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CRASH DATA ANALYSIS AND ENGINEERING SOLUTIONS FOR LOCAL AGENCIES

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16. Abstract <p>This report introduces the development process of an Internet-based, GIS-compatible software tool for Illinois local road crash analysis. This state-of-the-art tool is capable of performing crash information query, trend analysis, statistical analysis, color-coded mapping, and other safety information display within the web-based GIS compatible environment. The Internet-accessible user interface allows users to inquire about detailed information on vehicle crashes associated with road segments and intersections for any geographical regions or jurisdictions in the state of Illinois via query forms or zoom-enabled interactive maps. In addition, users can specify a data aggregation type, time range, and information type to display crash information in formats of tables, charts, or maps. This system helps the state and local transportation agencies in Illinois to screen dangerous highway segments, diagnose safety performance of the selected roads, and identify the most cost-effective countermeasures for safety improvements.</p> <p>This report addresses three major technical issues of the system design: (1) system architecture design and software development technologies, (2) supportive databases and data structure, and (3) user interfaces and system functionality. The report introduces system architecture and background components with used technologies for the full-scale implementation. In addition, descriptions on required datasets, their structures, and data-related issues are presented to explain the characteristics of databases. The system functionality section introduces functional definitions and explains the development purposes of all modules in the system. The report also explains how to utilize each module and provide required inputs for online crash data query and the decision support process based on web-based GIS applications.</p>					
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EXECUTIVE SUMMARY

This report introduces the development process of an Internet-based, GIS-compatible software tool for Illinois local road crash analysis. This state-of-the-art tool is capable of performing crash information query, trend analysis, statistical analysis, color-coded mapping, and other safety information display within the web-based GIS compatible environment. The Internet-accessible user interface allows users to inquire detailed information on vehicle crashes associated with road segments and intersections for any geographical regions or jurisdictions in the state of Illinois via query forms or zoom-enabled interactive maps. In addition, users can specify a data aggregation type, time range, and information type to display crash information in formats of tables, charts, or maps. This system helps the state and local transportation agencies in Illinois to screen dangerous highway segments, diagnose safety performance of the selected roads, and identify the most cost-effective countermeasures for safety improvements.

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DISCLAIMER

The contents of this report reflect the view of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Illinois Center for Transportation, the Illinois Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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CHAPTER 1 INTRODUCTION

In 2007, more than 400,000 vehicle crashes occurred in the state of Illinois, causing 1,248 fatalities and 103,156 injuries (DTS, 2007). This translates to three people killed per day and 12 persons injured each hour, on average, leading to a total estimated \$11.5 billion cost from traffic crashes. Half of these crashes occur on local roads. Though the number of crashes in Illinois has decreased steadily in recent years, traffic crashes still pose a huge threat to the social welfare.

Illinois has set a goal to reduce fatalities and severe injuries on Illinois roads. Diagnostic analysis of crash data is indispensable for government agencies to take measures to reduce vehicle crashes, especially those involving fatalities and severe injuries. In the United States, the state agencies typically have multiple years of centrally archived crash data in either SQL or GIS formats. However, provision of such crash data and safety information to safety engineers for their effective utilization turns out to be a big challenge; in order to develop highway safety programs and engineering solutions, professional knowledge and analysis skills from extensive training are normally required. Due to lack of systematic data access and qualified staff, local government agencies sometimes have difficulties in selecting appropriate safety improvement countermeasures for roadway sites in their jurisdictions.

In view of the need for an integrated crash data analysis and decision support system, the Illinois Department of Transportation (IDOT) has collaborated with the University of Illinois at Urbana-Champaign (UIUC) and the Illinois Institute of Technology (IIT), through the Illinois Center for Transportation (ICT) to build a full-service safety program that provides an Internet-based, GIS-compatible software tool for vehicle crash analysis in Illinois. This system includes both information provision and decision support functionalities. First, it allows dynamic queries that retrieve customized crash information (regarding user-specified geographical region, jurisdiction and time frame) through web-based graphical interfaces (query forms or zoom-enabled interactive maps) in real-time. Beyond that, the decision-support capability of the system helps screen roadway locations within any specified jurisdictions so that hazardous sites in the network will be identified. The system will also diagnose safety concerns at any selected sites and recommend site-specific countermeasures based on benefit-cost analysis. Overall, the system advances the state-of-the-art by the following features: (1) web-based user access; (2) integrated GIS application to safety analysis; (3) implementation of various advanced safety research concepts. Through this decision-support process, local agencies can evaluate current safety conditions more effectively and utilize available safety funds economically to reduce fatalities and severe injuries.

In cooperation with IDOT, the UIUC research team takes up the responsibility to design all functionalities of the system, build spatial and non-spatial databases, set up the web server, and develop programming codes. The *DataMart* team of IDOT prepares crash data in formats of GIS shape files and SQL tables as well as roadway data to be properly loaded into system databases. The IIT team provides safety improvement countermeasures, crash reduction factor (CRF) values, solution selection criteria, and other technical support to the project.

This final report supplements previous progress reports that are provided by UIUC and IIT research teams and summarizes the development efforts for the web-based GIS tool. The remainder of this report is organized as follows. A section on system design and data preparation follows this introduction. This section mainly discusses system architecture and development environment, including system structures, background system components, data-related issues, and their technological challenges. The subsequent two sections discuss the functions of the developed system and recommendations on maintenance and security issues. The last section includes several appendices with supplementary information.

CHAPTER 2 SYSTEM DESIGN AND DATA PREPARATION

2.1. SYSTEM STRUCTURE

To support the variety of functionalities, the web-based GIS software system consists of three major components: (1) Web user interfaces, (2) Web server (Web application server), and (3) databases (spatial and non-spatial databases). The relationships and information flows among these components are depicted in Figure 1.

The system needs to access both spatial and non-spatial databases (on crash information and roadway geometry information) directly from the IDOT database systems; 1) a spatial database that contains information on crash locations, roadway network, and jurisdiction boundaries, and 2) a non-spatial database that contains detailed crash information. The Web user interfaces allow users to create queries and view results. Upon receiving user inputs through the interfaces, the system dynamically retrieves information from the server databases, and sends processed outputs back to the interfaces for display. The Web application server supports the core functionality of the system. It generates SQL (structured query language) queries according to the user's inputs and sends the queries to databases. Then, the application server generates tables, charts, and maps based on retrieved data from the databases. The technologies used for the implementation of the system are shown in Table 1.

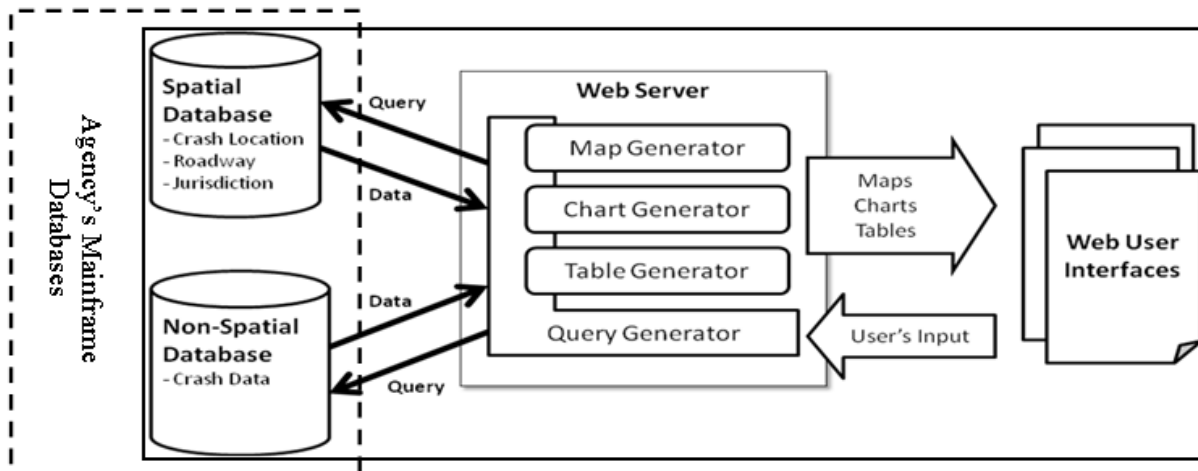


Figure 1. System architecture.

Table 1. System Development Environment and Technologies

Category	Technology
Web application framework	ASP.NET 2.0
Web server	IIS 6.0 (MS Windows Server 2003)
Database	MS SQL 2005
Spatial Database Management	ArcSDE 9.2
Web Mapping	ArcGIS Server 9.2
Charting	ZedGraph ¹

¹ <http://zedgraph.org>

2.1.1. Databases

The spatial database contains crash locations, roadway network, and jurisdiction boundaries; the non-spatial database includes detailed crash information such as crash occurrence date and time, fatality and injury, environmental conditions, severity, etc. In addition, the system has several tables that contain system parameters necessary for the network screening, countermeasure recommendation, and economic appraisal processes.

Spatial Database

The spatial database is in an ESRI geodatabase (ArcSDE on MS SQL 2005) format. The database contains three major feature classes: crash locations, roadway network, and jurisdiction boundaries. The feature class of crash locations contains only the point geometry as crash locations with crash ID numbers. Detailed crash information is not included in this dataset. The feature class of roadway network is a poly-line with attributes such as road name, route number, jurisdiction name, traffic volume (AADT), roadway functional class, number of lanes, etc. The feature class of jurisdiction boundaries is a polygon with attributes such as county name, area, population. All these datasets are stored and indexed in the spatially-enabled database in order to serve queries from the Web user interfaces (Worboys and Duckham 2004).

