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DEVELOPMENT OF A DYNAMIC SPATIAL DATA ANALYSIS SYSTEM FOR TRANSPORTATION

By

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A dissertation submitted in partial fulfillment
of the requirements for the

Doctor of Philosophy Degree in Engineering
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December 2005

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04 AUGUST, 2005

The Dissertation prepared by

MUKUNDA RAO DANGETI

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DEVELOPMENT OF DYNAMIC SPATIAL DATA ANALYSIS SYSTEM FOR TRANSPORTATION

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

Doctor of Philosophy in Civil and Environmental Engineering

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ABSTRACT

Development of a Dynamic Spatial Data Analysis System for Transportation

By

Mukunda Rao Dangeti

Dr. Shashi Nambisan, Dissertation Committee Chair
Professor, Department of Civil and Environmental Engineering
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Transportation systems are complex entities that are owned and operated by a diverse group of organizations. The management of such systems requires substantial amounts of data to be monitored, acquired, managed, analyzed, maintained and modeled. Due to the spatial and temporal nature of such data, Geographic Information Systems (GIS) and Global Positioning Systems (GPS) technologies offer significant promise to help with such activities. The focus of this dissertation is to develop a GIS based decision support system to help manage transportation systems. The purpose of the study is to develop a system, which compiles, pre-processes, and manages various transportation system related data including near real time transfer of data. This involves the development of a system architecture, and identification and integration of software and hardware elements. The system utilizes commercial off-the-shelf software and hardware, along with customized interfaces. The system is then evaluated using a pilot study. The pilot study includes components to facilitate data collection and analyses, as well as mechanism to disseminate the results of the analyses. The outcome of the dissertation is a system that utilizes GIS and GPS technologies to manage transportation related databases in real-time, and a demonstration of its use.

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CHAPTER 1

INTRODUCTION

Transportation systems are complex entities that are managed by a diverse group of organizations. This requires substantial amounts of data to be monitored, acquired, managed, maintained, analyzed, modeled, and improved. In general, data currently collected by a typical transportation agency can be loosely classified into three different categories: planning, engineering, and operational. Data collection, storage and retrieval plays a key role in the operation and management of any functional system. In transportation, such data relate to the network, vehicles/users, and the results of the network related activities. They include on-network characteristics of the network such as supply or demand indicators at node or link levels, infrastructure condition related information, safety and environment related attributes resulting from the interactions between the users and the network. Other data of interest include off-network characteristics such as proximate population and demographic characteristics, land use characteristics etc.

The accuracy and timeliness of the data are critical for managing the system. Here the term management includes planning, design, construction, operations, maintenance, and rehabilitation of the system. Agencies that have jurisdictional responsibilities over transportation systems are required to account for their infrastructure and develop a maintenance management system. The practice has been to use the "traditional" paper

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based mechanisms for this purpose. However, there has been a move to adapt computerized tools and systems such as Geographic Information Systems (GIS) and Geographical Positioning Systems (GPS) for transportation infrastructure management.

There are number of definitions for explaining the term GIS, but one of the best complete definition can be stated as follows [Lake County Water Authority website] *(15)*:

GIS is a system of computer software, hardware and data, and personnel to help manipulate, analyze and present information that is tied to a spatial location –

Spatial location – usually a geographic location

Information – visualization of analysis of data

System – linking software, hardware, data

Personnel – a thinking explorer who is key to the power of GIS

In simple words, a GIS combines layers of information about a place/location to give the user a better understanding of that place/location. However, the information combined depends on the user and his/her purpose. A GIS can be compared to a simple paper map with lot of information, any which can be displayed only if the user chooses to. All the information is stored in the form of a database. The power of GIS over a paper map is the user's ability to select the information to be displayed according to the user's goal. Visualization is one of the key strengths of a GIS. As has been said, "a picture is worth thousand words" and a GIS helps the user to visualize complex sets of data. One key advantage is the maps and the related databases are interactive unlike traditional paper map.

Figure 1 shows the visual display capabilities of GIS software to join different layers into one. In this figure, layers displaying information related to customers, streets,

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parcels, elevations, and land usage are integrated with the real world layer. Using paper maps, it is hard to combine two or more maps into one, unless they are on transparent media. However, using GIS software, it is easier as well as more effective to visualize several layers combined into one.

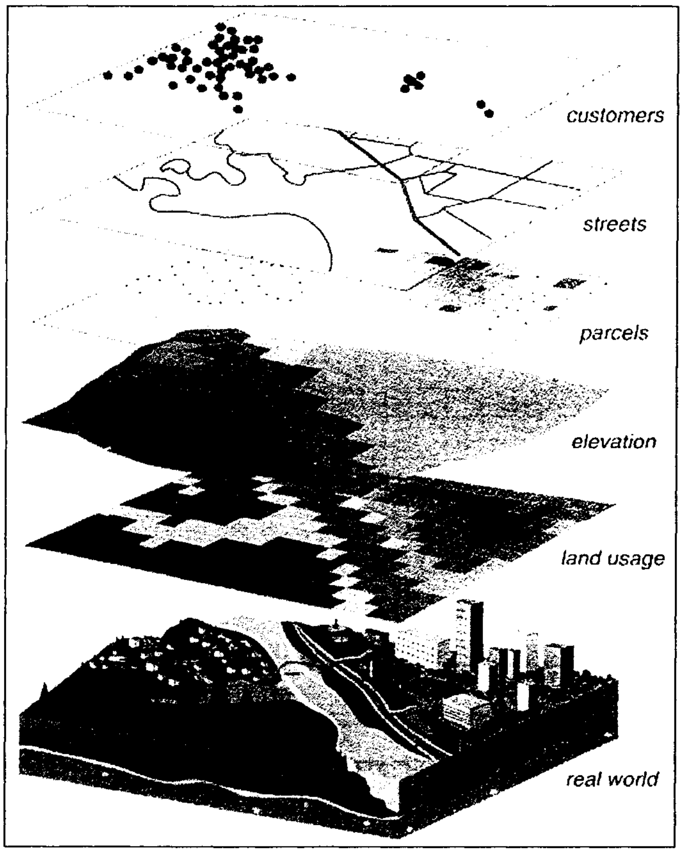

Figure 1 GIS Capability to join layers
(Source: http://geoworld.la.asu.edu/gis)

Most GIS environments support assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations. Presently GIS technology is being used in various fields like resource management,

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scientific investigations, social sciences and transportation. In this study, the capabilities of GIS software to process and manage real-time data will be analyzed and evaluated.

The Global Positioning System (GPS) is a satellite-based system initially developed and operated by the U.S. Department of Defense (DOD) [http://gps.faa.gov/FAQ/faq-gps.htm]. The space segment of the GPS consists of the satellites. These space vehicles (SVs) send radio signals from space. The nominal GPS Operational Constellation consists of 24 satellites that orbit the earth in 12 hours. (See Figure 2) There are often more than 24 operational satellites as new ones are launched to replace older satellites. The satellite orbits repeat almost the same ground track (as the earth turns beneath them) once each day. The orbit altitude is such that the satellites repeat the same track and configuration over any point approximately each 24 hours (4 minutes earlier each day). There are six orbital planes (with nominally four SVs in each), equally spaced (60 degrees apart), and inclined at about fifty-five degrees with respect to the equatorial plane. This constellation provides the user with between five and eight SVs visible from any point on the earth.

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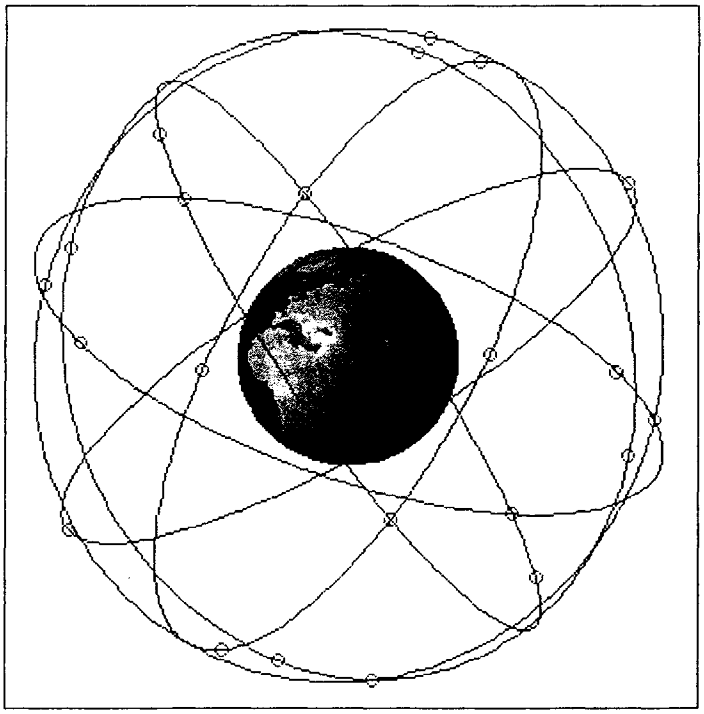

Figure 2 GPS Operation Constellation
(hypo.ge-dip.etat-ge.ch/ www/math/html/node54.html)

In 1996, a Presidential Decision Directive, later passed into law, transferred "ownership" of the GPS constellation and data from the DOD to an Interagency GPS Executive Board (IGEB), co-chaired by senior officials of the Departments of Transportation and Defense to provide management oversight to assure that the GPS meets civil and military user requirements (http://gps.faa.gov/FAQ/faq-gps.htm) *(6)*. The GPS permits land, sea, and airborne users to determine their three-dimensional position, velocity, and time 24 hours a day, in all weather conditions, anywhere in the world with a precision and accuracy far better than other radio-navigation systems available today. Presently the GPS technology is being used in various fields in transportation such as for navigational support of land, sea, and airborne travel, surveying, geophysical exploration, mapping and geodesy, vehicle location systems, and a wide variety of other additional

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applications. Telecommunication infrastructure applications include network timing and enhanced 911 for mobile phone users. Global delivery of precise and common time to fixed and mobile users is one of the most important, but least appreciated functions of the GPS technology.

Due to the spatial and temporal nature of such data, Geographic Information Systems (GIS) and Global Positioning Systems (GPS) technologies offer significant promise to help with such activities. The main purpose of this dissertation is to develop a GIS and GPS based decision support system to help manage transportation systems. The purpose of the study can be explained as a process of assimilating near real-time data and static data, with the GIS and GPS tools, and to develop a system, which compiles, pre-processes, and manages the data collected. This involves developing a system architecture, the identification and integration of software and hardware elements. The system utilizes commercial off-the-shelf software and hardware, along with customized interfaces. The use of system is then illustrated using a pilot project. The pilot project includes components to facilitate data collection and pre-processing of the collected data, as well as a mechanism to disseminate the results of the analyses. The outcome of the dissertation, in short, is a model/system utilizing GIS and GPS technologies for the management and analysis of transportation system data, and a demonstration of its application for managing transportation related databases in near real-time.

A short background and the motivation for the present research are presented in Chapter 2. A review of the literature including the software and hardware related topics are discussed in Chapter 3. The development of the system architecture and the design of the system are presented in Chapter 4. A pilot project to illustrate the application of the

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system is presented in Chapter 5. This includes discussions of the data collection, management and analysis efforts. Conclusions and recommendations are presented in Chapter 6.

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CHAPTER 2

BACKGROUND AND MOTIVATION

In the year 1998, the American Society of Civil Engineers (ASCE) developed their first national infrastructure report card *(30)* in order to raise the awareness and understanding of the role of civil engineers in the society and also to raise awareness of the declining condition of the infrastructure in the United States. In their first report, ASCE assigned a grade of "D" for the combined infrastructure in the country. This report card reports on the condition of the nation's roads, bridges, water supplies, hazardous waste sites, solid wastes, dams, airports and wastewater and estimated the expenditures required to bring each element into a satisfactory condition. The creation of the report card required collecting large amounts of data for assessing the condition of the infrastructure. This first report was followed by report cards in the years 2001, 2003 and 2005. The infrastructure grades determined by ASCE for these years were D+, D+ and D respectively. With new grades for the first time since 2001, nation's infrastructure has shown little to no improvement since receiving a collective D+ in 2001, with some areas sliding toward failing grades. Thus, regular collection, management and analyses of transportation system data are critical to the accurate and timely evaluation of system condition and performance.

In the year 2002, the Transportation Research Board (TRB) Executive Committee identified fourteen critical issues in the field of transportation *(3)*. They include topics

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such as transportation safety, congestion, system maintenance, and energy efficiency. Of these fourteen critical issues, five issues were identified as early as in the year 1976. This dissertation focuses on one of the critical issues identified by the TRB - the maintenance of a transportation system.

Regular updates and upgrades of information pertaining to the system are important processes in managing any transportation facility. Thus, databases form an important part of such management systems. The level of difficulty associated in maintaining the databases depends on a number of factors. These include the complexity of the data attributes maintained in the database, the scale of the network elements, the frequency with which each data element needs to be updated. The data updates can be performed either in real time or near time or at periodic intervals. Real-time updates may be more expensive than the conventional periodic upgrading process because of the complexity of the process. However, technological advances could change this and make real time updates to be an efficient and effective option.

In transportation engineering, real time data updates play a key role in the functioning of the system. Many a process ranging from the design of a simple actuated signal to a complex emergency medical response system depend on real time data from the field. The process involved in updating the transportation system databases with real time data depends on the type of data collected and the quantity of data to be updated. Currently, algorithms-based updating processes are commonly used for data updates. In addition, software such as CORBA have been used in various transportation projects by FedEx, American Automobile Association (AAA), and American Airlines *(12)*. Various Intelligent Transportation Systems (ITS) deployment initiatives also incorporate near real

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time data. For example, Kimley Horn Associates *(14)* was responsible for developing the freeway management component of Freeway and Arterial System of Transportation (FAST) for the entire Las Vegas valley and integrating it with the existing Las Vegas Area Computerized Traffic System (LVACTS) system.

The Las Vegas metropolitan area has been and continues to be one of the fastest growing urbanized areas in the country. Gaming and tourism, proximity to the natural scenic attractions, a favorable climate, and direct access by air and ground, are factors that make Las Vegas a unique place to live and visit. Table 1 list the top 15 metropolitan areas in the United States in terms of population change between the years 1990 and 2000 and ranks them in the descending order of percent change during this period. The population increase in Clark County, Nevada (which includes the Las Vegas metro area) from the year 2000 to 2003 was at an average annual growth rate of 4.96 %. *(1)*. Figure 3 shows the Las Vegas metropolitan area with various cities and townships.

As is evident from Table 1, the rate of population in growth in the Las Vegas metropolitan area is the highest in the whole nation. Figure 4 shows the growth in the population of Clark County, Nevada during the period of 1980 to 2003. Growth in the 1980s continued at a rapid pace, especially in Boulder City, and the townships of Enterprise, Whitney, and the Northeast, Northwest, and the South County areas. Additionally, Laughlin and Henderson (including Green Valley) experienced rapid development.

During the 1990s, the master planned community of Summerlin was recognized as the fastest growing community in the United States. Accelerated growth in the southern portion of the Las Vegas valley came with the development of various master planned

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communities such as Seven Hills, Anthem, Southern Highlands, Rhodes Ranch and Silverado Ranch. Figures 5, 6 and 7 show the development pattern in the Las Vegas metropolitan region during the 1980s, 1990s and 2000s.

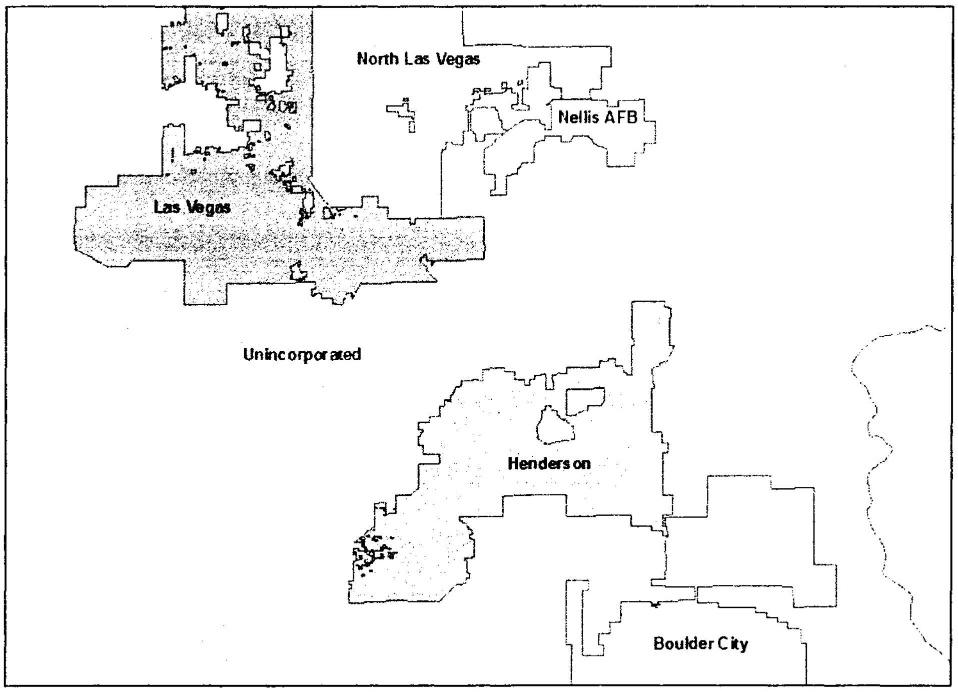

Figure 3 Various Cities and Townships in Las Vegas Metropolitan Area

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Table1 Top 10 Metropolitan Population Change 1990-2000 in United States

Rank	Metropolitan Area Name	Census Population		Change, 1990 to 2000	
		Apr. 1, 2000	Apr. 1, 1990	Number	Percent
1	Las Vegas, NV	1,563,282	852,737	710,545	83.3%
2	Naples, FL	251,377	152,099	99,278	65.3%
3	Yuma, AZ	160,026	106,895	53,131	49.7%
4	McAllen--Edinburgh--Mission, TX	569,463	383,545	185,918	48.5%
5	Austin--San Marcos, TX	1,249,763	846,227	403,536	47.7%
6	Fayetteville--Springdale--Rogers, AR	311,121	210,908	100,213	47.5%
7	Boise City, ID	432,345	295,851	136,494	46.1%
8	Phoenix--Mesa, AZ	3,251,876	2,238,480	1,013,396	45.3%
9	Laredo, TX	193,117	133,239	59,878	44.9%
10	Provo--Orem, UT	368,536	263,590	104,946	39.8%

Source: http://www.census.gov/population/www/cen2000/phc-t3.html

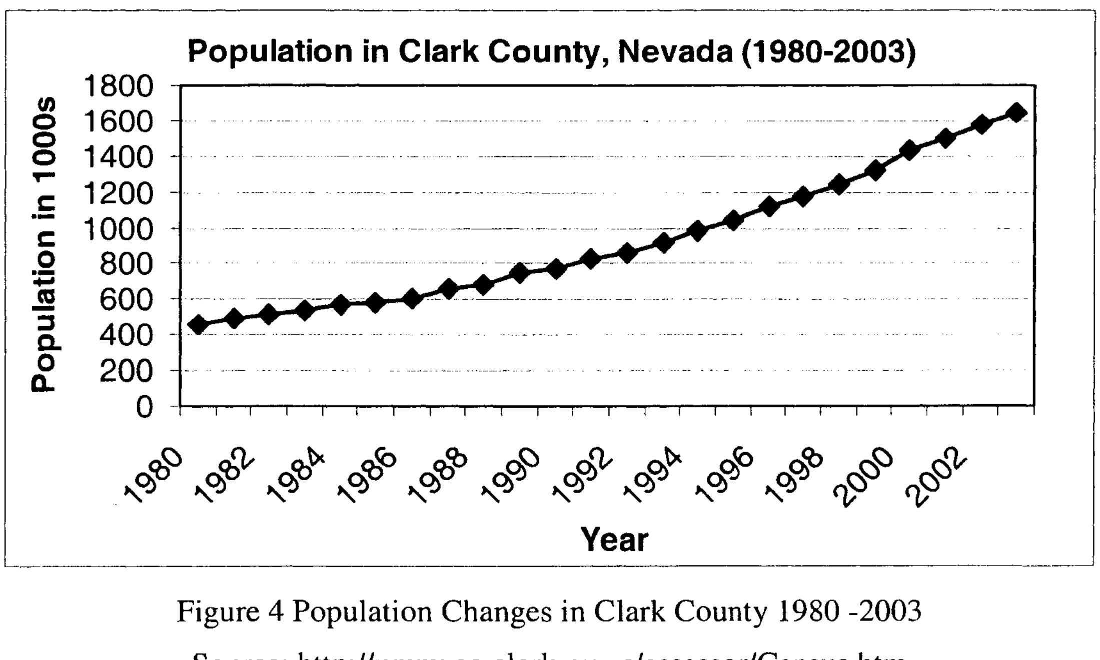

Figure 4 Population Changes in Clark County 1980 -2003

Source: http://www.co.clark.nv.us/assessor/Census.htm

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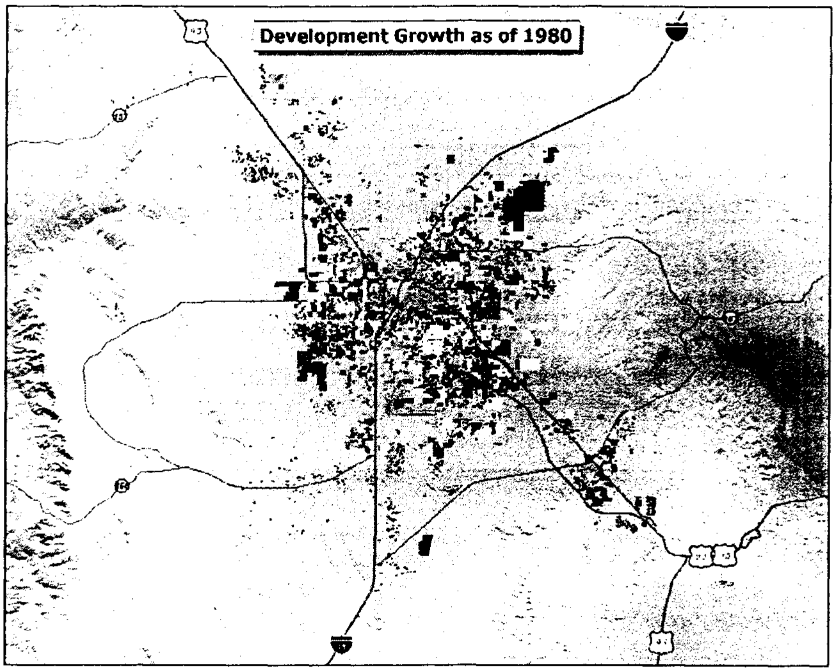

