Problematic Intersections and Contributing Environmental Factors within the City of Winona, Minnesota.

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Abstract

Winona, Minnesota was founded by a Mississippi river Steamboat captain in 1851. Winona is lodged between rolling limestone bluffs and the Mississippi river, once making it a focal point for lumber producers in the 1850's. During this period Winona enjoyed that status of being the largest city in Minnesota. Winona is still thriving, but in different ways, it is now home to three institutions of higher education, technology driven businesses, and various industries. This study will demonstrate how a Geographic Information System (GIS) can be used to identify problematic intersections that exist within the city of Winona. This study will be comprised of three years (1999-2001) of traffic accident data. In addition this study will involve identifying key factors in the environment that may contribute to these occurrences.

Introduction

Intersection safety has become a serious problem in the United States. In 2004 more than 2.7 million intersection-related crashes occurred, accounting for more than 45 percent of all crashes in the United States. During that same year, 21% of all traffic related fatalities occurred at intersections (Federal Highway Administration, 2006).

An intersection can be one of the most difficult areas for a driver to navigate because of the amount of variables encountered: right turns, left turns, multiple vehicles, bicyclists, and pedestrians. Furthermore, the situation can be compounded by speeding motorists and motorist disregard for traffic controls.

In recent years the Winona Police Department (WPD) has noticed a significant rise in the number of traffic accidents occurring, specifically at intersections within the City of Winona. In an effort to gain insight on the possible causes for this increase, the WPD wanted to understand exactly where these accidents were occurring and why. In the past the WPD has adopted the practice of using a hard copy street map, accompanied by pins that were placed on the map to represent the locations of accidents. This was a good practice in theory, but there are problems with this method. For example, who is responsible for updating the map? How does one decipher what year any given pin represented? What time of year did the accidents occur? This method limits the amount of information and the accuracy that is needed in order to comprehend all the variables at hand.

A Geographic Information System (GIS) was brought to the attention of the WPD as a solution to identify both problematic intersections and to give a historical synopsis of each

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accident. A GIS is a collection of hardware and software that is used to edit, analyze, and display geographical information stored in a database. The database of information can provide a user a visual depiction about the database through various means of data manipulation.

In order to fully understand the dynamics of the environment that surrounds a problematic intersection, the intersections must first be identified. Pinpointing these locations will better enable an overall understanding of spatial relationships that may exist between the environment and the intersections. Once the intersections are identified, key problem sources in the environment must be determined. Such key problem sources include: businesses, housing, schools, and traffic controls. Once these factors are identified, proactive countermeasures, such as traffic and safety programs can be incorporated and measured.

Objective

The goal of this project was to identify intersections in Winona that have a high volume of traffic accidents. Once these intersections have been identified, the focus of this project will shift to recognize objects within the surrounding environment that may have contributed to these crashes. Once this was achieved, possible countermeasures can be discussed and put into action to resolve this ongoing problem.

Methods

Data Acquisition/Assembly

Data was compiled from several sources.Traffic accident data was acquired via the WPD's traffic accident database in a hard copy format. In order to make the traffic accident data meaningful, base map data was assembled in the form of street centerline, water, railroads, and block groups from the U.S. Census bureau in the form Topologically Integrated Geographic Encoding Referencing (TIGER) system files from 2000. The City of Winona provided parcel data, aerial photos, and rental property information. Lastly, Winona State University provided student population and parking demographics for the corresponding years of this study.

