Title: A Cost-Effective GIS Safety Analysis Tool for Improving Highway Safety

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Abstract: The safety of highway travel in Florida is of paramount concern to the state authorities responsible for managing the highway system. The FAMU-FSU College of Engineering has developed a cost effective, user-friendly GIS-based safety analysis tool for law enforcement officers in Florida using MapObjects 2.2 development kit. The tool allows automatic creation of crash shapefiles using two crash location methods i.e., GPS coordinates and street information. The tool performs numerous crash analyses and creates crash maps by querying information from TraCS (Traffic Criminal Software) database. The tool was customized to allow law enforcement officers to perform numerous spatial analyses by integrating TraCS database with other spatial databases to obtain hazardous crash location in their jurisdiction and undertake appropriate measures. Through user-friendly interface, law enforcement officers and transportation officials could perform numerous analyses and produce maps that can be used for safety improvement programs in their jurisdictions.

Introduction

The use of GIS in crash analysis by different agencies has risen tremendously over the past decade. Geographical Information Systems (GIS) is considered to be a potential analysis and decision –making tool for different transportation purposes. This is due to the ability of GIS to handle a tremendous amount of data and perform analyses ranging from simple to complex analyses. GIS can be useful in handling data from diverse sources and form links and interconnection between them. The powerful aspect of GIS is its flexibility in modeling the aggregation of crash data and geographical data to obtain a much vivid evidence of the causes of high crash rates and their respective locations.

Traditionally, crashes are analyzed by querying required information from the crash database to produce graphs, charts and tables. The use of GIS has added another dimension in the way crashes are being analyzed. GIS has the engines for connecting to different databases including MS Access, SQL and Oracle making it capable of extracting crash data from different platforms. In addition to that, some of the powerful statistical analyses software such as SAS (Statistical Analysis Software) have a functionality of connecting to GIS, which makes it possible for running complex statistical models, and directly visualize the results of the model graphically in GIS.

GIS has its strength in providing display and analytical capabilities that model the physical proximity of spatial features. One powerful aspect of GIS is its flexibility in modeling spatial objects to suit the particular needs of the user or application. GIS provides a set of tools or computer programs that allow the user to perform a specific set of operations on the map and attribute data. These tools, which are in the form of operating commands, permit spatial inquiry, manipulation, and analysis of data.

Case Studies of GIS being used for Crash Analysis

Literature review indicated that GIS has been used widely for crash analysis across the United States. In Wisconsin, GIS is used for analyzing spatial distributions and densities of traffic collisions (Brose, 2001). Sun (2003) developed the crash analysis tool for Louisiana State Department of Transportation using GIS. According to Sun, with the previous system, it was hard to identify highway location that has high frequency of a particular type of accident. For example high run-off or head-on crash rate on the two-lane highways (effect of edge line or roadway lighting), high right-angle crash rate caused by improper signal timing (misleading green ball for left turn, yellow trap, running red light), and high crash rate during a particular time period. Sun therefore developed the GIS tool with the capability to evaluate crashes with the emphasis on:

- Trends over time
- Trends over space
- Stratify by highway type and geometric design
- Stratify by type of crash
- Stratify by environmental conditions

Tampa Florida Department of Transportation office (District 7 office) uses GIS for crash analysis in the state roadways. The district uses two main systems namely Intersection Magic V 6.640 and ArcView 8.2 to analyze crash data for the Hillsborough, Pasco County, and the City of Tampa. The Intersection Magic software allows querying of the data entered from the crash database. The software has the ability to draw colission diagrams for the intersections and the road segments. The software has the ability to hyperlink the scanned crash reports using the crash case number. In addition to the Intersection Magic software, District 7 uses Arc GIS software (ArcView 8.2) to map and analyze the crashes that take place in state roads. The maps are created using the section milepost information provided in the crash database provided for each district by Florida Department of Transportation (FDOT), head office.