Figure 5 Development Growth in the Las Vegas Metropolitan area - 1980
(Source: Regional Transportation Commission of Southern Nevada)

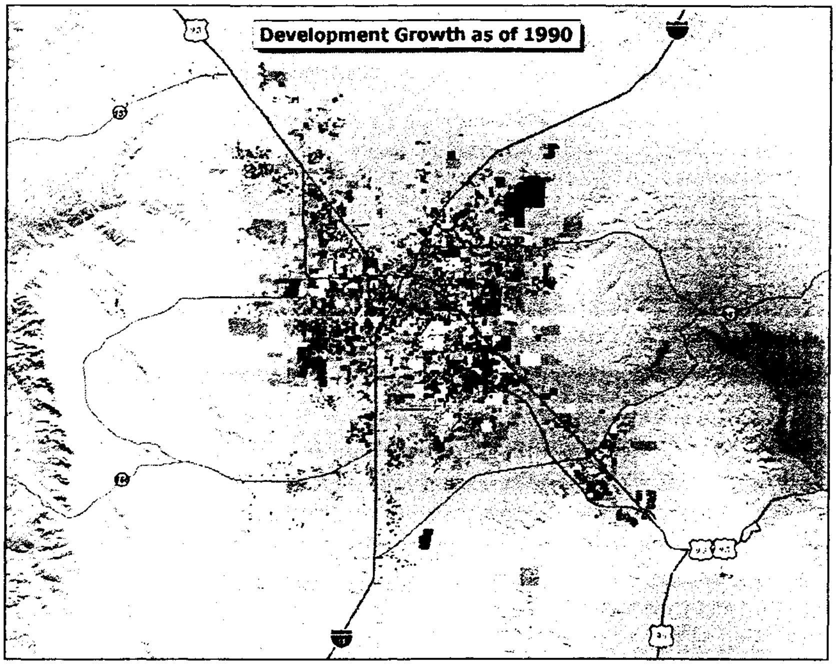

Figure 6 Development Growth in the Las Vegas Metropolitan area – 1990
(Source: Regional Transportation Commission of Southern Nevada)

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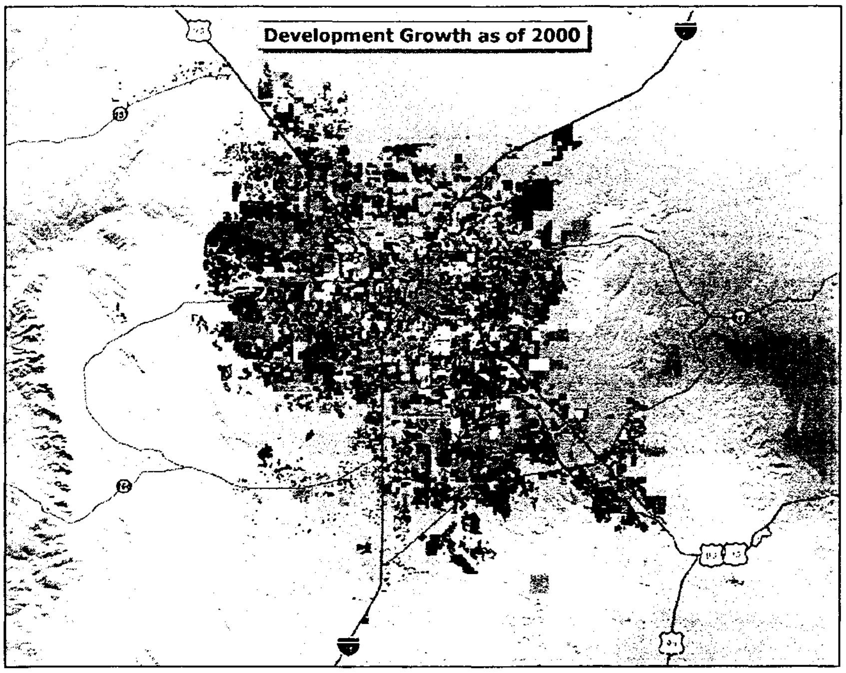

Figure 7 Development Growth in the Las Vegas Metropolitan area – 2000
(Source: Regional Transportation Commission of Southern Nevada)

In order to meet the population and the economic growth, the state and local government agencies with responsibilities for managing the transportation infrastructure in the Las Vegas metropolitan area have significantly expanded the road network. As the Las Vegas valley's population and the number of road miles continues to grow, so does the traffic volumes on the local roadways. For roads under the jurisdiction of Clark County, the department of Public Works Traffic Management Division (CCPW-TMD) is responsible for conducting the studies to determine what traffic control devices are needed, as well as designing, overseeing the installation and maintenance of these control devices. In addition, the CCPW-TMD also maintains streetlights, and supports the investigation of the fatal and serious injury vehicle accidents within unincorporated areas

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of Clark County. Such activities require access to information related to the transportation system and factors influencing transportation demand.

The database maintained by CCPW-TMD can be quoted as an example for the transportation database, which needs to be maintained by a local governmental agency with jurisdiction over road networks. This central database may contain several component sections such as right-of-way inventory, roadway and pavement characteristics, traffic characteristics, roadway and roadside infrastructure inventory etc. One such section is the traffic signal inventory maintained by CCPW-TMD. Presently CCPW-TMD maintains about 429 signals, as well as 56 emergency and school flashing beacons. From 1990 to 2001, approximately 226 new traffic signals were installed under CCPW-TMD's jurisdiction. This is an increase of 147% over the signal systems installed between 1965 and 1990. To maintain such a large system of traffic signals, it is important to have an effective database.

By nature, transportation networks are spatial. Temporal variations in several attributes of the transportation networks are of significant concern and value to system operators, managers, decision makers and to the users. The capabilities afforded by technologies such as Geographic Information Systems (GIS) and Global Positioning Systems (GPS) offer significant potential for the development and management of the spatial and temporal characteristics of transportation networks. Indeed, over the past decade these technologies have been increasingly used by transportation agencies and organizations. Examples of such applications include producing base maps of a region, developing inventories of transportation infrastructure, conducting travel time studies and so on *(11)*. However, such efforts have seen little emphasis on real time updates or near

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real time to the databases, and the subsequent use of such updated databases. The objective of this dissertation is to develop a model/system utilizing GIS and GPS technologies and demonstrate its application to update transportation databases in real time.

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CHAPTER 3

LITERATURE REVIEW

The review of the literature for the proposed research includes the subject areas of GIS and GPS applications in transportation engineering, and the capabilities and limitations of the software used in the process. The following is a short summary of the literature on different software related aspects such as the usage of the GIS software for transportation databases and those pertaining to the capabilities and limitations of different GIS software. For the process of real time updates, internet-mapping software needed to be considered. The two internet mapping software that are germane to this research are ESRI ArcIMS *(39)* and Autodesk Mapguide 6.3 *(40)*. Along with the software related issues, the different types of instruments/hardware of interest in the current study are also discussed.

Usage of GIS Software for Transportation Databases

Over the past decade or so, the use of GIS by transportation agencies and organizations around the world has increased. Intelligent transportation systems (ITS), when integrated into the transportation system infrastructure, and in vehicles themselves, help monitor and manage traffic flow, reduce congestion, provide alternate routes to travelers, enhance productivity, and save lives, time and money. ITS also provides the tools for skilled transportation professionals to collect, analyze, and archive data about

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the performance of the system during the hours of peak use. Having this data enhances traffic operators' ability to respond to incidents, adverse weather or other capacity constricting events. The Archived Data User Service (ADUS) requires ITS-related systems to have the capability to receive, collect, and archive ITS-generated operational data for historical, secondary, and non-real-time uses. ADUS prescribes the need for a data source for external user interfaces and provides data products to users. Literature was reviewed based on the above-mentioned topics such as GIS and GPS applications in transportation as well as ITS applications. A brief description of the literature on these topics follows.

Hsiao *et al* (1992) *(11)* describe how GIS techniques were applied to analyze commuter rail survey data from which the upcoming inter-county rail service design can be projected and tailored. The survey data were collected on three morning trains operating between San Diego and Los Angeles. The study showed that GIS provides a flexible approach for data analysis. Both short-term commuting service design and long-range transportation planning activities can be developed based upon a common GIS database structure.

Jha (2002) *(13)* used GIS as a dynamic decision making tool in performing highway cost analysis. A fully automated model was developed using GIS since optimal search algorithms do not allow manual intervention during program run-time. An example using real geographic information from Maryland was presented in this paper. The dynamic decision-making using GIS in highway alignment optimization was demonstrated in an example using property and stream layers for Baltimore County, Maryland. The author developed a GIS-based right-of-way cost estimation technique using compactness

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analysis in which after-values of affected land parcels were estimated based on the compactness of their shapes. The results indicate that bridge and intersection cost considerations are quite significant in highway alignment optimization. The results of the study also indicate that compactness analysis helps reduce damage to properties in alignment optimization.

Martin M.R. (1992) *(17)* describes an application of GIS for graphical display and data manipulation for highway maintenance, thereby dramatically improving evaluations of the maintenance process. Two maintenance areas namely (a) pavement management system, and (b) sign maintenance system were investigated in this paper using a pilot study. This paper also illustrates using GIS for an easy and efficient enhancement of the existing facility management. The author concludes the paper by saying that the pilot study demonstrates that GIS can quickly and cost-effectively becomes a beneficial part of highway management system.

Mendoza *et al*, (2002) *(17)* present the development of a system for assessing truck operating costs on the Federal Road Network by using ArcView, a GIS program. An assessment of costs of operating vehicle (COV) was carried out based on World Bank Model vehicular operating costs calibrated for Mexican vehicles.

Nambisan *et al*, (1999) *(23)* describes the development of a prototype system for the purpose of dissemination and analysis of information over the Internet is efficient and time effective in reaching a multitude of users, it is still difficult to perform these operations with transportation data in a graphical format using the Internet.

Ozbay *et al*, (2003) *(26)* describe the development of a Geographical Information Systems based Management Information System (GISMIS) application that ensures

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effective management and retrieval of requested documents from a very large scanned digital documents database. The paper also discusses overall application functionality from different perspectives of systems design and various GIS related aspects of the developed tool. The authors state that GISMIS is a powerful and highly useful application that allows end users to search and display their search results through a user friendly GIS-based Graphical User Interface (GUI) that takes full advantage of the GIS capabilities for pinpointing otherwise difficult to locate documents, which reside in large databases.

Quiroga, *et al*, (2001) *(28)* describe the architecture of a prototype global positioning system (GPS) / geographic information system (GIS) / Internet platform for the management of utility data that takes into consideration both utility data characteristics and roadway network characteristics. The model includes a GPS/GIS-based prototype to represent utility facilities located within a highway right-of-way (ROW) and associated attribute data such as ownership, purpose, size, type, and shared/multiple uses. The model also includes a prototype internet-based data entry procedure to facility the capture of utility data from a variety of utilities entities.

Rhoulac, *et al*, (2000) *(31)* developed different mathematical models to supplement Transportation Information Management System (TIMS) software used for school bus routing in the state of North Carolina. TIMS uses optimization methods to produce the most efficient, effective school bus routes and requires a lot as input, the travel speed of each link. The empirical models developed in this paper provide more accurate travel time estimates to produce more optimal routes. The authors state that the two most important contributors to the travel time of a school bus on a link are traffic and roadway

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conditions and students loading time. Mobile GPS equipment was used on-board several school bus routes to collect this data for model development.

Sarasua *et al*, (2002) *(32)* introduced a multicriteria dynamic segmentation approach that allows on-the-fly segment length specification prior to attaching a linear referenced table to a route. The paper describes the system architecture and identifies other types of spatial data that may benefit from this approach. The application developed has been proved to be a powerful tool in the analysis of the pavement marking retro-reflectivity data and is an efficient means to manage and display the data.

Spring, G.S. (1992) *(33)* examined the use of GIS for city traffic control inventories management programs. The work described includes assessment of various computer technologies and development of guidelines that may be used to select that combination of hardware and software that best meets the special needs of city departments of transportation. The author concludes that more cost effective, safer and more efficient highway systems can more readily provided for the community by providing better access to important traffic facilities data, by improving the quality of the data and by allowing integration of related data.

Stopher *et al*, (2002) *(34)* discussed pre-pilot and pilot GPS Household surveys conducted and the several important facts about the design of the surveys, data collection, and comparison with the other traditional surveys. The results of the pilot study were consistent with the findings of the pre-pilot and a number of other GPS surveys. The authors' state that a significant challenge in conducting a GPS based survey is processing the raw GPS data and producing the materials necessary for the prompted recall interview in a short period after the data are collected.

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Tsai *et al*, (2002) *(38)* describes how the Georgia Department of Transportation (GDOT) uses the technologies of GPS, GIS, Distance Measuring Instrument (DMI), and data-management to re-engineer current road inventory operations. The authors summarized some of the findings of the present study and also gave some possible directions for performing future research in this field.

The literature review has thus identified many technology-based application developed to support infrastructure management.

Software Related Literature Review

The functional requirements of the system drive the system architecture and the selection of the software and hardware. The selection of software depends on various factors such as the ease of use for database management, capability to support Internet-based applications, ability to store and retrieve spatial data (by the association of the geographic coordinates and time stamps), and manageability of a wide range of transportation data. As the proposed study is based on the applications of GIS in real time, two criteria will be evaluated to select software. One of the criteria was the ease of use of the software when combined with Internet applications. The second criterion is the ease of using the software on field instruments such as Portable Digital Assistants and similar handheld hardware devices. This is directly related to the data collection process envisioned for the end user. In addition to the above-mentioned criteria, software related to analysis of the data will also be discussed.

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Literature related to Internet mapping based software

As previously mentioned, one of the vital factors for the selection of the software is the compatibility consideration for developing Internet mapping applications in an easy-to-use web browser – for example to integrate local data sources with Internet data sources to display, query, and analyze spatial information. The two main software considered for the present study are Environmental Systems Research Institute (ESRI) ArcIMS 4.0 and Autodesk Mapguide 6.0. These are the two software that are widely used in the field of internet mapping applications. The advantages and limitations for these software are discussed next. Tables 2, 3 and 4 compare the two software from different perspectives – overall functionality, server functionality, and author functionality. Autodesk Mapguide release version 6.5 has additional features such as enhanced layer functionality with direct access to the analytical power of databases such as Oracle.

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Table 2 Comparison of Autodesk Mapguide and ArcIMS based on Overall Functionality

Function	Autodesk Mapguide Viewers Ver 6.3	ArcIMS Java Viewer
GENERAL		
Download required	√	√
Select objects by rectangle	√	
Select objects by radius	√	√
Select multiple objects on different layers	√	
Select objects with Shift-Pick	√	
BUFFERING		
Create buffer	√	√
Buffer created new layer	√	
Select within buffer	√	√
Complex buffer creation	√	
QUERYING		
Identify – Select geographic object and view data	√	√
Set map units	√	√
Set selection mode (centroid or intersection)	√	
Set mouse position display units (Lat/Long or Mapping Coordinate system)	√	
PRESENTATION		
MapTips/Map Tooltips	√	
Customized printing	√	
Online help files	√	

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Table 3 Comparison of Autodesk Mapguide and ArcIMS based on Server Functionality

Function	**Mapguide6**	**ArcIMS4**
Security-restrict access to resources	√	
Open data sources from remote web server	√	
Load balancing	√	√
Direct connection to OLE DB/ODBC	√	
NATIVE DATABASE CONNECTIVITY		
Oracle	√	
SQL Server	√	
Sybase	√	
SPATIAL DATA SUPPORT-VECTOR		
ESRI SHP (Shape File)	√	√
DWG (Drawing File)	√	
ESRI Arc/INFO Coverages	X	
Mapinfo MID/MIF	X	
Intergraph DGN	X	
Atlas BNA	X	
ASCII comma delimited CSV	X	
SPATIAL DATA SUPPORT-RASTER		
BMP (Bitmap File)	√	√
CALS (Computer Aided Acquisition and Logistics Support)	√	
ECW (Enhanced Compressed Wavelet)	√	
PNG (Portable/Public Network Graphic)	√	√
TGA (Truevision Targa Graphic)	√	
TIFF (Tagged Image Format File)	√	√
SPATIAL DATA SUPPORT-World Files/Geo-referencing		
Mapinfo tab files	√	
Geo TIFF files	√	√

X – Converted with SDF Loader

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Table 4 Comparison of Autodesk Mapguide and ArcIMS based on Author Functionality

Function	**Mapguide6**	**ArcIMS4**
Save as file format	.mwf, .mwx	.axl
Save individual layer	√	
Copy map as file format	.emf, URL	Jpeg
Open file from http location	√	
NAVIGATION		
Zoom Width	√	
Zoom Scale	√	
Zoom Selected Object	√	√
Zoom goto address-address matching	√	√
SELECTION		
Select objects by radius	√	
Select objects by map feature	√	√
Select object by polygon	√	
Select multiple objects on different layers	√	
Select objects with SHIFT-Pick	√	
BUFFERING		
Create buffer	√	
Buffer creates new layer	√	
Select within Buffer	√	
AUTHORING		
Link map features to URL	√	
Measure Distance	√	
Map Tips	√	
Add Scale		√
SECURITY		
Map password protected setting	√	
Track map usage	√	

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In summary, both Autodesk and ESRI provide technologies to simply view and query the data on the web, as required by most spatial data users. However, as the demand for more sophisticated analysis increases, Autodesk's MapGuide version that was evaluated was in a better position to meet those needs. ESRI's ArcIMS was still in an early phase of development. Its central strength is that it works with ESRI products (showing images of SHP files on the web). Because Autodesk MapGuide also works with ESRI products, its powerful capabilities and scalability currently made it a better choice for implementing a web-based system.

Literature related to Field-usage Software

As previously mentioned, the second criterion for the software selection is the simplicity and ease of use of the software on field instruments such as handheld devices, PDA etc. Two software satisfying this criterion were studied. They are the ArcPad software (product from the ESRI group) and Terrasync Software (product from Trimble). Even though there are other software available for the data collection in the field, the two software mentioned above were selected based on the fact they are among the more popular software used by the various public and private entities, especially in the Las Vegas metropolitan area.

Features of ESRI ArcPad 6.0.2

ArcPad Software has features that are similar to the ArcMap, but on a limited scale *(39)*. It supports various data formats to be accepted as input files such as ESRI shapefiles, MrSID by LizardTech, JPEG, Windows bit map, PNG and ArcIMS Image Services via the Internet including wireless communication. It has a number of map navigation display and query tools, including variable zoom and pan, fixed zoom, zoom

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to a specified layer or spatial or bookmark, center on the current GPS position, measure distance, area, and bearings of the displayed map, identify features by tapping on the map, display additional information about features through a hyperlink and locate, label, and zoom to a feature. It also offers integration with an optional GPS or differential GPS. ArcPad provides navigational information from the current GPS position to the destination, a GPS track log that illustrates the path traveled, and GPS data capture. It also affords the capabilities to set GPS quality controls, such as position dilution of precision (PDOP) and estimated position error (EPE), and perform position averaging for points and vertices. GPS support is available on receivers that support the following protocols: DeLorme Earthmate Binary Protocol, NMEA (National Maritime Electronics Association), and TSIP (Trimble Standard Interface Protocol).

ArcPad allows the user to create and edit spatial data using input from a mouse pointer, pen, or GPS. Editing capabilities in ArcPad include create, edit, delete, and move features; add, delete, and move vertices for lines and polygons; append vertices to existing line features; capture GPS points while in the process of capturing a line or polygon with a GPS (i.e., nested points); edit attribute information using custom forms created with the ArcPad Application Builder. Finally, ArcPad enables specialized mapping and data collection in a wide range of industries and applications, which include street sign inventory, power pole maintenance, meter reading, road pavement management, military fieldwork, toxic inventory, mineral exploration, habitat studies, crop management, property damage assessment, field surveying, and incident reporting and inspection.

