent the design number for the given number of lane (P). The fourth digits is assigned a 0 for no crossing of the center line permitted, 1 for crossing of the center line permitted in one direction only, and 2 for crossing of the center line permitted for both directions of the roadway. There are 18 design categories in total. The following is a brief explanation of the 18 design categories:

2010: a two lane road (represented by the first digit 2). The first design category of a two lane roadway (represented by the second and third digits 01), and with a type 1 centerline (represented by the last digit 0).

2021: a two lane road (represented by the first digit 2). The second design category of a two lane roadway (represented by the second and third digits 02), and with a type 2 centerline (represented by the last digit 1).

2032: a two lane road (represented by the first digit 2). The third design category of a two lane roadway (represented by the second and third digits 03), and with a type 3 centerline (represented by the last digit 2).
Figure 3.1 Center Line and Lane Line Types

Type 1 Center Line

Type 2 Center Line

Type 3 Center Line

Type 4 Lane Line

Type 5 Lane Line
3010: a three lane road (represented by the first digit 3). The first design category of a three lane roadway (represented by the second and third digits 01), and with a type 1 centerline (represented by the last digit 0). Also, a type 5 lane line is included for lane delineations for one side of the traffic flow.

3020: a three lane road (represented by the first digit 3). The second design category of a three lane roadway (represented by second and third digits 02), and with two type 1 centerline (represented by the last digit 0).

3031: a three lane road (represented by the first digit 3). The third design category of a three lane roadway (represented by the second and third digits 03), and with one type 1 centerline. Also, a type 2 centerline is included (represented by last digit 1), but only allowing for essentially two lanes of travel, one in each direction and a center turn lane.

3042: a three lane road (represented by the first digit 3). The fourth design category of a three lane roadway (represented by second and third digits 04), and with two type 2 centerline (represented by the last digit 2).

4010: a four lane road (represented by the first digit 4). The first design category of a four lane roadway (represented by the second and third digits 01), and with a type 1 centerline (represented by the last digit 0). Also, two type 5 lane line are included for lane delineations for directional traffic.

4022: a four lane road (represented by the first digit 4). The second design category of a four lane roadway (represented by the second and third digits 02), and with two type 2 centerline (represented by the last digit 2). Also, a type 5
lane line is included giving one side of the roadway two lanes of travel.

5010: a five lane road (represented by the first digit 5). The first design category of a five lane roadway (represented by the second and third digits 01), and with a type 1 centerline (represented by the last digit 0). Also, three type 5 lane line are included for lane delineations for directional traffic.

5022: a five lane road (represented by the first digit 5). The first design category of a five lane roadway (represented by the second and third digits 02), and with two type 2 centerline (represented by the last digit 2). Also, two type 5 lane line are included for lane delineations for directional traffic.

6010: a six lane road (represented by the first digit 6). The first design category of a six lane roadway (represented by the second and third digits 01), and with a type 1 centerline (represented by the last digit 0). Also, four type 5 lane line are included for lane delineations for directional traffic.

6022: a six lane road (represented by the first digit 6). The second design category of a six lane roadway (represented by second and third digits 02), and with two type 2 centerline (represented by the last digit 2). Also, three type 5 lane line are included for lane delineations for directional traffic.

7010: a seven lane road (represented by the first digit 7). The first design category of a seven lane roadway (represented by the second and third digits 01), and with a type 1 centerline (represented by the last digit 0). Also, five type 5 lane line are included for lane delineations for directional traffic.

7022: a seven lane road (represented by the first digit 7). The second design
category of a seven lane roadway (represented by the second and third digits 02), and with two type 2 centerline (represented by the last digit 2). Also, four type 5 lane line are included for lane delineations for directional traffic.

**8010:** an eight lane road (represented by the first digit 8). The first design category of a eight lane roadway (represented by the second and third digits 01), and with a type 1 centerline (represented by the last digit 0). Also, six type 5 lane line are included for lane delineations for directional traffic.

**8022:** an eight lane road (represented by the first digit 8). The second design category of a eight lane roadway (represented by the second and third digits 02), and with two type 2 centerline (represented by the last digit 2). Also, five type 5 lane line are included for lane delineations for directional traffic.

**9012:** a nine lane road (represented by the first digit 9). The first design category of a eight lane roadway (represented by the second and third digits 01), and with two type 2 centerline (represented by the last digit 2). Also, six type 5 lane line are included for lane delineations for directional traffic.

Additionally, roadways are either completely developed i.e. have curb and gutter at the edge of the pavement or are not completely developed in which case at the edge of the pavement the ground is sloped with compacted dirt. Pavement marking are installed at the edge of the road for both completely developed and not completely developed roads. A white solid line is placed at the edge of the pavement to mark the right edge of pavement. A solid yellow line is placed to mark the left edge of the pavement for divided roadway.

Figures 3.2 through 3.15 show the different design categories that have been used to set up
the system with solid lines showing edge line markings.

Figure 3.2 Design Categories (2010, 2021, 2032)
Figure 3.3 Design Categories (3010, 3020)
Figure 3.4 Design Categories (3031, 3042)

3031

3042

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Figure 3.5 Design Categories (4010)
Figure 3.6 Design Categories (4022)

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Figure 3.7 Design Categories (5010)
Figure 3.8 Design Categories (5022)
Figure 3.9 Design Categories (6010)
Figure 3.10 Design Categories (6022)
Figure 3.11 Design Categories (7010)
Figure 3.12 Design Categories (7022)
Figure 3.13 Design Categories (8010)
Figure 3.14 Design Categories (8022)
Figure 3.15 Design Categories (9012)
This application does not distinguish between divided or undivided roads. Therefore the quantities of markings or markers are overestimated for divided roadways. This may take place where medians or concrete barriers are used instead of a centerline type to separate directional travel, the amount of markings estimated will reflect quantities for additional travel lane, i.e. the application will compute markings quantities for the median divide although there are no markers or markings installed.

3.3 Database Setup

Once the design categories are defined, the next step is to set up the Decision Support Tool (DST) using Excel a spreadsheet program from Microsoft and ArcView GIS by Environmental Systems Research Institute (ESRI) a tool to visualize, explore, query, and analyze data geographically. The pavement markings of a roadway are based on the standardized typical centerline and lane line delineations discussed previously. The first part explains the setup of the application in Excel and the second discusses the setup in GIS.

3.3.1 Creating the Decision Support Tool (DST) in Excel

The Excel part of the application is developed by creating two different files that are linked to each other. The first file (Main.xls) consists of 5 individual spreadsheets that are linked within the file. The functionality of the five files in the first Excel file (Main.xls) is described below:

1. The spreadsheet labeled “Design Category” is a template sheet that identifies all the 18 design categories that are possible for roadways. The first column lists the 18
design categories, column two lists the number of lanes for each of the design categories, and columns three, four, and five list the number of lanes assigned for directional travel. Figure 3.16 shows the layout of the spreadsheet.

2. The spreadsheet labeled "Marker Design Types" is a template sheet that identifies the number of RPM’s per centerline and lane line type. There are six types of RPM’s used on roads. These are Type A through Type F, and three centerline and two lane line configurations that are used which have been explained previously. The basis for defining the number of RPM’s for each centerline and lane line, was to use the

<table>
<thead>
<tr>
<th>Design Category</th>
<th># of Lanes</th>
<th>Number of Lanes by Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>One Direction</td>
</tr>
<tr>
<td>2010</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2021</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2032</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3010</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3020</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3031</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3042</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4010</td>
<td>4</td>
<td>2</td>
</tr>
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<td>4022</td>
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<td>5</td>
<td>2</td>
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<tr>
<td>5022</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6010</td>
<td>6</td>
<td>3</td>
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<td>6022</td>
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<td>3</td>
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<td>7010</td>
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<td>4</td>
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<td>7022</td>
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<td>3</td>
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<tr>
<td>8010</td>
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<td>4</td>
</tr>
<tr>
<td>8022</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>9012</td>
<td>9</td>
<td>4</td>
</tr>
</tbody>
</table>
least common multiple (LCM). Using the distance of 720 feet as the LCM for the distance over which the RPM's are placed. This enabled the quantification of the number of RPM's for a fixed distance for each marker design type. The first column list the types of RPM's. Columns two, three, four, five, and six list all the various types of line delineations. Input into the corresponding cells are the type and the number of RPM's that will be used for 720 feet for the corresponding type of centerline or lane line. Also, the unit installed cost for each type of RPM is input into the corresponding cell as shown in Figure 3.17.