A series of data manipulation tasks performed on the data was necessary in order to narrow the focus on the primary area of study. The TIGER files mentioned above comprise the entire United States and are organized first by state level and then by county level. Counties are organized by Federal Information Processing standards codes (FIPS). FIPS codes are a standardized set of numeric or alphabetic codes issued by the National Institute of Standards and Technology (NIST). FIPS codes ensure uniform identification of geographic entities through all federal government agencies (U.S. Census, 2000). Once the county FIPS code is identified, downloadable data is possible. Once downloaded successfully, one must standardize all acquired data by projecting it into a common geographic coordinate system. This action ensures that each dataset to overlay properly thus enabling the identification of spatial relationships between objects. The TIGER files (street centerline, water, railroads, and block groups) still remain at the Winona County level; in order to narrow data to the study area, the clip function located

in ArcToolbox became an indispensable asset to the user. A data clip function can be accomplished through using the rectangle graphic, located on the draw toolbar on the ArcGIS interface. This tool enables the user to draw a rectangle around the area of interest and clip based on the selected graphic. After an area is clipped, one can select each feature independently and export into a shapefile or feature class within a geodatabase. A basemap was created (Figure 1) to help in understanding the environment. In order to utilize the geographic area for the intended purpose, accident locations were geocoded.

Figure 1. Winona Basemap.

Geocoding

The most critical element of this study involved accurately placing or geocoding accident locations based on the information received from the WPD. This presented a challenge for a number of reasons. At the time the data was acquired, the traffic accident program the WPD used could not be exported into a digital format, which would have saved an abundant amount of time. In addition, due the nature of the accident report database it did not offer details about specific accidents such as: time of the accident, weather conditions, age of the driver, or day of the week. In order to compile this information, each individual accident report would have to be reviewed independently. The information provided by the WPD included the following fields: AGENCY, ACCODE, LOC, and DREP. The AGENCY simply refers to the reporting agency, which in this case was the Winona Police Department. The ACCODE was the accident code, which refers to the type of accident such as, fatality (9410), personal injury (9420), and hit and run (9450). The LOC field was location, such as 10th and Hamilton. The DREP field indicated the date the accident was reported, for example, 20000511, which can be deciphered as May 11th, 2000.

The decision was made not to create a gecoding service due in large part to the constraints of the format the data was received in. Typically geocoding services are created to save time, but in this case the attribute table would have to be populated manually, thus time saved would not be much of a factor. Therefore each point representing an accident was placed manually and fields populated accordingly.

Data Format and Standardization

Upon completion of geocoding and the population of the attribute table in accordance with the WPD format, the need to redesign the schema of the attribute table for the purpose of executing queries became apparent. Several fields were added to increase the

ease of data analysis. A CLASS field was added to better enable an end user with lack of familiarity with accident codes to query. For instance, the letter A in the CLASS field equaled 9410, which represented a fatal accident. The DREP field was separated into three additional fields: MONTH, DAY, and YEAR. The creation of these fields will allow the data to be more powerful. In other words, the capability of querying four years of data to determine the highest accident volume by month or day offers insight that the current field did not offer. This was accomplished by performing several calculations to maneuver the data (Figure 2).

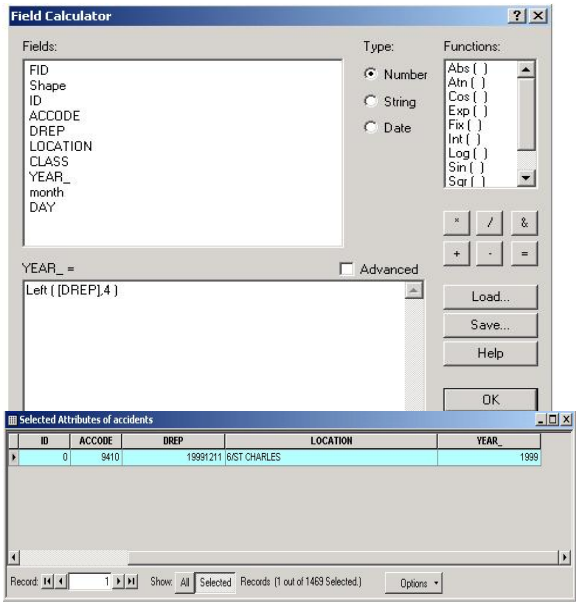

Figure 2. Calculation to achieve desired field.

