

Development of a GIS-based Traffic Safety Analysis System

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Abstract

Traffic safety analyses have historically been used by transportation officials as a means to reduce the impact of traffic crashes on roadways. This paper summarizes the methodology to develop a traffic safety analysis system – one that integrates crash data and roadway related information in a Geographic Information System (GIS) environment. The system includes customized user interfaces to support queries and capabilities to export results. These analyses may be performed either area wide or for individual locations such as intersections and roadway segments. The system further offers capabilities to query crash data based on attributes from the database. The system also contains a module to identify high crash locations based on methods identified from the published literature. The methods range from those based on simple crash frequency to more complex methods which incorporate different weights for crashed based on the crash outcomes. The system can be used to identify safety issues in a region, and to plan and deploy appropriate countermeasures to enhance safety. An application of the system is illustrated using data from the Las Vegas metropolitan area in the state of Nevada. ESRI's ArcGIS (version 9.2)^[1] was the software used to develop the system.

Introduction

Over the past decade, traffic crashes have resulted in more than 42,000 fatalities annually in the United States ^[2]. Analyses of relevant data are essential to develop strategies to improve road safety. However, data required for such analyses often come from multiple sources, in varied formats, with various levels of accuracy and reliability. Computerized tools and systems offer great potential to combine such data and to perform the required analyses. Due to the spatial nature of disparate datasets needed for transportation safety analysis, the GIS platform would be a good option to integrate them.

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Kumaresan provides additional information on the system development ^[3]. Further, the GIS platform offers a natural environment for development of a safety analysis system using the consolidated database due to its data integration and mapping capabilities. The advantage of viewing data in spatial format is perhaps a very important benefit of using GIS. Specifically, ESRI's ArcGIS (version 9.2) offers several advantages in this regard. Besides the technical capabilities offered, this was also the software used by agencies in the Las Vegas metropolitan area – the area used to demonstrate the implementation of the system. Thus, it was chosen as the environment to develop the system presented in this paper.

Objective

The objective of this paper is to describe the development of a safety analysis system. Examples from the Las Vegas Metropolitan area are used to illustrate the capabilities of the system developed.

Methodology and System Development

Advantages of using GIS

Motor vehicle crash data for metropolitan regions are typically collected and maintained by several agencies such as federal, state, local agencies and law enforcement agencies. Therefore, there likely are significant differences in their formats and in different data structures. In order to integrate crash data with other relevant information like roadway data, GIS provides an environment to facilitate data integration, analysis ^[4] and display of results. The use of GIS also extends the level of analyses to perform spatial analyses and grid-cell modeling ^[5]. More detailed commentary on the rationale for this approach is included in a report that forms the basis of this paper ^[6].

Data Assimilation

The initial step in the development of an analysis system is to identify the data required to support the desired analyses and the format in which they are available. Data assimilated included crash data for the time period 2002 to 2006 from the Nevada Department of Transportation and roadway network (street centerline) information from the Clark County GIS Management Office (GISMO) ^[7]. The crash database contains crash characteristics such as vehicle related, roadway related, crash related and person related details shown as points on a map ^[8]. One of the issues related to data assimilation in this research was the compatibility of both the data sets after incorporating them in a GIS environment.

System Architecture and Design

The system is intended to support performing safety analyses in terms of querying crash data and ranking of high crash locations. The analyses can be broadly classified into micro and macro levels of examination. Macro level analyses involve analyses on a larger spatial scale such as a city, while micro analyses focus at a smaller spatial extent such as an intersection or roadway segment. As for output, the system was required to support representation of the results in a form that would be acceptable for most users. Furthermore, the software and hardware requirements were to be easily available to the users. ESRI's ArcGIS software version 9.2 was used to develop the safety analysis

system. Its in-built VBA application was the programming environment used to develop the various analysis tools and operations. Microsoft Excel was also used for displaying the analysis results in tabular format. Another type of output possible using the ArcGIS software was to display the results graphically on the map window.

System Development

The safety analysis system was developed for the crash data as a whole and another section was dedicated solely to bicycle and pedestrian crashes for those users who wished to look at improvements to those particular categories of road users. The development of the entire safety analysis system can be described in two parts: 1) the crash data analysis system; and 2) the high crash ranking analysis system for various locations. Figure 1a describes the basic structure of the crash analysis tool and 1b describes the subdivisions under the multiple query option.