<table>
<thead>
<tr>
<th>RPM TYPES</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPM Type A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>54</td>
<td>54</td>
<td>90</td>
<td>210</td>
</tr>
<tr>
<td>RPM Type B</td>
<td>216</td>
<td>171</td>
<td>72</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>RPM Type C</td>
<td>72</td>
<td>63</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RPM Type D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>RPM Type E</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RPM Type F</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Unit Distance in ft</td>
<td>720</td>
<td>720</td>
<td>720</td>
<td>720</td>
<td>720</td>
<td>720</td>
<td>720</td>
</tr>
<tr>
<td>Total # of RPMs</td>
<td>288</td>
<td>234</td>
<td>90</td>
<td>72</td>
<td>72</td>
<td>150</td>
<td>330</td>
</tr>
<tr>
<td>Cost RPM Type A</td>
<td>$0.65</td>
<td>$0.65</td>
<td>$0.65</td>
<td>$0.65</td>
<td>$0.65</td>
<td>$0.65</td>
<td>$0.65</td>
</tr>
<tr>
<td>Cost RPM Type B</td>
<td>$0.68</td>
<td>$0.68</td>
<td>$0.68</td>
<td>$0.68</td>
<td>$0.68</td>
<td>$0.68</td>
<td>$0.68</td>
</tr>
<tr>
<td>Cost RPM Type C</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
</tr>
<tr>
<td>Cost RPM Type D</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
</tr>
<tr>
<td>Cost RPM Type E</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
<td>$1.40</td>
</tr>
<tr>
<td>Cost RPM Type F</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
<td>$3.20</td>
</tr>
<tr>
<td>Total Cost of RPMs</td>
<td>$247.68</td>
<td>$204.48</td>
<td>$74.16</td>
<td>$92.70</td>
<td>$60.30</td>
<td>$250.50</td>
<td>$520.50</td>
</tr>
</tbody>
</table>

3. The spreadsheet labeled “Marking Design Types” is a template sheet that identifies the markings used on a roadway. There are currently four types of marking materials used, namely paint, thermoplastics, film, and epoxy. For each centerline and lane
line type, the amount in linear feet can be estimated for a 4-inch yellow and white line. The first column lists the material types of markings available. Columns two, three, four, five, and six list all the various types of centerline and lane line delineations as shown in Figure 3.1. Column seven lists the centerline used when marking curb and gutter or edge lines. Figure 3.18 shows the layout of the spreadsheet.

<table>
<thead>
<tr>
<th>CENTERLINE TYPES</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<tbody>
<tr>
<td>Marking TYPES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4&quot; White Edge Line</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4&quot; White Lane Line</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4&quot; Yellow Line</td>
<td>2</td>
<td>1.25</td>
<td>0.25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Paint Edge Line</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Paint Lane Line</td>
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<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; Yellow Paint Line</td>
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<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Thermoplastics Edge Line</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Thermoplastics Lane Line</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; Yellow Thermoplastics Line</td>
<td>$0.45</td>
<td>$0.45</td>
<td>$0.45</td>
<td>$0.45</td>
<td>$0.45</td>
<td>$0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Film Edge Line</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Film Lane Line</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; Yellow Film Line</td>
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<td>$0.50</td>
<td>$0.50</td>
<td>$0.50</td>
<td>$0.50</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Epoxy Edge Line</td>
<td>$0.20</td>
<td>$0.20</td>
<td>$0.20</td>
<td>$0.20</td>
<td>$0.20</td>
<td>$0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Epoxy Lane Line</td>
<td>$0.20</td>
<td>$0.20</td>
<td>$0.20</td>
<td>$0.20</td>
<td>$0.20</td>
<td>$0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; Yellow Epoxy Edge Line</td>
<td>$0.40</td>
<td>$0.40</td>
<td>$0.40</td>
<td>$0.40</td>
<td>$0.40</td>
<td>$0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Other Edge Line</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Other Lane Line</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td>$0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; Yellow Other Edge Line</td>
<td>$0.50</td>
<td>$0.50</td>
<td>$0.50</td>
<td>$0.50</td>
<td>$0.50</td>
<td>$0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Other2 Edge Line</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; White Other2 Lane Line</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost 4&quot; Yellow Other2 Edge Line</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Input into the corresponding cells are the ratio amount of lines that are used per centerline type. The basis for this is that when a type 1 centerline is laid out there are two solid yellow lines that are placed on the roadway, therefore for every marking twice the amount of material is used, when compared to a single line,
therefore the value 2. When a type 2 centerline is laid out there is one solid yellow line and the second yellow line that is dashed, therefore looking at the ratio of quantity of paint used, a value of 1.25 is assigned. When laying out a type 3 centerline which only consists of a single dashed yellow line, the ratio of material quantity used, a value of 0.25 is assigned. Similarly, when placing a lane line either type 4 or type 5, only a single white line is placed. Therefore, the ratio of paint used for every feet would be 0.25. When placing pavement marking for type 8 (curb and gutter/edge line), a single solid white line is placed, therefore a value of 1 is assigned.

This is provided to account for edge of pavement markings. Also, input into the corresponding cells is the unit installed cost for each of the material type and design type.

4. The fourth spreadsheet titled “Markers” identifies the number of centerline and lane line delineations that are possible for a given design category. The spreadsheet shows the design categories that are available and the corresponding marker design types that are possible. The values of this sheet are fixed and they are not to be changed until the design standards change. Figure 3.19 shows the layout of the spreadsheet.

Figure 3.19 Quantities of Markers by Design Categories
5. The fifth and final spreadsheet titled “Markings” in the Excel file “Main.xls” is similar to the spreadsheet “Markers”, but the number of markings used for each of the centerline and lane line markings are identified. The spreadsheet shows the design categories that are available and the corresponding marking design types that are possible. The values of this sheet are they fixed and are not to be changed until the design standards change as shown in Figure 3.20.
Figure 3.20 Amount of Markings by Design Categories

<table>
<thead>
<tr>
<th>DESIGN CATEGORY</th>
<th>CENTERLINE TYPES</th>
<th>QUANTITY OF MARKING TYPES per (LF)</th>
<th>TOTAL LENGTH OF MARKINGS (LF)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8</td>
<td>4&quot; Yellow Line</td>
<td>4&quot; White Line</td>
</tr>
<tr>
<td>2010</td>
<td>1 0 0 0 0 0 0 0</td>
<td>2.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2021</td>
<td>0 1 0 0 0 0 0 0</td>
<td>1.25</td>
<td>0.00</td>
</tr>
<tr>
<td>2032</td>
<td>0 0 1 0 0 0 0 0</td>
<td>0.25</td>
<td>0.00</td>
</tr>
<tr>
<td>3010</td>
<td>1 0 0 1 0 0 0 0</td>
<td>2.00</td>
<td>0.25</td>
</tr>
<tr>
<td>3020</td>
<td>2 0 0 0 0 0 0 0</td>
<td>4.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3031</td>
<td>1 1 0 0 0 0 0 0</td>
<td>3.25</td>
<td>0.00</td>
</tr>
<tr>
<td>3042</td>
<td>0 2 0 0 0 0 0 0</td>
<td>2.50</td>
<td>0.00</td>
</tr>
<tr>
<td>4010</td>
<td>1 0 0 2 0 0 0 0</td>
<td>2.00</td>
<td>0.50</td>
</tr>
<tr>
<td>4022</td>
<td>0 2 0 1 0 0 0 0</td>
<td>2.50</td>
<td>0.25</td>
</tr>
<tr>
<td>5010</td>
<td>1 0 0 3 0 0 0 0</td>
<td>2.00</td>
<td>0.75</td>
</tr>
<tr>
<td>5022</td>
<td>0 2 0 2 0 0 0 0</td>
<td>2.50</td>
<td>0.50</td>
</tr>
<tr>
<td>6010</td>
<td>1 0 0 4 0 0 0 0</td>
<td>2.00</td>
<td>1.00</td>
</tr>
<tr>
<td>6022</td>
<td>0 2 0 3 0 0 0 0</td>
<td>2.50</td>
<td>0.75</td>
</tr>
<tr>
<td>7010</td>
<td>1 0 0 5 0 0 0 0</td>
<td>2.00</td>
<td>1.25</td>
</tr>
<tr>
<td>7022</td>
<td>0 2 0 4 0 0 0 0</td>
<td>2.50</td>
<td>1.00</td>
</tr>
<tr>
<td>8010</td>
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<td>2.00</td>
<td>1.50</td>
</tr>
<tr>
<td>8022</td>
<td>0 2 0 5 0 0 0 0</td>
<td>2.50</td>
<td>1.25</td>
</tr>
<tr>
<td>9012</td>
<td>0 2 0 6 0 0 0 0</td>
<td>2.50</td>
<td>1.50</td>
</tr>
</tbody>
</table>