Software Platforms

MapObjects 2.2 software was selected. Mapobjects was chosen in lieu of ArcView due to its capabilities to create stand alone applications using VB 6. The cost of MapObjects was also found to be less than 30% of the cost of ArcView. High savings are expected if the tool will be used statewide. MapObjects is an ActiveX control with nearly 50 programmable ActiveX automation objects that can be plugged in to many standard Windows development environments such as Visual Basic 6.0 (VB 6.0), Visual Basic for Applications (VBA), Visual C++, Visual Studio.NET (VB.NET and C#), Delphi, Borland C++ Builder, Visual FoxPro, and PowerBuilder. It offers many sophisticated capabilities to help insertion of dynamic maps into many applications including:

- Support for a wide variety of data sources and image formats
- Advanced data handling for optimized performance
- On-the-fly projection
- Advanced geocoding capabilities
- Global positioning system (GPS) management
- Built-in compatibility with ESRI's ArcIMS Web connectivity middleware, to enable building of a Web-based mapping and GIS applications

- A run-time deployment utility to help distribute applications easily and efficiently
- A legend and scale bar control, including source code, designed to make it easier to develop other applications

Model Formulation

Database Querying

The raw data were collected using the Traffic and Criminal Software (TraCS) in the field units. TraCS is a customizable data collection system used for collecting criminal and traffic data such as citation data and crash data. The data were saved in a long binary format and synchronized in the Microsoft Access Database (AdvData.mdb). SQL Queries were built in Visual Basic 6.0 to capture data of interest for GIS analysis.

Locating Crashes

The first important bit of information for GIS is the crash location. Traditionally, the location of the crash is reported by officers in time/location section of the crash report. In TraCS, the location of the crash is recorded in TimeLocation table in Access database. Location of the crash is recorded in the TimeLocation Table in Access. The location information include the street where the crash occurred, the intersecting street and the distance from the nearest intersecting street. In order to take the advantage of GPS information, a table was created in Access to record GPS coordinates in Latitude/Longitude form. A utility was created to allow an option of using either street names or latitude/longitude information for locating crashes on a map. This allows the agencies with no GPS receivers to have capabilities of performing crash analysis using GIS tool.

It should be noted that the process of creating shapefiles using street names is quite rigorous. The process involves searching a line segment in the street shapefile with the matching street name and then searching the crossing street name and locating the crash at the specified distance from the intersection of the two roads. On the other hand, locating crashes using latitude/longitude information is simpler. The crash is located on the specified latitude and longitude and then snapped to the nearest street segment.

User Interface

The tool is customized to allow users to perform numerous spatial analyses by integrating TraCS database with other spatial databases to crash patterns and undertake appropriate measures. The user interface was developed such that no prior GIS knowledge was needed to run the program.

Data Acquisition

Different sets from varying sources of data were used for analysis. Crash data were acquired from pilot agencies. Data were obtained in Microsoft Access Database format (AdvData.mdb). GIS street shapefiles were obtained from different sources including County offices, TIGER files and ESRI data sets. It should be noted that data from Jacksonville Sheriff Department was used for creating a prototype.

Types of Analyses

GIS has the ability to perform numerous types of crash analyses. Previous studies have reported on different GIS analyses (FHWA (2001), Kim (1996), FHWA (1999), and Falbo et. al (1991)). The types crash of analysis include intersection/spot analysis, segment analysis, cluster analysis, Sliding-Scale Analysis, Corridor Analysis, collision density analysis, area analysis, zonal analysis, pattern analysis, proximity analysis, and simple query analysis. The following sections describe some analyses that could be conducted by the developed tool.

Display/Query Analysis

The primary appeal of GIS is its graphical capabilities. As it has been stated, "a picture is worth a thousand words." Maps are pictures that GIS uses to communicate complex spatial relationships that human eyes and mind are capable of understanding. The user could determine what data and spatial relationships to be analyzed and portrayed, or how the data would be thematically presented to its intended audience. Using the database capabilities of GIS, the safety engineer can query the database and have the results graphically displayed. This query analysis, when spoken in everyday conversation, takes on the form of a "show me" question, such as "Can you show me all head-on collisions that resulted in a fatality?" However, query analysis capabilities in GIS can also be exploited for other purposes, such as database automation, which might be used for error checking and quality control of coded data. As an example, the GIS roadway database could be queried automatically during the crash data entry process to verify the accuracy of speed limit and other crash report variables coded by an officer.

