**GEOGRAPHIC INFORMATION SYSTEMS-BASED CRASH DATA ANALYSIS AND THE BENEFITS TO TRAFFIC SAFETY**

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**ABSTRACT**

Geographic Information Systems (GIS) have been used in the past to display crash locations and produce maps. Today, the potential uses of GIS include crash data analysis. GIS-based crash data analysis can influence the four E’s of traffic safety: engineering, enforcement, education, and emergency response.

Macroscopic applications of GIS provide the ability to analyze a large amount of data quickly. Macroscopic analysis can be used on large regions to identify areas of concern without getting into specifics. The greatest benefit of GIS-based crash data analysis is the microscopic applications that can be done to evaluate crashes in a selected region. Various queries can be performed on isolated groups of data.

By using GIS, the time and effort required to analyze crash data can be reduced. At the same time, an increasing number of scenarios and alternatives previously not possible can be evaluated. A literature review showcases potential applications of GIS-based crash data analysis as a tool to assist engineers, administration, policy makers, law enforcement, and emergency personnel make informed decisions on traffic safety issues.

**INTRODUCTION**

A geographic information system (GIS) is a computerized database management system that can capture, store, retrieve, assemble, manipulate, and display geographically referenced information. It is comprised of visual and tabular data in a format that allows the user to process large amounts of information quickly. GIS has been successfully applied to many fields outside the transportation realm.

In the field of transportation, GIS has been used to graphically display crash locations and produce maps. With technological advances in personal computers and GIS desktop software, GIS can now be used to perform crash data analysis. By using GIS, the time and effort required to analyze data can be reduced. At the same time, an increasing number of scenarios and alternatives previously not possible can be evaluated. With the use of GIS, crash data analysis can be applied to improving traffic safety. Tom Welch, chair of the Iowa Safety Management System Coordination Committee (SMSCC), summarized the benefits of GIS in traffic safety in three words: "Innovation, creativity, and flexibility (1)."
BACKGROUND

The need for highway safety information was recognized and data began to be collected after the Highway Safety Act of 1966 and the Highway Safety Program Standard 10 of 1967 (the Standard) were passed. The Standard mandated that state systems include data for the entire state and that information regarding drivers, vehicles, crashes, and roadways be compatible for analysis (2). An increased emphasis on transportation safety also occurred with the enactment of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). This act established safety management systems for each state to perform a systematic analysis of highway safety (3). Crash data collection for analysis continued with the implementation of the Transportation Equity Act for the Twenty-first Century (TEA-21).

POTENTIAL BENEFITS TO TRAFFIC SAFETY

GIS that are used for crash data analysis can benefit traffic safety. There are no research results that conclude that lives have been saved because of GIS. Rather, GIS has an indirect impact to traffic safety by assisting decision makers. Miller states it best, exclaiming “… the ultimate goal is not to conduct analysis, but instead, to take actions that will reduce crash frequency or severity (4).”

A case when GIS was successfully used to aid decision-making occurred in Miami County, Kansas. Twelve fatalities in 11 months occurred along a 20-mile stretch of two-lane U.S. Highway 169. The county sheriff was aware of the high fatality rate on this roadway section and approached the Land Information Management Office (LIMO) to create a GIS map showing the accident locations and the associated attributes. This graphical and tabular information allowed the Governor and other state officials to quickly analyze the situation and determine that a significant number of crashes were due to drivers failing to maintain control of their vehicles after leaving the travelway. After viewing the map, the Governor decided to widen this stretch of US 169. The Miami County Sheriff Department is now focusing on preventing future fatalities by performing GIS-based crash data analysis on other roadways (5).

Bob Thompson from the Iowa Governor’s Traffic Safety Bureau states that “GIS has the potential to revolutionize strategic enforcement applications for police and sheriff’s offices around the nation. This potential is just beginning to be explored. EMS and other emergency response services can use the dynamic mapping features of GIS to improve the efficiency of their operations with potential life saving benefits (6).”
Macroscopic Applications

As stated previously, one of the largest benefits of GIS is the ability to analyze a large amount of data quickly. Macroscopic analysis can be used on large regions to identify areas of concern without getting into specifics.

High Crash Locations

One of the most common macroscopic applications is the determination of high crash locations (HCLs). HCLs identify the areas that would potentially receive the largest benefit if safety funds were allocated. These locations can be analyzed in many different ways.

One method of HCL identification includes crashes within a specified distance of a major roadway. This method is performed to include ramp and crossroad crashes in the crash frequency locations along a route. Two examples of HCLs in Ames, Iowa illustrate where safety improvements would provide the most benefit in accident reductions. These different approaches to displaying high crash locations are shown in Figures 1 and 2 respectively. Another method determines the crash frequency within a specified distance. An example would be crashes within a certain proximity of intersections. The presence of intersections adds complexity to the driving task, increasing the risk of a crash. This method identifies all crashes that this additional complexity may have contributed to. These crashes are referred to as intersection-related crashes. An example of intersection-related crash frequency is shown in Figure 3.