Non-Spatial Database

The non-spatial database is in the MS SQL 2005 database format. This database contains two SQL tables: a detailed crash information table and a vehicle involvement information table. The former table includes crash ID, crash location (jurisdiction and road name), crash causal factor, collision type, crash severity, number of fatalities and injuries, road surface condition, weather condition, light condition, crash date, etc. The latter table includes crash ID, vehicle type, maneuver, direction, etc.

2.1.2. Web User Interfaces

The web user interfaces are the place that users create their queries and receive the results. They are dynamically generated depending on users' input. For example, if a user selects a certain county, the system will generate the list of road functionality classes that are available in the county selected by the user. Detailed user interfaces will be discussed in later sections.

2.1.3. Web Application Server

The Web application server is developed based on ASP.NET 2.0 and IIS 6.0 (MS Windows Server 2003). It contains the following information generators.

Query Generator

Generally, the user's input from the web interfaces is dynamic. Hence, the queries from the web servers to the databases should also be generated dynamically. The output of the query generator feeds into the table, chart and map generators.

Sometimes, the query generator needs to retrieve detailed crash information (from the non-spatial database) and crash location information (from the spatial database). Currently, in IDOT, the Traffic Safety Division maintains the non-spatial crash database and the Bureau of Information Processing maintains the GIS roadway network database. Such separate database structure precludes the application of the "join" SQL command, which is widely used to integrate information in relational databases. In this application, the crash ID number is utilized as the unique identification for each crash. In other words, one row in SQL crash information table corresponds to one crash point on the GIS crash location map, and both datasets have this

crash ID information in common. If a user builds a query based on SQL crash information table, the system retrieves crash ID numbers of SQL data with the user's query. Then, in the GIS crash location data, the query generator selects the crash points including the same ID numbers retrieved before in SQL data. Finally, selected crash points are displayed on the crash location map with detailed crash information from SQL data.

In accordance with the IDOT standard, the system uses stored procedures. In other words, the template of SQL statements are defined and stored in the databases. The query generator provides the parameters to the stored procedures to execute the procedures. However, for the map generator, it still uses plain SQL statements because the ArcGIS server only uses WHERE clause to execute the queries.

Table Generator

The result of query can be displayed in tabular format. In the system, GridView web control (which is available in ASP.NET framework) is used to display the table data. The table data can be a list of crash data, the number of crashes by severity level, the number of crashes by crash types, etc.

Chart Generator

The result of query can be displayed in chart format. In the system, ZedGraph web control (which is an open source project) is used to generate the chart. The example chart is a trend line chart of the number of crashes by county.

Map Generator

The system generates maps via ArcGIS server. Map service in ArcGIS server is used for the map generator (ESRI 2004). In order to provide the map service, the map file that contains layers (crash locations, roadways, and county boundaries) needs to be defined. And the map service using the map file needs to be defined via ArcCatalogue or ArcGIS server Manager (Web interfaces).

In the system, there are two kinds of maps; map with user interaction, and map without user interaction. The map with user interaction allows users to zoom in and out, to pan, and to select crashes on the map. The map without user interaction just displays the snapshot of the map image.

2.2. DATA SUMMARIES AND PROCESSING

One of the important components necessary for developing this Internet-based, GIS-compatible software tool for the Illinois local road crash analysis is the datasets loaded into the database. These datasets play key roles in the system, since information types that the system can provide depend on how many informative fields of data exist in the datasets. In addition, data structures can determine the efficiency of system operation at the implementation-level and database-level. (Based on requests of the UIUC research team, IDOT *DataMart* has prepared all crash, roadway, and jurisdiction boundary datasets in the format of SQL and GIS.) Therefore, in the spatial database of this system, all these datasets should be appropriately stored and should function according to system requirements. For example, in case of the GIS data, each GIS dataset is prepared to provide its unique information (location information / crash fact information) and all these GIS datasets should be properly merged to constitute efficient GIS data layers, as shown in Figure 2.

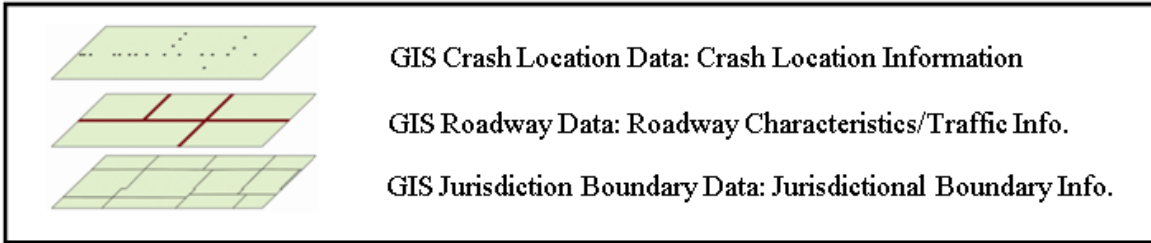


Figure 2. Schematic diagram for GIS data layers.

The following sections present a detailed description of these datasets and methodology used to process these datasets in order to implement the system.

2.2.1 Crash Data

The *DataMart* provides the UIUC research team with three types of crash dataset: GIS crash location dataset, SQL crash information dataset, and SQL vehicle information dataset. Following tables and figures represent a brief summary of each dataset.

[GIS Crash Location Dataset]

- File Name: VehicleCrashesAll (GIS Data)
- Data Type: GIS point-type spatial dataset in a shape-file format
- Number of Fields: 3
- Number of Records: 2233576
- Remarks: This GIS crash location/spatial dataset only includes CASE_ID information and there is no detailed crash information in the dataset. It only provides location information.
- A List of Fields: See Appendix A.

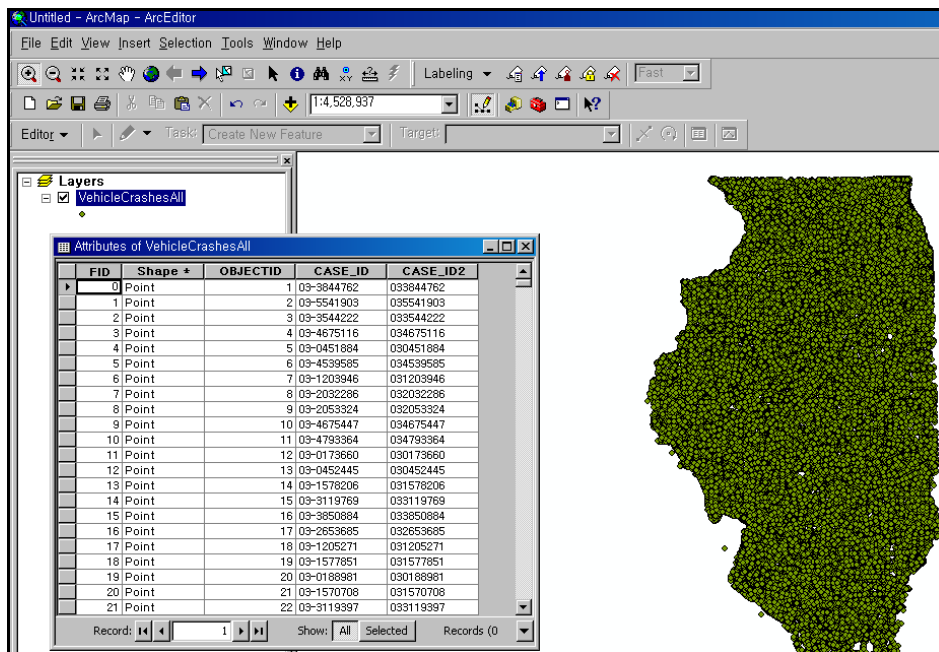


Figure 3. A snapshot of the GIS crash location dataset.

[SQL Crash Information Dataset]

- File Name: EDWUIS_Backup.zip (SDM.UofICrashes)
- Data Type: SQL Data
- Number of Fields: 55
- Number of Records: 1225561
- Remarks: This SQL dataset contains detailed crash information by each crash in a table.
In addition, crash ID of this SQL dataset can be matched with that of the GIS crash location dataset to join these two data sources.
- A List of Fields: See Appendix B.

JSTEST.EDW_A...M.UofICrashes										
CrashID	ICN	DistrictCode	CrashReportCountyCode	CrashReportCounty	CrashReportCityCode	CrashReportCity	TownshipIRISCode	TownshipName	HighwayOrStreetName	
1233424	050958503	1	99	Will	5745	Tinley Park	06	Frankfort Twp	I080 Westbound	
1752819	050960954	1	16	Cook	1051	Chicago	(N)	(N/A)	George	
1286799	050961440	1	16	Cook	1051	Chicago	(N)	(N/A)	W Eddy	
1753007	050964550	1	16	Cook	1051	Chicago	(N)	(N/A)	Irving Park	
1249994	050964808	1	16	Cook	1051	Chicago	(N)	(N/A)	N Sheridan	
1336862	050967785	8	61	Marion	0	Unincorporated	14	Salem Twp	Mp 1057 114	
1233060	050968973	8	60	Madison	115	Alton	52	Alton Twp	Johnson	
1259472	050969336	9	91	Union	150	Anna	(N)	(N/A)	East Drive Street	
1240851	050969567	7	15	Coles	3625	Mattoon	07	Mattoon Twp	Shelby	
1178488	050325380	3	6	Bureau	0	Unincorporated	03	Bureau Twp	1900N	
1178619	050326644	8	60	Madison	5055	Roxana	03	Chouteau Twp	S25S	
1178733	050328640	1	22	DuPage	890	Carol Stream	02	Bloomingtondale Twp	Andrew Ln	
1248453	050330000	1	16	Cook	1051	Chicago	(N)	(N/A)	W Harrison	
1179563	050331875	8	60	Madison	0	Unincorporated	20	Pin Oak Twp	Goshen	
1190308	050334663	9	100	Williamson	0	Unincorporated	01	Co Unit Road Dis...	Market	
1179905	050336692	1	16	Cook	1051	Chicago	(N)	(N/A)	W Devon	
1179927	050336981	1	16	Cook	1051	Chicago	(N)	(N/A)	S Ashland	
1179964	050337583	1	16	Cook	1051	Chicago	(N)	(N/A)	W North Ave	
1306218	050340546	1	16	Cook	1051	Chicago	(N)	(N/A)	100	
1210936	050340819	1	16	Cook	1051	Chicago	(N)	(N/A)	S Jeffery	
1190400	050341379	1	16	Cook	1051	Chicago	(N)	(N/A)	E 63Rd	
1186344	050341783	1	16	Cook	1051	Chicago	(N)	(N/A)	Armitage	
1190230	050344050	1	16	Cook	1051	Chicago	(N)	(N/A)	W Irving Pk	

Figure 4. A snapshot of the SQL Crash Information Dataset.