Figure 1 shows an example of query analysis. The tool queries the information of crashes and displays it in time interval. The user interface is created to allow the user to define the time interval among other parameters. Other query analyses that can be performed by the tool include analysis by the type of crash, age, day of the week, holiday crashes and so forth. The flow chart of the process used for performing display/query analysis is shown in Appendix 1.

Intersection/Spot Analysis

A safety engineer would be interested to know the intersections with high crash rates in a certain area such as the city or the county. An intersection/spot analysis can be used to address such a question. GIS presents intersections as point features on a map. In order to associate the crashes occurring at the intersections, crashes within a certain distance from the intersection, usually 100 feet are considered to be intersection crashes. A buffer of 100 feet radius was created to associate all crashes occurring within a radius of 100 feet from an intersection to their respective intersection. The total number of crashes in each intersection were summed and ranked to obtain the highest rated crash intersections. The same analysis could be accomplished by using the GIS symbology tools by associating symbols and colors to the intersections within each range of crash rates, the process known as classification. The intersection/spot analysis is also termed as point analysis. The intersection/spot analysis is reported by FHWA (2001), FHWA (1999), and Kim (1996). Figure 2 shows an example of high crash rate intersection analysis. The pictorial presentation with tabular output helps identify the location and magnitude of

crashes in high crash intersections. The intersection analysis process is shown in Appendix 2.