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Features of Trimble TerraSync Software

The TerraSync software is a flexible data collection and data maintenance tool. To collect high quality, precise data for informed decision-making, Terrasync software can be used with a wide variety of field devices and a supported Trimble GPS receiver. Either collecting identical assets or a range of assets with many different attributes, data collection is quick and easy with the help of Terrasync Software. To maintain data integrity, the data structure can be designed to meet the requirements of the required enterprise GIS. The software's flexible design and quality control functions enable a user to tailor settings and data collection methods to suit requirements. Smart timesaving features make verifying and updating data easy.

Terrasync runs on Trimble's integrated GeoExplorer CE series handhelds, the rugged GIS TSCe field device, the Trimble Recon handheld, or a user-supplied Microsoft Windows or Microsoft Windows CE field device. It has smart timesaving features such as pre-defined pick lists, map-centric operation, and graphical status display for effortless GIS data collection. It allows user for graphical navigation and real-time map display help to navigate back to assets with ease. It supports background images in map display, including satellite imagery, aerial photos, and images from ArcIMS and Open GIS internet map servers. It has intuitive touch screen operation for simple data entry, seamless GPS control for quality position data and Recognition Tool Kit (RTK) support for Trimble 5700 and 5800 GPS receivers. The software also works with ESRI Shapefiles. Files can be directly e-mailed from the field to a website *(www.gpspathfinderexpress.com)* for quick online differential correction, or to the office for immediate GIS update. Voice and image files also can be attached as attributes to the

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data collected. Finally, it is compatible with GPS Pathfinder Office software for efficient data processing, differential correction and two-way data flow from the GIS to the field.

Both ESRI and Trimble field usage software exhibit a wide range of capabilities. However, developing a data collection interface appears to be easier using ESRI ArcPad software. But both the software will be tested in the field to determine their efficiency in the process of data collection, by using them on different hardware.

Literature Related to Data Analysis Software

The present study does not limit itself by studying the software related to data collection and internet mapping, but also focuses on the software used for the data analysis purpose. Although, this software might not be used by the front-end users such as field data collectors or general public, it is used by the application / interface developers. The software strongly recommended for the analysis of the collected field data is ESRI ArcGIS with some of the commonly used add-ons. A discussion of the rationale for this recommendation follows.

Features of ESRI ArcGIS

ArcGIS is an integrated collection of GIS software products for building a complete GIS *(39)*. ArcGIS enables users to deploy GIS functionality where needed on desktops, servers, or custom applications; over the Web; or in the field. ArcGIS Desktop is a collection of software products that runs on standard desktop or laptop computers. It is used to create, import, edit, query, map, analyze, and publish geographic information. There are four products in the ArcGIS Desktop collection; each adds a higher level of functionality. They are described next.

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ArcReader is a free viewer for maps authored using the other ArcGIS Desktop products. It can view and print various maps and data types. It also has some simple tools to explore and query maps. ArcView provides extensive mapping, data use, and analysis along with simple editing and geoprocessing capabilities. ArcEditor includes advanced editing for shapefiles and geodatabases in addition to the full functionality of ArcView. ArcInfo is the full function, flagship GIS desktop. It extends the functionality of both ArcView and ArcEditor with advanced geoprocessing. It also includes the legacy applications for ArcInfo Workstation.

All ArcGIS Desktop products share a common architecture, so users working with any of these GIS desktops can share their work with each other. Maps, data, symbology, map layers, geoprocessing models, custom tools and interfaces, reports, metadata, and so on, can be accessed interchangeably. This means that all GIS users in an organization using the ESRI Suite of products can benefit from using a single, consistent user interface and set of functionality and data formats, thus minimizing the need to learn and deploy several different products. In addition, maps, data, and metadata created with ArcGIS Desktop can be shared with many users through the use of custom ArcGIS Engine applications and advanced GIS Web services using ArcIMS and ArcGIS Server.

Hardware Related Literature Review

The hardware selection process includes the identification, evaluation, and selection of the appropriate hardware for the study. Various hardware to be considered for the

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collection of the data in the field are listed in Table 5. The Literature reviewed for the following hardware products specify their characteristics and limitations.

Table 5 Hardware used in the study

	Hardware Description	**Manufacture & Model**
1	Personal Digital Assistant (PDA) *	HP-IPAQ 5555
2	GPS Handheld	GeoXT Handheld
3	Tablet PC *	Gateway Tablet PC
4	Laptop *	HP-Pavillion ZE 5375
5	GPS Receiver	Trimble Receiver

* Instruments used with GPS Receiver

Features of Selected Hardware

A brief description of each of the aforementioned products is discussed later in the chapter. At the end of the descriptions of the above-mentioned instruments, Table 6 summarizes the features of all the hardware listed in Table 5. Table 6 includes features such as processor type and speed, operating system, hard drive, networking capabilities, battery, battery life, price, dimensions, weight, input method, audio capabilities, etc.

Features of HP-IPAQ 5555 Trimble GPS Pathfinder Pocket Receiver

Mobile productivity of an individual can be increased by the use of HP-IPAQ 5555. (http://www.pdasupport.com/Ipaq5555.htm) *(10)*. It can wirelessly communicate while securely accessing and managing information on the user's own preferred schedule. Internet, e-mail and corporate data can be accessed at home, at work, or at any hot spot

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location with the integrated Bluetooth® technology and at least a WLAN 802.11b wireless capability, which is embedded in the instrument. For extra security for the data in the instrument, it comes with fingerprint recognition technology (biometric). Other notable features include its capability to print directly to a HP printer, brilliant color and image sharpness with the help of transflective TFT LCD (64,000 colors) screen, five way navigation button, touch sensitive display for stylus, built-in speaker and microphone, and so on.

Features of Trimble GeoXT Handheld

The Trimble GeoXT handheld combines sub-meter accuracy GPS with Microsoft Windows Mobile 2003 Software for pocket PCs in one rugged unit (http://www.trimble.com/geoxt.shtml) *(36)*. The GeoXT is optimized to provide the reliable, high accuracy location data the user needs. For attaining submeter accuracy in the real time, corrections from a satellite-based augmentation system (SBAS) like Wide Area Augmentation System (WAAS) or European Geostationary Navigation Overlay System (EGNOS) can be used. Its main advantage lies in the location of GPS receiver and antenna. Both of them are built into the handheld computer, making the system cable free and a totally integrated solution.

The instrument can be used as a wireless instrument because of its integrated Bluetooth® technology for connection to other Bluetooth-enabled devices, including cell phones and PCs. There is an option to use the USB support module to connect to a desktop/laptop computer, or use the optional serial clip for cabled connections in the field. The storage space in the GeoXT is large enough to accommodate a significant amount of GIS data. Big graphic files can be loaded quickly with the help of its fast

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processor and large memory. The screen for the instrument is advanced TFT outdoor color screen displaying the graphic files crisp and crystal clear.

Features of Gateway Tablet PC

The tablet PC combines the ease of pen and paper note taking with a powerful notebook computer. Tablet PCs can go to places where other computers cannot. They are silent, and efficient to use. Gateway is one of the few major manufacturers that sell Tablet PC, which is very different from the traditional ultra portable.

While the Tablet PC may have the smaller dimensions of an ultra portable computer system, it also lacks many features of a standard notebook. For example, the system relies upon the touch screen interface and pen for input instead of using a keyboard. This can be useful in certain areas, but for many individuals, writing on the screen is much slower than using a keyboard. Similarly, many of the features that a stylus interface can provide are better supported through the smaller palmtops.

When compared to a palmtop, the Tablet PC offers greater power and flexibility. The Tablet PC has the ability to run the same office applications as a traditional personal computer, something that palmtops cannot do. The Intel Pentium M processor also allows it to power through most applications without heavily draining the batteries. The Tablet PC does have its problems though; most notable of these are the storage options. While the unit does feature an internal hard drive, it does not have any optical drive. This makes installing software onto the Tablet PC difficult. While the Gateway Tablet PC may have the dimensions of an ultraportable, it lacks the same flexibility as competing ultraportable systems.

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Features of HP Pavillion ze5375us Laptop

The HP pavilion ze5375us has many features for serving as a high performance digital imaging studio for home or office related tasks. It works effectively with an Intel Pentium 4 processor 2.4GHz. It can be connected to the internet/network anywhere with its integrated 10/100 Ethernet LAN, 56 Kbps V.90/V.92 modem, and embedded 802.11b wireless LAN. It is sleek, lightweight (7.25 lbs.) and it comes with an all-in-one design. To simplify and greatly improve working skills on the system, HP pavilion ze5375us comes with the five one-touch buttons, quick-launch buttons, and touch pad with on/off button and scroll zone. Other features include integrated ATI MOBILITY RADEON AGP 4X and 3D architecture graphics and 64MB shared video memory.

Features of Trimble GPS Pathfinder Pocket Receiver

For the present study, three (Personal Digital Assistant, Laptop and Tablet PC) of the above-mentioned instruments need to be equipped with GPS capable accessories. One of such accessories is Trimble GPS Pathfinder pocket receiver. The GPS Pathfinder® Pocket receiver is a small, lightweight, and portable GPS receiver. Rugged and weatherproof, the GPS Pathfinder Pocket is built to work in tough, demanding environments. The user can carry the receiver in his/her pocket or in an optional pouch, while wearing the miniature antenna on the optional, specially designed cap. The GPS Pathfinder Pocket receiver integrates seamlessly with Trimble TerraSync data collection and data maintenance software, and the GPS Pathfinder Tools software development kit. Other key notable features of the GPS Pathfinder Pocket receiver includes continuous tracking of up to 8 satellites, 2 to 5 meter accuracy after differential correction, 1 second position and velocity update rate, autonomous accuracy to 10 meters.

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The characteristics of four different hardware elements used for the study are tabulated in Table 6. These characteristics include (but not limited to) processing speed, storage capacity, battery life, input method, and so on. From Table 6, it can be seen that different hardware identified exhibit different advantages.

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Table 6 Comparison Chart for Hardware

Property	**PDA**	**GPS Handheld**	**Tablet PC**	**Laptop**
Processor Type & Speed	400MHz Intel XScale	206MHz Intel StrongARM SA-1110	Pentium M, 1.0GHz	Pentium 4, 2.4 GHz
Operating System	Microsoft Windows Pocket PC2003 Premium	Microsoft Windows Mobile 2003 for Pocket PC	Microsoft Windows XP Tablet Edition	Microsoft Windows XP Home Edition
Display Size, Resolution	3.8 in., 240x320	5 in.,240x320	12.1 in., 1024x768	15 in., 1024x768
Hard Drive Capacity	5GB Storage Card	126MB	40 GB	40GB
Installed RAM, RAM Technology	128MB SDRAM	64MB	256MB, DDR SDRAM	512MB, DDR SDRAM
Networking	Integrated Bluetooth (ver.1.1); WLAN 802.11b	Bluetooth for wireless connectivity, USB, Serial	Integrated 10/100 Ethernet Adapter	Integrated network card, Ethernet, IEEE 802.11b
Battery	Lithium Ion	Lithium Ion	Lithium Ion	Lithium Ion
Battery Life	Up to 6 hrs.	Up to 8 hrs.	3 hrs.	1hr. 45 min.
Dimensions	5.43in. x 3.3in. x 0.63in.	8.5in. x 3.9in. x 3.0in.	11.7in. x 9.4in .x .90in.	12.96in. x 10.72in. x 1.77in.
Weight	7.3 Ounces	1.59 lbs	3 lbs	7.5 lb.
Input Method	Touch screen and Stylus	Touch screen and Stylus	Keyboard, Touchpad and Stylus	Keyboard, Touchpad
Audio	Microphone& Speaker, MP3 stereo	Microphone and Half Duplex speaker	Sound Card	Sound Card
Price	$ 499.99	$600.00	$2195.98	$1499.00
Warranty	1 year	1 year	1 year	1 year

With varying weights and other field operational capabilities, these instruments represent diversity in factors related to data collection. Images of the hardware / instruments used for the data collection in the present study are provided in Figure 8. The instruments shown in the figure were PDA (1), GPS Handheld (2), Laptop (3), and Tablet PC (4).

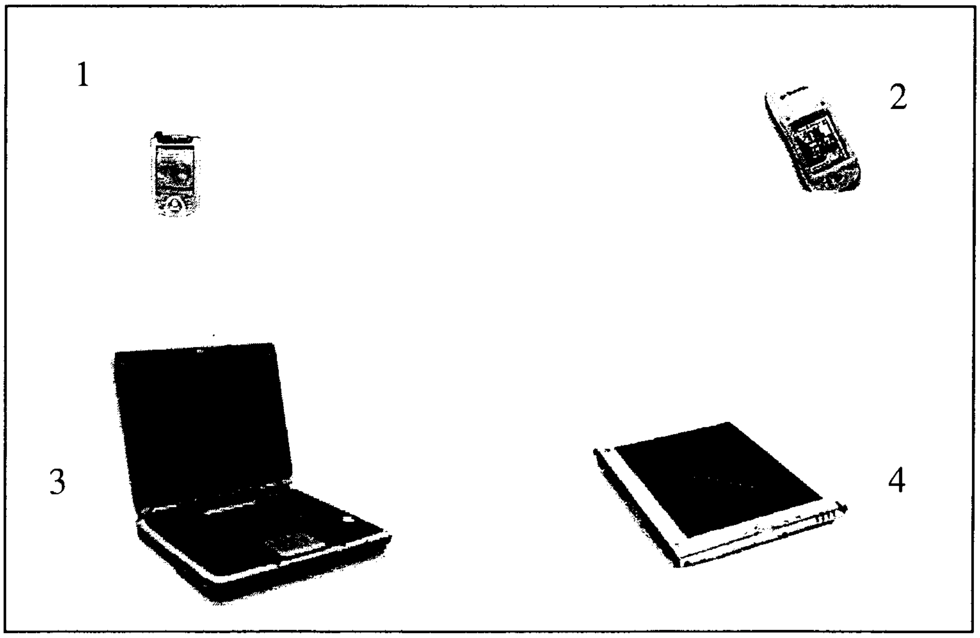

Figure 8 Images of the Instruments / Hardware used for data collection

As summary of the hardware identified, it can be stated that all the four types have different advantages. Unlike the process of software identification (where only one or two software are used from four different identified software), all the four identified hardware (four types) will be used for the data collection process. This is to test their capabilities and the ease of data collection in the present study.

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Functional Needs

People from different fields and expertise are interested in accessing information related to transportation systems. Three main questions need to be answered when it comes to the performance of the transportation systems. They are (1) who is interested. (2) what is of interest? and (3) why are they interested? The interested individuals may be from the public sector, private sector, or from general public. The users of such a system can be elected officials, administrators, managers, planners, engineers, technicians, secretarial staff or the public. Information related to road closure due to construction, improvement and maintenance activities, special events, flooding etc. might be of utmost importance to the general public, where as public and private sector personnel are more interested in information related to support their project management, resource allocation, coordination of activities and information storage. The timely availability of such information has significant ramifications to business and economic activities in terms of enhancing productivity, minimizing travel/shipment delays and transportation costs. Transportation data have tremendous impact on public safety, quality of life as well as on business and the regional economy.

The type of the analysis performed on the data depends on the level of details, as different analysis require different types of data. If an area wide study were considered such as a city/township, macro level analysis needs to be performed. This type of analysis will be performed at a global level, i.e. by considering a set of links or nodes, areas, polygons etc. The results of the analysis would benefit decision makers like public servants, elected officials etc. Another type of analysis is the micro level analysis. Unlike

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the macro level, this analysis is more at a specific link or node level. For example for crash data analysis at a particular intersection can be considered as a micro level analysis.

Different users utilize/require data in different styles or formats. The complexity of the data will also change depending on the needs of the end-user. An engineer or planner would desire data in depth for the planning, operational or engineering use. In the case of an elected official or administrator, for decision-making or policy making, they would view the summary of the collected data rather than having a look at the whole data. Depending on the type of the end-user, the format and scales of the data need to the changed accordingly. Data type also plays a role in setting up the functional needs for the system architecture. Data from different sources may be available in different formats such as paper maps, AutoCAD drawings, shape files, Microsoft Excel spreadsheet, Microsoft Access databases etc. These data would have to be captured into the system.

A challenge facing many organizations is whether to update or not to update existing GIS installations and the best approach for the updates. Data may need to be updated on a periodic basis such as daily, weekly, monthly, and so on. The frequency of updates mainly depends on the extent of changes in the data in a given time period. If the change is significant in a short span of time, then the data would need to be updated on a daily or a weekly basis. For example, data related to street center line network needs to be updated on a monthly basis as new roads are designed and built each month. Hence, data related to street centerline network requires a monthly update. In the case of zip code boundary data, one can hardly find changes in the boundaries in a short time period. Therefore, for such data, short terms updates such as daily, weekly, or monthly are not necessary. The best-suited update for zip code boundary data is bi-annual or annual

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update. For the present study, data are obtained from a wide range of sources such as Clark County GIS Management Office (GISMO), Nevada Department of Transportation, Regional Transportation Commission of Southern Nevada, Clark County Department of Public Works, Clark County Assessor's Office, Transportation Research Center, etc.

The combination of GIS and GPS technologies and the Internet offers a potential tool for disseminating information related to transportation networks in a timely and cost-efficient manner. Dissemination of spatial information related to the transportation network in a graphical format requires the development of application tools to work in an Internet server environment. There are several advantages exhibited by displaying data on the internet such as effective graphical display, dynamic availability of the information, timeliness of the information, scale dependent display of the level of detail, potential for extensive dissemination of data at low cost, environmentally friendly etc.

System Design / Specifications

System design includes identifying different data types, scales and formats required for the study. Various types of data required and their sources are discussed next:

Data Types and Sources

Data can be classified as four different categories depending on their availability, necessity and importance. Desired data is the complete data that the user wishes to acquire, under the circumstances that all the data sources were accessible and they provide the necessary data requested. Desired data can only be obtained under ideal conditions as some of the data sources might not respond to the user's request for the data. Existing data can be defined as the data, which is readily available with the user with no further efforts to be made for acquiring them. Obtainable data is the data that is

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not readily available with the user, but can be obtained or procured with some minimum efforts. Finally, surrogate data is the additional amount of data, which can be used in the case of non-availability of the above-mentioned obtainable data. Different types of above-mentioned data along with the examples are explained next:

Desirable

Desirable transportation data includes those related to road geometry such as width, number of lanes, pavement type, name of the road, road type, functional classification, address ranges, posted speed limit, etc. In addition, data related to the signal operations such as cycle length and phasing, lead or lag type of signal, actuated or semi-actuated etc are required for constructing a traffic inventory database. Additionally data related to signalized intersections such as pole or support identification numbers, mast arm identification numbers, beacon identification numbers, etc. could be linked to the master database. Data related to work orders can be crucial in determining the efficiency of the tool developed. This can be obtained from the CCPW-TMD. The source for this data can be either from the direct data collection in the field or by collecting the public complaints data. Collection of the complaints from the public can be done by the use of internet facilities (World Wide Web) or by traditional hard copy format. Also, crash data within the Clark County jurisdiction can be obtained from the Nevada Department of Transportation (NDOT) crash database or from the local law enforcement agencies.

Existing

Currently certain details about the street network can be obtained from the street centerline network from the Clark County Geographic Information Systems Management Office (GISMO). However, in-depth details such as the number of lanes, type of

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intersection control whether signalized or un-signalized details and 4-way stop controlled intersection details need to be added. The source of such detailed information is CCPW-TMD. These details can be obtained from the CCPW-TMD in the GIS format. Depending on the level of detail, the scale of the street network can be determined by the user. Generally, the street center line network will be updated on a monthly basis.

Obtainable

From resources such as GISMO, Assessor's Office, CCDPW, data related to the street centerline network, assessor's information, public works project details, work order details / complaints etc can be obtained. The data obtained from these sources will be in GIS format. However, data related to public works project details, work order details and complaints are in hard copy format / paper format. In addition, most of the layers mentioned above are not updated in a regular manner. Historical crash data at various locations are available from the NDOT records (presently available through the UNLV-TRC). Transportation related infrastructure development patterns can be obtained from the Regional Transportation Plan prepared by the Regional Transportation Commission of Southern Nevada.

Surrogate

Additional data sources, which may be useful in data collection, include, but are not limited to, aerial photographs, and land parcel level data. Aerial photographs are generally commissioned by local government or Metropolitan Planning Organization (MPO) type agencies. Aerial photos for the Las Vegas metropolitan area may be obtained from GISMO. Parcel level data are generally developed and maintained by the Tax

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Assessor's office at the local government level. Such data for the Las Vegas metropolitan area may be obtained from the Clark County Assessor's office or through GISMO.

Data Collection Techniques

Various data collection techniques are available in the development of a transportation database. These techniques can be classified as location-based techniques and non-location based techniques as explained in the software and hardware process of the study. Location based data collection techniques include mobile mapping application such as GIS, GPS, remote sensing, etc. Non-location based data collection techniques include Bar-coding, Radio Frequency Identification, Vehicle Data collecting etc. Brief descriptions of these techniques follow.