[SQL Vehicle Information Dataset]

- File Name: EDWUIS_Backup.zip (SDM.UofIVehicles)
- Data Type: SQL Data
- Number of Fields: 37
- Number of Records: 2293011
- Remarks: This SQL dataset contains information on vehicles involved in crashes.
By using crash ID, this dataset can be also matched with the GIS crash location dataset and SQL crash information dataset.
- A List of Fields: See Appendix C.

JSTEST.EDW_AL.....UoflVehicles											
Object Explorer Details											
CISCrashID	ICN	CrashReportUnitNbr	VehTypeCode	VehType	VehUseCode	VehUse	VehDefectsCode	VehDefects	VehManeuverPriorCode	VehManeuverPrior	
1209824	050660893	1	1	Sport utility vehi...	2	Personal	1	None	15	Skidding/control loss	
1209825	050485572	1	5	Passenger	2	Personal	1	None	1	Straight ahead	
1209825	050485572	2	2	Passenger	2	Personal	1	None	22	Parked in traffic lane	
1209825	050485572	3	1	Passenger	2	Personal	1	None	22	Parked in traffic lane	
1209826	050661750	1	3	Passenger	2	Personal	99	Unknown	1	Straight ahead	
1209826	050661750	2	2	Passenger	2	Personal	99	Unknown	11	Slow/stop in traffic	
1209826	050661750	3	1	Unknown/NA	2	Personal	1	None	1	Straight ahead	
1209827	050661776	1	1	Passenger	2	Personal	2	Brakes	1	Straight ahead	
1209827	050661776	2	1	Passenger	2	Personal	1	None	11	Slow/stop in traffic	
1209827	050661776	3	6	Passenger	2	Personal	1	None	11	Slow/stop in traffic	
1209828	050661826	1	1	Passenger	2	Personal	1	None	3	Turning left	
1209828	050661826	2	1	Passenger	2	Personal	1	None	1	Straight ahead	
1209829	050661859	1	1	Passenger	2	Personal	1	None	1	Straight ahead	
1209829	050661859	2	2	Passenger	2	Personal	1	None	1	Straight ahead	
1209830	050661867	1	1	Passenger	2	Personal	1	None	14	Avoiding vehicles/obj...	
1209830	050661867	2	1	Passenger	2	Personal	1	None	11	Slow/stop in traffic	
1209830	050661867	3	1	Passenger	2	Personal	1	None	11	Slow/stop in traffic	
1209831	050614205	1	1	Passenger	99	Unknown/NA	1	None	15	Skidding/control loss	
1209831	050614205	2	1	Passenger	2	Personal	1	None	11	Slow/stop in traffic	
1209832	050614403	1	1	Passenger	2	Personal	99	Unknown	9	Slow/stop - right turn	
1209832	050614403	2	1	Sport utility vehi...	2	Personal	99	Unknown	9	Slow/stop - right turn	

Figure 5. A Snapshot of the SQL Vehicle Information Dataset.

As shown in Figure 3, the GIS crash location dataset named “VehicleCrashesAll” is a point-type spatial dataset in a shape-file format and these GIS crash points represent locations where crashes occurred. Each record of the dataset indicates one crash occurred and this dataset contains historical crash records from 1999 to 2008. In the GIS crash location dataset, 2,233,576 records exist, meaning that there are 2,233,576 crash points. The dataset contains two fields, named “CASE_ID” and “CASE_ID2,” respectively. This CASE_ID represents a unique number for each crash’s identification (crash ID). Since the format of this CASE_ID is different between the GIS crash location dataset and SQL crash information dataset, the field of “CASE_ID2” is generated to make the ID format of these two datasets identical. As mentioned before, because the GIS crash location dataset does not contain any crash information except for the CASE_ID, this dataset needs to be matched with the SQL crash information dataset based on the CASE_ID in order to display detailed crash information with crash locations. As a result, the GIS crash location dataset is used to display crash locations on the web-based GIS map and is used as a mechanism to add detailed crash information of SQL crash data to the GIS spatial/location data.

The SQL crash information dataset named “EDWUIS_Backup.zip (SDM.UoflCrashes)” includes a variety of detailed crash information in the SQL table, such as crash ID, crash location, crash causal factor, collision type, crash severity, number of fatalities and injuries, surface condition, weather condition, light condition, crash date, etc. Therefore, when users query crash information, all results come from this SQL crash information dataset. This SQL dataset contains historical crash records from 2005 to 2008. In addition, most fields of the dataset include both a description and a code. For instance, in case of crash severity information, there exist two fields: one is called “CrashSeverityCode” and the other is called “CrashSeverityDescription.” Furthermore, each record in the table indicates one crash occurred and detailed crash information is included in the fields of the table. Various fields, especially fields related to the jurisdiction (District, County, and Township) and crash date (Year and Month), are directly used for every crash query. This SQL crash information dataset can be also linked to the GIS crash location dataset through the crash ID (CASE_ID).

As shown in Figure 5, the SQL vehicle information dataset named “EDWUIS_Backup.zip (SDM.UoflVehicles)” provides information on vehicles involved in crashes occurred from 2005 to 2008. In the SQL table, each record indicates one involved vehicle and its crash information, such as vehicle type, maneuver, direction, usage, crash ID, etc. in the fields of corresponding record. If two vehicles were involved in a certain crash, then two records exist which have a

common crash ID (CASE_ID) in the SQL dataset. Therefore, users can know how many vehicles were involved in each crash through the number of records, containing the same crash ID (CASE_ID). Herein, the number of records is equal to the number of vehicles involved in crashes during the above period. This SQL vehicle information dataset can be merged with the SQL crash information dataset through the crash ID (CASE_ID).

2.2.2 GIS Roadway Data

The GIS roadway dataset is essential when this Internet-based, GIS-compatible software tool displays crash locations on the Illinois highways. In addition, when users query crashes through a buffer analysis, GIS roadway segments are encompassed by the buffer to select crash points located on these segments. The following summary is an overview of the GIS roadway dataset provided by *DataMart*.

[GIS Roadway Dataset]

- File Name: RoadwayPeerGroups2007 (GIS Data)
- Data Type: GIS poly-line type dataset in a shape-file format
- Number of Fields: 116
- Number of Records: 1102744
- A List of Fields: See Appendix D.

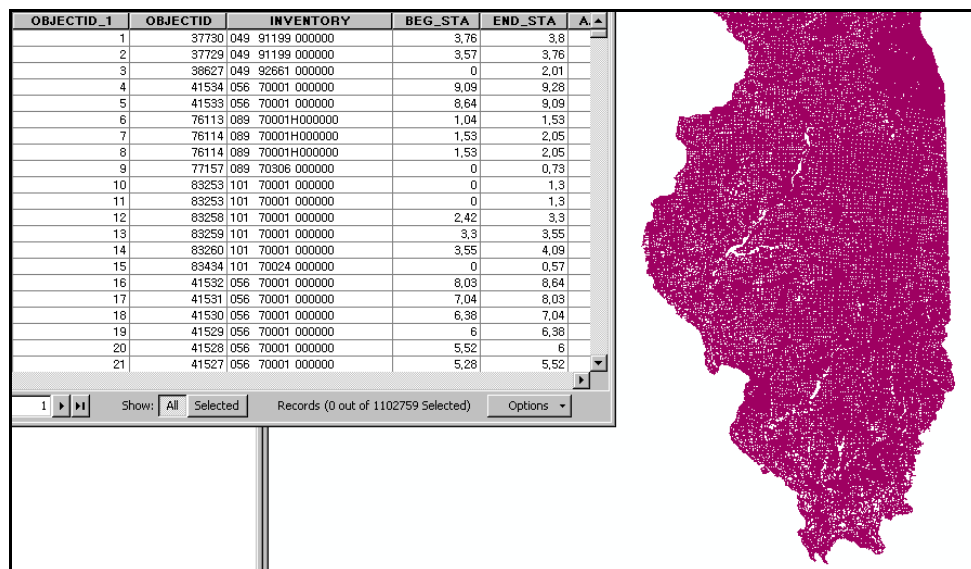


Figure 6. A snapshot of the GIS roadway data.

As shown in Figure 6, the GIS roadway dataset named “RoadwayPeerGroups2007” is a poly line type data in a shape-file format. Many entangled lines of this GIS roadway data represent the Illinois highway network. One of the features of this GIS roadway data is that one route consists of several discrete segments instead of one continuous connection, even though all these discrete segments have the same road names. In the attribute table of this GIS roadway data, each record indicates one discrete segment and contains various geometric/traffic information of the segment in the fields. Types of the geometric/traffic information are inventory number, road name, segment length, roadway functional class, AADT, number of lanes, etc. In this GIS roadway data, the number of records is 1102744, meaning that there exist 1102744 segments.

2.2.3 Jurisdiction Boundary Data

The Internet-based, GIS-compatible software tool also uses GIS county boundary data. The GIS county boundary data is used when the system displays a GIS interactive map with roadway and crash data on the screen and provides county based crash severity information through the color-coded map. The following summary is an overview of the GIS county boundary data provided by *DataMart*.