The second Excel file (TIMS.xls) is linked to the file Main.xls. “TIMS.xls” is linked to the Excel file “Main” and the GIS program. The file TIMS retrieves the corresponding relevant information from the first five spreadsheets in the Excel file “Main.xls” and using that information is able to compute the total number of RPM’s and linear feet of marking.
required for a given link of the road network.

In “TIMS.xls” columns one, two, three, four, five, ten, eleven, twelve, and thirteen are required fields that need to be populated by the user. These fields correspond to the a) link i.d: which is a unique identifier that is fixed for a given roadway link, b) number of lanes: the number of lanes for which pavement markers or marking is placed, c) Type of material: the type of material being used for the roadway markings, d) Curb and gutter: provide information if curb and gutter has any pavement marking being placed, e) length of the link: the link length for which pavement markings are being placed, f) percent design category: select the percentage of variation in design categories within a link.

Once this information is available to the TIMS.xls file various attributes required for pavement markers and markings of a roadway are computed. The following is a description of the layout of this spreadsheet. Column numbers six, seven, eight, and nine provide the correct design category corresponding to the number of lanes entered by the user. Columns fourteen through seventeen provide the number of markers/linear feet of markings corresponding to each design category. Column eighteen provides the total number of raised pavement markers for the entire link selected. Column number nineteen provide the total amount of longitudinal marking for the entire link selected. Columns twenty through twenty five computes the number of raised pavement markers for each type of RPM based on the design category. Columns twenty six through thirty one compute and list the installed cost for each type of raised pavement marker. Column thirty two lists the total cost of having raised pavement markers installed on the link selected by the user. Columns thirty three through thirty six compute and list the linear feet of marking and the total cost of installing
pavement markings on the link selected. Columns thirty seven and thirty eight compute and provide the linear feet and installed cost for curb and gutter pavement markings. Column thirty nine computes and lists the total cost of pavement markings including curb and gutter markings for the selected link. Column forty lists the total install cost of pavement markers and markings for the link selected. Column forty one list the date the edits for a specific link were made. Appendix B shows the spreadsheet with all the various attributes displayed for a few links.

3.3.2 Linking GIS to Excel

ArcView, a GIS product from Environmental Systems Research Institute (ESRI), is the environment used to develop the user interface that enables the user to select desired link(s) for analysis and provides the necessary input into the TIMS.xls spreadsheet. Avenue can be used to customize the way one works with ArcView; to perform a specific task that needs to be done; or one can even develop a complete application that works along with ArcView's graphical user interface. In addition, scripts can be linked, written in Avenue to other events such as starting up and shutting down a view in ArcView, or another program such as Microsoft Excel. Using Avenue, ArcView is linked with Excel. Avenue is a programming language and development environment that is part of ArcView. There are several scripts written for this application to be able to communicate with excel.

1. TIMS Startup:

This script performs six functions. The script initializes the global variables, it prompts the user to input his or her name, records the system date, opens the view.
on starting ArcView session, deactivates and clone the virtual table (VTab) necessary for Excel, starts Excel if it is not running already, and activates the VTab.

2. TIMS Excel Write:

This script writes the street attribute data from the street centerline file in a GIS format for a given link and it also records the data input by the user into Excel. The fields that are copied from the street centerline file are; Link I.D., and the length of the link selected. The user data recorded into Excel is number of lanes, type of marking, presence or absence of curb and gutter marking, design category, and the date the data is edited.

3. TIMS Record Change:

This script evaluates all the answers after the menu is completed and records it in Excel while running the ArcView session.

4. TIMS Edit Street:

The TIMS Edit Street set of scripts open the edit dialog box, manage the dialog menu, and they are used to update the values of the “sliders” used in the user interface. The user inputs the relevant information by checking off the appropriate boxes in the editing form that appears as shown in Figure 3.21.

5. TIMS Slider and Drag:

These set of scripts control the value of the design category percentages. Each slider shown in the Figure 3.21 can be moved to select the correct amount of design category present for a link or type in the number.
6. TIMS Copy Records:

This script copies the selected records in the active table specified by the user as many times as indicated and duplicates all item values of the selected record (streets) to the added record. This is done so that if any record is re-selected in ArcView and is edited, the changes that are made to a particular record will be rewritten over the cells in the Excel spreadsheet that already contain previous information for a street.

Details of the above mentioned scripts are provided in Appendix C.
CHAPTER 4

ANALYSIS

The analysis section discusses how the application developed is used i.e. implementation of the methodology discussed previously. This section discusses the process of loading the application, populating the street centerline database using the program, and data management.

4.1 System Requirements and Installation

The following sections discuss the hardware and software requirements to install and use the Infrastructure Management system application using Microsoft Excel and ArcView.

4.1.1 Hardware Requirements

The minimum hardware requirements for installing and running this application are as follows:

- Computer: a personal or multimedia computer with at least a Intel 486 or higher speed processor, a 2.0 giga byte (GB) hard disk with a minimum capacity of 640 MB, a 1.44 MB capacity 3.5" floppy drive, and a CD-ROM
drive

- **Random Access Memory (RAM):** to run the application, the minimum memory required is at least 12 MB. Larger databases need more RAM and disk space

- **Display or monitor:** video graphics adapter (VGA) or better resolution monitor.

- **32-Bit Object Database Connectivity (ODBC) complaint drivers**

- **Pointing Device:** a mouse

- **Data output:** require a plotter with minimum 4 MB of RAM to plot pavement information with the street centerline.

The recommended hardware to achieve optimal performance, and operation of the application is:

- Pentium III (500 MHZ) personal computer

- 64 MB of RAM

- 8 MB of video memory

Other considerations are that the computer components be Y2K compliant.

4.1.2 Software Requirements

The Infrastructure Management System application is developed using both Microsoft Excel and ESRI's ArcView. Microsoft Excel 97 is used as the tool to perform all the various data analyze, while ArcView 3.0a is used as the interface to input the data into Excel. Therefore, ArcView Version 3.0a and Microsoft Excel 97 must be installed on the
PC where the Infrastructure Management System will be operated.

4.1.3 Data Needs

The first essential step for any kind of data management system is identifying the data needs. For the proper and complete implementation of the Infrastructure Management System, the data fields required to be populated are as follows:

1. Link I.D.: This is a unique number given to each link of the road network. This unique number must remain constant as long as the road is maintained as a part of the pavement management program.

2. Number of Lanes: For every link of the road network the number of lanes present on the link for both directions of travel must be identified and any continuous median turn lanes.

3. Type of Pavement Marking: The pavement marking types must be identified. As stated earlier example of the marking types are, RPMs, Paint, Thermoplastics, Film, and Epoxy.

4. Curb and Gutter/Edge Line Markings: Instances must be identified where there are markings placed when the edge of the road has a curb and gutter, or when markings are placed to delineate the edge of the road.

5. Length of the Link: Each link has a defined length. The length of each link must be known to compute the number of RPM's required or linear feet of markings used. The unit of measurement for length of links used are feet.