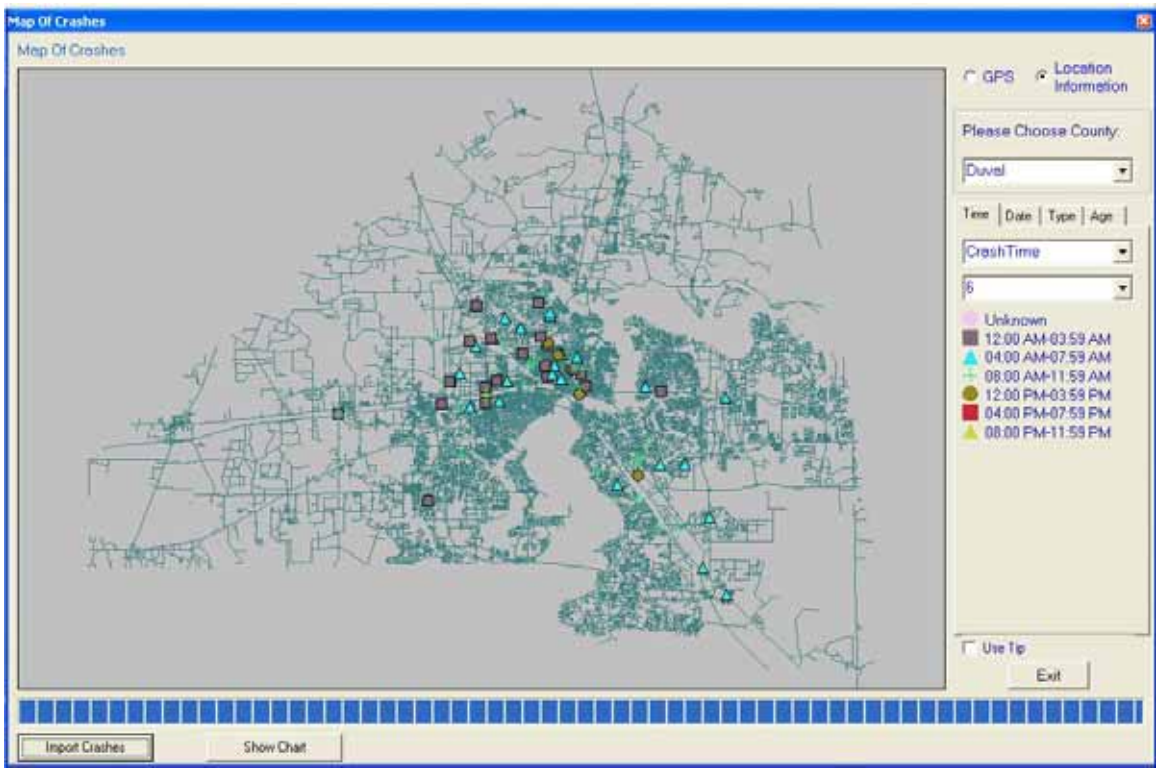


Figure 1. An Example of Query/Display Analysis

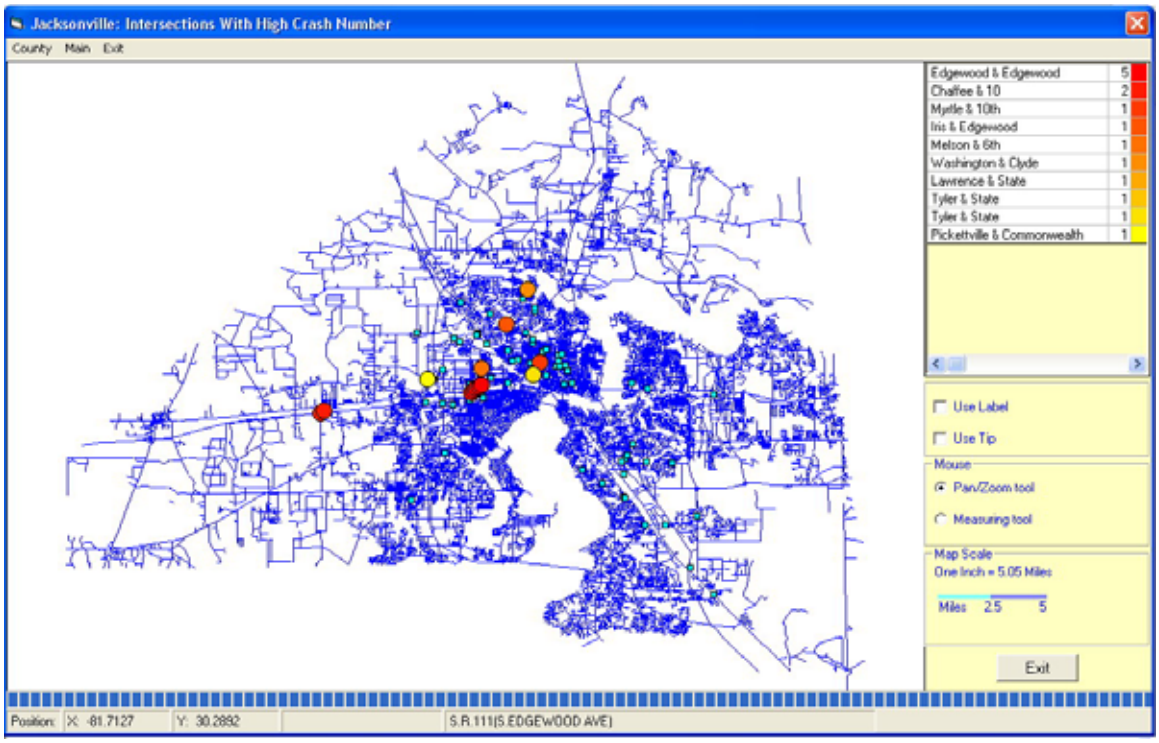


Figure 2. An Example of Intersection Analysis

Segment/Strip Analysis

While the intersection/spot analysis deals with a point, strip analysis considers crashes occurring along the roadway segment. The Strip analysis can be conducted to determine the road segments with severe crash rates. The strip analysis can vary from the analysis of the whole street segment to a designated segment length such as 1 mile, 0.5 mile and so forth. GIS is capable of computing and mapping crashes occurring in each selected segment length and provide specific symbols and colors to crashes in different segments. An example of segment analysis is depicted in Figure 3. The tool searches for streets with crashes and further determines the street segment with highest crash rate. Appendix 3 shows a flowchart of the segment analysis procedure.