Analysis

Manually geocoding traffic accident data provided early indications of trends in specific areas of Winona. Once the geocoding process was completed, the trends came to fruition visually. It was obvious that the downtown area, particularly intersections on Huff Street, were extremely vulnerable to traffic accidents in comparison to the rest of Winona. This makes sense because this is a major corridor between Wisconsin and Minnesota. Upon further visual inspection of the environment, the recognition that the location of these problematic areas relative to the location of Winona State University (WSU) may prove to be a factor. In order to test this new theory for validation, a new feature class layer was created based on the customer name field in the Winona parcel shapefile to represent WSU's location. The buffer function was then utilized to determine the number of accidents that occurred within a specified distance. The distance used in this scenario was 1,760 feet of WSU. Once the buffer was applied, a clip operation based on the buffer was executed; this allowed for the selection of all accidents within this buffer (Figure 3).

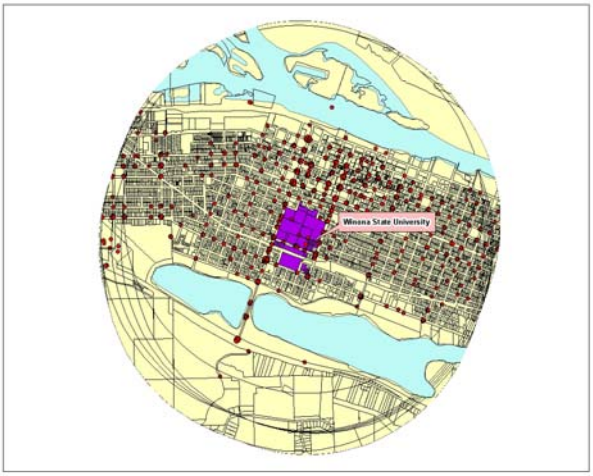

Figure 3. Buffer around WSU.

The result of this analysis proved to be worthwhile. Out of 1469 accidents occurring at intersections in Winona, 1102 or 75% occurred within the buffered distance of WSU. This evidence would suggest that there is

credibility to this theory, thus further analysis could be justified.

The next logical step involved determining which months had the highest number of overall accidents. This was a critical step in that most WSU students are not permanent residents of Winona, therefore there will be a significant decrease in the student population during winter break in December, spring break in March, and of course summer break in mid May-August. If the highest volume months coincide with WSU student breaks, this would suggest that the location of WSU is not a contributing factor in this study. In order to attain the monthly accident information, a general summarize operation was performed on the month field, which calculates the total number of accidents for each month (Figure 4).

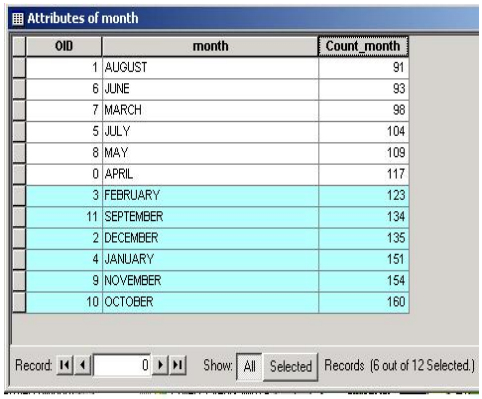

Figure 4. Total accidents by month.

The figure above indicates that five out of the six highest traffic accident months occur while WSU students are in session. It should be noted that December student break does not begin until mid-month, and over half or 54% of all accidents occurring in December occurred between December 1st and the 15th of the month (Figure 5 and 6). It could be argued based on the statistics for the first half of December that all highest traffic accident months occur while WSU students are in session.