[GIS County Boundary Data]

- File Name: cnty_bndys_s (GIS Data)
- Data Type: GIS polygon-type spatial dataset in a shape-file format
- Number of Fields: 9
- Number of Records: 102
- A List of Fields: See Appendix E.

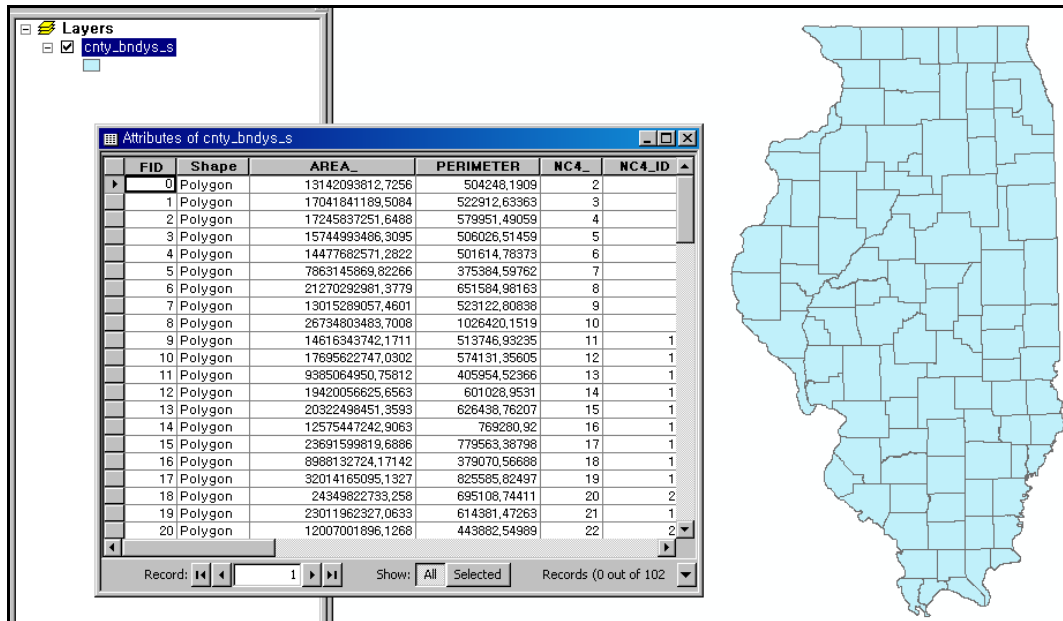


Figure 7. A snapshot of the GIS county Boundary data.

Illinois consists of 102 counties. As shown in Figure 7, 102 counties exist in the Illinois county boundary map, and the total number of records is 102 in the attribute table because each record indicates one county. In addition, a variety of county information, such as area, population, county name, etc., is included in the fields of the data.

CHAPTER 3 FUNCTIONALITY

This integrated Web-based, GIS compatible software tool consists of three main modules: crash information provision module, safety analysis support module, and education module. Each module contains sub-modules with several options for each analytical purpose. This section briefly explains and describes each module's functions, design of query structures, snapshots of user interfaces, benefits, and algorithms/technologies used.

3.1. CRASH INFORMATION PROVISION MODULE

The main role of the "crash information provision" module is to provide crash information to users using dynamic tables, bar charts, trend lines, thematic color coded maps, and zoom-enabled interactive maps. Therefore, based on user-selected inputs in the query process, a variety of types of crash information are displayed on the web screen in the Internet-based GIS environment. The crash information in this module contains different historical crash statistics, such as numbers of crashes, fatalities, injuries, as well as crash environmental conditions like crash causal factors, weather condition, road surface condition, vehicle and driver condition, etc. of each crash. In accordance with their analytical purpose and preference, users can also specify different data aggregation types, time ranges, and crash information types to search for general crash statistics or detailed crash information by jurisdictional area or location type. Since crash data and safety information are indispensable for governments and local agencies to achieve the goal of reducing vehicle crashes, this crash information provision module is very important and useful to all users. Through this module, local agencies can obtain diverse crash information dynamically and conveniently. In addition, this crash information can provide a good basis for further safety analysis. This module has two sub-modules: general crash information and user-specified crash information.

3.1.1. General Crash Information

The "general crash information" sub-module provides historical crash statistics, including the numbers of crashes, fatalities and injuries by jurisdictional areas (entire Illinois state, county, and township/municipality). Also, dynamic tables, bar charts, trend lines, and thematic color coded maps are used to deliver crash information in an efficient manner. This "general crash information" sub-module includes six options as follows:

- Statewide Crash Information
- Crash Information by County
- Crash Information by Township/Municipality
- Trend Line Analysis for Statewide
- Trend Line Analysis by County
- Color Coded Map Analysis

Statewide Crash Information

The "statewide crash information" option provides crash information using a dynamic tabular format and all statistics (numbers of crashes, fatalities, and injuries) in the tables are based on crashes occurred in the entire Illinois. Thus, users do not need to select any jurisdiction or geographical area. The only required inputs in the query process are selection of time range and crash information types that users want to display. The crash information types that users can select in this option are as follows:

- Number of Crashes

- Number of Fatalities
- Number of Injuries
- Number of Crashes by Road Type
- Number of Crashes by Collision Type
- Number of Crashes by Weather
- Number of Crashes by Light Condition
- Number of Crashes by Road Surface Condition
- Number of Crashes by Day of Week
- Number of Crashes by Traffic Control Type
- Number of Fatalities and Injuries by Road Type
- Number of Fatalities and Injuries by Collision Type
- Number of Fatalities and Injuries by Weather
- Number of Fatalities and Injuries by Light Condition
- Number of Fatalities and Injuries by Road Surface Condition
- Number of Fatalities and Injuries by Day of Week
- Number of Fatalities and Injuries by Traffic Control Type

As shown in Figure 8, users can select time range and single or multiple information types on the Web-screen. Then, dynamic tables are generated immediately after users' selection.

1. Time Range Selection
Please select a time range (crash occurred period).

From to (Format: mm/yyyy)

2. Information Type Selection
Please choose information types which you want to know.

- Number of Crashes
- Number of Fatalities
- Number of Injuries
- Number of Crashes by Road Type
- Number of Crashes by Collision Type
- Number of Crashes by Weather
- Number of Crashes by Light Condition
- Number of Crashes by Surface Condition
- Number of Crashes by Day of Week
- Number of Crashes by Traffic Control Type
- Number of Fatalities and Injuries by Road Type
- Number of Fatalities and Injuries by Collision Type
- Number of Fatalities and Injuries by Weather
- Number of Fatalities and Injuries by Light Condition
- Number of Fatalities and Injuries by Surface Condition
- Number of Fatalities and Injuries by Day of Week
- Number of Fatalities and Injuries by Traffic Control Type

Number of Fatalities and Injuries by Light Condition

Light Condition	Fatality	A-Injury	B-Injury	C-Injury
Darkness	107	990	2042	1034
Darkness, lighted road	73	1002	2938	2661
Dawn	13	96	205	147
Daylight	163	3164	8458	9100
Dusk	5	113	319	270
Unknown	0	34	95	55

Figure 8. User-interface for statewide crash information.

Through this option, users can diagnose safety conditions quantitatively by generating historical crash statistics for the entire Illinois highway system, as well as view Illinois crash facts at a glance.

Implementation

The query generator builds the query with time constraints and crash information types. Each crash information type requires a different way of querying against the crash database (non-spatial database). Therefore, different query statements and settings are stored in a table

in the database (currently, the table resides in the spatial database, though it can reside in any database).

In short, the query generator retrieves a template of query statement from the setting table according to the crash information type selected by the user. The generator adds the time constraints to the template and sends out the query to the database as shown in Figure 9. The result of query is sent to the table generator. It generates the table in the web page of result.

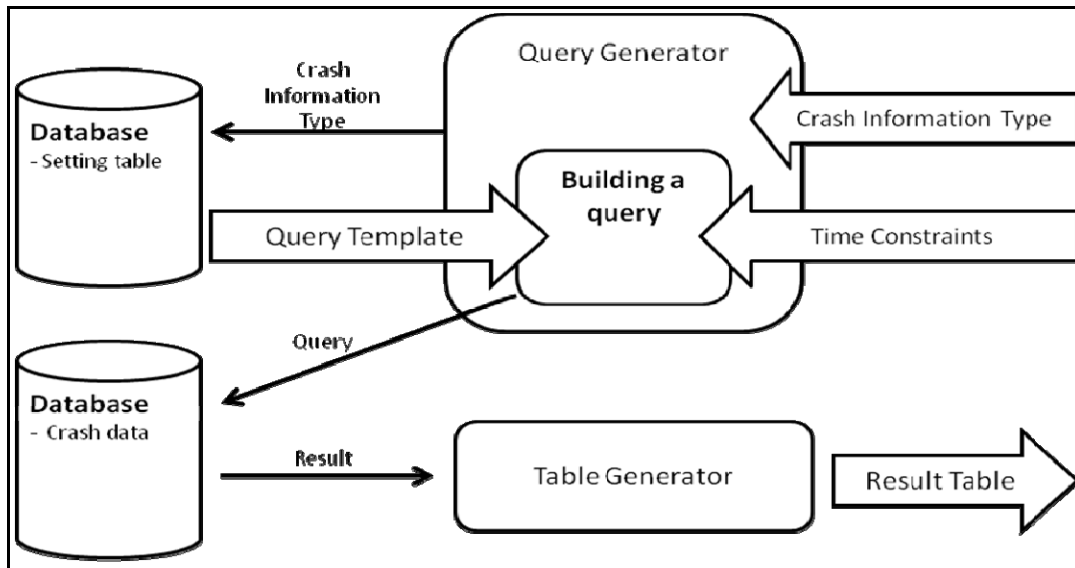


Figure 9. Query: table generator logic.