6. Percent Design Category: Since within a link there can be variations in the
centerline type layout, it is possible that for a fixed number of lanes within a link, the possible designs available can be used and this, the need to use percentages of design categories to quantify the pavement marking materials accurately.

7. Unit Cost of Marking Materials: The installed unit cost of each type of raised pavement marker must be identified. Also, the unit installed cost of 4-inch white and yellow pavement lines for different types of materials be identified. Identifying the unit installed cost of marking materials can be used to compute the total pavement marking cost for a link of the road network.

The Link I.D., and length of links for the entire road network is maintained in a GIS street coverage. These values of the street database are neither inputted by the user nor are they edited by the user. The number of lanes, percentage of design type, type of marking, presence of curb and gutter marking are values edited/input by the user into the system. The Design Categories, unit installed cost for marking types maintained in the Excel spreadsheets are not to be edited by the user on a routine basis. If the cost of the pavement material types change from project to project or due to added cost of inflation, the user can edit the template spreadsheets that store the unit installed cost price for the pavement materials to reflect the change in cost.

4.1.4 Installing the Program

Special attention is to be given when installing the application package developed onto a desk top computer. Since the application uses both Excel and GIS (ArcView), the desk top computer must have both these software packages pre-loaded.
A new folder must be created on the “C” drive called “TIMS”. The executable path for Microsoft Excel must be “C:\Program Files\Microsoft Office\Office\Excel.exe”. When installing Microsoft Excel if the standard defaults are used, the Excel executable path defaults to “C:\Program Files\Microsoft Office\Office\Excel.exe”. The Excel executable path needs to match the above mentioned since the ArcView script “TIMS Excel write” has this path hard coded into the script. If the executable path for Excel is not the same as coded in the script, the user will receive an error message shown in Figure 4.1.

Figure 4.1 Error Message Due to Incorrect Excel Path

The Infrastructure Management application comes loaded with three main files: two Excel files named (Main.xls, and TIMS.xls) and an ArcView project named (TIMS.apr). The three files Main.xls, TIMS.xls, and TIMS.apr must be copied into the folder “C:\TIMS”. The five spreadsheets in the Excel file Main.xls are write protected—i.e. there can be no changes made to any of the cells without entering the correct password to unlock the cells. TIMS.xls spreadsheet is also write protected, except those cells that need to populated by the cells when editing the street data in ArcView.
4.2 Program Startup

Upon successfully copying the files into “C:\TIMS”, and ensuring that the Excel executable path is correct, the program is ready for use. When an ArcView session is started and the TIMS.apr project is opened the first screen to open is the view with the streets and the corresponding table. The next window opened is the “User Authentication” window. This window prompts the user to input his or her name which is recorded so as to keep a record of the individual who make any changes to the attributes of the street data. If the user name is not input, the system will not proceed with the process of opening the view and the dynamic link with Excel, thus making the application un-operational. Figure 4.2 shows the screen as it is displayed in ArcView.

![User Authentication Screen](image)

Once the user name is entered the next windows prompts the user whether the Excel program should be started. Figure 4.3 shows the message as it would appear.

![Microsoft Excel Startup Prompt](image)
If the Excel program is not running the user must select "Yes", selecting "Yes" will start Excel. If Excel is running, the user has two options. The first is to save and close the Excel files that were previously opened or the second is to select "Yes" at the prompt which will open the Excel spreadsheet "TIMS.xls" and deactivate the existing Excel files. Before the Excel file "TIMS.xls" is opened the system prompts the user if the linked workbook needs to be updated. The user must select "Yes". Selecting "Yes" here will update the links between the Excel files Main.xls, and TIMS.xls. Figure 4.4 is the screen that prompts the user to make the selection of updating the Excel spreadsheets.

Figure 4.4 Prompt for Updating Microsoft Excel Links

Once the above discussed steps are successfully completed the program is ready for data capture and editing.

4.3 Data Integration

Data are most essential for any database. Therefore, it is important that data capture be accurate and detailed for efficient management of the pavement markings inventory. This section discusses the process by which the data can be entered or edited in the application.
Once the application files are copied into the appropriate directories and both Excel and ArcView software packages are loaded on the PC, the system is ready for use.

First, the user starts up ArcView and opens the project stored as “TIMS.apr”. Opening “TIMS.apr” starts the Avenue scripts to open the view and start Excel if it is not running (discussed earlier). The view in ArcView shows the streets located within the entity’s jurisdiction. Figure 4.5 shows the screen as would be seen by the operator of the system. The user has the option of selecting a single link to add data to or select multiple links having the same roadway design categories, and pavement material types. If a single street is desired the user will use the ArcView tool “select” and click on the desired street from the view, multiple links the user selects multiple desired links from the view using the same ArcView “select” tool. Figure 4.6 shows a single link selected for data entry, while Figure 4.7 shows multiple links selected for data editing. Once the desired link(s) is (are) selected, the next step is to select the icon with a red shaded diamond inside on the ArcView tool bar at the far right hand side as shown in Figure 4.8.

Selecting the icon will start the script “TIMS Edit Street” to bring up the “Street Editing Form” as shown in Figure 3.21. The user simply checks off the relevant boxes that identify the number of lanes, type of markings, presence of curb and gutter markings, percentage of each design categories present within the selected link. Once the editing form
is completed, the user can press the "Record Change" button. Pressing the "Record Change" button writes the information that just has been input into the editing form into the ArcView street data table, and into the Excel Spreadsheet "TIMS.xls, along with the date and the name of the user. Figure 4.9 shows the corresponding table in ArcView with the row highlighted, the first row in this figure is the street for which the data has been input. The same information can be seen written in the Excel spreadsheet labeled TIMS.xls. The highlighted cells of Row 3 in the Excel spreadsheet in Figure 4.10 show the same values that
are input into the ArcView table when the "Record Change" button is selected in ArcView.

Based on the information the user has provided for the roadway links, the ArcView scripts automatically populates the following fields in the Excel spreadsheet named TIMS: Link I.D., Number of Lanes in a Link, Type of Pavement Marker, Curb and Gutter Markings, Percent Design Category I, Percent Design Category II, Percent Design Category III, and Percent Design Category IV which are columns one, two, three, four, five, ten, eleven, twelve, and thirteen respectively.
The information provided by the user in turn is used to then compute the number of raised pavement markers, the associated cost of the installing the markers, type of pavement markings, and cost of pavement markings used for the link of the road network. The spreadsheet lists the quantity of all the raised pavement markers types (columns 20 through 25), as well as the total number of raised pavement markers used per link (column 18) of the road network. This is clearly shown in the columns of the Excel spreadsheet “TIMS” (see Appendix B) which displays the quantities of each marker and marking types used for a specific link.

4.4 Example Application

The Infrastructure Management System developed by linking the street coverage to the Excel computational spreadsheet has many advantages. The user of the application has the option of using the Microsoft Excel query tools, as well as using the ArcView query tools. If displaying the data on a map is needed, all the queries can be conducted in ArcView and a graphical view can be presented of the data. If only prices and quantities of the pavement marking are required, the query tools in Excel are sufficient to provide the user with the required information that is stored in the database. An example of the Excel spreadsheet “TIMS” with the computed quantities for the total number of raised pavement markers, linear feet of markings and cost of the markers and markings for each specific link is shown in Figure 4.11. For this example the Clark County street centerline information was used as the view in ArcView and the attributes for each link in the database was used as the input parameters for the Excel spreadsheet “TIMS”. The spreadsheet “TIMS” displays
additional pavement marking information and has not been shown in Figure 4.11 due to space consideration, thus hiding the columns of the Excel spreadsheet and only displaying the Link I.D., the quantities and cost of the pavement markers in the table. A detailed summary of the "TIMS" spreadsheet is attached in appendix B.