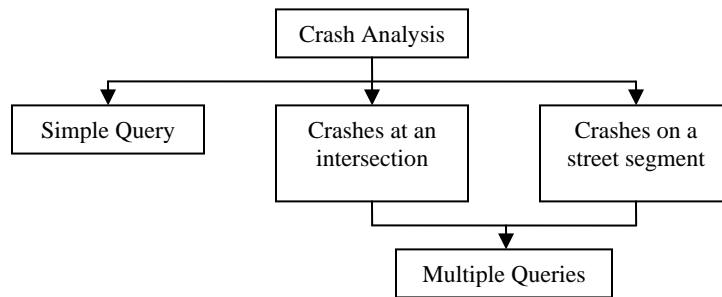


Figure 1a. Basic structure of Crash Analysis Tool

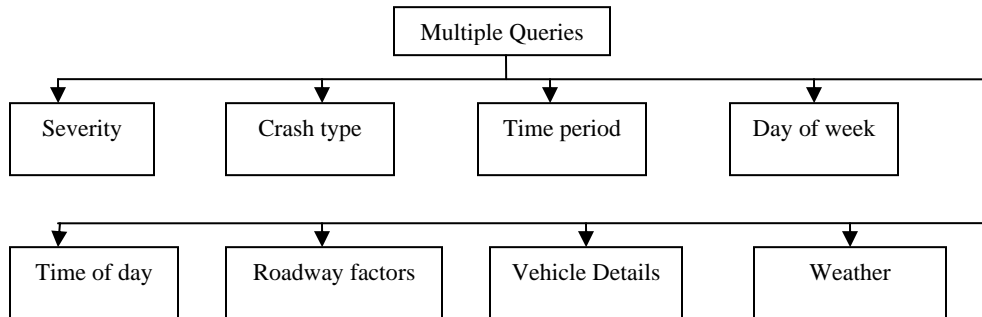


Figure 2b. Multiple Query-related data

The system provided the user with options to query for crash data on a macro (areawide) level or on micro (location-specific) level. After deciding on the type of query the system listed the options that could be included in querying the crash data pertaining to the specific location. Most of the attributes listed in the crash database such as severity, crash type, day of week, time of day etc. could be included in developing a query.

- (a) *Simple Search* - This is the basic search option that is provided to the user to perform a quick search of the crash data for any criterion that the database supported on a macro or area wide level. The user entry in this section is restricted to three entries.
- (b) *Crashes at an Intersection* - The main objective of the intersection level analysis option is to analyze safety aspects at an intersection location. The data entry section

involved the entry of the names of the cross streets and the buffer distance to be considered around the intersection.

- (c) *Crashes on a Street Segment* - The third option for crash analysis is based on identifying street segments. This option permits evaluation of long segment of a street comprised of several smaller sections or just one section. The data entry for the street segment analyses required the choice of the names of the main street as well as the cross streets between which the main street segment was to be located.
- (d) *Multiple query criteria* - Based on the selected intersection or street segment, the system provides the user an interface to build a query based on various user defined criteria using data fields from the crash database. The user options to select the criteria for the multiple query analysis are placed on four tabs in four broad categories as follows: date & time, crash characteristics, vehicle characteristics, and road characteristics.
- (e) *High Crash Ranking* – The system facilitates the identification of high crash locations based on total crashes and weighted ranking ^[9]. The methodology that was followed for identification of high crash ranking was (1) simple crash frequency procedure – assigning ranks based on the total number of crashes in that particular location and (2) weighted ranking procedure – assigning ranks based on weights specified for different levels of severity – fatal, injury or PDO.

Case Study: Las Vegas Metropolitan area

The various analyses tools listed in the methodology section have been illustrated using examples from the Las Vegas metropolitan area in the case study section.