The previous step required a few assumptions concerning student enrollment based on breaks during the course of the school year. It is important to understand that winter and spring breaks were approximate timelines and should be treated as such. However, these timetables are for the most part accurate, as these are standard breaks for most Universities. These assumptions

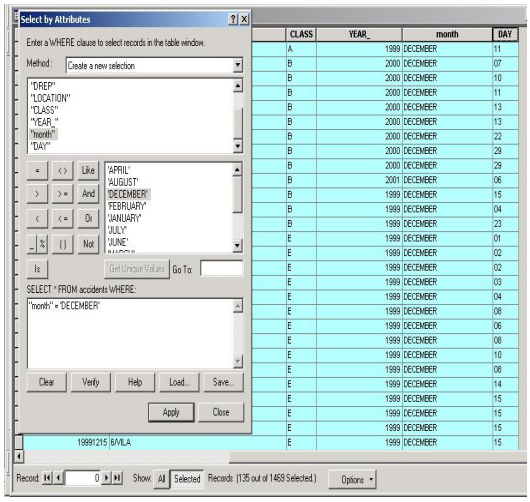

Figure 5. Total accidents in December

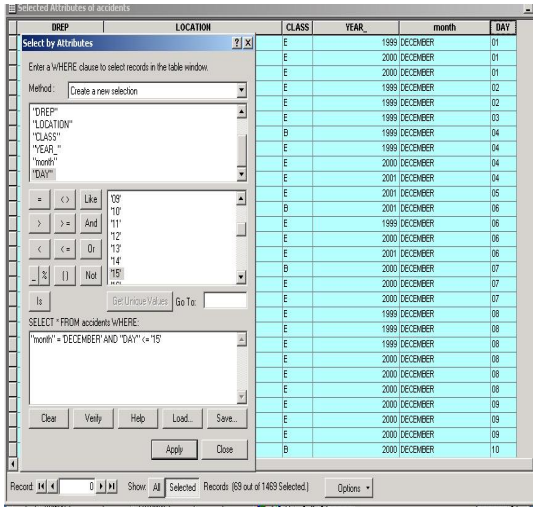

Figure 6. Total accidents December 1st – 15th

were made in order to show that a possible relationship exists between traffic accidents and the location of Winona State University.

In order to fully comprehend the decrease in student enrollment during specific times of the school year it would be advantageous to examine the student demographics for the corresponding years of this study 1999 – 2001. It was particularly important to look over the summer sessions in comparison to the fall and spring semesters. This gives a general understanding of how many students do actually leave Winona during the winter, spring, and summer breaks (Table 1).

Table 1. WSU student demographics.

Year	Fall/Spring Semester	Summer Session
1999	6,402	1,582
2000	6,736	1,615
2001	7,114	1,731

As shown above, there was a significant decline in attendance from the fall and spring semesters in comparison to the summer sessions. In 1999 there was a 75% decrease in enrollment, and in both 2000 and 2001 there was a 76% decrease in enrollment from the fall and spring semesters to the summer sessions (Winona State University, 2006). This is an important aspect of the analysis - knowing there is a substantial decline in WSU's student population over the course of the year, and that the highest accident months coincide with student sessions suggests there is a direct correlation between the location of WSU and the number of accidents occurring at intersections.

It is important to look at the distribution of WSU students that live off campus for a few reasons. WSU students who live off campus are more likely to have vehicles, they have a need to get to campus for class whether it is by car, foot, or bike, and they also have more of a need to get around town for work, groceries, etc. As a result, these off campus students are more likely to be contributors to traffic accidents than students living on campus. In order to gain a spatial perspective on the off campus distribution of these students, a join procedure based on the rental housing information and the parcel information acquired from the city of Winona was performed. Both datasets contained a parcel identification number (PIN), which allowed this operation to be accomplished successfully. A buffer of 1,760 feet was used once again to determine how many rental properties existed around WSU. This step offered a general idea as to the location of parcels that contain rental units, however it does not indicate a one to many relationship on that parcel. In other words, a PIN is assigned to a parcel, but that parcel could contain many units or apartments, which are rented, and owned by one individual. The only way a parcel is assigned more than one pin is if there is more than one owner on one parcel. For example, a condominium complex on one parcel may have multiple PIN numbers because there are multiple owners. This being stated, the City of Winona has not assigned a unique number to each rental property, which reflects that a one to many relationship exists. Instead it only has one PIN, which will reflect parcels as being rental properties, but it will not indicate if there is more than one

apartment on that parcel. Consequently, the total number of rental properties in Winona amounts to 1,396. Out of 1,396 1,155 fall that within 1,760 feet of WSU (Figure 7). According to Winona State's Institutional Research Department approximately 2800 students live on campus each year. This means in 1999 approximately 3,602 students lived off campus, in 2000 approximately 3,956 students lived off campus, and in 2001 approximately 4,314 students lived off campus.