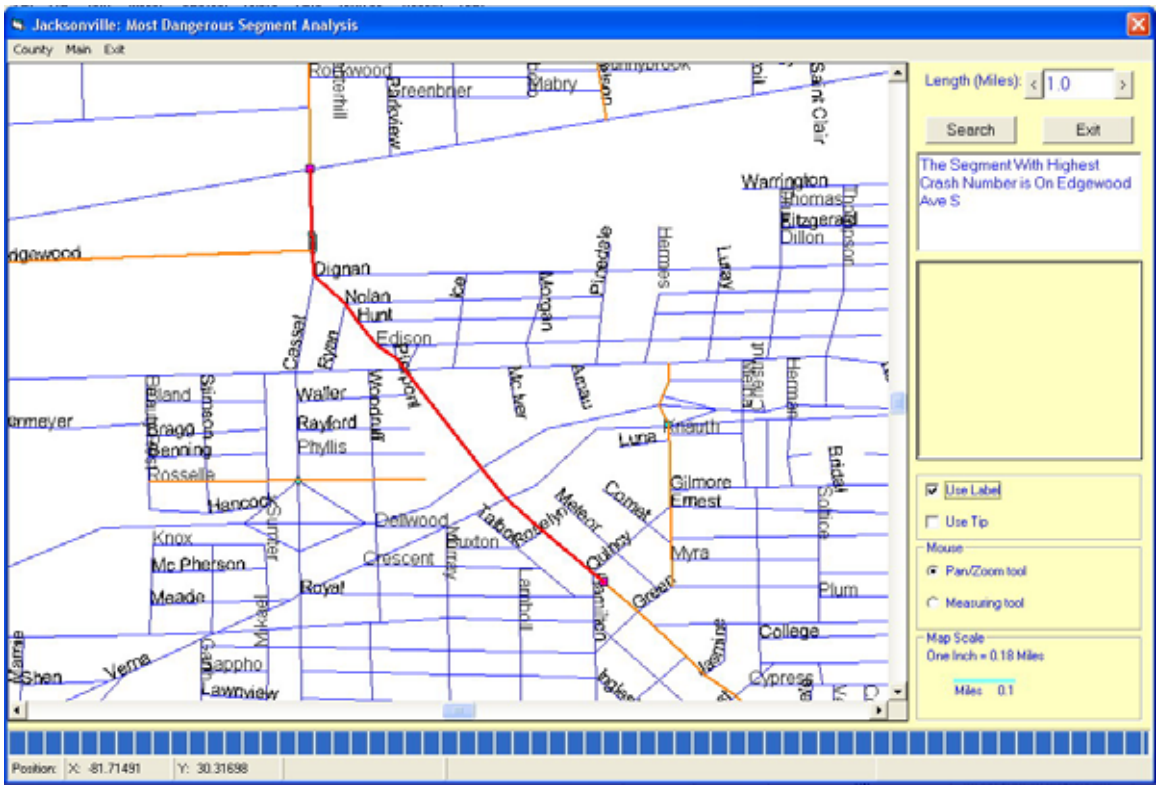


Figure 3. An Example of Segment Analysis

It is worth noting that this tool was developed with capabilities of conducting a Sliding-Scale analysis. The Sliding- Scale Analysis is a modified GIS method used to identify roadway segments with a high crash occurrence, by varying the segment length. This analysis differs from the Strip Analysis program in that the analysis segment is not fixed, but rather slides along the route in an incremental fashion.

Intersection Crash Stacking Analysis

Stacking analysis is reported by Andaluz et.al (1997) and Kamiya et. al (2004). This is a method of presenting intersection crashes in three dimension view using symbols with the height of the symbols corresponding to the number of crashes. By using the method of stacked crashes at intersection, both location and number of crashes can be conveyed at the same time. The analysis can be taken one step further by categorizing stacks by crash

type (single vehicle, head on, rear end, etc). By using stacking analysis, visual identification of the magnitude of the crash hazardousness of each intersection can be made easy. This creates a three dimensional view with the height of the circles corresponding to the number of crashes.