(a) *Simple Search* – In order to illustrate this Simple Search option, the following sample query statement (broken down into three parts) is shown:

- First Criterion: Crash type – Angle, and
- Second Criterion: Severity – Injury, and
- Third Criterion: Year – 2005

Figure 2. Final appearance of sample query in Simple Search window

The first step for a user to perform this sample query was to click on the 'First Criterion' combo-box (Figure 2a). Upon doing so, the list with all possible data fields would be displayed. Next, the user would choose 'Crash Type' from the list displayed. This was to set the first criterion to crash type being angle. After choosing 'Crash Type' as the data field to be queried on, the user had to click on the 'Load unique values' button as shown in Figure 2b. This would activate the program to load all the available data entries for the data field 'Crash Type' that could be found by the system in the crash database. The values would be loaded on to the combo-box beside the 'Load unique values' button shown in Figure 2c. The next step was for the user to choose 'Angle' from the list that could be viewed on clicking the combo-box's drop down button. Thus, the first criterion is to set to crash type to "angle." Next, the connection between the first and second statement was to be mentioned. The relationship between the first and second criteria could be specified in the box shown in Figure 2d). The operators available for use are: 'And' and 'Or', and they would be displayed on clicking the down arrow button next to the box. For this example, the use of the 'And' operator was required. After choosing 'And' as the operator, the user could move on to select the second criterion.

The same procedure of selection of criteria had to be followed for criteria two and three also. The final appearance of the screen after data entry is shown in Figure 2. The results for this query are shown in Figure 3 (zoomed in for clarity).

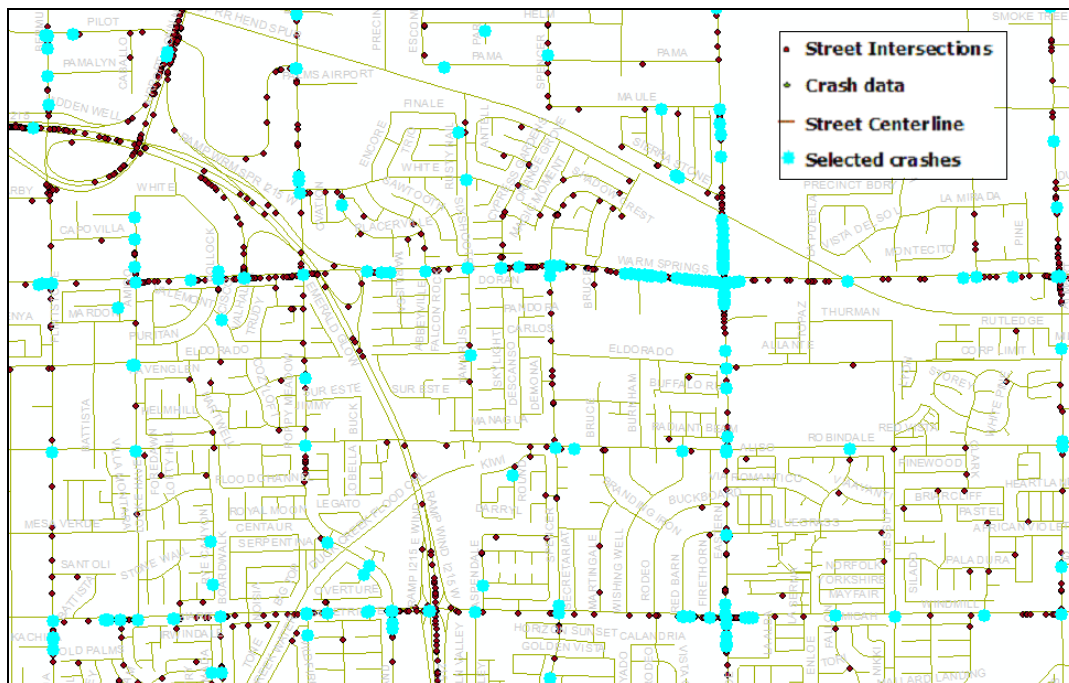


Figure 3. Results of the query: Angle crashes that caused injuries in 2005

(b) *Crashes at an intersection* - In the first step, the user had to choose the names of the intersecting streets. Clicking the button shown in Figure 4(a) resulted in the streets names of Las Vegas area from the Street Centerline database being loaded on to the combo-box labeled 'Choose the First Street.' For example, for the Maryland-Flamingo intersection, the user selected 'Maryland' for the 1st street and 'Flamingo' for the 2nd

street or vice versa. The next step was to enter the buffer distance into the textbox titled 'Input the Buffer Distance' (Figure 4b) and specify the unit (Figure 4c.) For illustration purposes, the buffer distance was chosen as 250 and the unit for this distance was chosen as 'feet.'