Crash Information by County

Unlike the “statewide crash information” option, the “crash information by county” option allows users to aggregate crash information by county. Thus, users need to select one or more counties, besides choosing time ranges and information types. Dynamic tables are generated in the same manner as the “statewide crash information” option. Crash statistics in the tables, however, are based on crashes occurred in selected counties, instead of the entire Illinois state. Users can select the following crash information types:

- Number of Crashes
- Number of Fatalities
- Number of Injuries
- Number of Crashes by Road Type
- Number of Crashes by Collision Type
- Number of Crashes by Weather
- Number of Crashes by Light Condition
- Number of Crashes by Road Surface Condition
- Number of Crashes by Day of Week
- Number of Crashes by Traffic Control Type
- Number of Fatalities and Injuries by Road Type
- Number of Fatalities and Injuries by Collision Type
- Number of Fatalities and Injuries by Weather
- Number of Fatalities and Injuries by Light Condition
- Number of Fatalities and Injuries by Road Surface Condition
- Number of Fatalities and Injuries by Day of Week
- Number of Fatalities and Injuries by Traffic Control Type

As shown in Figure 10, all required query inputs on the Web-screen are exactly the same as those of the “statewide crash information” option, except for the county selection part.

1. Please select a time range (crash occurred period).
 From to (Format: mm/yyyy)

2. Please select counties to show crash information.

ADAMS HARDIN MORGAN
 ALEXANDER HENDERSON MOULTRIE
 BOND HENRY OGLE
 BOONE IROQUOIS PEORIA
 BROWN JACKSON PERRY
 BUREAU JASPER PIATT
 CALHOUN JEFFERSON PIKE
 CARROLL JERSEY POPE
 CASS JODAVIESS PULASKI
 CHAMPAIGN JOHNSON PUTNAM
 CHRISTIAN KANE RANDOLPH
 CLARK KANKAKEE RICHLAND
 CLAY KENDALL ROCK ISLAND
 CLINTON KNOX SALINE
 COLES LAKE SANGAMON
 COOK LASALLE SCHUYLER
 CRAWFORD LAWRENCE SCOTT
 CUMBERLAND LEE SHELBY
 DEKALB LIVINGSTON ST. CLAIR

Number of Crashes by Surface Condition

Surface Condition	Fatal Crash	Injury Crash	Property Damage Only Crash
Dry	17	378	1454
Ice	1	26	55
Other	0	12	11
Sand or mud or dirt	0	3	4
Snow or slush	0	31	89
Unknown	1	10	120
Wet	3	63	222

GREENE MENARD WILL
 GRUNDY MERCER WILLIAMSON
 HAMILTON MONROE WINNEBAGO
 HANCOCK MONTGOMERY WOODFORD

3. Please choose information types.

Number of Crashes
 Number of Fatalities
 Number of Injuries
 Number of Crashes by Road Type
 Number of Crashes by Collision Type
 Number of Crashes by Weather
 Number of Crashes by Light Condition
 Number of Crashes by Surface Condition
 Number of Crashes by Day of Week
 Number of Crashes by Traffic Control Type
 Number of Fatalities and Injuries by Road Type
 Number of Fatalities and Injuries by Collision Type
 Number of Fatalities and Injuries by Weather
 Number of Fatalities and Injuries by Light Condition
 Number of Fatalities and Injuries by Surface Condition
 Number of Fatalities and Injuries by Day of Week
 Number of Fatalities and Injuries by Traffic Control Type

Figure 10. User-interface for crash information by county.

If the users are only interested in one or multiple counties' crash statistics instead of those for entire Illinois, this "crash information aggregated by county" option is very useful.

Implementation

The implementation of this functionality is similar to the statewide crash information query. A difference is that the query generator adds the county aggregation to the query statement. It still uses the setting table to retrieve the template of query statement.

Crash Information by Township/Municipality

The "crash information by township/municipality" option helps users to aggregate crash information by township or municipality. Thus, it is required to select single or multiple townships or municipalities besides choosing a county where these towns are located. By selecting the time range, county, one or more townships/municipalities and information types, statistics on crashes occurred in user-selected townships/municipalities are displayed in the dynamic tables. Crash information types used in this option are as follows:

- Number of Crashes
- Number of Fatalities
- Number of Injuries
- Number of Crashes by Road Type
- Number of Crashes by Collision Type
- Number of Crashes by Weather
- Number of Crashes by Light Condition
- Number of Crashes by Road Surface Condition
- Number of Crashes by Day of Week
- Number of Crashes by Traffic Control Type
- Number of Fatalities and Injuries by Road Type
- Number of Fatalities and Injuries by Collision Type
- Number of Fatalities and Injuries by Weather
- Number of Fatalities and Injuries by Light Condition
- Number of Fatalities and Injuries by Road Surface Condition
- Number of Fatalities and Injuries by Day of Week
- Number of Fatalities and Injuries by Traffic Control Type

Figure 11 presents a snapshot of the user-interface in "crash information by township/municipality" option. As mentioned before, the only different input is the selection of township/municipality in the query process.

1. Please select a time range.
 From 2006-01 to 2007-07

2. Please select a county.
 CHAMPAIGN

3. Please select townships.

Ayers Twp Kerr Twp Sadorus Twp
 Brown Twp Ludlow Twp Scott Twp
 Colfax Twp Mahomet Twp Sidney Twp
 Compromise Twp Newcomb Twp Somer Twp
 Condit Twp Ogden Twp South Homer Twp
 Crittenden Twp Pesotum Twp St Joseph Twp
 East Bend Twp Philo Twp Stanton Twp
 Harwood Twp Rantoul Twp Tolono Twp
 Hensley Twp Raymond Twp

Number of Crashes	
Crash Type	Number of Crashes
Fatal crash	1
Incapacitating injury crash	3
Injury reported, not evident crash	5
Non-incapacitating injury crash	7
Property damage crash	44

4. Please choose information types.

Number of Crashes
 Number of Fatalities
 Number of Injuries
 Number of Crashes by Road Type
 Number of Crashes by Collision Type
 Number of Crashes by Weather
 Number of Crashes by Light Condition
 Number of Crashes by Surface Condition
 Number of Crashes by Day of Week
 Number of Crashes by Traffic Control Type
 Number of Fatalities and Injuries by Road Type
 Number of Fatalities and Injuries by Collision Type
 Number of Fatalities and Injuries by Weather
 Number of Fatalities and Injuries by Light Condition
 Number of Fatalities and Injuries by Surface Condition
 Number of Fatalities and Injuries by Day of Week
 Number of Fatalities and Injuries by Traffic Control Type

Figure 11. User-interface for crash information by township/municipality.

Since this option provides township/municipality-based crash information, it is useful when users are interested in obtaining crash data aggregated by township or municipality and analyzing the safety conditions of them.

Implementation

The implementation of this functionality is the same as the previous one--crash information by county--while this one aggregates the information by township/municipality.

Trend Line Analysis for Statewide

Instead of using the dynamic tables, the "trend line analysis for statewide" option displays a trend line with a bar chart as shown in Figure 12.

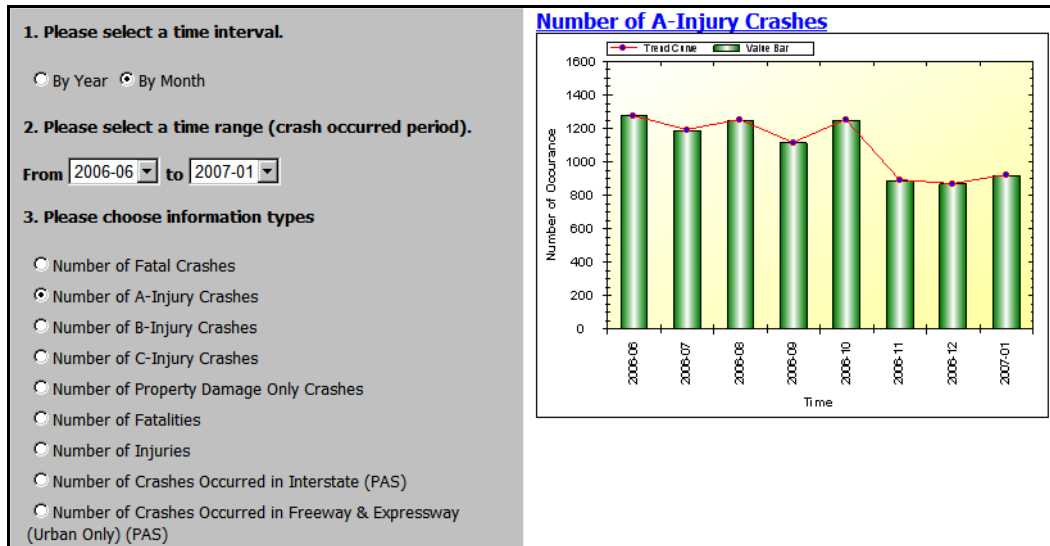


Figure 12. User-Interface for Trend Line Analysis for Statewide.