Location based data collection technologies

GIS: A GIS is a system for management, analysis and display of spatial information, which is represented using a series of information sets. These include maps and globes, geographic data sets in computerized format, processing and workflow models, data models and metadata. In simple words, modern GIS are computerized database management systems for the capture, storage, retrieval and display of the spatial data. GIS primarily contain spatially referenced information stored in a database.

GPS: GPS, or satellite surveying systems, allows an object to be located in terms of longitude, latitude, and altitude based on the observations of signals transmitted from the satellites. GPS use a worldwide radio-navigation system formed from the constellation of satellites and their ground stations. At any given point of time, there are a minimum of 24 satellites revolving around the earth. New ones replace old and non-functional satellites periodically. A GPS uses these man-made satellites as reference points to calculate

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positions that could be as accurate as within one centimeter. Over the last few years, GPS receivers have been miniaturized to just a few integrated circuits that can fit on one's palm, and they also are becoming very economical.

Remote Sensing: Remote sensing may be broadly defined as the collection of information about an object without being in physical contact with the object. Aircraft and satellites are the common platforms from which remote sensing observations are made. Other examples include unmanned aerial vehicles, tethered balloons (heli-kites), and observations from high vantage points.

Non-location based data collection technologies

Bar-coding: A bar code can best be described as an "optical Morse code." A series of black bars and white spaces of varying widths are printed on labels to uniquely identify items. The bar code labels are read with a scanner, which measures reflected light and interprets the code into numbers and letters that are passed on to a computer. Because there are many ways to arrange these bars and spaces, numerous symbologies are possible. Combined with data-collection technology, bar codes provide a rapid, accurate, and efficient means to collect, process, transmit, record, and manage data in a variety of industries. Retail, package delivery, warehousing and distribution, manufacturing, healthcare, and point-of-service applications can all benefit from the use of bar codes.

Radio Frequency Identification: Radio frequency identification (RFID) is a method of remotely storing and retrieving data using devices called RFID tags. An RFID tag is a small object, such as an adhesive sticker, that can be attached to or incorporated into a product. RFID tags contain antennae to enable them to receive and respond to radio-

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frequency queries from an RFID transceiver. The RFID tags are coded with information specific to the object to which the tag is associated.

Vehicle Data Collectors: A vehicle data collector is an automated facility inventory and location system for right-of-way (ROW) measurement. The vehicle is a high-speed, mobile data acquisition platform that carries various subsystems. The vehicle collects and stores the road data in one pass while travelling at high speeds. Examples of data collected by such vehicels include roadside information (e.g. signs, vegetation etc.), pavement characteristics (e.g. cracking, rutting, pavement type. etc.)

Tools to Support Analysis

The development of the system architecture for the integration of real-time data or near real time data and static data, using GIS/GPS-based and internet mapping-based tools is discussed in this chapter. The system architecture will be used to develop and evaluate a functioning system that compiles, analyzes, and manages the data collected. To meet these goals, various combinations of software and hardware will be evaluated on different field data collecting instruments. Once the data are collected, they will be analyzed with the system developed. In addition, the results of the analysis will be evaluated with the traditional methods of data upgrade. A broad overview of the research design is shown in Figure 9. A description of different tasks in the study will be provided in the following sections. Following four major tasks make up the system design process.

(a) Identification of the appropriate GIS Software for analysis of real-time data (Software Process) and selection of appropriate hardware (Hardware Process) and combination of hardware and software for data collection.

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(b) Development of the GIS-based system (Application Development Process).

(c) Collecting, updating and storing the data, (Data Process) and

(d) Performing necessary analyses with the updated real time data (Application Process)

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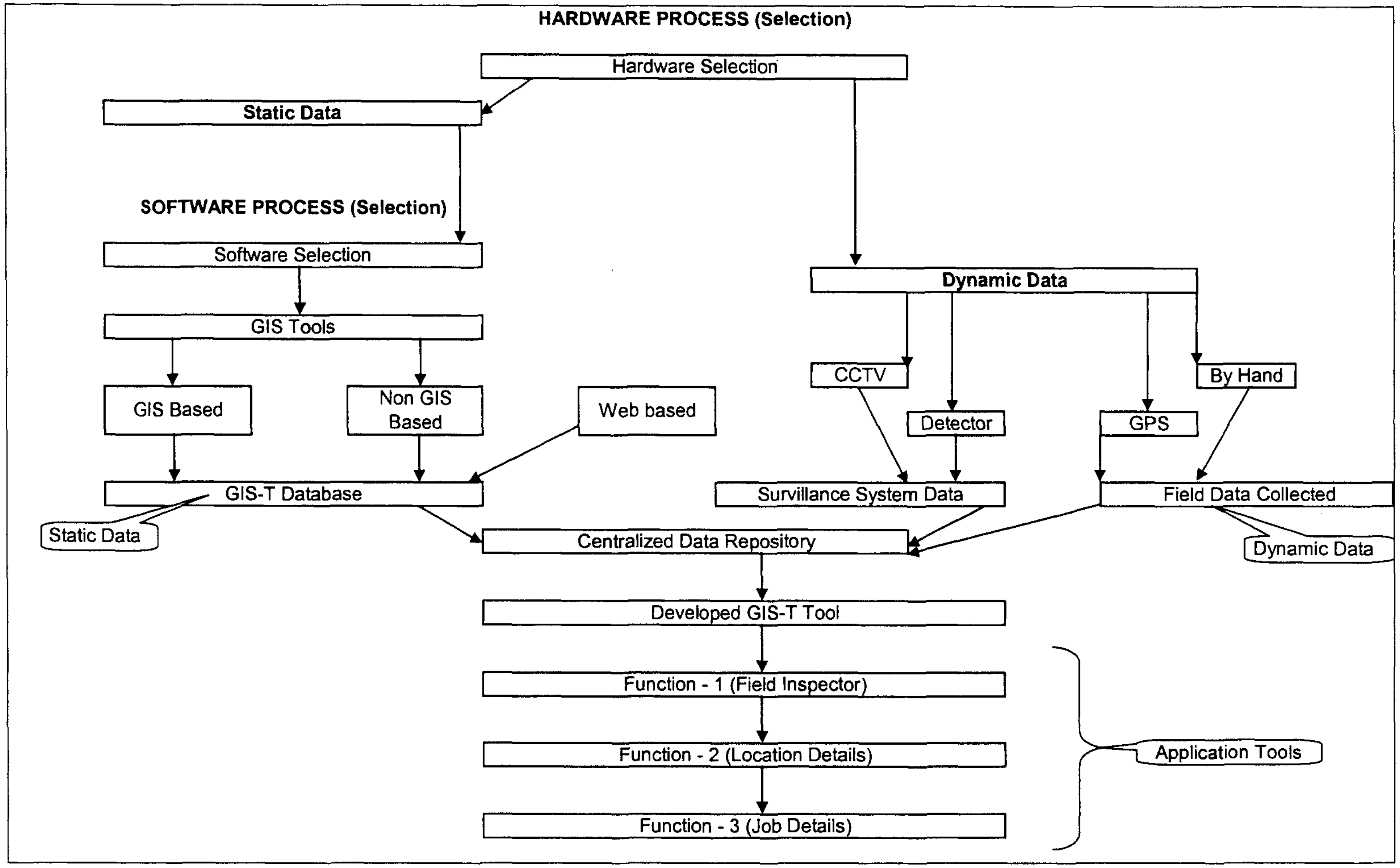

Figure 9 Schematic Representation of the Study Processes

Software and Hardware Process

The Software and Hardware Process includes selection of appropriate software and hardware for the study. The software used for the study can be classified according to the purpose they serve. They can be used for the data collection and analysis, or they can be used for displaying the data on the World Wide Web for public/private use.

Internet Mapping is a powerful communication tool that allows user to utilize the data by making it available to everyone with the help of internet. Around the world, spatial data infrastructure portals are being used to share data between organizations as well as public communities (http://www.gisdevelopment.net/application/miscellaneous/ma04076 pf.htm) *(9)*. The key function of the internet mapping software is to convert the dynamic/static spatial data into visually enabled web displays. In addition, some of the additional capabilities afforded by the internet mapping software include spatial queries, interactive displays etc. Currently there are number internet mapping software available in the market such as Autodesk MapGuide, ESRI ArcIMS, ObjectFX, ASPMap3.0 *(9)*. Of these, the software selected for the present study are Autodesk's MapGuide and ESRI's ArcIMS. The selection of the software was done primarily based on their applicability with the GIS data. As most of the data related to the present study are in a GIS format, the software selected were capable of dealing with such GIS data. As discussed in Chapter 3, of these two software Autodesk MapGuide version 6.3, was strongly preferred over the ESRI ArcIMS software in many regards. Hence, Autodesk MapGuide6.3 was selected as the final choice for the internet mapping software. As per the study by Nambisan et al. *(24)* a prototype was developed using an off-the-shelf suite

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of software programs (MapGuide). This greatly reduced startup costs, time and configuration management tasks without compromising the desired functionality.

Field software (data collection software) can be divided into two principal categories based on whether they operate on location data or not. Some of the field data can be collected without location details using technologies such as bar-coding, laser range finding, vehicle data collector, feature tagging etc. These data collection technologies need not operate on the precise location details like latitude, longitude etc. However, for the other data collection technologies such as GIS, GPS, remote sensing, etc, location details were most essential for the functioning of the technologies. A brief explanation of the different data collections techniques is provided later in this chapter. Mobile GIS is composed of a number of technologies that include GIS, mobile hardware in the form of lightweight devices and rugged field PCs, GPS, and wireless communications for Internet GIS access.

Traditionally, the process of field data collection and editing has been time consuming and error prone. Geographic data have traveled into the field in the form of paper maps. Field edits were performed using sketches and notes on paper maps and clipboards. Once back in the office, these field edits were deciphered and manually entered into the GIS database. The result has been that GIS data have often not been as up-to-date or as accurate as they should have been. Consequently, GIS analysis and decisions have been adversely affected. However, recent developments in mobile technologies have enabled GIS information to be taken into the field as digital maps on compact, powerful mobile computers, providing field access to enterprise geographic information. This enables GIS users to add real-time (and near real-time) information to

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their enterprise database and applications, speeding up analysis, display, and decision making processes by using up-to-date, more accurate spatial data.

Based on the advantages and disadvantages of the two different field data collection software, ESRI ArcPad Software was selected for the present study because of the ease of developing applications afforded by it when compared to Trimble TerraSync software. The format of the output data also played an important role in the selection of the field data collection software. The final output of the data collection process can be varying from a simple text file (*.txt) to a complex GIS database. The software identified for the field data collection should exhibit the capability and ease to generate output file/files that are in a GIS format. Table 7 shows the different categories of the software considered for the present study and the final selections.

Table 7 Comparison Chart for Software

Category	**Software**		
	Identified	**Evaluated**	**Selected**
Internet Mapping Application Software	Autodesk MapGuide	X	X
	ESRI ArcIMS	X	
	ObjectFX		
	ASP Map3.0		
Field Data Collection	ESRI ArcInfo	X	X
	Trimble TerraSync	X	
Data Analysis	ESRI ArcGIS	X	X

At the end of the software selection process, the two software selected are ESRI ArcPad software for field data collection and Autodesk MapGuide 6.3 for internet mapping. The field data collection software was used for developing applications, which were to be used on the different hardware selected for the study as shown in Table 6.

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Unlike the software process, all of the hardware identified in Table 6 were evaluated in the field for the data collection process. This concludes the software and hardware process for the study. With the help of selected software, the applications were developed for the data process portion of the study.

Sample Data Collection Tool Developed

Project Description and Process Description

The sample data collection tool is developed using a project to evaluate performance of pavement marking materials. Previously, data used to be collected manually in the field (paper and pen mechanism). The data relate to various elements about the condition of pavement marking at several locations. In order to study the parameters based on location, these data needed to be uploaded to a spreadsheet, and they also need to be linked to the street network map separately. This process is laborious, as it includes a collection of data on hard (paper) format in the field, conversion into electronic copy by typing the data into a database format, and next joining this database to the street centerline coverage in a GIS environment. The various types of data collected at various points are listed as below:

1. Material used for Pavement Marking
    a. Film
    b. Paint
    c. Polymer
    d. Thermo-plastic
2. Direction of Lane
    a. East bound

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b. West bound

c. North bound

d. South bound

3. Location

a. Up-stream of the intersection

b. Down-stream of the intersection

4. Turning Information of the Lane and Lane Number

a. Right Turn only

b. Left Turn only

c. Through

d. Through and Right

e. Through and Left

5. Type of Marking

a. Stop-bar Marking

b. Pedestrian-crossing Up-stream bar

c. Pedestrian-crossing Down-stream bar

6. Durability Factor

7. Retro-reflectivity between wheel tracks

8. Retro-reflectivity between lanes

9. Color

By developing a data collection tool for this project, the level of effort for the data collection and data entry was reduced to great extent. The software used for the developing this tool is ESRI ArcPad, and it is used with the combination of HP-IPAQ-

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5555 PDA for the field data collection. The front-interface for the data collection process was developed in ArcPad Software in the VBA (Visual Basic Applications) environment. The interface developed for the data collection process is shown in Figure 10.

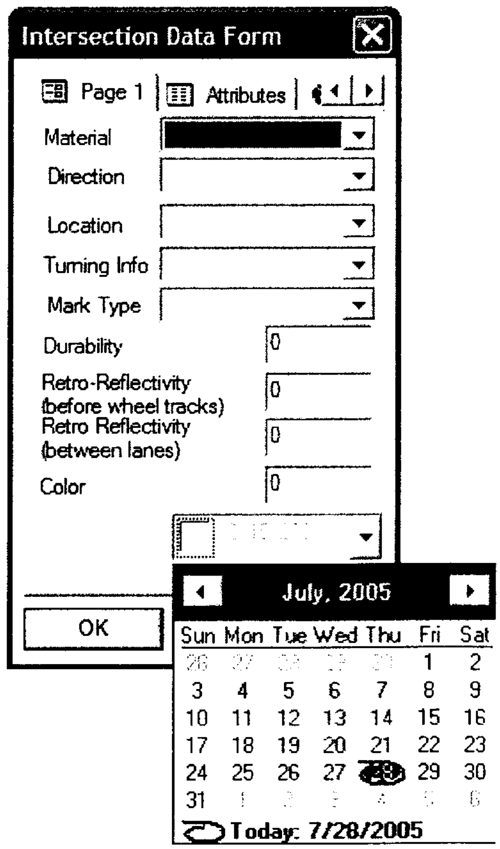

Figure 10 User Interface for data collection

As can be viewed from the Intersection Data form, the top five data elements are designed as dropdown menu boxes as their values are to be selected from a range of values. For example, values in the dropdown menu for the material data elements are limited to Film, Paint, Polymer and Thermo-plastic. Similarly, for the direction data element, the dropdown menu values to be selected are East, West, North and South. The

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last four parameters are to be entered at the field based on the field observations. In addition, an additional date parameter is also used to maintain a log file of the data entered. By default, the value for the date parameter was set to the current date. If the user wishes to select the current date, he just needs to use the check box. If the user wish to select a different date other than the current date, then he/she needs to use the dropdown button. This parameter can be In the field when the GPS receiver is switched on, the tool will recognize its location automatically, so that when the parameters are entered on the form; the parameters are automatically linked to the location details to eliminate the process of locating the points later in the street centerline can be avoided. After all the parameters are entered, the data related to that particular record can be viewed as shown in Figure 11. The data collection point layer can be saved separately or can be combined with the street centerline network. This tool simplifies the process of data collection.

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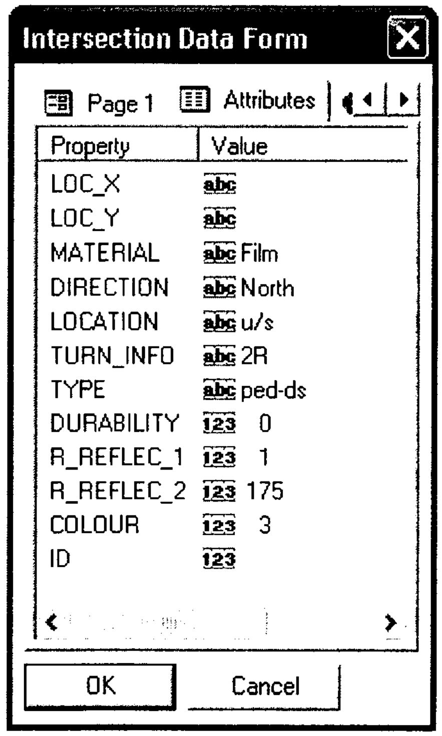

Figure 11 Sample Record of the Collected Data

Application Development Process

The application development process for the current study involves different modules. Different applications developed in this process represent different purposes/goals to be served/achieved. Listed below are two major purposes to be served by the applications developed.

1. To be used in the field by the field personnel for data collection. This can be either collecting new data or editing existing data. Applications for this process were developed using ESRI ArcPad and ESRI ArcPad Application Builder Software.

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2. To be used in the office by staff members who are responsible for recording feedback from the citizens. Autodesk MapGuide Author software is used for this application along with some Active Server Pages (ASP) coding.

Application Development for the Field Personnel

In general, field personnel working on data collection may not be as technically oriented or aware of using technologies like GIS/GPS as might be other engineers, analysts who may be seasoned users. The development of the GIS tool was done primarily to ease the efforts of the data collection for the field personnel. The application was developed using ArcPad Application Builder Software to develop the interface for the data collection. The user needs to enter data such as the name of the individual collecting the data, nature of the problem / problem description, priority and other comments. Details such as the location of the problem and the date and time of data entry will be automatically stored in the database. The option of automatic storage of the time and date of data collection can be changed depending on the need of the user. If the date and time fields do not require the interaction of the individual collecting the data, i.e. the individual should not be allowed to change the date and time, then the fields can protected in such a way that the user cannot over write the default values.

Figure 12 shows the ArcPad interface that is displayed on the screen of the handheld instrument to add a new data point or to edit an existing data point. Figure 13 shows the interface used by the personnel during data collection to enter data attributes for a selected item. This interface will be displayed when the user clicks on the "add a point" button as shown on the Edit tool bar in Figure 12. In addition, one more additional feature available with the ArcPad software is to edit the existing data. The user can select his

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choice of entering a new point data or edit existing point data. As can be seen in Figure 13, the labels for each data point are displayed on the screen, which represents the priority of the work order data collected. When a GPS receiver is connected to the handheld and is active, a special cursor blinks on the screen showing the position of the user at that exact time. The cursor position coordinates are calculated and added to the location data collected at that point. The number of attributes displayed on the interface can vary depending on the project for which the data was being collected.

The interface shown in the Figure 13 is user friendly. Attributes such as name of the person collecting the data need not be typed; rather it can be selected from a drop-down list containing already existing names. Similarly, the date and time of collection of the data also need not be entered.

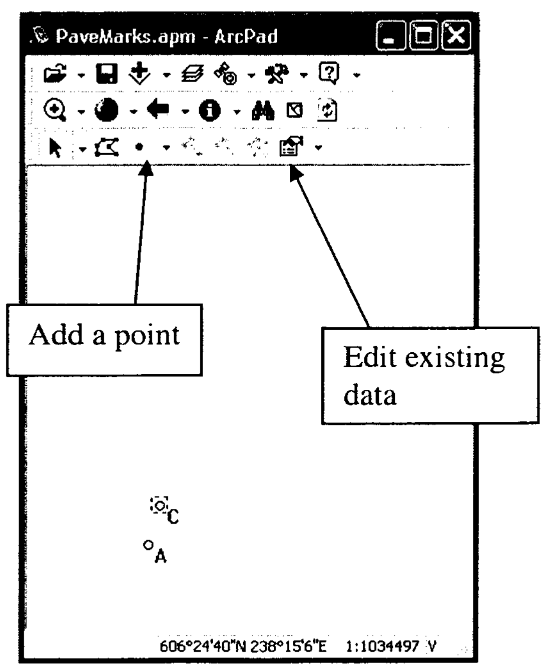

Figure 12 Basic ArcPad Window

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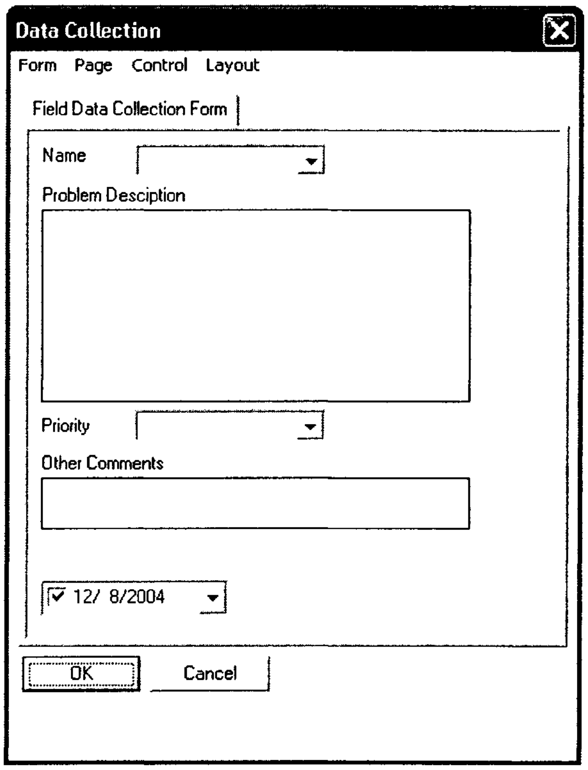

Figure 13 Interface for Field Data Collection (New Data)

The ArcPad software will assign the current date and time values to the corresponding fields. By default, the date attribute will assign a value of the current date; however, the user can change this. Location details such as street name, and distance from the reference streets need not be entered as the GPS connected to the hardware gives the exact location of the data collection point. The location details will be stored in the data database in the form of Latitude and Longitude of the point. These features of auto-detection of such location and time related to data significantly reduce the time and effort needed for data collection.