Figure 4. Appearance of intersection crash query window

Clicking the 'Search' button would prompt the system to check for the existence of the specified intersection location and then performance of the sequence of operations to extract crashes that occurred around the intersection. The output for the sample query that was run with the data entry as given in the previous figure is shown in Figure 5.

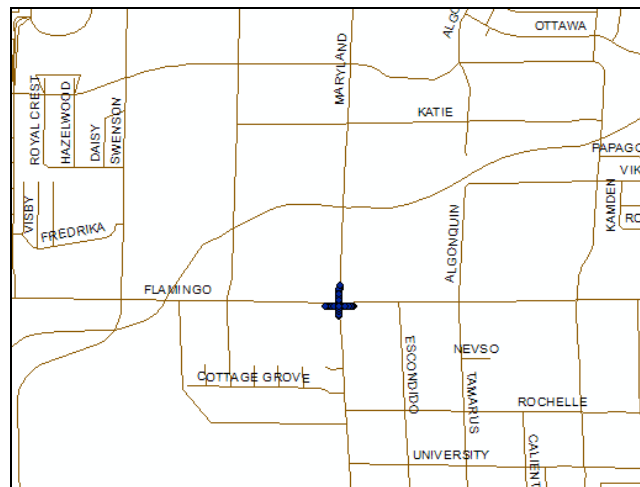


Figure 5. Results: Crashes at Maryland Pkwy – Flamingo Rd for a 250 foot radius

Note – There exists a minimal offset of the crash data from the street centerline database owing to the fact that the crashes were geocoded to the street system while creating the database whereas the line represents the centerline of the street and the offset corresponds to the original geocoding process.

- (c) *Crashes on a street segment* - In order to illustrate the operation extraction of crashes that occurred on a street segment, the segment of Maryland Parkway between Flamingo Road

and Tropicana Avenue is shown. The data entry for this example is shown in Figure 6 and the results are shown in Figure 7.

Figure 6. Crashes on a street segment window

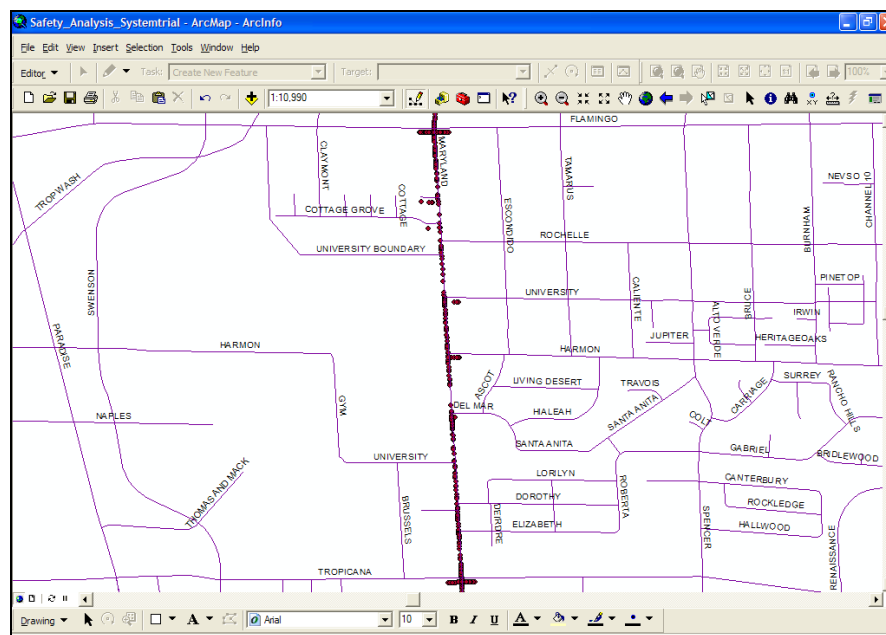


Figure 7. Results of crashes on Maryland Pkwy between Flamingo and Tropicana

- (d) *Multiple Query Criteria* - After either of the two above-mentioned tools – location of crashes at an intersection or on a street segment is performed; the multiple query criteria window pops open to enable the user to include a variety of criteria in his/her query statement. For previously run street segment query example, the multiple query window

is shown in Figure 8. The various crash characteristics are grouped under the 4 tabs highlighted in Figure 8a: Date/Time, Crash, Vehicle, Road details. Sample results for the query and export options would be as shown in Figure 10a shapefile and 10b table.