Crash Image Hyperlink

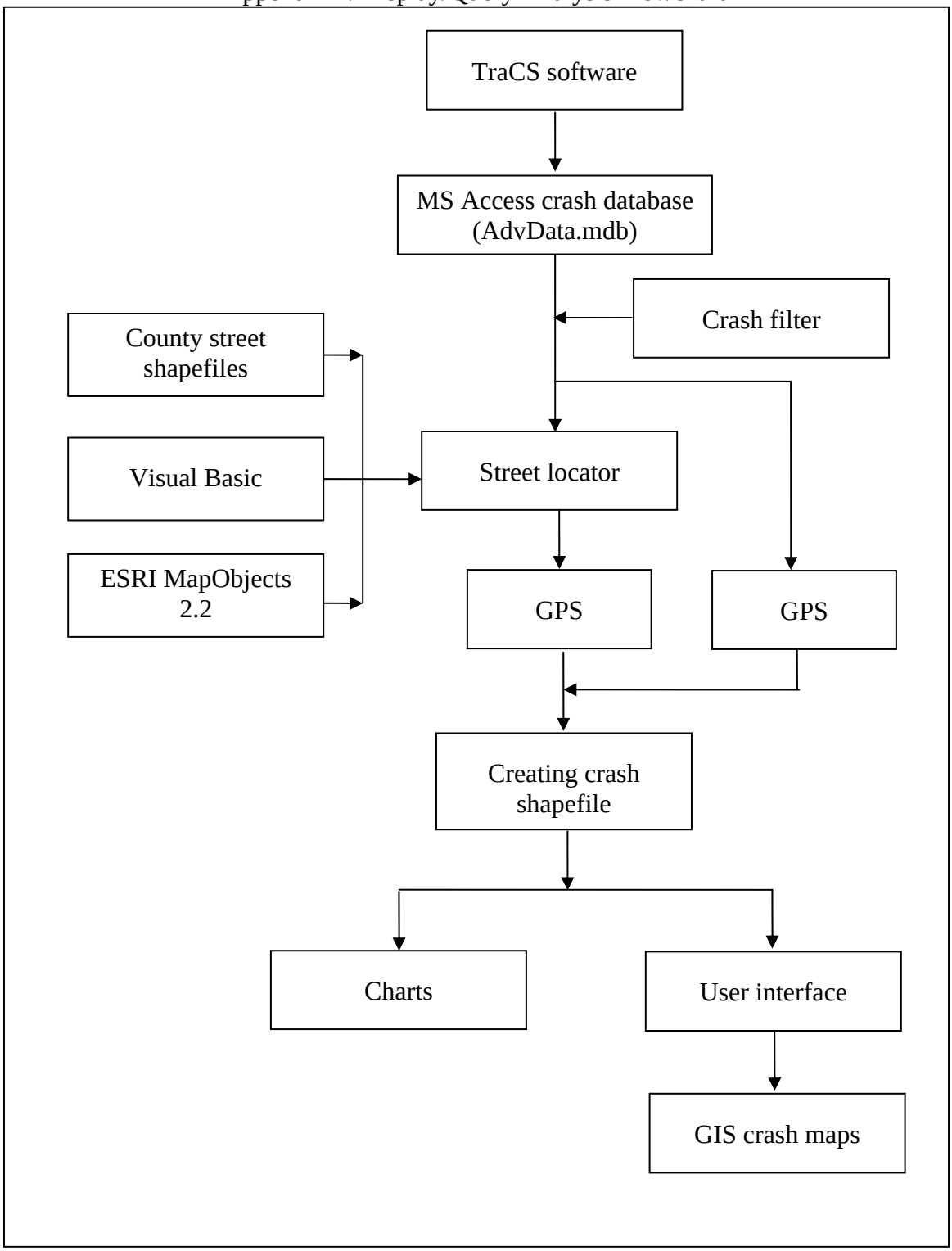
One of the useful tools for understanding the nature of the problem is the capability to click on the point features on the map and retrieve the crash report. Each symbol is linked to a crash record. User can click on a symbol to display the associated crash record on the screen. In order for the hyperlink tool to work, crash reports had to be converted to images. One attribute called C_Image was then added and for each record the name of the image file was added in the crash shapefile attribute table. The Visual Basic code was written to link the symbols and their images which were saved in a specified directory. This tool is useful especially when a user wants to examine the crash diagram and other information such as notes written by an officer in the narrative section of the crash report.