The next attribute to be entered by the person collecting the data is the nature of the problem or "problem description". This attribute is essential as it explains the necessity,

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need, time expectancy, and the importance of the problem at hand. The description enclosed in this text box serves as the guideline for the crew rectifying the problem. Hence, the field personnel while entering this data should take care.

The "Priority" of the problem reported plays a key role in deciding the time response for addressing the problem. This priority can be selected from the drop-down menu, which includes the following priority classes: Emergency, Urgent, Routine, and Special. The description of each of the priority class will be explained later in the chapter.

The "Other comments" attribute field can be filled by the user, if he/she has any additional comments to be documented about the problem.

The length of the field or maximum number of data entry characters allowed for the fields such as "Problem Description" and "Other Comments" can be preset according to the user's needs. For example, in the above shown example, the maximum number of characters allowed for "Other Comments" field are 180.

Application Development for the Personnel in the Office

Unlike field personnel, the personnel in the office, who receive feedback / complaints from the citizens, have direct contact with the public through the phone, internet, and other media. Complaints regarding the malfunctioning of the public works facilities such as streetlights, traffic signal heads, traffic signposts or other traffic control devices in the jurisdiction of Clark County will be received by the staff at CCPW-TMD. At present, after receiving a complaint, the staff member has to fill out forms (paper and pen based system) and forward them to the corresponding group for necessary actions.

The application development for the office-based personnel was done using Autodesk MapGuide 6.5 and Active Server Pages (ASP). Figure 14 shows the toolbar developed

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for the office-based personnel. Various functions are provided in the toolbar are described next. Locating the problem location can be done either by using search button or by zoom goto button as shown in Figure 14.

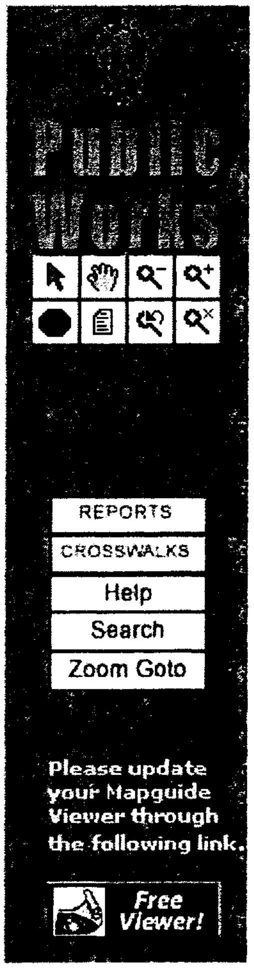

Figure 14 Toolbar developed for the Office-based personnel

The search functions make it easier for the user to find and view a certain location or area. The desired location or area can be found either by its address, intersection, the owner's name of the parcel, parcel number, or zip code. These search functions are divided into the following categories:

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- 

Searches: Contains address, owner, and parcel searches for finding a specific location or parcel quickly.
- 

Zoom Goto: Contains intersection, Township-Range-Section (TRS), fire-map, and zip code searches for finding a specific location or area quickly.
- Intersection (sub-function of Zoom Goto): Finds an intersection using the two cross streets. The intersection search prompts the user to enter the street names of the two crossing streets of the intersection. After searching for the two streets, Mapguide zooms-in to the intersection and centers it on the screen, displaying all previously viewed layers.

Figure 14 also displays other shortcut buttons which can be used by the user for better navigation such as zoom in and zoom out, pan, pointer, report generation etc. They can be explained as follows:


Pointer: Used to view tooltips and to select lines, polygons, or points.


Pan: Allows viewing areas that are currently off the edge of the map. Press and hold the mouse button. The cursor is to be dragged in the direction that one wants to move the map.


Zoom Out: Zooms out, by a factor of two, centered around the selected location.

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Zoom In: Zooms in, by a factor of two, centered on the selected location. Alternatively, one can press and hold the mouse button while dragging the cursor to enclose a rectangular area. When the mouse button is released, the map will be redrawn to the zoomed in rectangular area.

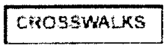
Stop: Stops or interrupts the map display update process.

Reports: Allows viewing reports, prefabricated for selected objects on a map.

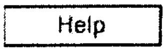
Zoom Previous: The map is redrawn to the previous zoom scale.

Zoom Full Extents: Redraws the map so that the full extent of the map is displayed in the current window.

Generates electronic complaint recording form (Streetlight complaint related form) as shown in Figure 17.



Generates a form containing information related to Maintenance Work Order for a Crosswalk as shown in Figure 16.



Links to Mapguide Viewer help page

Figures 15 and 16 show the interfaces developed for recording complaint data by the office personnel. Figure 15, which was developed using MapGuide, was intended to

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locate the exact problem / complaint location. For locating the exact location of the reported problem, the toolbar (located on the left hand side in Figure 15) can be utilized.

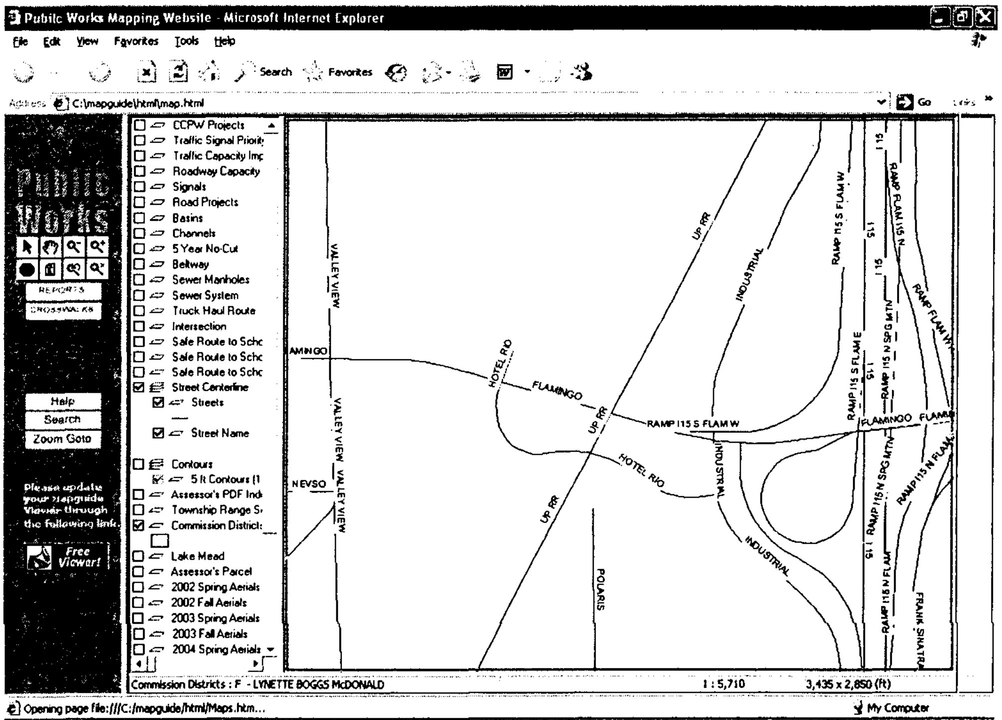

Figure 15 MapGuide Interface for the Complaints Receiving Personnel

Once the complaint location is located, the user needs to enter the data related to that specific complaint. Entering the complaint related data can be done by a single click at the complaint location on the map. This click on the map opens a new window. The new window contains various elements to be addressed for a complaint, which are presented in a form. The user now has to complete the form, which contains information such as the name of the employee who received the complaint, date the complaint was recorded, priority etc. Figure 16 shows one such form, which was developed using ASP. This

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illustration shown in Figure 16 relates to the maintenance work order for a crosswalk. The fields on the electronic complaint form are easy for the field crew to fill. General details such as employee name, jurisdiction and so on are to be filled. Problem specific details such as problem definition, location, and crosswalk type were also to be completed by the office staff. The field staff need to enter data related to marking type, intersection leg direction, date inspected, current traffic conditions, number of bars required to be painted, material used for repair, date of installation (in case of new installations), and visibility conditions of the current crosswalk section.

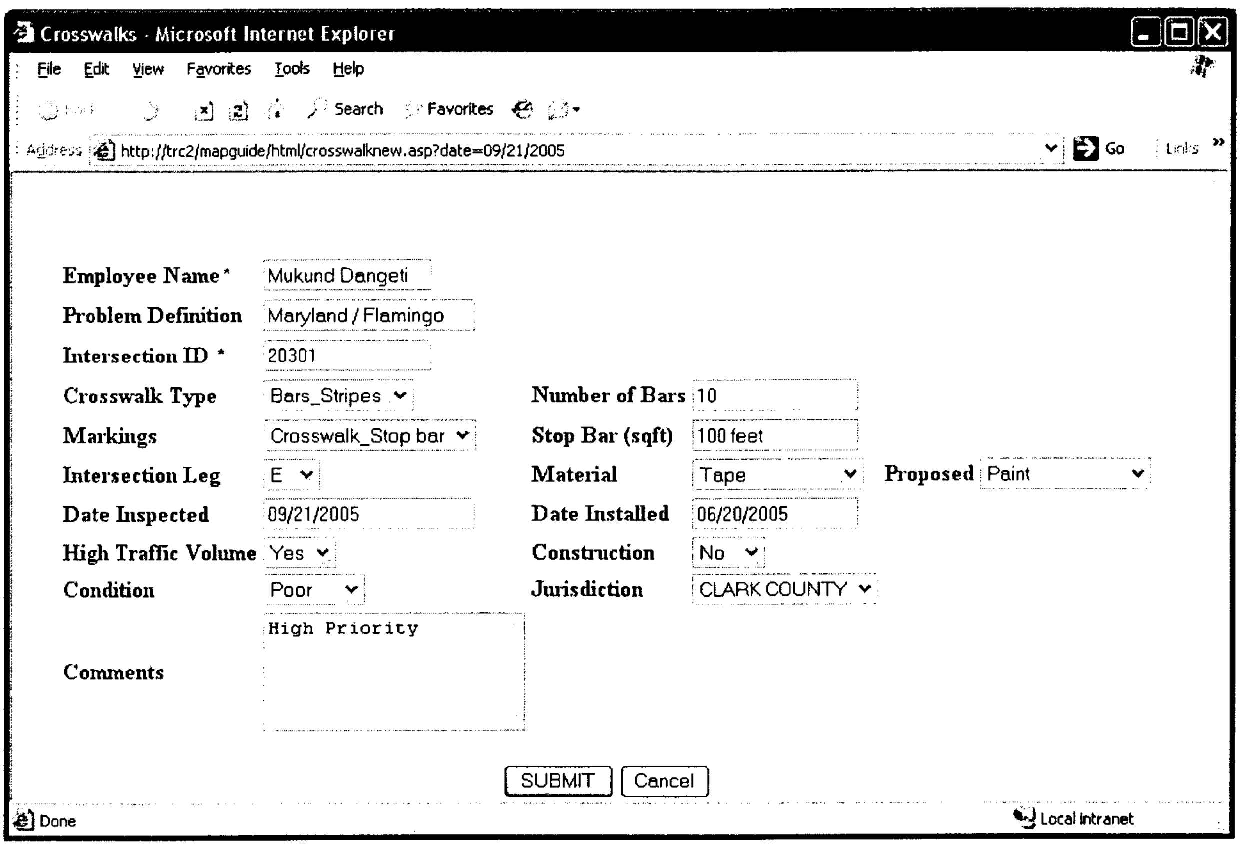

Figure 16 Complaint Recording Form

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Currently, a paper based format of the streetlight trouble report was being used in the CCDWP, which is shown in Figure 18. As it is evident from the form shown in Figure 18, the various details to be filled include location details, received complaint call details, incident details, and performed maintenance details. Half of the form needs to be filled by the complaint receiving office personnel and the remaining half by the field crew attending the problem. Figure 17 shows the screenshot of the form in an electronic format. ASP was used in developing the form, which was mainly intended for the use of office-based staff. This for is related to streetlight trouble report. Instead of filling the fields on a paper, all the details can be entered on the electronic form. Almost all the details on the paper format needs to be filled out on the electronic sheet too. The only parameters, which need not be filled, are the location details. Once after locating the address of the complaint, the user needs to click on the screen. By this click, the software detects the latitude and longitude of the point. These latitude and longitude details will be automatically assigned to the form.

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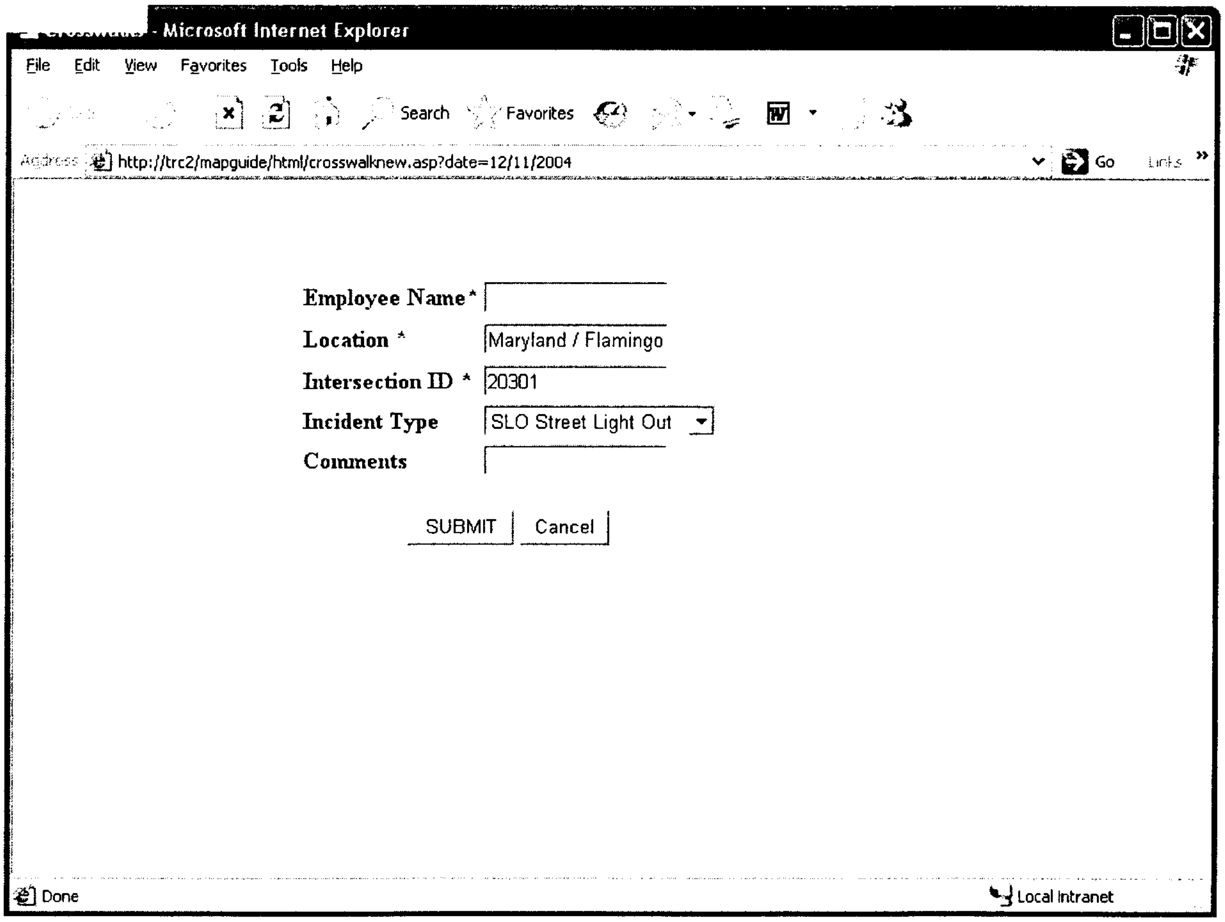

Figure 17 Screenshot of the complaint recording form of Streetlight Trouble Report

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STREETLIGHT TROUBLE REPORT

Street Address / Location____

On The (N S E W) Side Of The Street________ Pole (N S E W) Of ________________________(street)

Nearest Major Intersection____

Book #____________________Section #____________________ Zone (circle one) 1 2 3 4 outlying

Call Received by ____ Date/Time______________

Source of Call ____ Phone # ______________

Call Serviced by________________________________ Date/Time Repaired______________

Incident Type:

- ☐ SLO - Street Light Out.
- ☐ Circuit Out
- ☐ Cycling on/off
- ☐ On during the day
- ☐ Corrosion/Falldown.
- ☐ Accident/Knockdown.
- ☐ Retrofit project.
- ☐ Other ______________

Replace Streetlight Base/Pole/Arm:

Base:

- ☐ Standard 4 bolt base
- ☐ Safety break-away 4 bolt base
- ☐ Other______________

Pole Type:

- ☐ 30 foot galvanized.
- ☐ Other______________

Arm Type:

- ☐ Single pipe arm.
- ☐ Double pipe arm
- ☐ Single tapered mast arm.
- ☐ Double tapered mast arm.
- ☐ Other______________

Arm Length:

- ☐ 8 foot.
- ☐ 15 foot.
- ☐ 18 foot.
- ☐ Other ______________

Replace Wiring:

- ☐ _______ feet #4 AWG stranded
- ☐ _______ feet #6 AWG solid
- ☐ _______ feet #8 AWG stranded
- ☐ _______ feet #10/2 AWG type UF
- ☐ _______ feet - other ______________

Replace Streetlight Fixture:

- ☐ 100 W HPS
- ☐ 150 W HPS
- ☐ 200 W HPS
- ☐ 250 W HPS
- ☐ 400 W HPS
- ☐ 175 W MV, 6.6A series
- ☐ 400 W MV, 6.6A series
- ☐ Incandescent
- ☐ Other______________

Replace Streetlight Lamp:

- ☐ 100 W HPS
- ☐ 150 W HPS
- ☐ 200 W HPS
- ☐ 250 W HPS
- ☐ 400 W HPS
- ☐ 175 W MV
- ☐ 400 W MV
- ☐ Incandescent
- ☐ Other______________

Miscellaneous:

- ☐ Replace service assembly.
- ☐ Replace contactor.
- ☐ Replace ________ Amp circuit breaker.
- ☐ Reset Circuit Breaker - cause of trip ______________.
- ☐ Replace photocell.
- ☐ Replace ignitor.
- ☐ Replace lens/reflector.
- ☐ Replace fuse.
- ☐ Replace single fuseholder.
- ☐ Replace double fuseholder.
- ☐ Replace/Tighten connector.
- ☐ Replace overhead hardware/insulators.
- ☐ Replace handhole cover.
- ☐ Replace missing/damaged junction/pullbox cover.
- ☐ Paint/touch-up streetlight pole.
- ☐ Remove graffitti.
- ☐ Trim trees.
- ☐ Other ______________

COMMENTS:______________________________

____

____

____

____

____

____

____

SLRSPLST.SAM 6/1/9•

Figure 18 Street Light Trouble Report

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Once the form (shown in Figure 17) is completed and it can be uploaded on to the intranet. This is done by clicking on the "Submit" button located at the end of the form. After the complaint information form is submitted, the information in the form will be recorded in a spatial data file (*.sdf) database directly with 'X' and 'Y' coordinates as location details for that complaint. Once the form is uploaded on to the intranet, different sub-divisions in the department, can view the most recent complaint information. Hence, the time gap between the data assigning personnel and data collecting personnel can be reduced by sharing the information instantly. The 'X' and 'Y' coordinates are obtained from the map coordinates in MapGuide. The 'X' and 'Y' can be converted into latitude and longitude to convert the recorded complaint into a shapefile. The values obtained (by filling the form shown in Figure 17), are converted into field names in the shape file. Once created, the shapefile can be transferred to the field instruments (PDAs, Laptops etc.). This can be done using wireless access of the internet and through periodic (daily, weekly etc.) downloads at the office.

The field personnel can now work on the new / updated complaint, without coming back to the office to collect the new work order. It is to be noted that the office-based personnel will not assign values to all the fields in the form. They will fill few of the parameters. The remaining parameters will be dealt with the field personnel. The interfaces used by the field-based personnel is shown in figures 19 and 20. The field crew will primarily use the second page in the form as shown in Figure 20. After the reported complaint has been fixed, the field data collection crew can synchronize field instruments with the office instruments for downloading the latest information related to the work order (complaint).