Figure 8. Multiple Query Criteria screen

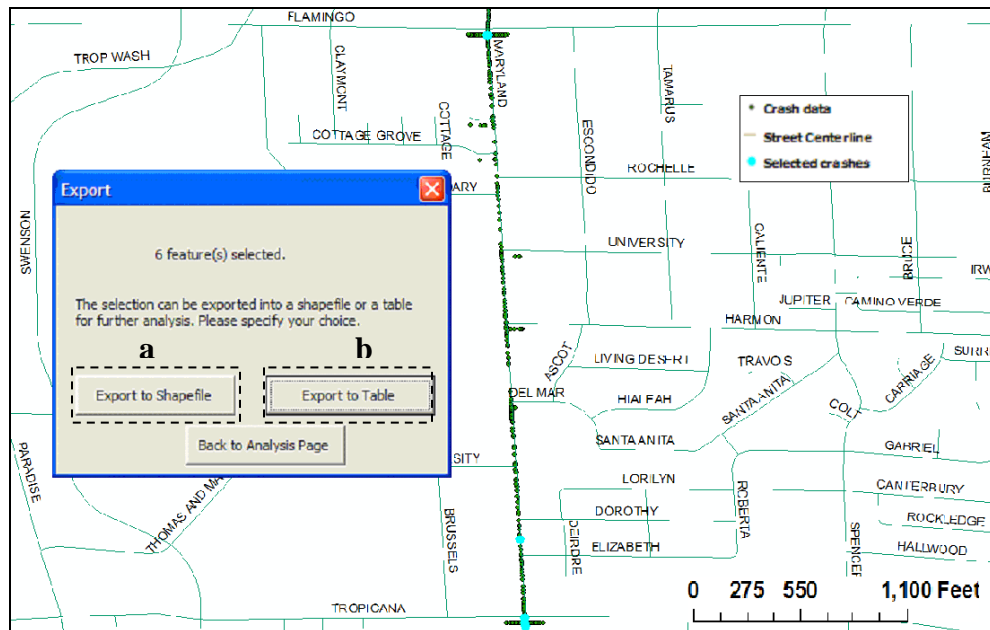


Figure 9. Results of Multiple query criteria

At this point the system allows the user to either export the results as a shapefile (Figure 10a) or as a spreadsheet table (Figure 10b).