Illustrated next are some simple example queries that can be performed on the database in ArcView once it has been populated with the necessary pavement inventory attributes of the road network:

1. Database query based on the number of lanes:

   The street center line theme is made active in the ArcView view, and the query tool is selected in ArcView. "Number of Lanes" is selected from the query list and is equated to appropriate value for number of lanes. Performing this query will select streets from the road network based on the number of lanes specified by the user. Figure 4.12 shows the view of the streets for the road network which have

<table>
<thead>
<tr>
<th>Link I.D. #</th>
<th>Length of Link (ft)</th>
<th>Total Cost of Lane Markings</th>
<th>TOTAL COST per RPM TYPES</th>
<th>Total Cost of Markings</th>
<th>Total Cost for Markers and Markings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4&quot; Yellow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31012</td>
<td>969.45</td>
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<td>$307.69</td>
<td>$680.23</td>
<td>$307.69</td>
<td>$987.92</td>
</tr>
</tbody>
</table>
number of lanes equal to four.

Figure 4.12 Query Based on Number of Lanes

2. Query based on the type of marking:

The street center line theme is made active in the ArcView view, and the query tool is selected in ArcView. "Type of Marking" is selected from the query list and is equated to appropriate value for type of marking. This query will select all the links of the road network that have used raised pavement markers. Figure 4.13 illustrates the result of the query.
3. Query based on the user name:

The street center line theme is made active in the ArcView view, and the query tool is selected in ArcView. “User_Name” is selected from the query list and is equated to appropriate value for user name. This query will select all the links of the road network that have been edited or data input into the database by a specific user of the application. Figure 4.14 illustrates the result of the query.

The application developed as illustrated above takes two different existing software packages, links them together and provides the user the ease of populating the infrastructure data, and using the analysis tools of ArcView and Excel to perform queries.
Figure 4.14 Query Showing the Links Selected Based on User Name
CHAPTER 5

SUMMARY AND RECOMMENDATIONS

The public infrastructure of an area includes many assets. Owners of urban infrastructure assets such as federal departments, state or local agencies have jurisdiction over many such constructed facilities. The management of these assets is a very important governmental concern and requirement. Pavement markers and markings are integral components of roadway infrastructure. However, there is no automated tool to manage pavement markings and markers. The GIS-based Infrastructure Management System, developed and described in this thesis, helps develop inventories of and management of pavement markers and markings and related information for any region. This functional infrastructure management tool processes and supports data for several elements of paved road sections. It also could be used as a decision support tool by various governmental agencies in choosing between alternatives related to maintenance and repair.

The developed system uses Microsoft Excel a spreadsheet program and ArcView a GIS program as the analysis tools to store data and perform queries. Over the last decade GIS has gained wide acceptance by many governmental agencies. In order to set up the pavement management system and make it functional, the required data for each of the
streets within the road network will have to be populated in the database of the developed system. To develop the system, the land base, i.e. the road network of the area (also called the street center line file) must already exist as a shape file or the road network shape file needs to be created. The shape file of an area consisting of the street center lines can then be opened as part of the ArcView view. Thus, the various roads in the network can be selected and the appropriate fields populated.

It is essential that each road be identified or tagged with a specific number in the street center line database, for example the Link I.D. This number must be unique for each segment of the road network and remain unchanged when new roads are constructed and added to street center line database. Special attention must be given to ensure that the database populated is accurate and that all the attributes gathered for each road of the network are sufficient enough for better management of pavement marking. Preserving the integrity and the security of the system and data are facilitated by requiring the entry of the user name to start the application. Once the user name is entered, the database records the system date and all the changes made to the records within the database by that specific user. This enables the managers or the person responsible for the database to track the individuals editing the records in the pavement management system. The database must be maintained, and updated as often as necessary to reflect the current condition and status of the roads within the network.

Since the data are stored in tables both in Excel and in ArcView, the street data can be exported in an ASCII format and then imported into any other application for additional analysis or if there is need to change the application platform. The ability to export from a
certain application and to import it into another is essential. Applications may be changed by governmental agencies as new and better ones are made available. This eliminates the need to re-populate the database.

The Infrastructure Management System developed in this thesis facilitates data acquisition, analysis, and display. It is easy to use and requires limited training time to be able to operate. This tool can help in providing management guidelines for better pavement management and engineering. Its capabilities facilitates various analyses to support policy development, engineering planning, design, operations and maintenance activities. The analytical capabilities range from those at project specific or “micro” level to those at the area wide or “macro” level. Thus, it could benefit and support activities of policy makers such as elected officials, managers, engineers, planners, and technicians.

There is need to further enhance this application, to integrate transverse pavement marking information on the network, pavement marker information at intersections (nodes) of roadways such as transitional markings at nodes, and pavement legends such as “SCHOOL”, and “STOP”, on roadways. The inventory of pavement markings and markers at the intersection can be implemented using a principle similar to the design category setup and then integrating it with the existing link part of the infrastructure management system. The transverse pavement markings and legends can be implemented by adding new modules to the existing system.

By definition, node is located at the point of intersection of the centerlines of the links that meet at the node. Thus, the length of a link includes the widths at intersections where the longitudinal markings are not present. Since the application estimates quantities based
on the length of the link that is stored in the GIS database, there is an overestimation of quantities as the length of the link is measured from one node to another. Also, since there is no clear distinction made in the application for divided or undivided roads, the quantities of markings are overestimated, in places where medians are used instead of a centerline type to separate directional travel. This is because the application will still compute markings quantities for the median divide although there are no markers or markings. This overestimation can be minimized by subtracting a certain quantity of markings based on the percentage of length of the link or specifically accounting for the same in the computations.

Based on the needs of asset management, careful evaluation of potential asset management tools for an area must be performed. Generally, the cautious and judicious integration of appropriate technologies such as geographic information systems with other maintenance management systems will assist governmental agencies better manage public infrastructure.
APPENDIX I

A SAMPLE OF CURRENT PAVEMENT INVENTORY DATABASE AT

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APPENDIX II

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APPENDIX III

AVENUE SCRIPTS FOR ARCVIEW
' TIMS.ExcelWrite - write data from the street attribute table to Excel
' Globals Used: _theUser
'        _recCount

' Get table information for later use
theView = av.GetProject.FindDoc("TIMS Pilot Study")
theTheme = theView.FindTheme ("Pilot Area")
theVtab = theTheme.GetFtab
theBitmap = theVtab.GetSelection
theFields = theVTab.GetFields

'#################################################################
'        JUST EDIT THE fieldList FOR EXCEL FIELDS -----------------

fieldList1 = List.Make
fieldList2 = List.Make
fieldList1 = { "Scl_id", "No. of Lanes", "Type of Marking", "Curb & Gutter Marking", "Length"}
fieldList2 = {"Design Category I", "Design Category II", "Design Category III", "Design Category IV"}
theDDE = DDEClient.Make ("EXCEL", "SYSTEM")
if (theDDE.HasError) then
    errMsg = theDDE.GetErrorMsg
    '--copy the template
    av.run("TIMS.housekeeping","")
    if ( errMsg = "Failed to establish link with application" ) then
        if(MsgBox.YesNo ("Excel may not be running."+nl+"Should I Start EXCEL?", "START EXCEL",true))then
            System.Execute(_Excelpath)
            av.DelayedRun(script.The.GetName,nil,2)
            exit
        end
    else
        msgBox.Info(errMsg,"DDE Error occurred accessing EXCEL")
    end 'if
    return nil
end

' Create the Excel worksheet
aFile = _Timsdata.AsFilename.GetFullName
'theTask = "[CLOSE(""Book1".Quote")]]"
'theDDE.Execute( theTask)
'theTask = "[OPEN("++aFile.Quote+")]"
theDDE.Execute( theTask)

systemClient = DDEClient.Make("Excel", "System")
' Get the name of the new worksheet. Selection is an Excel item
' supported for the System topic.
selection = systemClient.Request("Selection")
spreadsheet = selection.Left(selection.IndexOf("!"))