Conclusions and Recommendations

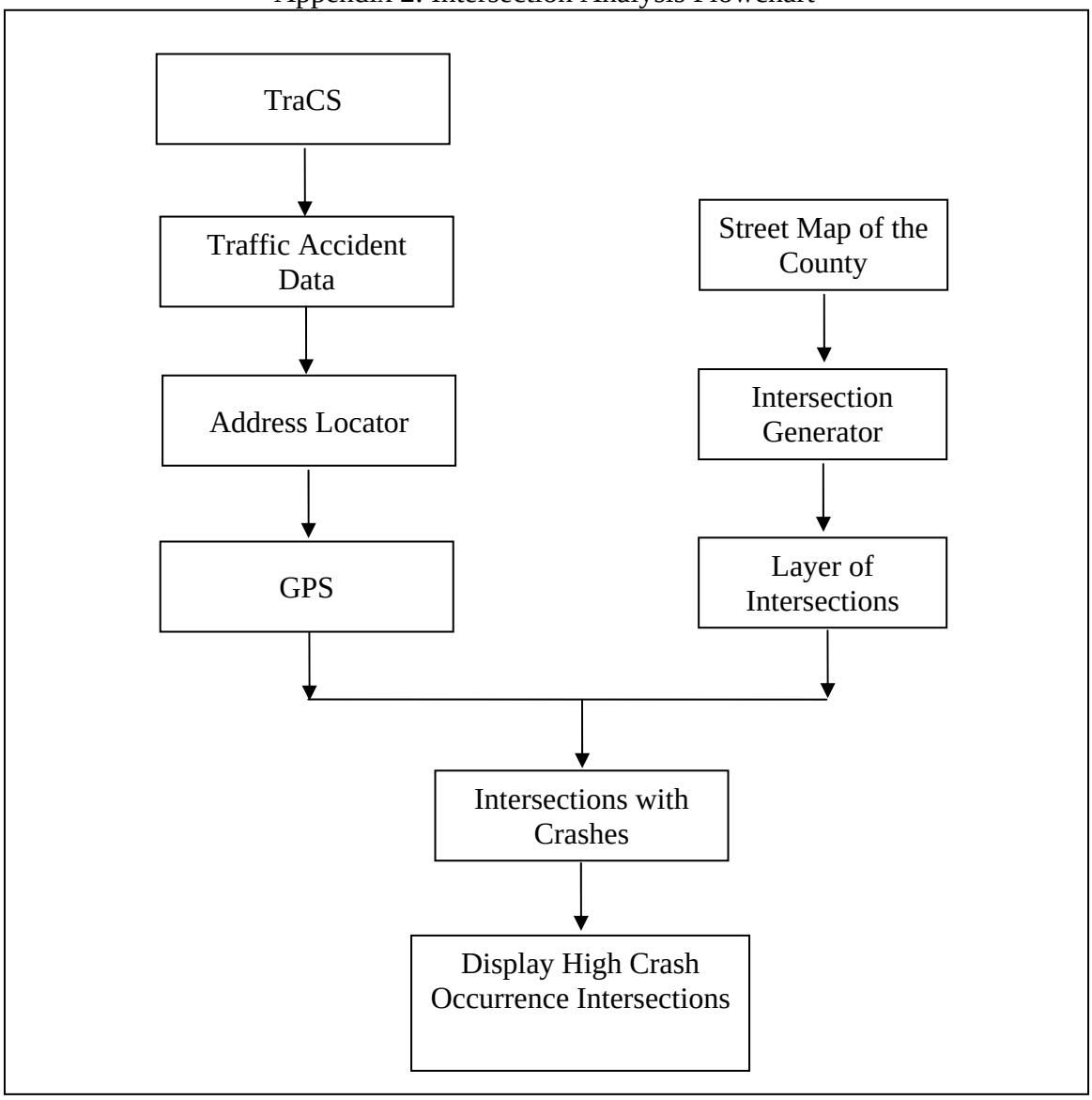
The increasing influence and the use of GIS can be largely attributed to its ability to support decision making process. This paper has presented a cost effective analysis tool that was created for improving highway safety in Florida. The tool performs numerous GIS crash analysis tools including query and crash categorization analysis, intersection analysis and segment analysis. Through a range of analyses performed by the tool, enforcement agencies and Florida Department of Transportation could identify problematic road sites and apply appropriate measures to remediate the situation for the safety of motorists and pedestrians. Plans are underway to improve the presented tool.