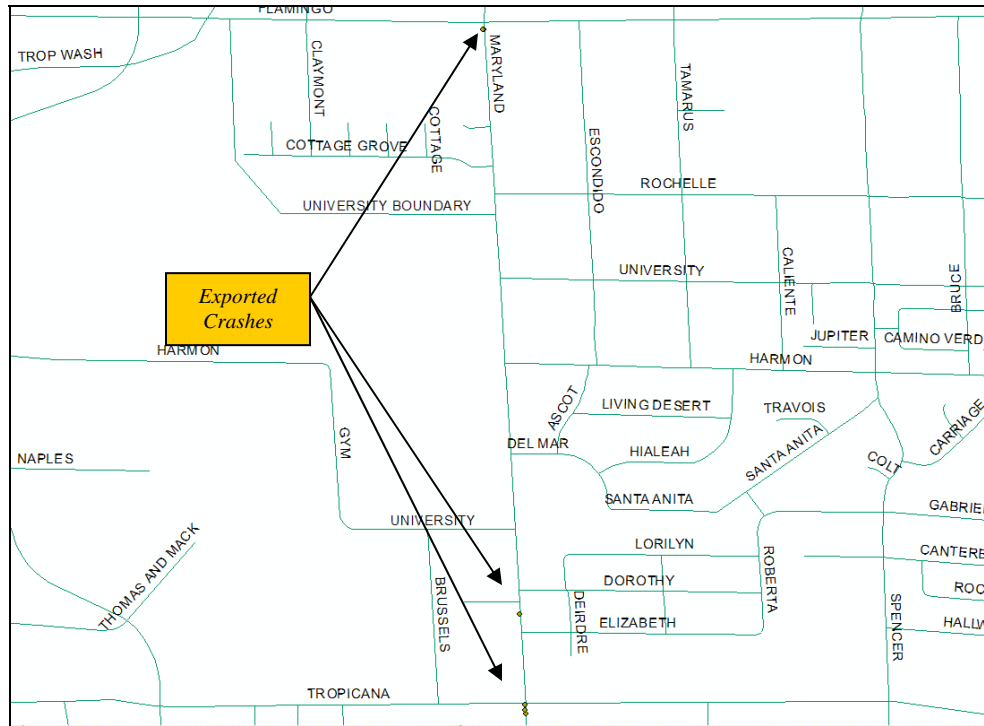


Figure 10a. Results of exported shapefile

AccidentID	County	CollisionD	CollisionT	PrimaryRoa	Distance	Direction	SecondaryR
030830-2101	CLARK	8/30/2003	8/30/2003	FLAMINGO RD	25.00	West	MARYLAND PKWY
273529	CLARK	4/6/2003	4/6/2003	TROPICANA AVE	0.00		MARYLAND PARKWAY
273530	CLARK	4/6/2003	4/6/2003	TROPICANA AVE	185.00	E	MARYLAND PARKWAY
273670	CLARK	3/28/2003	3/28/2003	MARYLAND PARKWAY	150.00	W	FLAMINGO RD
LVMPD-030108-0766	CLARK	1/8/2003	1/8/2003	MARYLAND	30.00	North	TROPICANA

Figure 10b. Query results exported to Microsoft Excel document

(e) *Identification of High Crash Ranks* - For the crash frequency procedure, assuming that the user wished to rank the locations in Las Vegas area based on the total number of crashes that occurred at each location in the year 2004 for a buffer distance of 200 feet around the intersection, the High Crash Ranking feature shown in Figure 11a had to be used. After clicking the High Crash Location button, the ranking would be performed by the system. The resulting ranks obtained for the year 2004 and buffer size 200 feet are shown in Figure 15. If the user wishes to make use of the option to include weights while ranking the locations, the feature shown in Figure 11b had to be used. In order to illustrate this feature, assuming the user wished to append weights for severity to the previously mentioned query year and buffer distance, fatal being 10, injury being 5 and PDO being 2, clicking the 'Weighted Ranking' button triggered the system to calculate the sum of weights. The results obtained for the specified weights of severity levels having been incorporated in the ranking procedure, are shown in Figure 12.

High Crash Ranking

High Crash Location

Year

Buffer feet

Weighted Ranking

Year

Buffer feet

Crash Severity	Weight
Fatal	10
Injury	5
PDO	2

High Crash Location

Weighted Ranking

Figure 11. High Crash Ranking screen

Attributes of 200buf04year

FID	Shape	STRNAME1	STRTYPE1	STRNAME2	STRTYPE2	TOTALCRASH	FATAL	INJURY	PDO	RANK
73	Point	15		RAMP N I1		227	0	68	159	1
850	Point	PARADISE	RD	TROPICANA	AV	118	0	40	77	2
803	Point	95		RAMP N US		111	0	31	80	3
1397	Point	LAS VEGAS	BLVD	TROPICANA	AV	110	0	27	82	4
1318	Point	KOVAL	LA	TROPICANA	AV	102	0	33	68	5
153	Point	CHEYENNE	AV	LOSEE	RD	101	0	21	80	6
40	Point	215		RAMP S US		99	0	23	76	7
76	Point	15		RAMP S I1		98	1	24	72	8
1296	Point	FLAMINGO	RD	MARYLAND	PKWY	92	0	34	58	9
4	Point	GREEN VAL	PKWY	WARM SPRI	RD	90	0	25	65	10
137	Point	CARROLL	ST	LAKE MEAD	BLVD	88	0	16	72	11
1367	Point	FLAMINGO	RD	FLAMINGO	RD	88	0	23	65	12
1337	Point	LAS VEGAS	BLVD	SAHARA	AV	82	0	27	55	13
1440	Point	HARMON	AV	LAS VEGAS	BLVD	80	0	35	44	14
923	Point	CHARLESTO	BLVD	NELLIS	BLVD	77	0	25	52	15
1465	Point	FLAMINGO	RD	VALLEY VI	BLVD	74	0	28	46	16
1581	Point	FLAMINGO	RD	PARADISE	RD	74	0	28	46	17
220	Point	15		LAKE MEAD	BLVD	73	0	20	53	18
85	Point	15		CHARLESTO	BLVD	72	0	22	50	19
239	Point	MARKS	ST	SUNSET	RD	72	0	22	50	20