The final aspect of this analysis was to obtain a general idea of how many vehicles are on campus during a given day while in session. This portion of the analysis proved to be difficult in that there is no information documented by WSU officials pertaining to student vehicles. Data in regard to parking permits that can be purchased by students was made available for the purposes of this study. According to WSU parking permit data, 1,286 parking spaces are available on any given day at WSU during the course of this study (Winona State University, 2005). There are three types of parking lots students can purchase permits for. The first type is the gold lots; 295 spaces are available for parking, and they are oversold by 10%, bringing the total permits to 325. The second type of parking lots is the purple lots, which can accommodate 259 vehicles; these permits are oversold by 40%, bringing the total permits available to 363. The last type of parking lot, and the primary lots used by students are the silver parking lots, which can hold a total of 512 vehicles; these spaces are oversold by 10%, bringing the total permits to 563. In addition to permit parking there are overflow lots, which amount to 120 spaces, metered spaces which total 50 available spaces, and handicap spaces that include 50 spaces. The total permits sold along with the other spaces available bring the total to 1,471 (Figure 8). The parking data gives a broad idea of the number of vehicles on campus each day. This was

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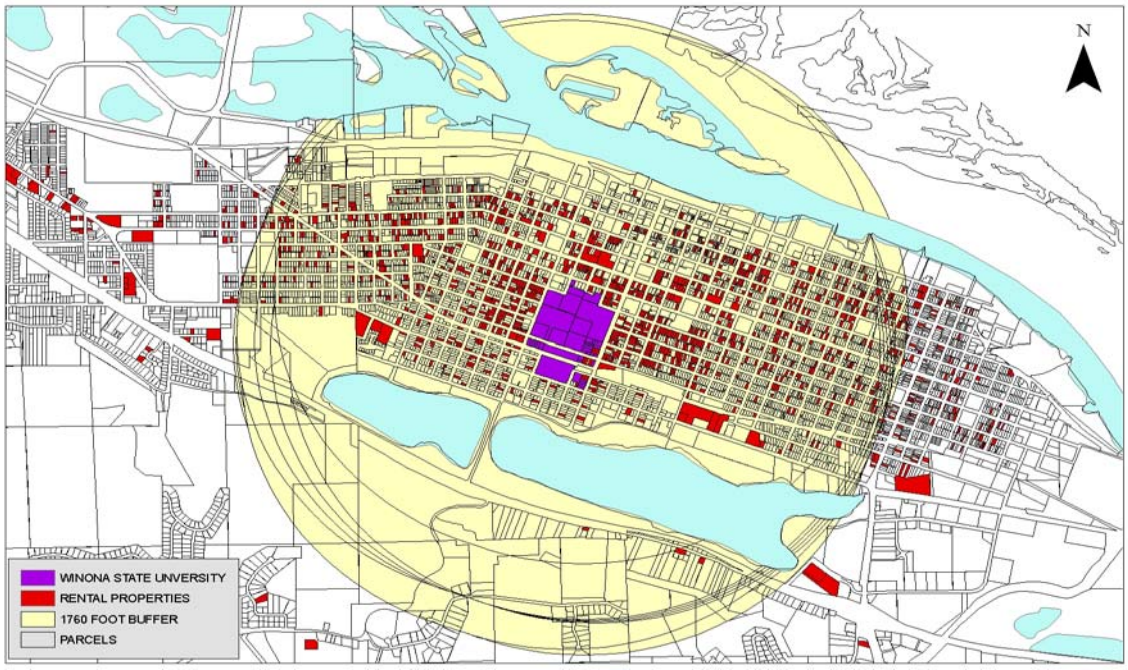

Figure 7. Rental properties within 1760 feet of WSU.