Users can generate either a year-based trend line or month-based trend line by selecting a time interval (year or month) as one of the inputs. If the month-based trend line is selected with the time range, x-axis of the diagram will indicate one month as a time unit and y-axis will mean the number of crashes, fatalities, or injuries that can be selected as an information type. Here, since users cannot select multiple crash information types, only one can be chosen among the following information types:

- Number of Fatal Crashes
- Number of A-Injury Crashes
- Number of B-Injury Crashes
- Number of C-Injury Crashes
- Number of Property Damage Only Crashes
- Number of Fatalities
- Number of Injuries
- Number of Crashes Occurred in Interstate (PAS)
- Number of Crashes Occurred in Freeway & Expressway (Urban Only) (PAS)
- Number of Crashes Occurred in Collector (Urban)
- Number of Crashes Occurred in Major Collector (Non-Urban)
- Number of Crashes Occurred in Minor Arterial (Urban)
- Number of Crashes Occurred in Minor Arterial (Non-Urban)
- Number of Crashes Occurred in Local Road or Street (Non-Urban)
- Number of Crashes Occurred in Local Road or Street (Urban)
- Number of Crashes Occurred in Minor Collector (Non-Urban)
- Number of Crashes Occurred in Other Principal Arterial (PAS)
- Number of Crashes Involving Pedestrians
- Number of Crashes Involving Trains
- Number of Crashes Involving Animals
- Number of Crashes Involving Parked Motor Vehicles
- Number of Crashes Involving Pedal Cyclists
- Number of Crashes Occurred in Stop Sign / Flasher Placed Roads
- Number of Crashes Occurred in Yield Sign Placed Roads
- Number of Crashes Occurred in Traffic Signal Placed Roads
- Number of Crashes Occurred in Railroad Crossing Gates

Right after specifying all these inputs on the web-screen, both the trend line and bar chart are displayed. Heights of the trend line and bar chart are determined based on the numbers of crashes, fatalities, or injuries occurred in the entire Illinois. However, in the “trend line analysis by county” option, only the numbers of crashes, fatalities, or injuries occurred in selected counties are used to determine the heights of the trend line and bar chart, since crash data is aggregated by county.

By using the visual trend line analysis, the users can not only generate the trend lines of various crash information types but also easily recognize sequential changes of crash facts.

Implementation

The query generator builds the query with time constraints, time type (i.e. monthly or yearly), and crash information type. Each crash information type requires a different way of querying against the crash database (non-spatial database). Therefore, different query statements and settings are stored in a table in the database (currently, the table resides in spatial database, though it can reside in any database). This will be called the trend setting table. In short, the query generator retrieves a template of query statement from the setting table according to the crash information type selected by the user. The generator adds the monthly or yearly time constraints to the template and sends out the query to the database, as shown in Figure 13. The results of the query are sent to the chart generator. It generates the chart in the web page of result.

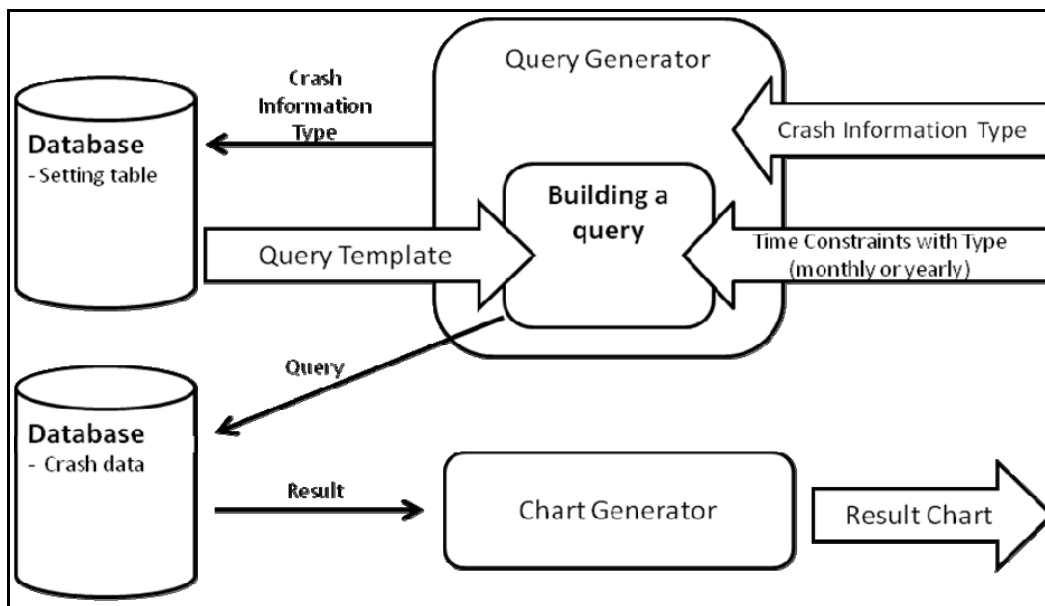


Figure 13. Query: Chart Generator Logic.

Trend Line Analysis by County

As shown in Figure 14, except for the county selection input, all query inputs are exactly the same as those of the “trend line analysis for statewide” option. Users need to select one or multiple counties to aggregate crash data by county, and heights of the trend line and bar chart are determined by crash data related only to selected counties.

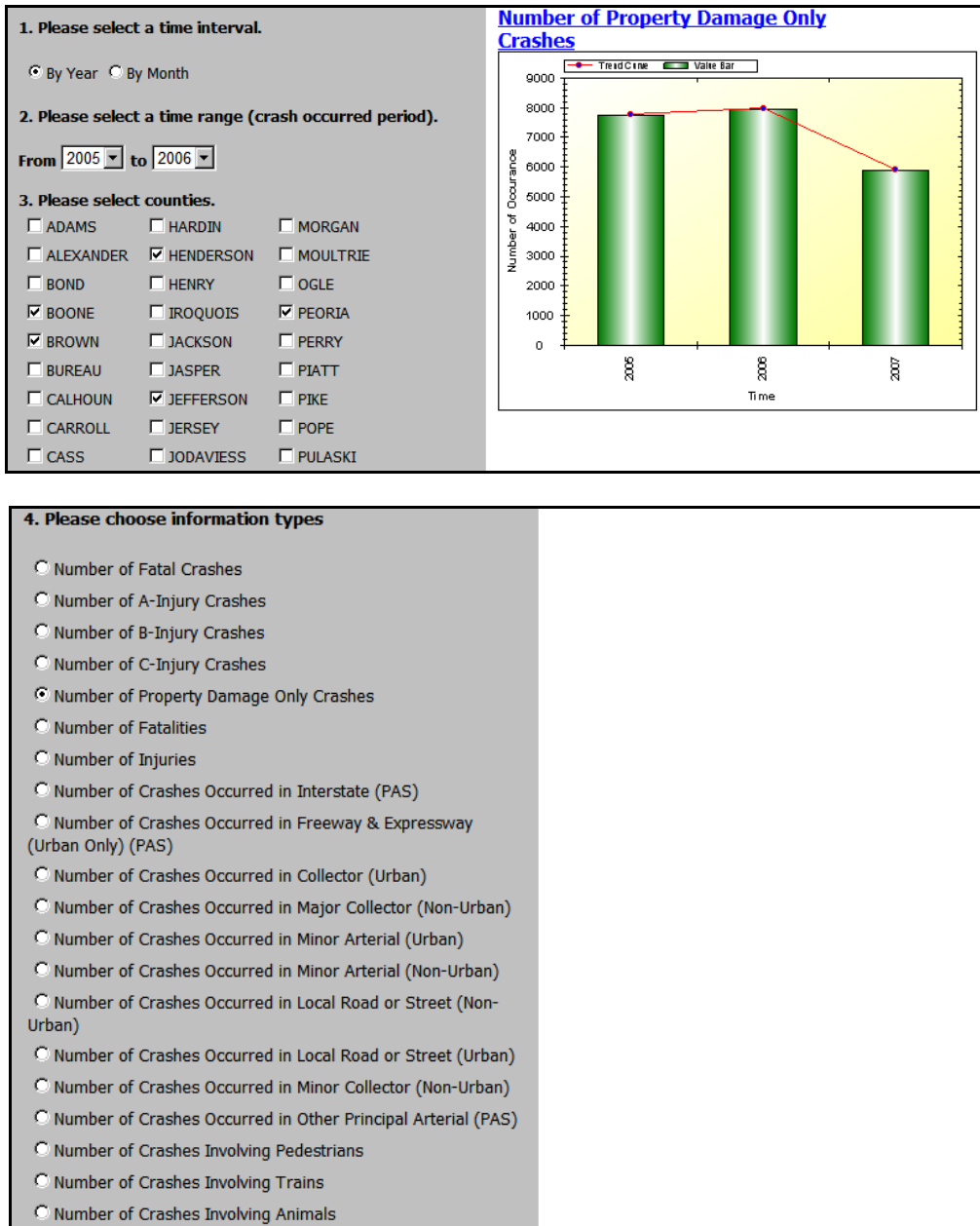


Figure 14. A user-interface for trend line analysis by county.

Users can choose one of the following crash information types:

- Number of Fatal Crashes
- Number of A-Injury Crashes
- Number of B-Injury Crashes
- Number of C-Injury Crashes
- Number of Property Damage Only Crashes
- Number of Fatalities
- Number of Injuries
- Number of Crashes Occurred in Interstate (PAS)
- Number of Crashes Occurred in Freeway & Expressway (Urban Only) (PAS)
- Number of Crashes Occurred in Collector (Urban)

- Number of Crashes Occurred in Major Collector (Non-Urban)
- Number of Crashes Occurred in Minor Arterial (Urban)
- Number of Crashes Occurred in Minor Arterial (Non-Urban)
- Number of Crashes Occurred in Local Road or Street (Non-Urban)
- Number of Crashes Occurred in Local Road or Street (Urban)
- Number of Crashes Occurred in Minor Collector (Non-Urban)
- Number of Crashes Occurred in Other Principal Arterial (PAS)
- Number of Crashes Involving Pedestrians
- Number of Crashes Involving Trains
- Number of Crashes Involving Animals
- Number of Crashes Involving Parked Motor Vehicles
- Number of Crashes Involving Pedal Cyclists
- Number of Crashes Occurred in Stop Sign / Flasher Placed Roads
- Number of Crashes Occurred in Yield Sign Placed Roads
- Number of Crashes Occurred in Traffic Signal Placed Roads
- Number of Crashes Occurred in Railroad Crossing Gates

Implementation

The implementation of this functionality is similar to the query of the trend line analysis for statewide. A difference is that the query generator adds the county aggregation to the query statement. It still uses the trend setting table to retrieve the template of query statement.