Record: 0 Show: All Selected Records (of 6303) Options

Figure 12. High Crash Ranking for the year 2004 and buffer size 200 feet

Attributes of 200buf04year

FID	Shape	STRNAME1	STRTYPE1	STRNAME2	STRTYPE2	FATAL	INJURY	PDO	WeightSum	WtRank
73	Point	15		RAMP N I1		0	68	159	658	1
850	Point	PARADISE	RD	TROPICANA	AV	0	40	77	354	2
803	Point	95		RAMP N US		0	31	80	315	3
1318	Point	KOVAL	LA	TROPICANA	AV	0	33	68	301	4
1397	Point	LAS VEGAS	BLVD	TROPICANA	AV	0	27	82	299	5
1296	Point	FLAMINGO	RD	MARYLAND	PKWY	0	34	58	286	6
76	Point	15		RAMP S I1		1	24	72	274	7
40	Point	215		RAMP S US		0	23	76	267	8
153	Point	CHEYENNE	AV	LOSEE	RD	0	21	80	265	9
1440	Point	HARMON	AV	LAS VEGAS	BLVD	0	35	44	263	10
4	Point	GREEN VAL	PKWY	WARM SPRI	RD	0	25	65	255	11
1337	Point	LAS VEGAS	BLVD	SAHARA	AV	0	27	55	245	12
1367	Point	FLAMINGO	RD	FLAMINGO	RD	0	23	65	245	13
1320	Point	RAINBOW	BLVD	SAHARA	AV	0	36	30	240	14
1329	Point	DECATUR	BLVD	FLAMINGO	RD	1	28	41	232	15
1465	Point	FLAMINGO	RD	VALLEY VI	BLVD	0	28	46	232	16
1581	Point	FLAMINGO	RD	PARADISE	RD	0	28	46	232	17
923	Point	CHARLESTO	BLVD	NELLIS	BLVD	0	25	52	229	18
1292	Point	CHARLESTO	BLVD	LAMB	BLVD	1	27	41	227	19
137	Point	CARROLL	ST	LAKE MEAD	BLVD	0	16	72	224	20

Record: 0 Show: All Selected Records (of 6303) Options

Figure 13. Ranking Results: Weights for Severity – 10, 5 and 2

Issues and Errors

The Safety Analysis System was developed using ArcGIS 9.2. However, after completion of the project, ESRI released ArcGIS 9.3. When tried to use the tool in the new version, error messages ‘Can’t find project or library’ were shown. This issue was fixed by changing settings in the Tools -> References and unchecking the missing reference.

Conclusions and Recommendations

The main objective of this research was to develop a tool to perform traffic safety analyses using user-friendly interfaces to analyze data and display the results in graphical/tabular format. The system was developed in a GIS environment using ArcGIS version 9.2 software. Such a system could be used to identify safety issues in an area. It could also be used to monitor traffic safety programs and their effectiveness. The safety analysis system thus developed was able to perform crash analysis at a specific location in a detailed manner as well as rank locations based on number of crashes.

- The safety analysis system helps evaluate safety concerns on roadways in an area or at specific locations.
- The High Crash Ranking tool can be used to assign ranks to locations based on the total number of crashes that occurred around it.
- Key advantages of the safety analysis system include its ability to integrate various formats of data and obtain results based on queries, and to display results as maps.
- The safety analysis system can be used to perform before and after studies to determine the effectiveness of a transportation safety program. Also, the user interface helps users who are not familiar with GIS functionalities to make use of the developed analysis tools.

Some of the recommendations of the study are:

- From the crash database, it was found that the records contained numerous misspelled entries. Since the querying of data depended entirely on the individual entries in the database, addressing all possible spellings of a particular factor could not be achieved entirely. Creation of a reliable crash database would help to improve the accuracy of the results obtained by using the various analysis tools.
- Use of information technology by means of handheld/PDA type devices while recording crash reports would help in minimizing data inconsistencies and misspells in addition to the time saved in manual inclusion of each report into the crash database.
- Incorporation of other traffic-related information such as traffic volumes/mix, traffic control and operational information, roadway-related information in evaluating traffic safety would help in improving the analyses possible. For example, computation of crash rates such as the crashes per million entering vehicles at an intersection would provide a measure for ranking crashes.

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