One of the drawbacks of identifying locations with high crash frequencies is that traffic volume or exposure is not taken into account. This can be accomplished by the crash rate method. The crash rate method for roadway segments divides the total number of crashes by the annual average daily traffic (AADT) and the length of the segment to obtain crashes per vehicle miles traveled (vmt). The crash rate for intersections divides the number of crashes by the number of entering vehicles determined by AADT to determine crashes per entering vehicles. An example of a crash rate analysis is shown in Figure 4.
Figure 1  High Crash Locations, Ames, Iowa 1997.

Figure 2  High Crash Locations, Grand Avenue, Ames, Iowa 1997.
Spatial Queries

Large-scale spatial queries can be performed on an entire roadway network as well. A spatial query involves selecting an entire region and specifying crashes of a particular type. This is done to simplify the data to be studied. Only limited analysis can be done due to the large volume of information available. An example of this would be to evaluate only the location of fatal crashes for an entire county.

All of the macroscopic applications described could be carried out without the use of GIS by tables and spreadsheets. However, the GIS format makes these applications easy to perform and provides a visual display as well.

Microscopic Applications

The greatest benefit of GIS-based crash data analysis is the microscopic applications that can be done to evaluate crashes in a selected region. Various queries can be performed on isolated groups of data. Practical GIS applications are discussed to show how they can benefit each of the 4 Es of traffic safety: engineering, education, enforcement, and emergency response.
Engineering

GIS-based crash data analysis could have the largest impact on engineering improvements. There are only limited funds available for redesign and reconstruction of existing roadways and these funds need to be spent efficiently. Suppose the county engineer in Allamakee County, Iowa has a major roadway with many horizontal curves. There are some safety funds available for improvements. The engineer wants to know how best to spend these funds. With a GIS-based crash data system, the engineer can go to a personal computer and query all crashes that occurred on this roadway for a specified time period. The search can be refined to include only crashes that occurred on horizontal curves. The query can be refined by a number of characteristics. For example, the search could be narrowed down by injury severity, such as fatal and major injury crashes, so as to be concerned with only the most tragic events. The engineer can compare similar curves on different roadways with approximately the same physical features (e.g. number of lanes, lane and shoulder width, traffic volume) to determine if the curve of concern has a higher rate of crashes. Next, the engineer could look at the contributing circumstances of the crashes. If a contributing circumstance such as driver inattentiveness has a high number of occurrences, perhaps greater delineation or warning signs are needed. Perhaps the speed limit should be lowered or the curve redesigned so that drivers can maintain their initial travel speed without losing control. Many different possibilities and alternatives can be analyzed in a relatively short amount of time. All of this information can then be taken into consideration along with good engineering judgment when allocating the safety funds and making improvements.

Another microscopic application that can easily be done with a GIS database is the creation of computer-generated collision diagrams. First, GIS could be used to determine intersection HCLs as discussed previously. Once these locations have been determined, the user can select the desired intersection for a given time period and all of the crashes are shown with symbols depicting vehicle movement on a schematic drawing. Any attribute contained in the crash record databases can be shown on the collision diagram. Using GIS to create collision diagrams saves time and resources that would be spent creating these by hand (on paper or by a drawing program). This GIS-based collision diagram can then be used to study crash patterns and determine their causes. From this, patterns can be found and recommended improvements made to reduce the number of crashes. An example of a GIS-based collision diagram is shown in Figure 5.

One concern that is beginning to attract attention is older drivers. Iowa has the third highest percentage of drivers over the age of 65 and the second highest percentage of drivers over the age of 85 in the United States (7).
Within the next ten years, the "Baby Boomer" generation will be added to this group of drivers over the age of 65. GIS-based crash data analysis can be used to quickly identify locations of elderly driver crashes so their causes may be studied. Engineers could take those locations and causes into account when considering such things as wider pavement markings, larger traffic control devices, and paved shoulders.

**Enforcement**

There are several benefits GIS-based crash data analysis applications can have in law enforcement. Law enforcement can improve traffic safety by targeting crashes of specific types, particularly those that endanger the lives of others. Most notable would be alcohol-impaired and alcohol-involved crashes. Alcohol-impaired means that the driver was legally intoxicated, while alcohol-involved means that the driver had consumed alcohol, but was under the legal limit. If a police chief wants to know where to place sobriety checkpoints, he could analyze the alcohol-involved and -impaired crash locations. GIS also has the ability to overlay and integrate land use information. This allows such analysis as alcohol-involved crashes and their location with respect to businesses that sell alcohol. An example of this is shown in Figure 6. Alcohol crashes can be further analyzed to determine such things as the day of the week and time of day. This can be used to help make decisions on staffing and shift hours.
Red-light-running (RLR) is also becoming an important topic in traffic safety. With these RLR locations known, patrol cars or mounted cameras could be strategically placed to observe offenders. Figure 7 shows the number of broadside (potential RLR) crashes compared to the total crashes at the designated intersections.