Color Coded Map Analysis

The “color coded map analysis” option provides a thematic map to display the entire Illinois state with county boundaries. The state of Illinois consists of 102 counties, and counties on the map are coded with different colors according to crash severity. As shown in Figure 15, in this option, users can specify 4 different color classes to display severity levels. Each class of the color is defined as follows:

- Class 1: Average - 2*Standard Deviation
- Class 2: Average - 1*Standard Deviation
- Class 3: Average + 1*Standard Deviation
- Class 4: Average + 2*Standard Deviation

Time range and information types are also selected by users. Following list represents crash information types that users can choose.

- Number of Fatal Crashes
- Number of A-Injury Crashes
- Number of B-Injury Crashes
- Number of C-Injury Crashes
- Number of Property Damage Only Crashes
- Number of Fatalities
- Number of Injuries

1. Please select a time range

From to (Format: mm/yyyy)

2. Please choose information types

Number of Fatal Crashes
 Number of A-Injury Crashes
 Number of B-Injury Crashes
 Number of C-Injury Crashes
 Number of Property Damage Only Crashes
 Number of Fatalities
 Number of Injuries

3. Please choose colors of classes

Class	Color
1	#FFFF00 <input type="text" value="Yellow"/>
2	#FF0000 <input type="text" value="Red"/>
3	#0000C0 <input type="text" value="Blue"/>
4	#808080 <input type="text" value="Grey"/>

Figure 15. User-interface for color coded map analysis.

After selecting all inputs, the color coded map is displayed based on counties with different colors as presented in Figure 16. In addition, a table below the color coded map indicates each county's statistics of chosen crash information. The average, standard deviation, maximum, and minimum values of the selected information are also displayed on the web screen. Through this option, the users can easily identify which counties have severe crashes, fatalities, or injuries as well as crash severity level of the entire state of Illinois at a glance.

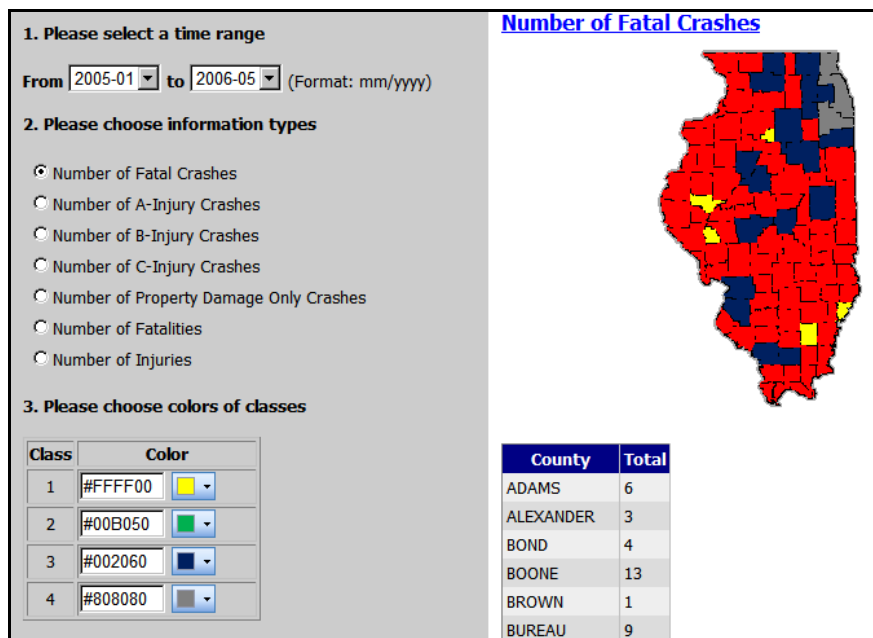


Figure 16. A result of color coded map analysis.

Implementation

The query generator builds the query with time constraints and crash information types.

Each crash information type requires a different way of querying against the crash database (non-spatial database). Therefore, different query statements and settings are stored in a table in the database (currently, the table resides in spatial database, though it can reside in any database). This will be called the map setting table.

In short, the query generator retrieves a template of query statement from the setting table according to the crash information type selected by the user. The generator adds the constraints to the template and sends out the query to the database as shown in Figure 17. The results of the query are sent to the map generator. It generates the map in the Web page of result.

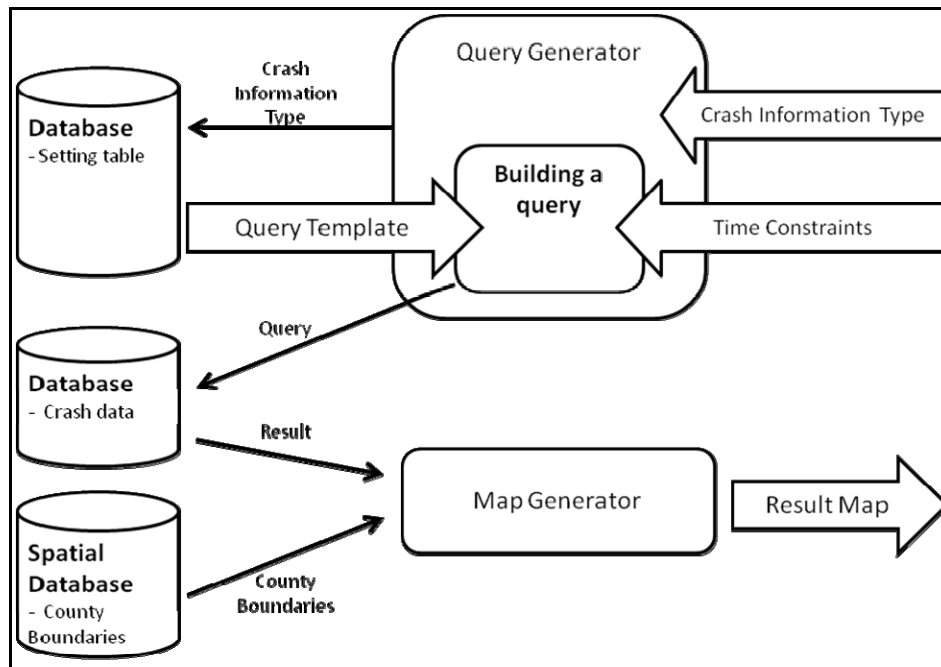


Figure 17. Query: Map Generator Logic.

3.1.2. User-Specified Crash Information

As described earlier, most options included in the “general crash information” sub-module aim to provide aggregated crash information by geographical areas or jurisdictions such as the entire state, county, or township, instead of focusing on an individual crash at a specific location. In addition, most crash information is general crash statistics, like the number of crashes, fatalities, and injuries. When users need to search for detailed crash information for each crash that occurred at a certain intersection or road segment, they need to use this “user-specified crash information” sub-module.

Through query inputs or zoom-enabled interactive maps, this sub-module makes it possible to select any intersections or segments, after which a list of crashes occurred at the chosen location is displayed on the screen with detailed information of each crash. This detailed crash information contains crash location and time, crash severity, fatality and injury, crash environmental data, involved vehicle data, etc. According to the purpose of analysis, the users can choose one of the four options in the “user-specified crash information” sub-module as follows:

- Crash Query by Road Name
- Crash Query by Roadway Functional Class
- Crash Query by Route Number

- Crash Query Using Interactive Map

Crash Query by Road Name

When users want to search for detailed information about crashes that occurred on a certain road using a road name, the “crash query by road name” option can be used. By selecting a road name with other types of inputs in the query forms, a list of all crashes that occurred on the selected road is provided with detailed crash information.

As shown in Figure 18, the users need to specify a time range, county, township, and road name as inputs. Then, as an output of the query, the selected crashes and road are displayed on the crash location map.

CISCrashID	ICN	DistrictCode	CrashReportCountyCode	CrashReportCounty	CrashReportCityCode	CrashReportCityName
1159441	050114966	5	10	Champaign	990	Char...
1206569	050530146	5	10	Champaign	0	Unin...
1235522	050866565	5	10	Champaign	0	Unin...
1313016	051443059	5	10	Champaign	5845	Urba...

Figure 18. User-interface for crash query by road name.

Types of detailed crash information displayed on the screen are as follows:

- CISCrashID
- ICN
- DistrictCode
- CrashReportCounty
- CrashReportCity
- TownshipName
- HighwayOrStreetName
- FunctionalClassDescription
- RouteNbr
- MileStation
- XCoordinate
- YCoordinate
- CrashDateTime
- CrashSeverityDescription
- TotalFataIs
- TotalInjured
- CrashVehicleCount
- CollisionTypeDescription

- WeatherCond
- RoadSurfCond
- LightingCond
- ContribCausePrim
- ContribCauseSec
- RoadwayFeature
- TrafControlDevice
- AInjuries
- BInjuries
- CInjuries
- OInjuries
- CrashLocationIntersectionRelated

Implementation

In this module, users will query crash information with user-selected street segment by road name. The spatial relationship between crash data and the selected spatial entity is utilized. Spatial query enables users to query data via the spatial relationship. Especially, buffer and intersection-overlay operations are utilized for this module (ESRI, 2006). Figure 19 below shows the general mechanism of the spatial query. The first spatial operation is to generate a buffer polygon based on the selected spatial entity, such as a roadway segment. The buffer operation generates the polygon with certain buffer distance, which is selected by users. Second spatial operation is an intersect overlay between the buffered polygon and crash data. In other words, from the operation, crashes which intersect with the buffered polygon are selected.