Future enhancements include integration of the tool with the demographic and other social economic data sources to produce a comprehensive safety support decision tool. The tool will also be extended to perform multi-agency GIS safety analysis and further a statewide GIS safety analysis.

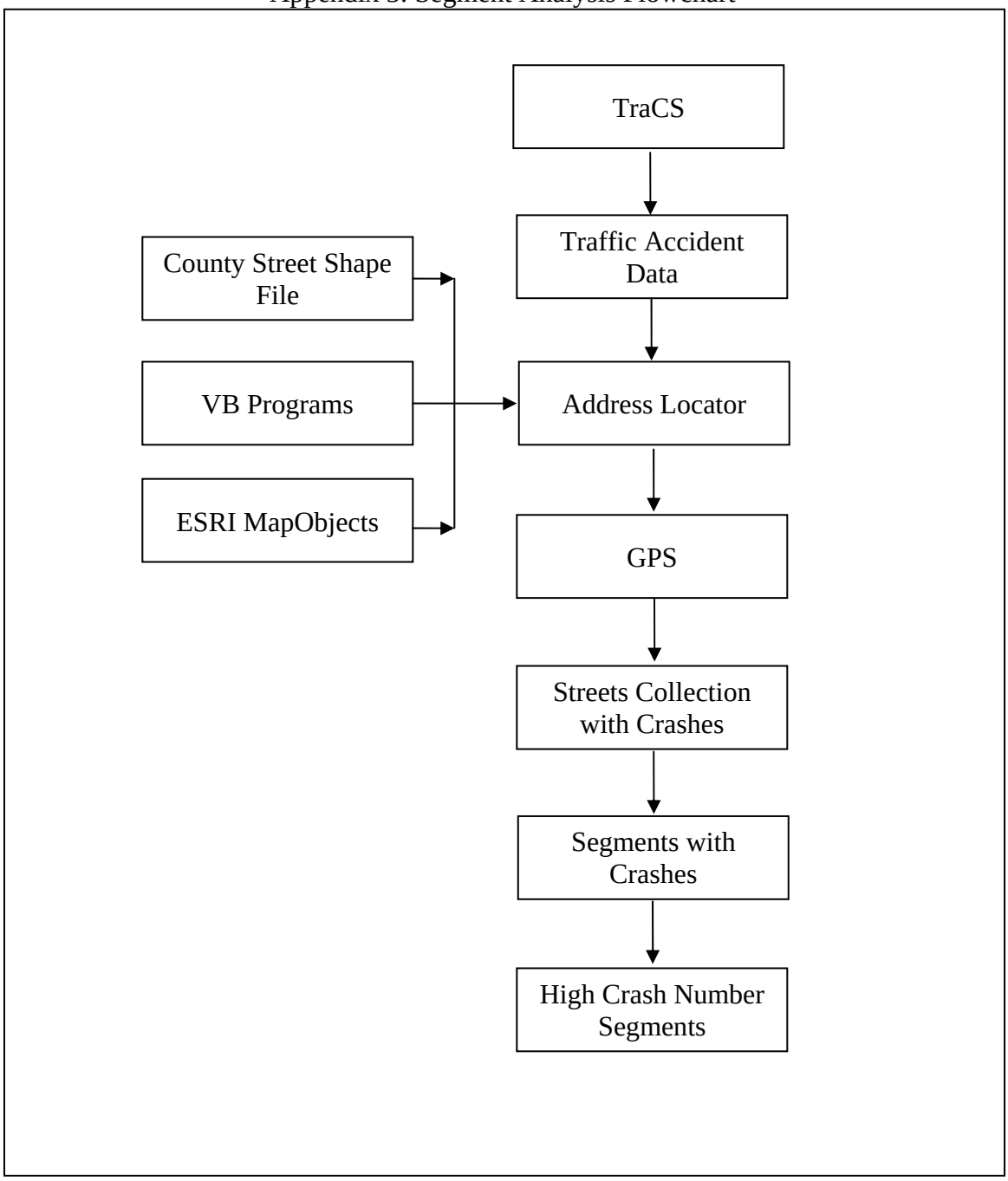
Appendix 1: Display/Query Analysis Flowchart



Appendix 2: Intersection Analysis Flowchart



Appendix 3: Segment Analysis Flowchart



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