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As summary of the chapter, appropriate software and hardware were chosen based on their capabilities. Various interfaces were developed using these selected software. These interfaces were installed on field instruments as well as office instruments for data collection.

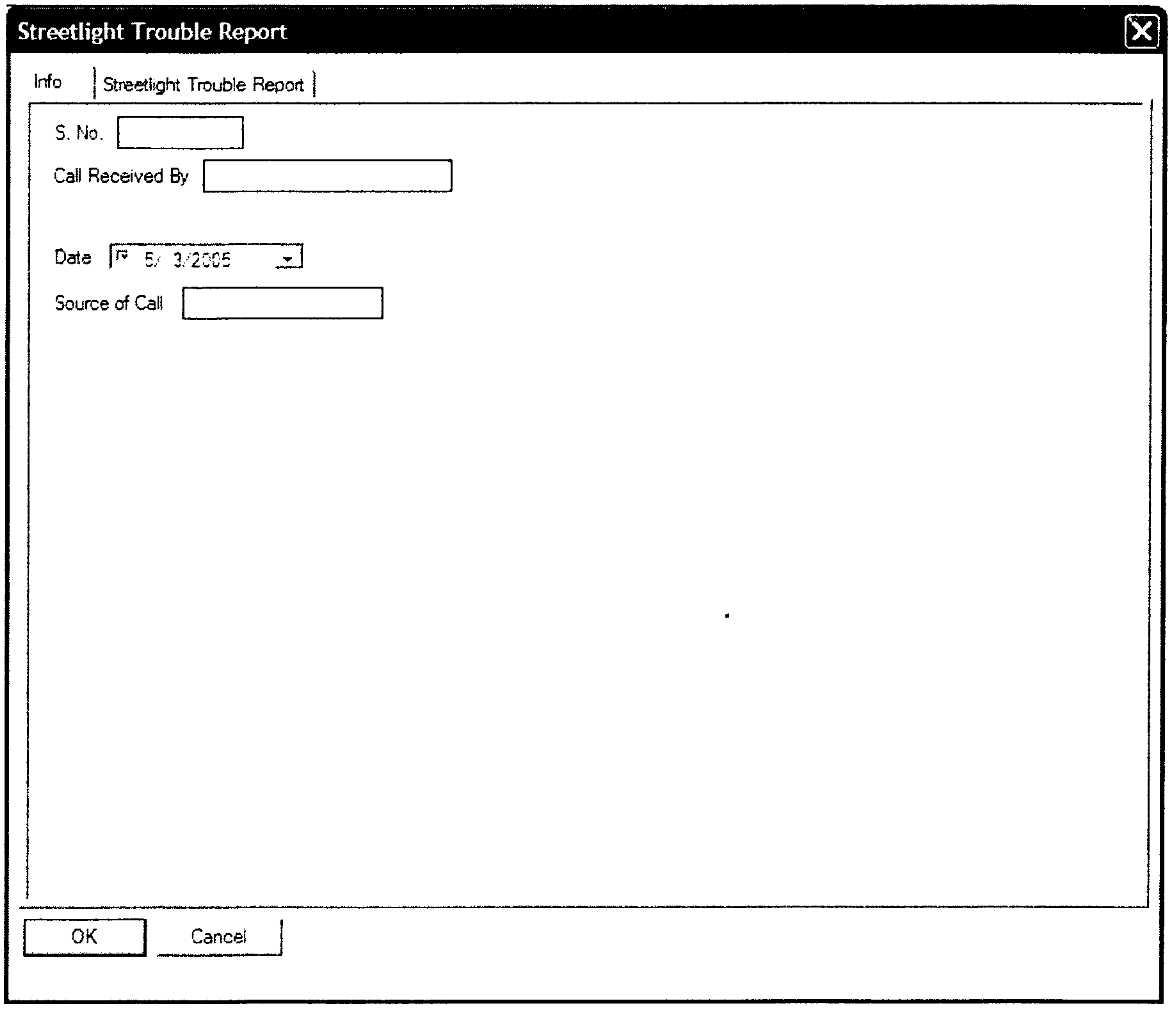

Figure 19 Screenshot of first page of the field data interface

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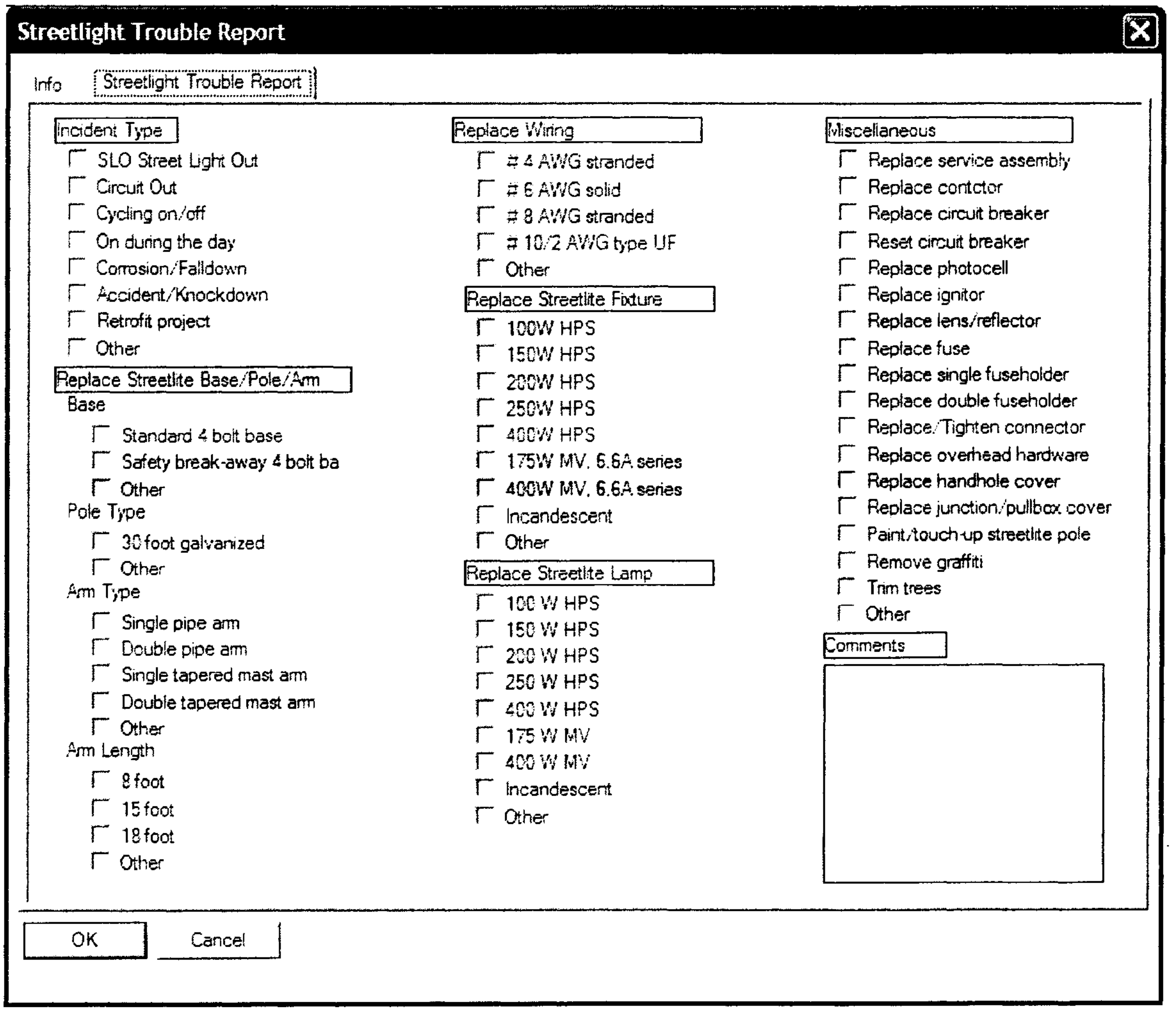

Figure 20 Screenshot of second page of the field data interface

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CHAPTER 5

ILLUSTRATIVE APPLICATION: A CASE STUDY

Current Practice for Data Collection

The current practice adopted by many public works departments is to manually record complaints and problems in a hard-copy (paper) format. The recorded complaints are then processed and assigned manually to the responsible staff to address the problems. Occasionally, field staff attends to problems at various locations. These locations may be dispersed spatially at significant distances due to the lack of proper tools to assign tasks to staff based on spatial proximity. Thus, there is a need for a system to help address such concerns – a computerized tool which can upload complaints or general public concerns, store the data, process the data and assign work orders to responsible department and staff. The development of such a system involves integration of the internet, programming languages, software and computer hardware components.

Several off-the-shelf software and hardware components can be used to collect and process data to meet the aforementioned goals and objectives. Such components include personal digital assistants, Tablet PC, and Laptops. Each of these components has its own merits and limitations. It is imperative that the use of these components be evaluated to identify one, which will be best suited to meet the goals and objectives.

As previously, mentioned, complaints are received in a hard (paper) format and they are passed on to the respective sections for the necessary follow up actions. Figure 21 shows one such form that is used by personnel to record complaint from the public. The

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form shown in this figure relates to concerns with traffic signals. Figure 21 shows a paper format, where as Figure 22 shows a computerized interface application that could replace the hard copy form shown in Figure 21. This interface was developed with the ArcPad application builder software.

The interface showed in Figure 22 can be used only in instruments having larger display areas. These include instruments such as laptops and tablet PCs. These large sized interfaces cannot be used in handheld instruments such as IPAQ and GeoXT used in the study. For the purpose of data collection in these instruments the interface developed before is divided into different small divisions. Figures 23 and 24 show the interfaces that can be used in the handheld instruments.

As seen in the following figures, the data in Figure 22 can be split into different sections and placed under different pages. The transition from page to page can be done just by clicking the required page at the top of the form. Figure 25 shows the top portion of the data form where different pages can be accessed. Entering the data in the form is the same in all the forms shown in Figure 22, 23 and 24.

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CALL TRACKING #: ____________________ WORK ORDER #: TS 04402

TRAFFIC SIGNAL WORK ORDER/TROUBLE REPORT

Intersection/Location: Eastern & Vegas Valley (Valley High)

Corner (NE / NW / SE / SW), Through (NB / SB / EB / WB), Left (E-N / N-W / S-e / W-S), Right (E-S / N-E / S-W / W-N)

Call Received By: Marvin Date/Time: 6-20-04

Source of Call: ____________ Phone #: ____________

Call Serviced By: Jim & TY Vehicle #: 10402 Date/Time Repaired: 10:30 am/pm

Incident Type:

- ❑ Lamp Out, Type/Location: ____________
- ❑ Signal On Red Flash
- ❑ Signal Dark (Check With N.P.Co.)
- ❑ Check Timing/Cycling. ____________
- ❑ Cabinet Knockdown, Controller/Service
- ❑ Pole (Knockdown/Damaged), Type/Location: ____________
- ❑ Head (Hit/Turned/Bag), Type/Location: ____________
- ❑ Emergency Vehicle Pre-Emption, Check/Repair
- ❑ Special Project/Modification (Information Attached)
- ☑ Other: Upgrade Pager Module

Replace Traffic Signal Head/Detector/Luminaire: 5/10X +

- ❑ Qty. ____ 3 Section (overhead/sidemount/poletop)
- ❑ Qty. ____ 5 Section (overhead/sidemount/poletop)
- ❑ Qty. ____ Ped Head (sidemount/poletop)
- ❑ Qty. ____ Lamp Socket (overhead/sidemount/poletop)
- ❑ Qty. ____ 400W HPS Fixture (NE / NW / SE / SW)
- ❑ Qty. ____ Luminaire Fuses
- ❑ Qty. ____ Fuse Holder (NE / NW / SE / SW)
- ❑ Qty. ____ Photocell (NE / NW / SE / SW)
- ❑ Qty. ____ Luminaire Lens (NE / NW / SE / SW)
- ❑ Qty. ____ Backplate, Type ____________
- ❑ Qty. ____ Opticom Head, Type: ____________
- ❑ Qty. ____ Illuminated Streetname Frame (6 foot/8 foot)
- ❑ Qty. ____ Illuminated Streetname Sign (6 foot/8 foot)
- ❑ Qty. ____ Video Camera, Type: ____________
- ❑ Qty. ____ (NE / NW / SE / SW) Plumbing: ____________
- ❑ Qty. ____ (NE / NW / SE / SW) Jbox: ____________
- ❑ Qty. ____ Ped Station (NE / NW / SE / SW)
- ❑ Qty. ____ Ped Button (NE / NW / SE / SW)
- ❑ Qty. ____ Pullbox (NE / NW / SE / SW), Type: ____________
- ❑ Qty. ____ Handhold Cover (NE / NW / SE / SW)
- ❑ Other: ____________

Repair/Replace Traffic Signal Device/Hardware:

- ❑ Qty. ____ 1-A Ped (NE / NW / SE / SW)
- ❑ Qty. ____ 1-B Ped (NE / NW / SE / SW)
- ❑ Qty. ____ XX Shaft (NE / NW / SE / SW)
- ❑ Qty. ____ XX-A Shaft (NE / NW / SE / SW)
- ❑ Qty. ____ Arm. (NE / NE / SE / SW) Length: ____________
- ❑ Other: ____________

Replace Hardware:

- ❑ Other: ____________

Replace Wiring:

- ❑ ____ Feet #14 UF
- ❑ ____ Feet IMSA Signal, Type: ____________
- ❑ ____ Feet IMSA Loop Lead-In, Type: ____________
- ❑ ____ Feet Loop Wire
- ❑ ____ Feet Other: ____________

Replace Lamp:

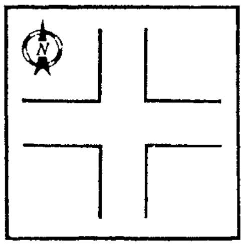
- ❑ Qty. ____ 69 Watt Ped (Walk/DW) Direction: ____________
- ❑ Qty. ____ 1950 Lumens (R / Y / G) Direction: ____________
- ❑ Qty. ____ 3M PV Lamp (R / Y / G) Direction: ____________
- ❑ Qty. ____ 400 / 250 Watt Luminaire (NE / NW / SE / SW)
- ❑ Qty. ____ 6' / 8' D-3 Flourescent (NE / NW / SE / SW)
- ❑ Other: ____________

Repair/Replace Miscellaneous:

- ❑ Signal Cabinet
- ❑ Service Pedestal
- ❑ Loop Amplifier (4ch / 2ch / 1 ch), Phase(s): ____________
- ☑ Controller, Type: CPR 2102 with data rec
- ❑ Video Processing Unit, Type: ____________
- ❑ CMU, Type: ____________
- ❑ Opticom Unit, Type: ____________
- ❑ Qty. ____ Loadswitch, Phase: ____________
- ❑ Flash Relay
- ❑ Mercury Contactor
- ❑ Line Filter
- ❑ NEMA Flasher
- ❑ ____ Amp Circuit Breaker
- ❑ Replace/Repair Fire Station Pushbutton
- ❑ Other: ____________

Miscellaneous Actions:

- ❑ Adjusted Timing / Place Recall, Phase(s): ____________
- ❑ Trim Trees
- ❑ Remove Graffitti
- ❑ Power Outage In Area
- ❑ Emergency Vehicle Strobe Left On
- ❑ Bag Head(s), Type/Location: ____________
- ❑ Adjust/Tighten Head, Type/Location: ____________
- ❑ Lock/Unlock Cabinet For Project
- ❑ Other: ____________



COMMENTS: New sticker & locks installed meter # 874-66029

Figure 21 Paper format of Traffic Signal Problem Report

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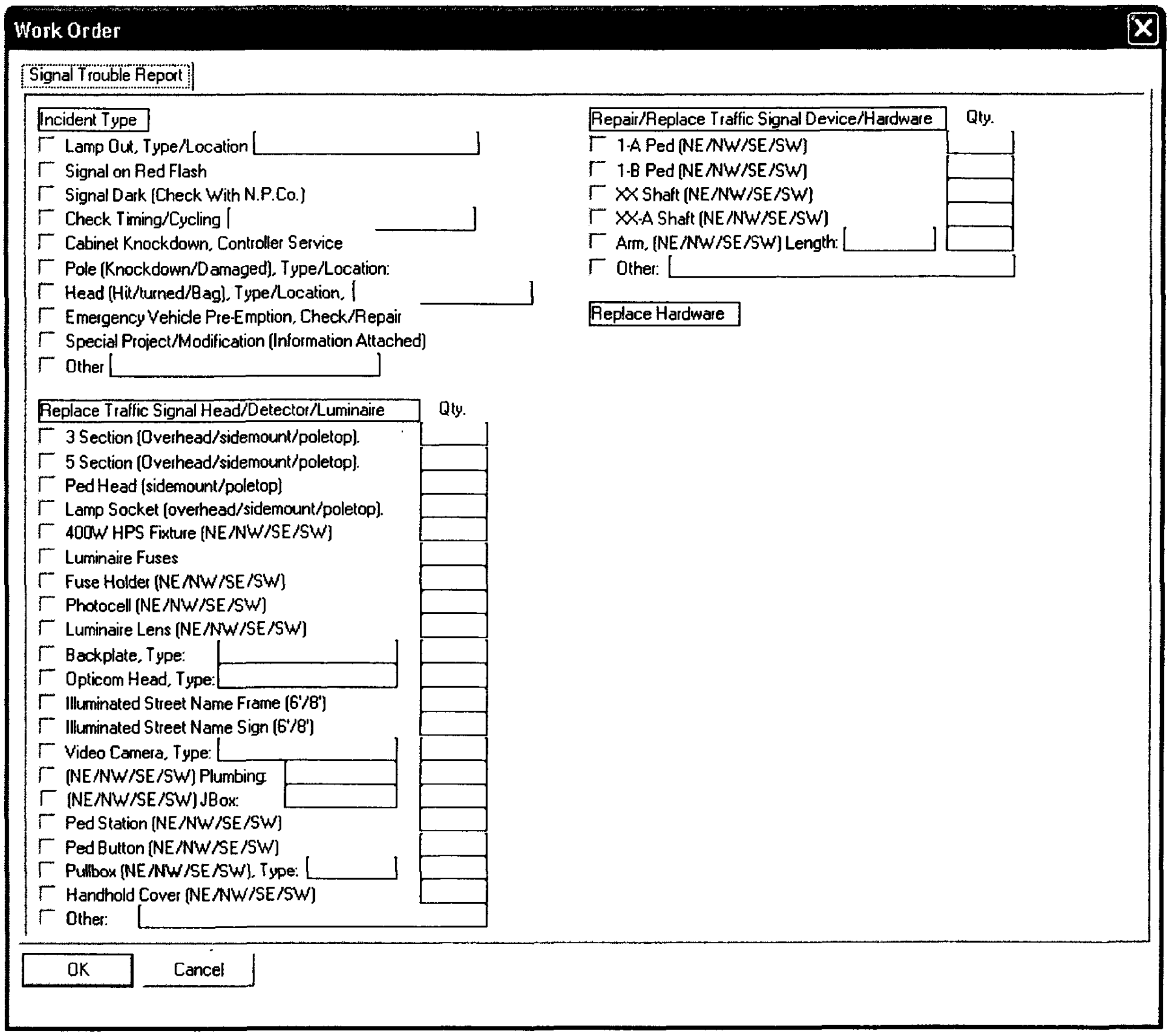

Figure 22 Application Interface for Traffic Signal Problem Report

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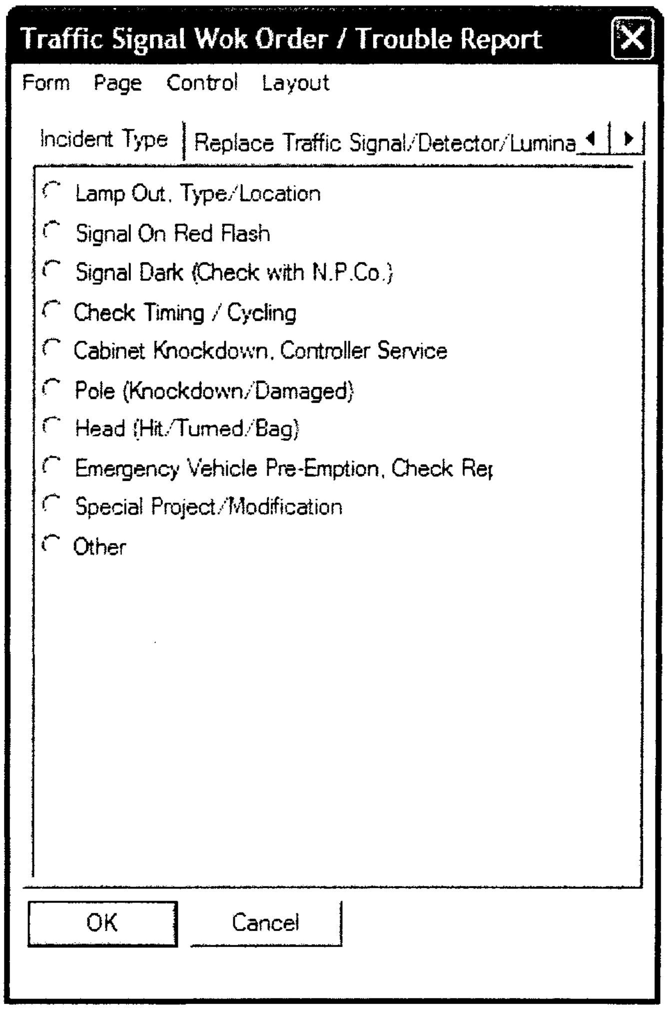