'Ensure R1C1 format
SystemClient.Execute("[Workspace(.TRUE)]")
SystemClient.Close

' Open a new conversation with the Excel spreadsheet as the topic
'ssClient = ddeClient.Make("Excel", spreadsheet)
   ssClient = ddeClient.Make("Excel", "TIMS.xls")
' Write the table name to the spreadsheet
'row = 1
'column = 1
'ssClient.Poke("R"+row.AsString+"C"+column.AsString, theVtab.GetName)

' Write chosen field names to the spreadsheet
'row = 2
'column = 0
'for each f in fieldList
  'theField = theVTab.FindField(f)
  'column = column + 1
  'ssClient.Poke("R"+row.AsString+"C"+column.AsString, theField)
'end

'******Find the number of rows in the excel sheet TIMS.xls******

rcheck = ssclient.request("R1000".asString+"C1".asString)
   _rownum = 3
   rowval = ssClient.request("R"+_rownum.AsString+"C"+column.AsString)
   while (rowval <> rcheck.asstring)
      _rownum = _rownum + 1
      rowval = ssclient.request("R"+_rownum.AsString+"C"+column.AsString)
   ' msgbox.info(rowval.asstring,"rownum")
   end
   _rownum = _rownum - 1

'****** now, row_num represents the number of rows in the excel sheet *****
'Write the values for selected features to spreadsheet

'row = _recCount+2
'row = 2

****** Check if the record is already present******
for each rec in theVTab.GetSelection
' row = row + 1
column = 0
row = 3
theField = theVTab.FindField("Scl_Id")
dataString = theVTab.ReturnValueString(theField, rec)+rcheck.asstring
rowval = ssclient.request("R"+rowAsString+"C1".AsString)
while ((rowval <> datastring) And (row <= _rownum))
  row = row + 1
  rowval = ssclient.request("R"+rowAsString+"C1".AsString)
end
if (row > _rownum) then
  _rownum = row
end

****** Replace old data or append new data into the excel sheet ***
for each f in fieldList1
  theField = theVTab.FindField(f)
column = column + 1
dataString = theVTab.ReturnValueString(theField, rec)
'msgbox.info(ssclient.request("R"+rowAsString+"C"+column.AsString),"writing")
ssClient.Poke("R"+rowAsString+"C"+column.AsString, dataString)
end

column = 9
for each f in fieldList2
  theField = theVTab.FindField(f)
column = column + 1
dataString = theVTab.ReturnValueString(theField, rec)
'msgbox.info(ssclient.request("R"+rowAsString+"C"+column.AsString),"writing")
ssClient.Poke("R"+rowAsString+"C"+column.AsString, dataString)
end
column = column + 1
ssclient.poke("R"+row.AsString+"C41".AsString, _theday)
end

****** End of writing data ********
_recCount = _recCount + theVTab.GetSelection.Count

ssClient.Close

" Run the loadTable macro
'theTask = "[Run("+"loadTable".Quote+"])"
'theDDE.Execute( theTask )
" Close the DDE Link
theDDE.Close
av.ShowMsg("Sent Generate Report Request to Excel")
theDDE.Close
av.ShowMsg("Sent Generate Report Request to Excel")
'TIMS.Drag1

'get the text label control
aLabel = self.GetDialog.FindByName("aTextLine34")
aLabel.SetText(self.getValue.AsString)

'get the text label control values
sub1 = self.GetDialog.FindByName("aTextLine34").GetText
sub2 = self.GetDialog.FindByName("aTextLine35").GetText
sub3 = self.GetDialog.FindByName("aTextLine40").GetText
sub4 = self.GetDialog.FindByName("aTextLine39").GetText
total = sub1.AsNumber + sub2.AsNumber + sub3.AsNumber + sub4.AsNumber
self.GetDialog.FindByName("aTextLine48").setText(total.AsString)

'TIMS.Drag2

'get the text label control
aLabel = self.GetDialog.FindByName("aTextLine35")
aLabel.SetText(self.getValue.AsString)

'get the text label control values
sub1 = self.GetDialog.FindByName("aTextLine34").GetText
sub2 = self.GetDialog.FindByName("aTextLine35").GetText
sub3 = self.GetDialog.FindByName("aTextLine40").GetText
sub4 = self.GetDialog.FindByName("aTextLine39").GetText
total = sub1.AsNumber + sub2.AsNumber + sub3.AsNumber + sub4.AsNumber
self.GetDialog.FindByName("aTextLine48").setText(total.AsString)

'TIMS.Drag3

'get the text label control
aLabel = self.GetDialog.FindByName("aTextLine40")
aLabel.SetText(self.getValue.AsString)

'get the text label control values
sub1 = self.GetDialog.FindByName("aTextLine34").GetText
sub2 = self.GetDialog.FindByName("aTextLine35").GetText
sub3 = self.GetDialog.FindByName("aTextLine40").GetText
sub4 = self.GetDialog.FindByName("aTextLine39").GetText
total = sub1.AsNumber + sub2.AsNumber + sub3.AsNumber + sub4.AsNumber
self.GetDialog.FindByName("aTextLine48").setText(total.AsString)

'TIMS.Drag4

'get the text label control
aLabel = self.GetDialog.FindByName("aTextLine39")
aLabel.SetText(self.getValue.AsString)

'get the text label control values
sub1 = self.GetDialog.FindByName("aTextLine34").GetText
sub2 = self.GetDialog.FindByName("aTextLine35").GetText
sub3 = self.GetDialog.FindByName("aTextLine40").GetText
sub4 = self.GetDialog.FindByName("aTextLine39").GetText
total = sub1.AsNumber + sub2.AsNumber + sub3.AsNumber + sub4.AsNumber
self.GetDialog.FindByName("aTextLine48").setText(total.AsString)

'TIMS.Dialog.Cancel - general dialog cancel button
self.GetDialog.Close
return nil

'TIMS.EditStreets.Open - invoke the edit dialog
aDialog = "TIMS.EditStreets"
av.FindDialog(aDialog).Open

'TIMS.EditStreets.Run - initialize dialog TIMS.EditStreets

' set stuff for sliders
' the self object is the dialog
startTextLine1 = self.FindByName("aTextLine34")
startSlider1 = self.FindByName("aSlider26")
startTextLine2 = self.FindByName("aTextLine35")
startSlider2 = self.FindByName("aSlider36")
startTextLine3 = self.FindByName("aTextLine40")
startSlider3 = self.FindByName("aSlider43")
startTextLine4 = self.FindByName("aTextLine39")
startSlider4 = self.FindByName("aSlider38")
startTextLine5 = self.FindByName("aTextLine48")
startTextLine1.SetListeners({startSlider1,startSlider2,startSlider3,startSlider4})
startTextLine2.SetListeners({startSlider1,startSlider2,startSlider3,startSlider4})
startTextLine3.SetListeners({startSlider1,startSlider2,startSlider3,startSlider4})
startTextLine4.SetListeners({startSlider1,startSlider2,startSlider3,startSlider4})
startTextLine5.SetListeners({startSlider1,startSlider2,startSlider3,startSlider4})
cancel = self.FindByName("lbt_cancel")
'Table.CopyRecords
'Author: Michael Ciscell, IDWR
'Purpose: Copies the selected record in the active table a user-specified number of times.
'   Duplicates all item values of the selected record to the added records
',

tabGUI = av.FindGUI("Table")
tablelist = av.GetProject.GetDocsWithGroupGUI (tabGUI)
for each TableElement in tablelist
   TableElement.GetVTab.UnIinkAll
   theVTab = TableElement.GetVTab
   if (theVTab.IsEditable) then
      saveEdits = MsgBox.YesNo("Save Edits to"++theVTab.GetName++"?", "Stop Editing", True)
      theVTab.StopEditingWithRecovery(saveEdits)
   end
end

theTable = av.GetActiveDoc
theVtab = theTable.GetVTab

' Check to see that the table is not an FTab

if (theVTab.is(fTab)) then
   MsgBox.Info("Cannot Copy Records in a Theme's attribute table","No Can Copy")
   exit
end

' Do some record accounting

SelectedRecords = theVTab.GetSelection.count
if (SelectedRecords = 0 ) then
   return (nil)
end

if (SelectedRecords > 1 ) then
   correctNumRec = MsgBox.YesNo("There are "++SelectedRecords.asString++" selected records in "++theVTab.GetName++". Is this correct?","Number Selected",true)
   if ((correctNumRec).not) then
      return (nil)
   end
end

numstring = MsgBox.Input("Enter the number of times to copy each selected record to