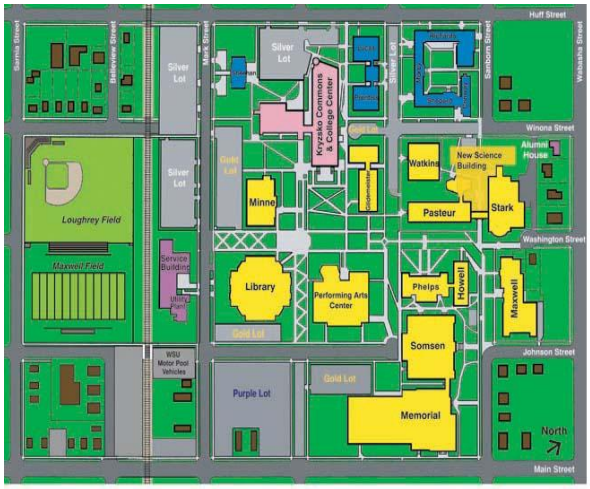

Figure 8. WSU campus parking map.

extremely difficult to measure accurately due to the variables involved. For example, there is street parking available near campus that is not controlled by WSU, parking permits are only enforced until 6 PM, which makes students taking night classes unaccounted for. Regardless, it can be assumed that there are over 1,200 vehicles each weekday added to the regular traffic mix in Winona.

Results & Discussion

The problematic intersections in Winona were identified. A key element within the environment was determined as being a factor in these intersection crashes. In addition, several potential factors were investigated in order to establish credibility to this study, which included:

- Months WSU students are in session coupled with the highest accident months.
- Student demographics from 1999-2001.
- Student housing locations relative to the WSU campus.
- The general number of vehicles on campus everyday.

The areas analyzed suggest that this theory is valid. The mere fact that five out of the six highest crash months occur while WSU students are in session, and drops off in the summertime was detrimental in proving this theory. The concentration of rental properties, student demographics, and the total number of vehicles were instrumental in providing additional support of this theory.

The use of a GIS proved to be a critical tool in analyzing this data. The core features allowed for a visual illustration of multiple layers of data at once, which allowed for identification of spatial relationships. That data was then manipulated through various means of built in functionality. The many different types of operations performed in this analysis, i.e. buffer, join, and clip operations offered the ability to tell a story that paper never could, this adds a whole new level of sophistication to traffic crash analysis. A GIS is only as good as the data, and in this project that data was made useful through the flexibility of a GIS.

Conclusion and Recommendations

Anytime one has an influx of people into an area, the probability of traffic accidents is likely to increase by default. Winona, Minnesota as of the 2000 census had a population of 27,069 people, plus the addition of 6,000 to 7,000 Winona State students every fall. Winona, is eighteen square miles, this is a relatively small area to sustain this margin of increase per year.

A cause in the environment has

been pinpointed as a contributing factor to intersection crashes in Winona. The next step would be to take this data to the City of Winona's traffic engineer, police department, as well as their GIS Analyst. These individuals together could conduct more analysis on the data that is meaningful to their purposes. This data may perhaps be used to designate a formal traffic study to establish the best possible countermeasures available to thwart the existing problems. At some point officials at Winona State University would have to be involved. One thing WSU could consider might be to restrict incoming freshmen from having cars. This would help eliminate some of the congestion around campus. This practice has been adopted by many universities throughout the country, including the University of Wisconsin.

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References

Federal Highway Administration. 2006. Retrieved June 22, 2006 from http://www.fhwa.ddot.gov/crt/lifecycle roundabouts.cfm.

U.S. Census Bureau, United States Department of Commerce. 2000. Retrieved December 1, 2002 from http://www.census.gov/..

Winona State University. 2006. Student population demographics gained Institutional Research Department.

Winona State University. 2005. Winona State University campus parking permit information.