It is important to note that GIS cannot tell the user where to place enforcement solely by crash locations. For example, an area that has a high patrol rate may have no alcohol-involved crashes due to the existing enforcement in place. It does however help the user ask questions to ascertain their enforcement level and performance.

**Education**

GIS-based crash data analysis can also be used to help identify areas where additional education may be needed. Seatbelt use is one program that continues to get more and more support. In 1998, two-thirds of Iowa fatalities involved unbelted persons (8). With the state seatbelt usage at an all-time high of 78 percent, the focus has now switched to rural areas where seat belt usage is typically below the statewide average (8). GIS can make targeting these areas in need of increased education easy to determine.

Young drivers also remain a primary concern to the education world. New programs such as the graduated driver license have been implemented, targeting younger drivers who are over-represented in traffic crashes. GIS-based crash data analysis can help provide information on crash characteristics allowing more focus on the young driver errors.

A new application that GIS-based crash data analysis can be used for is to establish safe walking routes for school children. A "safe route to school plan" could be developed using GIS-based crash data analysis to generate a map, highlighting each child's safest route to and from school (9). This analysis could also be used to identify locations where to install warning signs, to place crosswalks, to staff crossing guards, and load and unload buses.

**Emergency Response**

Emergency response is the newest addition to the four E's of traffic safety. Emergency response is concerned with providing transportation to hospitals and providing emergency equipment to the scene of the accident.
Figure 5  GIS-Based Collision Diagram, Ames, Iowa 1996-1997.
GIS-based crash data analysis can also be used to assist emergency medical services. Knowing the location of crashes as well as the frequency and severity can be used to determine satellite locations to place emergency personnel. The relative distance from a crash to the nearest hospital could identify where EMS access time could be critical. A GIS database could contain information such as the roadway system and the location of the nearest hospitals, including attributes, such as trauma level, hospital capacity, and even hospital specialization. In the future, it is expected that an ambulance driver with a global positioning satellite (GPS) receiver and a GIS base map will be able to look at the screen of an on-board laptop computer to determine which roads to take to get to the nearest hospital in the shortest amount of time. This also would allow for the nearest ambulance or fire/rescue unit to respond to a crash. This would be particularly applicable in rural regions where emergency response vehicles sometimes come from farther away than necessary due to established district boundaries. Injury crash location, severity, and frequency information could also be used in an urban setting to strategically place emergency vehicles and personnel in the field in order to shorten response time.
CONCLUSIONS

With the increasing availability of crash data and popularity of GIS software, GIS-based crash data analysis will be very useful to roadway designers, policy makers, decision makers, law enforcement, and emergency response personnel. Many applications have been presented that show how the time and effort required to display and analyze crash data can be effectively reduced.

At the macroscopic level, applications including high crash location identification, intersection-related crash frequency, crash rate analysis, and spatial queries allow the user to analyze and manipulate data quickly and identify potential problem areas. Some of these applications such as identifying high crash locations could be determined and summarized in a table without even using GIS. However, the GIS-based map connected to the tabular data provides the user with a visual representation and can assist in performing large-scale analysis.

At the microscopic level, crash data analysis can be performed to determine if a pattern or patterns exist. If such a pattern does exist, this may be a red flag that engineering, enforcement, education, or emergency response improvements or modifications are needed at those locations. Scenarios and alternatives that previously could not
be analyzed can be considered. Traffic safety agencies can perform detailed queries on small subsets of data to effectively determine the potential causes of crashes and recommend potential countermeasures in their specialized areas.

As stated previously, GIS-based crash data analysis is only a tool. It can help the user make more-informed choices. It allows for a more thorough analysis while at the same time quickening the decision-making process. Used in conjunction with the traffic safety countermeasures already in place, GIS-based crash data analysis can have a significant impact on the traffic community.

SUMMARY OF FINDINGS

Although GIS crash data analysis began over 10 years ago, GIS-based crash data analysis has still not been used to its fullest potential. One main reason for this is the lack of interagency coordination. Collecting the crash data records involves several agencies and requires jurisdictions to work together. Also, some agencies have and use GIS independently of each other, resulting in duplication of data, incompatibility between systems, and inefficient use of resources. Another fundamental reason is that GIS-based crash data analysis requires additional staff, hardware, and software. The necessary funding is also not always available.

These difficulties can be overcome by coordination among agencies and departments by pooled funding and eliminating the duplication of data/effort. By using GIS-based crash data analysis, the time and effort required to analyze data can be reduced. Resources previously allocated to staff can then be applied more efficiently to other traffic safety issues. At the same time, an increasing number of scenarios and alternatives previously not possible can be evaluated, improving traffic safety.

REFERENCES

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