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"++theVTab.GetName, "CopyRecords", "1")
if (numstring = (nil)) then 'User hit Cancel
    return (nil)
end
if (numstring.AsNumber = 0) then
    MsgBox.Info("Can't copy 0 records", "Error")
    return (nil)
end
numrecs = numstring.AsNumber
' find out about the fields in theVTab
fieldlist = theVTab.GetFields
theVTab.SetEditable(true)
theVTab.StartEditingWithRecovery
RecnumList = List.Make
' Add the number of records specified by user
for each SelRecord in theVTab.GetSelection ' Get and set item values
    for i in 1 .. numrecs
        AddedRecord = theVTab.AddRecord
        RecnumList.Add(AddedRecord)
        for each FieldName in fieldlist
            FieldValue = theVTab.ReturnValue(fieldName, SelRecord)
            theVTab.SetValue(FieldName, AddedRecord, FieldValue)
        end
    end
end
theVTab.StopEditingWithRecovery(true)
theVTab.SetEditable(false)
theVTab.Refresh
theBitmap = theVTab.GetSelection
for each NewRecord in RecnumList
    expr = "(rec = " + NewRecord.AsString + ")"
    theVTab.Query(expr, theBitmap, #VTAB_SELTYPE_OR)
end
theVTab.UpdateSelection

StartEdit = MsgBox.YesNo("Edit the copied records?", "Edit the file?", True)
if (StartEdit) then
    theVTab.StartEditingWithRecovery
    for each aToolEntry in tabGUI.GetToolBar
        if (aToolEntry.HasScript("Table.Edit")) then
            aTool = aToolEntry
        end
    end
end
aTool.Select
aTool.Apply
end
end
end

if (SelectedRecords > 1) then
  SortItem = MsgBox.List (Fieldlist, "Pick an item to sort on", "Items Names")
  theTable.Sort(SortItem, False)
end
theTable.PromoteSelection
'TIMS.RecordChange
'do not close the calling dialog until eval finished
'note: need rewrite using table clones
'if there are no records in existing set, return
'start by evaluating the dialog answers
theDoc = av.GetActiveDoc

'------------construct the date variable
today = Date.Now
today.SetFormat("yyyy,MM,dd")

'------------set the user variable prompted at start
theUser = _theUser.AsString

'------------Evaluate the number of lanes
theLanes = 0
if (self.GetDialog.FindByName("rad_L1").IsSelected) then
    theLanes = 1
end
if (self.GetDialog.FindByName("rad_L2").IsSelected) then
    theLanes = 2
end
if (self.GetDialog.FindByName("rad_L3").IsSelected) then
    theLanes = 3
end
if (self.GetDialog.FindByName("rad_L4").IsSelected) then
    theLanes = 4
end
if (self.GetDialog.FindByName("rad_L5").IsSelected) then
    theLanes = 5
end
if (self.GetDialog.FindByName("rad_L6").IsSelected) then
    theLanes = 6
end
if (self.GetDialog.FindByName("rad_L7").IsSelected) then
    theLanes = 7
end
if (self.GetDialog.FindByName("rad_L8").IsSelected) then
    theLanes = 8
end
if (self.GetDialog.FindByName("rad_L9").IsSelected) then
    theLanes = 9
end
'-------------Assign the pavement marking types
thePMType = 0
if (self.GetDialog.FindByName("aRadioButton5").IsSelected) then
' -RPM
  thePMType = 1
end
if (self.GetDialog.FindByName("aRadioButton6").IsSelected) then
' -Paint
  thePMType = 2
end
if (self.GetDialog.FindByName("aRadioButton10").IsSelected) then
' -Thermoplastic
  thePMType = 3
end
if (self.GetDialog.FindByName("aRadioButton11").IsSelected) then
' -Film
  thePMType = 4
end
if (self.GetDialog.FindByName("aRadioButton12").IsSelected) then
' -Epoxy
  thePMType = 5
end
if (self.GetDialog.FindByName("aRadioButton13").IsSelected) then
' -New Type
  thePMType = 6
end
if (self.GetDialog.FindByName("aRadioButton14").IsSelected) then
' -New Type
  thePMType = 7
end
if (self.GetDialog.FindByName("aRadioButton15").IsSelected) then
' -Unknown
  thePMType = 0
end

'-------------Curb and gutter
theCG = 0
if (self.GetDialog.FindByName("aRadioButton21").IsSelected) then
' -None
  theCG = 0
end
if (self.GetDialog.FindByName("aRadioButton22").IsSelected) then
' -One Side
theCG = 1
end
if (self.GetDialog.FindByName("aRadioButton23").IsSelected) then
' -Both Sides
theCG = 2
end

'--------------Evaluate the Design Category entries here
sub = self.GetDialog.FindByName("aTextLine48").GetText
total = sub.AsNumber
if (total < 100) then
    MsgBox.Error("Total Design Category Percentage is not 100. Please adjust.","")
    return nil
end
dc1 = self.GetDialog.FindByName("aTextLine34").GetText.AsNumber
dc2 = self.GetDialog.FindByName("aTextLine35").GetText.AsNumber
dc3 = self.GetDialog.FindByName("aTextLine40").GetText.AsNumber
dc4 = self.GetDialog.FindByName("aTextLine39").GetText.AsNumber

'--------------now close the dialog
self.GetDialog.Close

'---------------------now edit the table ----------------------
theView = av.GetProject.FindDoc("TIMS Pilot Study")
theTheme = theView.FindTheme("Pilot Area")
theDpy = theView.GetDisplay
theVtab = theTheme.GetFtab
theTheme.EditTable
theBitmap = theVtab.GetSelection
'--- if no records are selected return
if (theBitmap.Count = 0 ) then
    return nil
end
theVTab.SetEditable(true)
theVTab = theTheme.GetFtab
unameField = theVTab.FindField("User_name")
updField = theVTab.FindField("Update")
laneField = theVTab.FindField("No_of_lan")
pmTypeField = theVTab.FindField("Type_of_ma")
curbField = theVTab.FindField("Curb_gut")
dc1Field = theVTab.FindField("Design Category I")
dc2Field = theVTab.FindField("Design Category II")
dc3Field = theVTab.FindField("Design Category III")
dc4Field = theVtab.FindField("Design Category IV")
' Put the VTab in edit mode and if successful, do some edits.
if (theVTab.StartEditingWithRecovery) then
' these editing operations contained in this Begin/End transaction
' block can be undone or reapplied as a group using Ftab.Undo or FTab.Redo
theVTab.BeginTransaction
for each rec in theBitmap
    theVTab.SetValue(uniqNameField, rec, theUser)
    theVTab.SetValue(updField, rec, today)
    theVTab.SetValue(laneField, rec, theLanes)
    theVTab.SetValue(pmTypeField, rec, thePMType)
    theVTab.SetValue(curbField, rec, theCG)
    theVTab.SetValue(dc1Field, rec, dc1)
    theVTab.SetValue(dc1Field, rec, dc1)
    theVTab.SetValue(dc2Field, rec, dc2)
    theVTab.SetValue(dc3Field, rec, dc3)
    theVTab.SetValue(dc4Field, rec, dc4)
theVTab.EndTransaction
end
end
saveEdits = TRUE
' Since saveEdits is set to TRUE the edits will be committed, if saveEdits
' was FALSE the edits would be discarded
theVTab.StopEditingWithRecovery(saveEdits)
'--------------------------------------------------------------
' ----------- now send the results to Excel -----------
av.Run("TIMS.ExcelWrite","")
'
' Return to display of the view
theView.GetWin.Open
' av.GetActiveDoc.GetDisplay.Invalidate(True)
' theView.GetDisplay.Flush
return nil
TIMS.Startup - start the application

Steps are:
- Initialize globals
- Set the user name
- open the view
- deactivate and clone the VTab (necessary for Excel)
- copy the Excel template (if required not programmed)
- start Excel (**NOTE: hardcoding of pathname needs rewrite)
- and add the header info (file name, column names)
- activate the VTab