Figure 23 Screenshot of the Interface developed for handhelds (Page 1)

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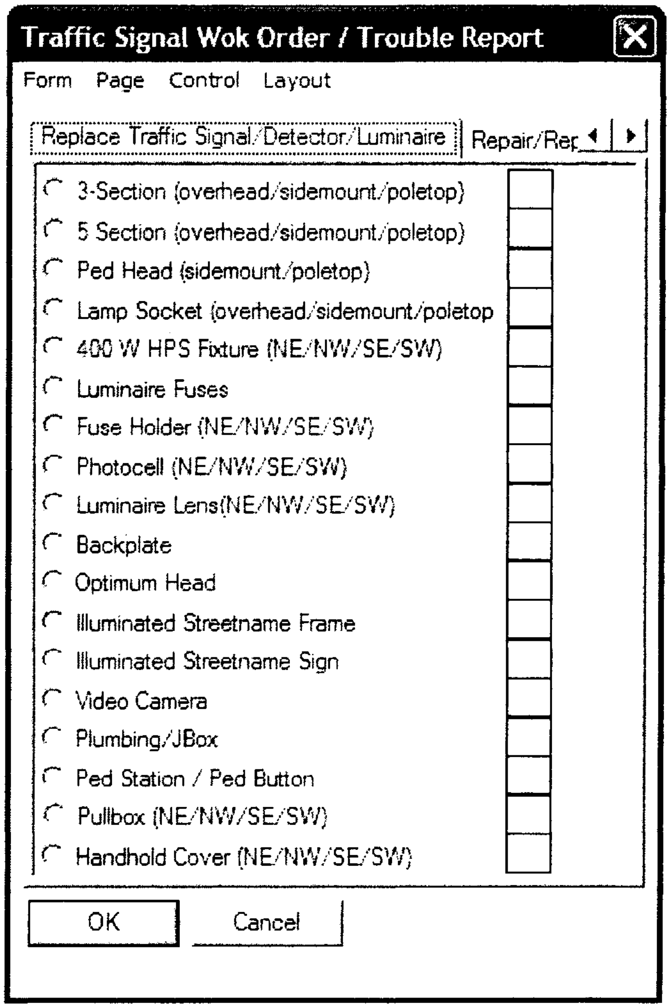

Figure 24 Screenshot of interface developed for handheld (page 2)

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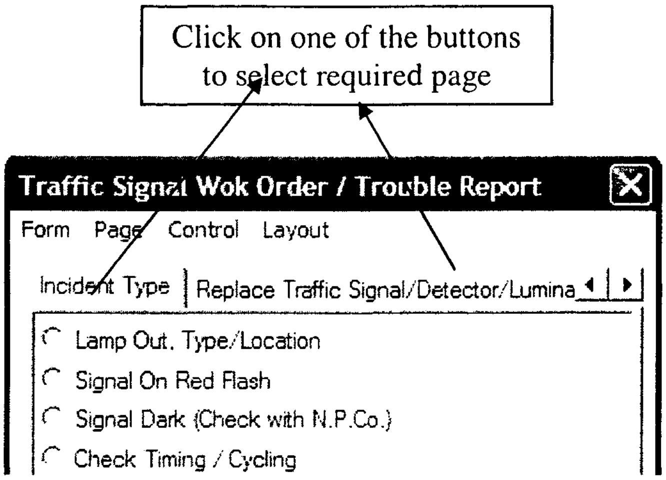

Figure 25 Changing Pages in the form used in Handhelds

Proposed Data Collection Process

The proposed methodology eliminates the use of paper to a large extent. Also, this data collection method is fast, reliable, efficient and accurate. After receiving complaints from the public, the data needs to be entered into the Spatial Data File (*.sdf file). First, the user can zoom to the particular location. This can be done easily by the user just by clicking the location of the problem. To locate the location of the problem, the user can use search functions located on the tool bar as shown in Figure 14. The user can use the buttons available on the tool bar of the interface shown in Figure 14. After the complaint location is zoomed into, the user needs to click on the map. Upon clicking on the location in the map, a new window (with a complaint form) will be generated. Details of the complaint are to be completed on this form. After entering the details, the user has to click Submit button at the bottom of the form. Once the form has been submitted, it can be viewed over the intranet / internet instantly. The current practice is for the the users file the complaint paperwork at the end of each day, and forward the same to the

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corresponding divisions. The new method can deliver in near real time the complaint to the necessary department the recorded complaint. The importance of the complaint will be recorded in the field named Priority. This field is categorized into four different types. They are Emergency, Urgent, Routine and Special. They are explained as follows:

(a) Emergency: Emergencies are situations which pose an immediate threat to personal health or safety, or of major damage to the infrastructure or equipment. Emergencies are to be handled immediately.

(b) Urgent: Urgent situations pose a threat of personal injury, equipment damage, serious distruption to the operations etc. These situations are to be handled as quickly as possible (6 hours) and within 48 hours.

(c) Routine: Routine work orders are for tasks that do not pose a immediate threat to life, property, or of serious disruption to the operations. These requests are put in the job queue and are processed in the order in which they are received.

(d) Special: Special priority is assigned to requests which require special handling for a variety of reasons.

The above mentioned priority classification also needs to be used by the field personnel when they record information. Data collection in the field can be done with the help of computerized interfaces as illustrated in Figures 19, 20 and 22.

Sample Data Collected

Field data was collected for a sample project using the interfaces developed and the instruments selected for the study. The data collected was related to the news-racks located in various locations around the Las Vegas Metropolitan valley which fall under

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unincorporated Clark County region. The rational for using news-racks for the case study is explained as follows:

Pedestrian level of service mainly concentrates on the pedestrains comfort and safety. Level of Service for the pedestrians on the road network depends on various parameters such as waiting time to cross at an intersection, width of the crosswalk in an intersection, width of sidewalk, sidewalk presence, number of travel lanes, presence of on-street parking, presence of street trees, volume and speed of the motor vehicle traffic, etc. Effective width of the sidewalk is the distance available from the edge of the driving lanes, that can be safely utilized by an pedestrian to walk. Level of service varies as the width of the sidewalk changes. Level of service of the pedestrians degrades because of the presence of external objects on the sidewalks. These objects include street furniture, street lighting poles, fire hydrants, traffic signals, parking meters, newsracks, telephone booths, building protrusions, busstops, and other installations. Presence of these objects on the sidewalk reduces the effective width of the cross walk to a large extent. It is the responsibility of the local government to assure the safety of the pedestrians by eliminating or limiting the number of obstructions on the sidewalks. Clark County Department of Public Works (CCDPW) maintains the database of the news-racks located through out its jurisdiction. As seen in Figure 28, at some locations sidewalk widths were greatly reduced due to the presence of news-racks. Hence, inorder to improve the safety and level of service of the pedestrian, CCDPW proposed to collect data related to news-racks in its jurisdiction.

The various parameters collected in the field are as shown below:

(a) News-rack Identification Number

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(b) Location of the news-rack

(c) New location

(d) Date updated

(e) Distance

(f) Photo Identification Number

(g) Data collectors name/names

Brief description of the parameters mentioned above follows:

(a) News-rack Identification Number: This is a unique number assigned to each news-rack in the Clark County Jurisdiction area. The unique number includes a combination of alphabets and numbers. The compostion of the unique number consists of abbreviated name of the street, number, and direction of the location of the news-rack.

(b) Location of the news-rack: This field contains the location details such as the direction and the distance of the newsrack from the end of the reference street. In general, the news-racks location details are maintained in a database with the CCDPW.

(c) New Location: This field is filled only if the data collected was related to a new news-rack (not in the existing database of the Clark County) or if the location of the news-rack has been changed from its old location.

(d) Date uploaded: Date of the data collected. This field is setup in such a way that the user need not fill any required values. The software fills the date column for itself. The system can be modified in such a way that the user can/cannot change the date.

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(e) Distance: This field shows the distance between the news-rack tag (fixed on the sidewalk/ground) and the actual location of the news-rack.

(f) Photo Identification Number: The field collects data related to the photos associated with the particular news-rack.

(g) Data collector name/names: Name of the individual/individuals who collected the data will be noted down in this field.

Data collection for the news-racks can be divided into two categories namely (1) correcting the data of the existing news-rack, and (2) data entry of a new news-rack. Although the same interface was used for both the procceses, the data collected slightly differs. One more additional parameter was to be collected for entering the data related to a new news-rack. Also, during the data collection process, the Global Positioning System (GPS) coordinates of the news-racks "tag" are to be corrected. These coordinates determine the exact position and spacial proximity of the news-rack. The interface used for collecting the data for the news-racks is shown in Figure 26.

Figure 26 shows the form in which various attributes are entered in the fields. As it is evident that not all the fields in the above shown form need to be filled. Fields like date and data collector's name are already stored in the form. These can be entered by selecting the required value in the drop down menu. The date field shown in the Figure 26 can be set in such a way that the field-collecting person would be able to change it or it can be set to the default value like current date, which cannot be changed by the field person. In order to change the date field to a value other than the default, the user needs to click on the dropdown arrow next to the date field. A calendar with the current month

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and date (circled in red) will popup as shown in the Figure 27. In order to change to a different date, the user needs to select the required date.

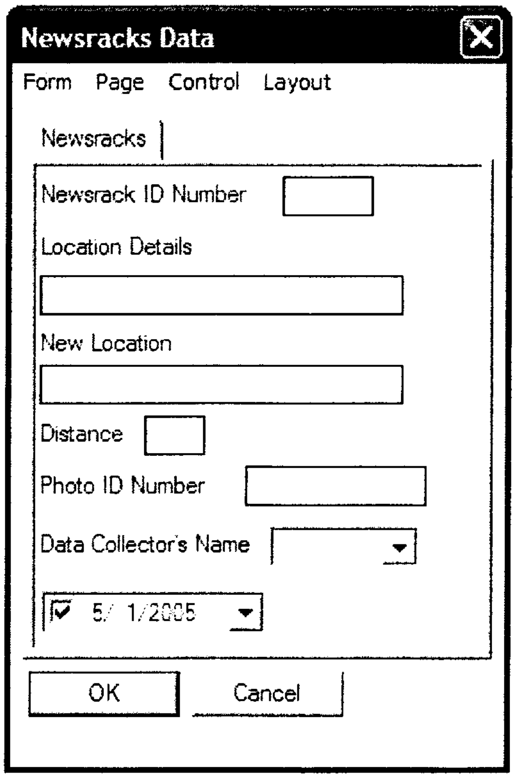

Figure 26 Screenshot of the news racks data collection form

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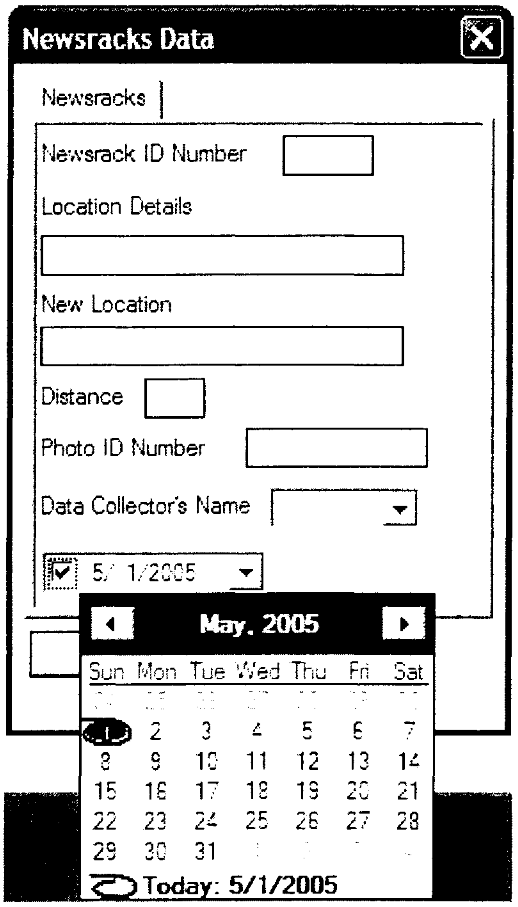

Figure 27 Screenshot of the news-racks data collection form with calendar popup window

Figure 28 shows the data collector in the field collecting news-racks data using a Tablet PC (connected to the Trimble Pathfinder for tracking GPS satellites). The GPS receiver needs to be placed on the news racks tag, which is located on the sidewalk in and around news racks. If the battery strength of the GPS unit is low, if there are lot of obstructions like buildings and trees, or if satellites are launched in one part of the sky, the unit might not be able to get a satellite fix. Such conditions should be avoided during the data collection process.

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Figure 28 Data collection in the field using Tablet PC

After the required data was collected from the field, the data needs to be transferred from the field instruments to the office computers for analysis. For the transfer of data from the field instruments, the instrument needs to be placed in the cradle and connected physically to the main system or can be connected using a USB cable. Once the instrument is physically connected to the main system, Microsoft Activesync software is used to transfer the data from the field instrument to the main system. Another method to transfer the data from the instrument to the main computer is with the help of a wireless

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internet connection. Using this method, data is transferred from the field to the remote server without physically being connected to the system. However, for the present data collection process, traditional approach of physically connecting the instrument to the main system was used. Figures 29 show the screenshot of the Microsoft Activesync window before and after the field instrument is connected.

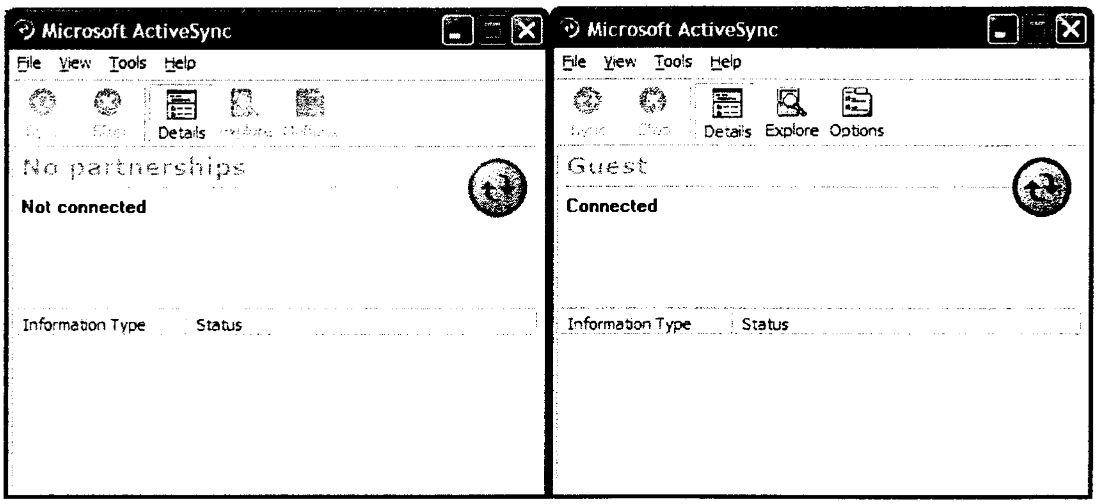

Figure 29 Screenshots of the Activesync windows before and after connecting

For easy access to the files on the handheld, guest partnership can be selected when prompted. Figure 30 shows the screenshot of the partnership selection window. The office-based personnel do the selection of the type of partnership for data transfer between the field instrument and the office system. After the collected data are transferred from the field instruments to the main system, data analyze can be performed.

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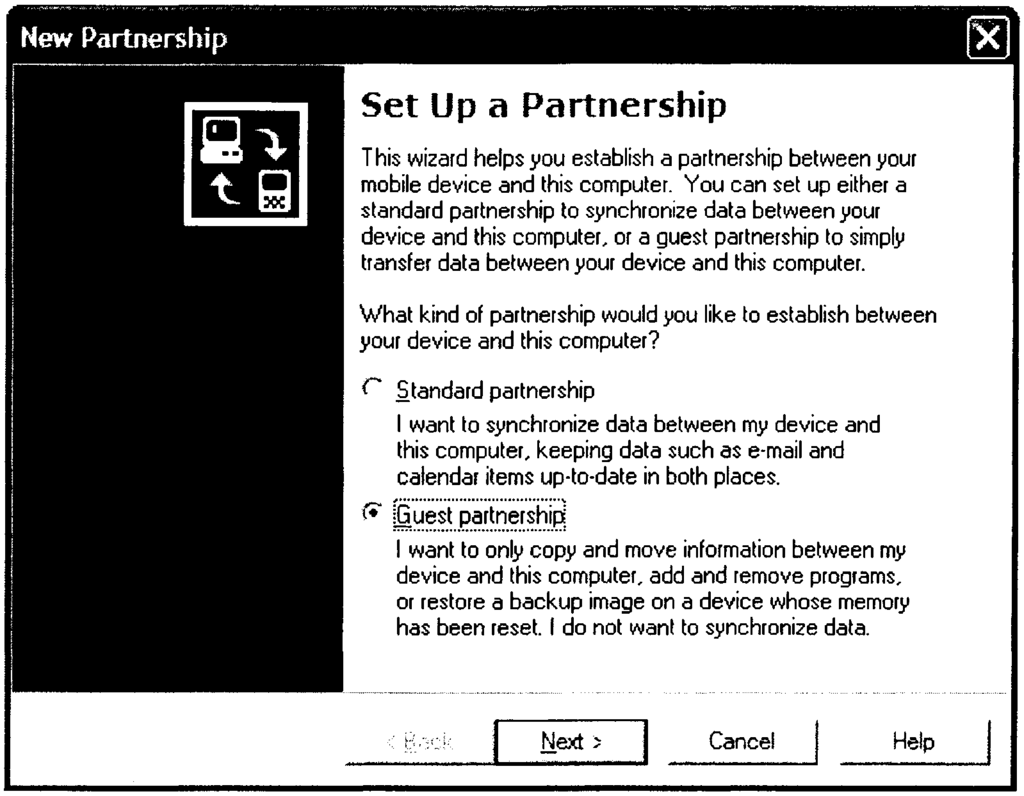

Figure 30 Screenshot of the partnership selection window

Data Analysis

A total number of 341 records (which consists of new as well as edited news-racks data) were collected during the data collection process using different instrument and the developed interface. Table 8 shows the summary of the data collection process i.e. date, instrument used, amount of data collected (number of records), number of data collection hours, battery remaining at the end of the data collection, weather condition, temperature and humidity. Data were collected in the field for 9 days at about 3 hours per day. The time required for collection was mainly dependent on the amount of the battery left remaining in the instrument used for the data collection.

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Table 8 Summay of the data collection efforts

Date	Instrument Used	Data Collected	Hours	Battery Left	Weather	Temp(F)	Humidity (%)
10/27/2004	Laptop	40	3	20%	Cloudy	60/50	75-100
10/28/2004	Laptop	38	2.5	15%	Sunny	65/52	20-50
10/29/2004	Laptop	26	2.25	10%	Sunny	69/50	15-40
11/2/2004	Geo XT	34	4	55%	Sunny	64/42	15-35
11/3/2004	IPAQ	27	4	50%	Sunny	67/49	15-40
11/5/2004	Tablet PC	32	3	20%	Sunny	72/53	20-40
11/9/2004	Tablet PC	46	3	35%	Sunny	61/48	60-85
11/23/2004	Tablet PC	50	3	45%	Cloudy	58/41	40-75
11/25/2004	Tablet PC	48	3	30%	Sunny	63/42	35-70
		341					

As evident from the table listed above, a total of 27.75 hours were spent in the field for the data collection. Apart from these hours, an additional 12 hours was spent to develop the interface to this newsracks project. The total amount of time spent for the project was about 45 hours, which includes quality control of the data collected, as well as training the personnel using the field instruments. Hence, total time of 45 hours was spent for collecting the data related to 341 newsracks as well as to develop the interface for the data collection. This averages about 4.8 minutes per newsrack record.

As per the traditional method of data collection and conversion to GIS format, data collection for each record needs to follow a certain procedure. The procedure includes a manual method of recording the data in the field. Once the data are recorded, converting the collected data into GIS format is to be done in the lab. Converting the data to the GIS format includes manual placement of the newsrack points on the map. For placing these points on the map, paper maps and aerial photographs were used. During the data collection process, the placement of the newsracks with respect to fixed assets was noted down. These fixed assets include (but not limited to) fire hydrants, streetlight supports,

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busstop location, storm water drains etc. Later in the lab, these points are transferred on to the map using paper maps. Also, aerial photographs were placed as the background of the map and the points were placed according to the distances from the fixed objects, which can be identified on the aerial photographs.

For transferring each newsrack data point from the paper format to the GIS format, it takes about 8-10 minutes. At this rate, in the traditional method for transferring 341 newsracks points it would take 45 – 55 hours. Additional time and efforts need to be employed for quality control. Also, more GIS expertise is required in this method for converting the data to the GIS format.

At the end of the data collection, the field collecting personnel were provided an evaluation sheet to be filled out. Figure 31 shows the evaluation form used for collecting feedback from the field data collecting personnel. The information was documented and analyzed to understand their comments/feedback on the automated field data collection process.