`theProject = av.GetProject`

--- Step 00 - initialize global variables

_ExcelPath = "C:\Program Files\Microsoft Office\Office\EXCEL.EXE"
_ExcelTemplate = "D:\tims\copytims.bat"
_TimsData = "D:\tims\TIMS.xls"
_ExcelTemplate = "C:\final98\tims\copytims.bat"
_TimsData = "C:\final98\tims\TIMS.xls"
_rowNum = 3 'Record Counter for number of rows; First data value on 3rd row
_recCount = 0 'Record Counter for Excel append
_theUser = "" 'Name of user
_fieldList = List.Make
_fieldList = { "Link I.D#", "No. of Lanes", "RPMS =1,Paint =2", "Curb & Gutter Marking", "Length", "Design Category I", "Design Category II", "Design Category III", "Design Category IV" }

--- Step 0 - validate the user

THIS NEED TO BE ENHANCED FOR PRODUCTION

_theUser = MsgBox.Input("Enter user name:", "User Authentication", "anonymous")
_theDate = MsgBox.Input("Enter the date:", "Today's DATE", "")
if (_theUser = nil) then
  return nil
end

--- Step 1 - open the view

theView = theProject.FindDoc("TIMS Pilot Study")
theTheme = theView.FindTheme("Pilot Area")
theView.GetWin.Activate
if (theTheme.IsVisible.Not) then
  theTheme.SetVisible(true)
end

--- Step 2 - deactivate the VTab

theVTab = theView.FindTheme("Pilot Area").GetFTab
theVtab.GetSelection.ClearAll
theVtab.UpdateSelection
theVtab.DeActivate

'--- Step 3 - handle the Excel template
'av.run("TIMS.housekeeping",""")

'--- Step 4 - start Excel
theDDE = DDEClient.Make ( "EXCEL", "SYSTEM")
if (theDDE.HasError) then
  errMsg = theDDE.GetErrorMsg
  if ( errMsg = "Failed to establish link with application" ) then
    if(MsgBox.YesNo ("Excel may not be running."+nl+"Should I Start EXCEL?", "START EXCEL",true))then
      System.Execute(_Excelpath++_Timsdata)
    end
  else
    msgBox.Info(errMsg,"DDE Error occurred accessing EXCEL")
  end 'if
end

' Create the Excel worksheet
aFile = _Timsdata.AsFilename.GetFullName
theTask = "[CLOSE("+"Book1".Quote+")]"
theDDE.Execute( theTask)

theTask = "[OPEN("++aFile.Quote+")]"
theDDE.Execute( theTask)

systemClient = DDEClient.Make("Excel", "System")
' Get the name of the new worksheet. Selection is an Excel item
' supported for the System topic.
'selection = systemClient.Request("Selection")
'spreadsheet = selection.Left(selection.IndexOf("!"))

'Ensure R1C1 format
SystemClient.Execute("[Workspace(,,TRUE)]")
SystemClient.Close

' Open a new conversation with the Excel spreadsheet as the topic
'ssClient = ddeClient.Make("Excel", spreadsheet)
' Write the table name to the spreadsheet
't = 1
'column = 1
'ssClient.Poke("R"+row.AsString+"C"+column.AsString, "TIMS")
'_recCount = _recCount + 1
'Write chosen field names to the spreadsheet
'row   = 2
'column = 0
'for each f in _fieldList
'    theField = theVTab.FindField(f)
'    'DEBUG msgbox.info(thefield.asstring,"")
'    column = column + 1
'    ssClient.Poke("R"+row.AsString+"C"+column.AsString, "the field")
'end
'_recCount = _recCount + 1
'ssClient.Close

'--- Step 5 - activate the VTAB
theVTab = theView.FindTheme("Pilot Area").GetFTab
theVTab.GetSelection.ClearAll
theVTab.UpdateSelection
theVTab.Activate

'assuming the Pilot Area is active from Step 1
av.Run("View.ShowTable","")
theView.GetWin.Open

'Make the Streets Active
theThemes = theView.GetThemes
for each one in theThemes
    One.SetActive(FALSE)
end
theTheme = theView.FindTheme("Pilot Area")
if (theTheme = nil) then
    MsgBox.Info("You must have a streets theme.","")
    exit
end
theTheme.SetActive(TRUE)
'refresh the view
theView.InvalidateTOC(theTheme)
av.GetActiveDoc.GetDisplayInvalidate(True)
theView.GetDisplayFlush
'TIMS.Slider.Apply

total = self.getText
if ((total = Nil) or (total.IsNumber.Not)) then
    total = "0"
end

if ((total < 0) or (total > 100)) then
    total = 0
end

get the text label control values

aLabel1 = self.GetDialog.FindByName("aTextLine34")
aLabel1.SetText(self.getValueAsString)
aLabel2 = self.GetDialog.FindByName("aTextLine35")
aLabel2.SetText(self.getValueAsString)
aLabel3 = self.GetDialog.FindByName("aTextLine40")
aLabel3.SetText(self.getValueAsString)
aLabel4 = self.GetDialog.FindByName("aTextLine39")
aLabel4.SetText(self.getValueAsString)

total = aLabel1.AsNumber + aLabel2.AsNumber + aLabel3.AsNumber + aLabel4.AsNumber

self.GetDialog.FindByName("aTextLine48").setText(totalAsString)

'TIMS.Slider1.Apply

distance = self.getText
if ((distance = Nil) or (distance.IsNumber.Not)) then
    distance = "0"
end

distance = distance.AsNumber
if ((distance < 0) or (distance > 100)) then
    distance = 0
end

self.GetDialog.FindByName("aTextLine34").setText(distanceAsString)

self.GetDialog.FindByName("aSlider26").setValue(distance)

'TIMS.Slider2.Apply

distance = self.getText
if ((distance = Nil) or (distance.IsNumber.Not)) then
    distance = "0"
end

distance = distance.AsNumber
if ((distance < 0) or (distance > 100)) then
distance = 0
end
self.GetDialog.FindByName("aTextLine35").setText(distance.AsString)
self.GetDialog.FindByName("aSlider36").setValue(distance)

'TIMS.Slider3.Apply
distance = self.getText
if ((distance = Nil) or (distance.IsNumber.Not)) then
distance = "0"
end
distance = distance.AsNumber
if ((distance < 0) or (distance > 100)) then
distance = 0
end
self.GetDialog.FindByName("aTextLine40").setText(distance.AsString)
self.GetDialog.FindByName("aSlider43").setValue(distance)

'TIMS.Slider4.Apply
distance = self.getText
if ((distance = Nil) or (distance.IsNumber.Not)) then
distance = "0"
end
distance = distance.AsNumber
if ((distance < 0) or (distance > 100)) then
distance = 0
end
self.GetDialog.FindByName("aTextLine39").setText(distance.AsString)
self.GetDialog.FindByName("aSlider38").setValue(distance)
'Name: Table.ReportInfo
'Title: Reports on a table's structure
'Topics: Tables
'Description: Working off a table document this script reports on the structure of the table
'Requires: The active document must be a table.
'Self:
'Returns:

atbl=av.getactivedoc
if(atbl.is(table).not) then
    msgbox.error("A table document must be active.","Error")
    exit
end

theVTab = atbl.getvtab
theBitMap = theVTab.GetSelection
flist = theVTab.GetFields
atab = tab+tab+tab+tab

totalchar = "Alias"+atab+"Type"+atab+"Width"+atab+"Decimal"

longname=0
for each afld in flist
    aname=afld.getalias
    if (aname.count > longname) then
        longname=aname.count
    end
end

for each subitem in flist
    aspace=" 
    itList = subitem.gettype
    itPrecision=subitem.getPrecision
    itwidth=subitem.getwidth
    aname=subitem.getalias
    compilation=aname+","+atab+itlist.asString+","+atab+itWidth.asString+","
        +atab+itPrecision.asString
    totalchar=totalchar +nl+ compilation
end

MsgBox.report(totalchar, "Items from "+atbl.getname.asstring)
BIBLIOGRAPHY


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