As a summary of the chapter, data were collected by the field personnel using the developed interfaces. Data were analysed and compared with the traditional method of data collection.

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Evaluation of PDA Based Data Collection Process

Date: ____

Data Collector's Name: ______________________________

Data Collection Location: ____________________________

What type of instrument are you using for the data collection?

HP IPAQ 5555 ☐ Trimble Geo XT ☐ Tablet PC ☐ Laptop☐

What software is used in the above product?

ESRI ArcPad ☐ Trimble Terra Sync ☐

Time of the day data was collected: *AM/PM*

Weather condition:

Bright & Sunny ☐ Cloudy ☐ Rainy

Number of data variables collected:

Amount of data collected with the above-mentioned instrument (Number of Records):

Ease of entering values:

1☐ 2☐ 3☐ 4☐ 5☐

V. Difficult Medium V. Easy

Outdoor Visibility:

1☐ 2☐ 3☐ 4☐ 5☐

V. Bad Medium V. Good

Battery Life:

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Poor Medium V. Good

Weight of the Instrument:

Light ☐ Medium ☐ Heavy ☐

Overall satisfaction:

1 2 3 4 5

(Not at all satisfied) (Fully Satisfied)

Figure 31 Evaluation Sheet for the data collecting personnel

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CHAPTER 6

SUMMARY AND CONCLUSIONS

The purpose of this dissertation was to develop a system utilizing GIS and GPS technologies and demonstrate its application to upgrade transportation related databases in real-time. The development of the system includes identification of the appropriate software and hardware that are to be used in the office as well as in the field. The system was developed using the identified software, and tested in the field using different hardware. For the purpose of testing the model in the field, newsracks data were collected around the Las Vegas valley. These data were collected by field personnel using different instruments and was done on different days. A review of the feeback of the field data collecting personnel is explained later in the chapter.

Various advantages were identified by implementing the automated field data collection process. One of the biggest advantages of this system is effective and efficient utilization of the personnel resources. Public works agencies such as CCDPW can operate more efficiently through automating and integrating data upload, processing and assignment of tasks to various departments and personnel.

Developing automated tools (such as the present system) reduces efforts, handling requests, and processing time. GIS/GPS environments can be integrated to provide powerful automated tools. According to the previous studies, the primary advantage of using off-the-shelf software is that it would permit immediate deployment of the system.

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However, immediate deployment might not be possible in the present scenario, as it takes time for the system to be developed (using the off-the-shelf software) and deployed. Using off-the shelf products could lead to potential problems like compatibility issues with the selected software products. As most of the CCDPW data (used for the present study) were in GIS format, this potential problem was reduced to a large extent.

Various software products were studied to review their flexibility and ease of deployment in the field instruments. Another criterion for the reviewed software is the ability to create user-friendly interfaces. The interfaces produced should be easy to understand by the field personnel who may not be technically sound. The adoption of new technologies requires significant investment of resources: fiscal, personnel and time. Before adopting any new technology, extensive pilot tests need to be conducted to assess the various benefits, risks, costs, and implications of each such technology. Its takes time for the new technologies to be adopted in place of existing practices. But once they are adopted, they could lead to significant benefits to staff, and the organization. The long term benefits of developing such automated tools can be linked to the overall productivity, improved efficiency, effectiveness and timeliness of scheduled and emergency operations.

Hardware selection for the study depends on various factors such as weight, screen resolution, battery life, and hard drive space. Also the ability of the hardware to function in different weather conditions was also studied. As mentioned before, feedback was obtained from the field personnel about the hardware and software usage. The feedback provided by the field personnel were instrumental in deciding the overall functionality.

As a summary, the following recommendations are made:

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- Weight of the hardware always plays an important role. The weights of the hardware considered for the present study ranged from 5.8 oz to 7.5 lb. As per the feedback, most of the field personnel recommended handheld instruments and Tablet PC for data collection.
- Between handhelds and the tablet PC, the tablet PC had better capabilities than handhelds. This can be related to the bigger screen size, which in turn attributes to easy data collection.
- More number attributes can be collected with laptop and tablet PC when compared to IPAQ and GeoXT. Also, IPAQ and GeoXT are slower in collecting and processing data when compared to laptop and tablet PC because of the limited screen area and limited processor speed.
- Handhelds offer more battery life than laptops and tablet PCs. But the battery life is dependent on the outside temperature. This is evident from Table 7. It can be viewed that lower number of records are collected during days with high temperature. Also the battery depletes more rapidly with higher temperatures. However, battery consumtion for the initial starting of the instrument was comparitively lower in handhelds when compared to others.
- Wireless transfer of the data from the field instrument to the base office can be performed more efficiently using the tablet PC and laptop with the integrated 802.11b/g wireless networking card.
- Larger interfaces can be divided into multiple small interfaces as large interfaces cannot be displayed on the handhelds because of their limited display area.

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- Standard quality control measures based on the collected information should be developed, to ensure the database quality.
- Data was collected in the field for 9 days about 3 hours per day. As evident from the table listed above, a total of 27.75 was spent in the field for the data collection. Apart from these hours, an additional 12 hours was spent to develop the interface to this newsracks project. The total amount of time spent for the project was about 45 hours, which includes quality control of the data collected, as well as training the personnel using the field instruments. Hence, total time of 45 hours was spent for collecting the data related to 341 newsracks as well as to develop the interface for the data collection. This averages about 4.8 minutes per newsrack record.
- Where as in the traditional method, it used to take about 8 minutes for collecting details of each newsrack in the field and converting the point into GIS format in the office. Hence time savings in this particular case was about 40%.
- Finally, time savings (man hours in the lab and in the field) as well as financial benefits (less man hours of skilled labour) for the developed system are significantly large when compared to the traditional pen and paper based system, which is evident from the above two conclusions.

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APPENDIX

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A. ASP code for Generating Data Form

```
<%@LANGUAGE="VBSCRIPT"%>
<!--#include file="data.asp" -->

<html>
<head>
<title>Crosswalks</title>
<script language="Javascript">

function vol()
{
if (document.form1.traffic.value == "Yes")
        document.form1.cond.value = "Fair"
else
        document.form1.cond.value = "Poor"
}

function date()
{
        var copyright = new Date();
        var update=copyright.getYear();
        var month=copyright.getMonth() + 1;

        if (month >= 0 && month <= 9)
                var newmonth = "0" + month;
        else
                var newmonth = month;

        var day = copyright.getDate();

        if (day >= 0 && day <= 9)
                var newday = "0" + day;
        else
                var newday = day;

        var year=copyright.getYear();
        var days = copyright.getDay();
        var time = copyright.toLocaleTimeString();
        var hours = copyright.getHours();

        if (hours > 12)
                var nights = "PM";
        else
```


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```
                var nights = "AM";
}
</SCRIPT>
</head>
<body  bgcolor="white"   topmargin="0" onload = 'date()'>
 <center>
<form action='updatecross.asp' method="POST" id="form1" name="form1">
<%
Dim cnn
Dim cmd
Dim rst

Set cnn = Server.CreateObject("ADODB.Connection")
Set cmd = Server.CreateObject("ADODB.Command")
Set rst = Server.CreateObject("ADODB.Recordset")

cnn.Provider = "Microsoft.Jet.OLEDB.4.0"
cnn.Mode = adModeShareDenyNone
cnn.ConnectionString = "Data Source=C:\mapguide\sdf\crosswalk.mdb"
cnn.Open

Set cmd.ActiveConnection = cnn
cmd.CommandText = "SELECT DISTINCT id, employee, location, sign_code,
date_insp, date_inst, supportid, interid, hightraff, construct, condition, jdiction,
int_leg, material, xwalk_type, proposed, markings, num_bars, bar_length,
comments FROM crosswalknew WHERE id IN ( " & _
        Request.Form("OBJ_KEYS") & " )"

cmd.Prepared = False
rst.CursorType = 0
rst.Open cmd
Response.Write("<table align=center>")

While Not rst.EOF
Response.Write("<tr>")

        if not (rst.Fields("employee").value = "") then
                Response.Write("<td                          align=left><b>Employee
Name<B><B><FONT COLOR='brown'>*</FONT></B></B></b></td>")
                Response.Write("<td align=left><input type='text' value='" &
rst.Fields("employee").value & "' name='name' size='15' maxlength='30' ></td>")
        else
                Response.Write("<td                          align=left><b>Employee
Name<B><B><FONT COLOR='brown'>*</FONT></B></B></b></td>")
                Response.Write("<td align=left><input type='text' value='Dayan
Brown' name='name' size='15' maxlength='30' ></td>")
```


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```
        end if
        Response.Write("</tr>")
        Response.Write("<tr>")
        if not (rst.Fields("location").value = "") then
                Response.Write("<td align=left><b>Location <B><B><FONT
COLOR='brown'>*</FONT></B></B></b></td>")
                Response.Write("<td align=left><input type='text' name='location'
value='" & rst.Fields("location").value & "' size='20' maxlength='255' ></td>")
        else
        Response.Write("<td align=left><b>Location <B><B><FONT
COLOR='brown'>*</FONT></B></B></b></td>")
                Response.Write("<td align=left><input type='text' name='location'
size='20' maxlength='255' ></td>")

        end if
        Response.Write("</tr>")
        Response.Write("<tr>")
        if not (rst.Fields("interid").value = "") then
                Response.Write("<td align=left><b>Intersection ID
<B><B><FONT COLOR='brown'>*</FONT></B></B></b></td>")
        Response.Write(" <td align=left><input type='text' value='" &
rst.Fields("interid").value & "' name='id' size='15' maxlength='30' ></td>")
        else
                Response.Write("<td align=left><b>Intersection ID
<B><B><FONT COLOR='brown'>*</FONT></B></B></b></td>")
                Response.Write(" <td align=left><input type='text' name='id'
size='15' maxlength='30' ></td>")
        end if

        Response.Write("</tr>")
        Response.Write("<tr><td align=left><b>Crosswalk Type</b></td><br>")

        if not (rst.Fields("xwalk_type").value = "") then
                Response.Write("<td align=left><select size='1' name='type'>")
                Response.Write("<option value ='" &
rst.Fields("xwalk_type").value & "' selected>" & rst.Fields("xwalk_type").value
& "</option>")
                Response.Write("<option value =
'Bars_stripes'>Bars_Stripes</option>")
                Response.Write("<option value = 'Stripes'>Stripes</option>")
                Response.Write("<option value ='Bar'>Bar</option>")
                Response.Write("<option value ='NONE'>NONE</option>")
                Response.Write("</select></td>")
        else
                Response.Write("<td align=left><select size='1' name='type'>")
                Response.Write("<option value ='Bar' selected>Bar</option>")
```


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```
                    Response.Write("<option                    value                    =
'Bars_stripes'>Bars_Stripes</option>")
                    Response.Write("<option value = 'Stripes'>Stripes</option>")
                    Response.Write("<option value ='NONE'>NONE</option>")
                    Response.Write("</select></td>")
          end if
                    Response.Write("<td><b>Number of Bars<B></B></b></td>")
                    Response.Write("<td  align=left><input  type='text'  value='" &
rst.Fields("num_bars").value & "' name='bar' size='15' maxlength='30' ></td>")
                    Response.Write("</tr>")
                    Response.Write("<tr><td
align=left><b>Markings</b></td><br>")

          if not (rst.Fields("xwalk_type").value = "") then
                    Response.Write("<td align=left><select size='1' name='mark'>")
                    Response.Write("<option value ='" & rst.Fields("markings").value
& "' selected>" & rst.Fields("markings").value & "</option>")
                    Response.Write("<option                    value                    =
'Crosswalk'>Crosswalk</option>")
                    Response.Write("<option value = 'Stop bar'>Stop Bar</option>")
                    Response.Write("<option                                        value
='Crosswalk_stopbar'>Crosswalk_Stop bar</option>")
                    Response.Write("</select></td>")
          else
                    Response.Write("<td align=left><select size='1' name='mark'>")
                    Response.Write("<option          value          ='Crosswalk_stopbar'
selected>Crosswalk_Stop bar</option>")
                    Response.Write("<option                    value                    =
'Crosswalk'>Crosswalk</option>")
                    Response.Write("<option value = 'Stop bar'>Stop Bar</option>")
                    Response.Write("</select></td>")
          end if
                    Response.Write("<td><b>Stop Bar (sqft)<B></B></b></td>")
                    Response.Write("<td  align=left><input  type='text'  value='"  &
rst.Fields("bar_length").value & "' name='stop' size='15' maxlength='30' ></td>")
                    Response.Write("</tr>")
                    Response.Write("<tr><td                    align=left><b>Intersection
Leg</b></td><br>")
          if not (rst.Fields("int_leg").value = "") then
                    Response.Write("<td align=left><select size='1' name='leg'>")
                    Response.Write("<option value ='" & rst.Fields("int_leg").value &
"' selected>" & rst.Fields("int_leg").value & "</option>")
                    Response.Write("<option value = 'S'>S</option>")
                    Response.Write("<option value = 'E'>E</option>")
                    Response.Write("<option value = 'W'>W</option>")
                    Response.Write("<option value ='N'>N</option>")
```


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```
else
        Response.Write("<td align=left><select size='1' name='leg'>")
        Response.Write("<option value ='N' selected>N</option>")
        Response.Write("<option value = 'S'>S</option>")
        Response.Write("<option value = 'E'>E</option>")
        Response.Write("<option value = 'W'>W</option>")
end if
        Response.Write("</select></td>")
        Response.Write("<td><b>Material <B></B></b></td>")
if not (rst.Fields("material").value = "") then
        Response.Write(" <td align=left><select size='1' name='mater'>")
        Response.Write("<option value ='" & rst.Fields("material").value
& "' selected>" & rst.Fields("material").value & "</option>")
        Response.Write("<option value = 'Tape'>Tape</option>")
        Response.Write("<option value = 'Thermal Plastic'>Thermal
Plastic</option>")
        Response.Write("<option value = 'Other'>Other</option>")
        Response.Write("<option value ='Paint'>Paint</option>")
        Response.Write("</select></td>")
else
        Response.Write(" <td align=left><select size='1' name='mater'>")
        Response.Write("<option value ='Paint' selected>Paint</option>")
        Response.Write("<option value = 'Tape'>Tape</option>")
        Response.Write("<option value = 'Thermal Plastic'>Thermal
Plastic</option>")
        Response.Write("<option value = 'Other'>Other</option>")
        Response.Write("</select></td>")
end if
        Response.Write("<td><b>Proposed <B></B></b></td>")
if not (rst.Fields("proposed").value = "") then
        Response.Write(" <td align=left><select size='1'
name='proposed'>")
        Response.Write("<option value ='" & rst.Fields("proposed").value
& "' selected>" & rst.Fields("proposed").value & "</option>")
        Response.Write("<option value = 'Tape'>Tape</option>")
        Response.Write("<option value = 'Thermal Plastic'>Thermal
Plastic</option>")
        Response.Write("<option value = 'Other'>Other</option>")
        Response.Write("<option value ='Paint'>Paint</option>")
        Response.Write("</select></td>")
else
        Response.Write(" <td align=left><select size='1'
name='proposed'>")
        Response.Write("<option value ='NONE'
selected>NONE</option>")
        Response.Write("<option value ='Paint'>Paint</option>")
```


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```
                Response.Write("<option value = 'Tape'>Tape</option>")
                Response.Write("<option value = 'Thermal Plastic'>Thermal
Plastic</option>")
                Response.Write("<option value = 'Other'>Other</option>")
                Response.Write("</select></td>")
        end if
                Response.Write("</tr>")
                Response.Write("<tr><td><b>Date
Inspected<B></B></b></td>")
                Response.Write("<td align=left><input type='text' value ='" &
rst.Fields("date_insp").value & "' name='date' size='20' maxlength='30' ></td>")
                Response.Write("<td><b>Date Installed<B></B></b></td>")
                Response.Write("<td align=left><input type='text' value ='" &
rst.Fields("date_inst").value & "' name='install' size='15' maxlength='30'></td>")
                Response.Write("</tr>")
                Response.Write("<tr><td><b>High Traffic
Volume<B></B></b></td>")
        if not (rst.Fields("hightraff").value = "") then
                Response.Write("<td align=left><select onchange= 'vol()' size='1'
name='traffic'>")
        if rst.Fields("hightraff").value = "Yes" then
                Response.Write("<option value ='No'>No</option>")
        else
                Response.Write("<option value ='Yes'>Yes</option>")
        end if
                Response.Write("<option value ='" & rst.Fields("hightraff").value
& "' selected>" & rst.Fields("hightraff").value & "</option>")
        else
                Response.Write("<td align=left><select onchange= 'vol()' size='1'
name='traffic'>")
                Response.Write("<option value ='Yes' >Yes</option>")
                Response.Write("<option value ='No' SELECTED>No</option>")
        end if
                Response.Write("<td><b>Construction<B></B></b></td>")
        if not (rst.Fields("construct").value = "") then
                Response.Write("<td align=left><select size='1' name='const'>")
                Response.Write("<option value ='" & rst.Fields("construct").value
& "' selected>" & rst.Fields("construct").value & "</option>")
                Response.Write("<option value = 'Yes'>Yes</option>")
                Response.Write("<option value ='No'>No</option>")
        else
                Response.Write("<td align=left><select size='1' name='const'>")
                Response.Write("<option value ='No' selected>No</option>")
                Response.Write("<option value = 'Yes' >Yes</option>")
        end if
                Response.Write("</tr>")
```


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```
			Response.Write("<tr><td><b>Condition<B></B></b></td>")
		if not (rst.Fields("condition").value = "") then
			Response.Write("<td align=left><select size='1' name='cond'>")
			Response.Write("<option value = '" & rst.Fields("condition").value
& "' selected>" & rst.Fields("condition").value & "</option>")
			Response.Write("<option value = 'Retired'>Retired</option>")
			Response.Write("<option value = 'Good'>Good</option>")
			Response.Write("<option value = 'Fair'>Fair</option>")
			Response.Write("<option value = 'Poor'>Poor</option>")
			Response.Write("<option value = 'New'>New</option>")
		else
			Response.Write("<td align=left><select size='1' name='cond'>")
			Response.Write("<option value = 'Poor' selected>Poor</option>")
			Response.Write("<option value = 'Retired'>Retired</option>")
			Response.Write("<option value = 'Good'>Good</option>")
		Response.Write("<option value = 'Fair'>Fair</option>")
			Response.Write("<option value = 'New'>New</option>")
		end if
			Response.Write("<td><b>Jurisdiction<B></B></b></td>")
		if not (rst.Fields("jdiction").value = "") then
			Response.Write("<td align=left><select size='1' name='jurisd'>")
			Response.Write("<option value ='" & rst.Fields("jdiction").value &
"'  selected>" & rst.Fields("jdiction").value & "</option>")
			Response.Write("<option value = 'NDOT'>NDOT</option>")
			Response.Write("<option value = 'CLV'>CLV</option>")
			Response.Write("<option value = 'CNLV'>CNLV</option>")
			Response.Write("<option value =
'HENDERSON'>HENDERSON</option>")
			Response.Write("<option value = 'BC'>BOULDER
CITY</option>")
			Response.Write("<option value = 'NELLIS'>NELLIS
AFB</option>")
			Response.Write("<option value ='CC'>CLARK
COUNTY</option>")
		else
			Response.Write("<td align=left><select size='1' name='jurisd'>")
			Response.Write("<option value ='CC' selected>CLARK
COUNTY</option>")
			Response.Write("<option value = 'NDOT'>NDOT</option>")
			Response.Write("<option value = 'CLV'>CLV</option>")
			Response.Write("<option value = 'CNLV'>CNLV</option>")
			Response.Write("<option value =
'HENDERSON'>HENDERSON</option>")
			Response.Write("<option value = 'BC'>BOULDER
CITY</option>")
```


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```
Response.Write("<option value = 'NELLIS'>NELLIS AFB</option>")
        end if
                Response.Write("</tr>")
                Response.Write("<tr><td><b>Comments<B></B></b></td>")
    if rst.Fields("comments").VALUE = "NONE" then
                Response.Write("<td align=left><textarea name='comments' cols='20' wrap=HARD rows='5'></textarea></td>")
        else
                Response.Write("<td align=left><textarea name='comments' cols='20' wrap=HARD rows='5'>" & rst.Fields("comments").value & "</textarea></td>")
        end if
                Response.Write("<input type='hidden' value='alert' name='alert' size='15' maxlength='30' ></td>")
                Response.Write("<input type='hidden' value='" & rst.Fields("id").value & "' name='ids' size='15' maxlength='30' ></td>")
                Response.Write("</tr>")
rst.MoveNext
Wend
%>
</table>
<br>
<input type="submit" VALUE="SUBMIT"> <input type="button" value="Cancel">
</form>
</body>
</html>
```


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B. Required Data Fields for Public Works Streetlights Trouble Report

Call received by

Date

Source of Call

Call Serviced by

Incident Type

Replace Streetlight Base/Pole/Arm

- Base
- Pole Type
- Arm Type
- Arm Length

Replace Wiring

Replace Streetlight Fixture

Replace Streetlight Lamp

Micellaneous

Comments

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