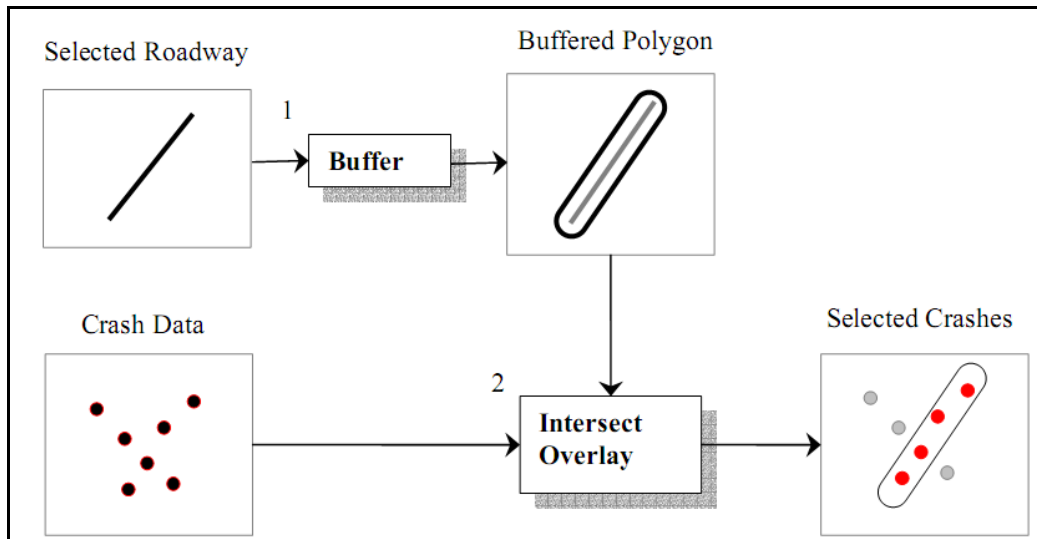


Figure 19. General mechanism of the spatial query.

With CASE-IDs of the selected crashes, the query generator generates the query against the crash data. The results will be sent to map generator and table generator to generate a map and a table on a roadway selected by the user.

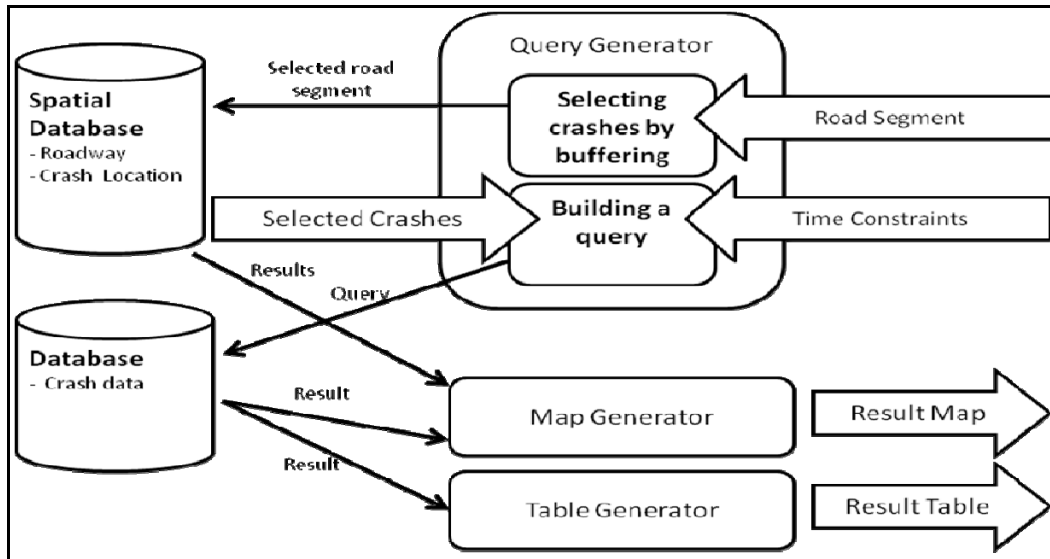


Figure 20. Spatial query logic.

Crash Query by Roadway Functional Class

The “crash query by roadway functional class” option can be used, when users want to select one road considering the road’s functional class to search for crash information of the selected road. Thus, it is required to add one step in the query forms to allow users to select the functional class before choosing a road name. Except for the selection of roadway functional class in the query, all other inputs, user-interface of the Web, and algorithms used in this option are exactly the same as those of the “crash query by road name” option.

As shown in Figure 21, after a time range, county, and township are chosen, one of the roadway functional classes should be selected. Then, only road names classified as the selected functional class are displayed in the drop down list. Next, users choose one road name to find information about crashes that occurred on that road. Same as the previous “crash query by road name” option, the selected crash points and road are displayed on the map. A list of crash information types for each case is as follows:

- CISCrashID
- ICN
- DistrictCode
- CrashReportCounty
- CrashReportCity
- TownshipName
- HighwayOrStreetName
- FunctionalClassDescription
- RouteNbr
- MileStation
- XCoordinate
- YCoordinate
- CrashDateTime
- CrashSeverityDescription
- TotalFatals
- TotalInjured
- CrashVehicleCount
- CollisionTypeDescription

- WeatherCond
- RoadSurfCond
- LightingCond
- ContribCausePrim
- ContribCauseSec
- RoadwayFeature
- TrafControlDevice
- AInjuries
- BInjuries
- CInjuries
- OInjuries
- CrashLocationIntersectionRelated

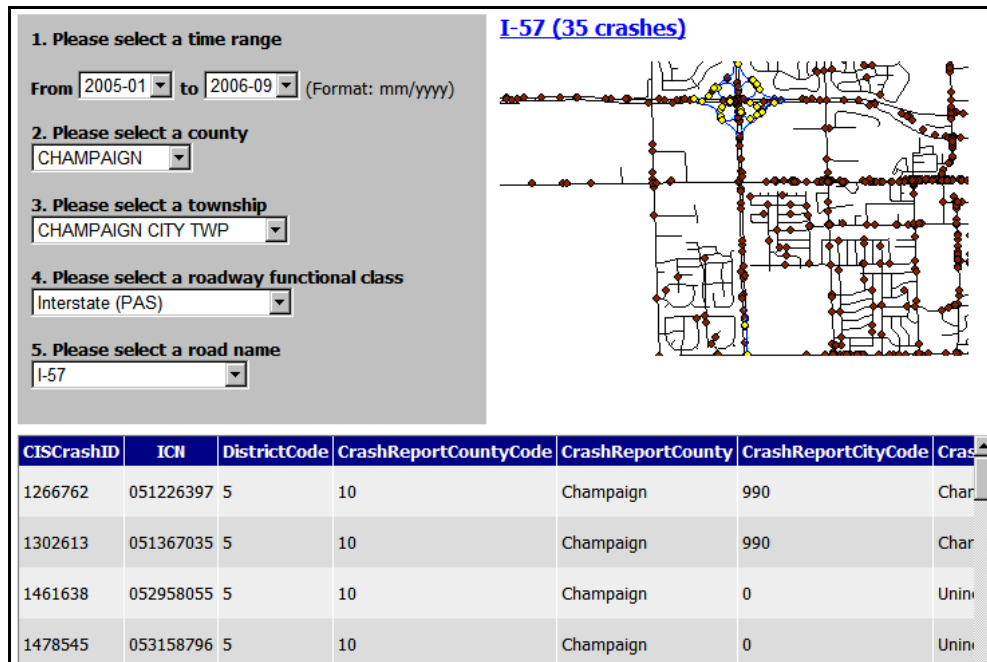


Figure 21. User-interface for crash query by roadway functional class.

Implementation

The same implementation method as mentioned in the previous “crash query by route number” option is used. One difference is that users will have an additional query criterion, which is “roadway functional class.”

Crash Query by Route Number

If users want to select a road using a route number instead of the road name, the “crash query by route number” option can be used. As shown in Figure 22, after a time range, county, and township are chosen, users can select one route number among possible route numbers on the drop down list. Same as the previous two options, both crash points and the selected road are displayed. The following list presents crash information types displayed on the Web-screen:

- CISCrashID
- ICN
- DistrictCode
- CrashReportCounty

- CrashReportCity
- TownshipName
- HighwayOrStreetName
- FunctionalClassDescription
- RouteNbr
- MileStation
- XCoordinate
- YCoordinate
- CrashDateTime
- CrashSeverityDescription
- TotalFatals
- TotalInjured
- CrashVehicleCount
- CollisionTypeDescription
- WeatherCond
- RoadSurfCond
- LightingCond
- ContribCausePrim
- ContribCauseSec
- RoadwayFeature
- TrafControlDevice
- AInjuries
- BInjuries
- CInjuries
- OInjuries
- CrashLocationIntersectionRelated

1. Please select a time range

From to (Format: mm/yyyy)

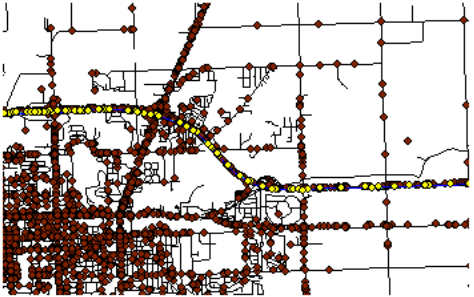
2. Please select a county

3. Please select a township

4. Please select a roadway functional class

5. Please select a route number

1074 (109 crashes)



CISCrashID	ICN	DistrictCode	CrashReportCountyCode	CrashReportCounty	CrashReportCityCode	CrashReportCity
1158855	050130202	5	10	Champaign	5845	Urbana
881676	050237536	5	10	Champaign	5845	Urbana
762087	050242957	5	10	Champaign	5845	Urbana
1187632	050322510	5	10	Champaign	5845	Urbana

Figure 22. User-interface for crash query by route number.

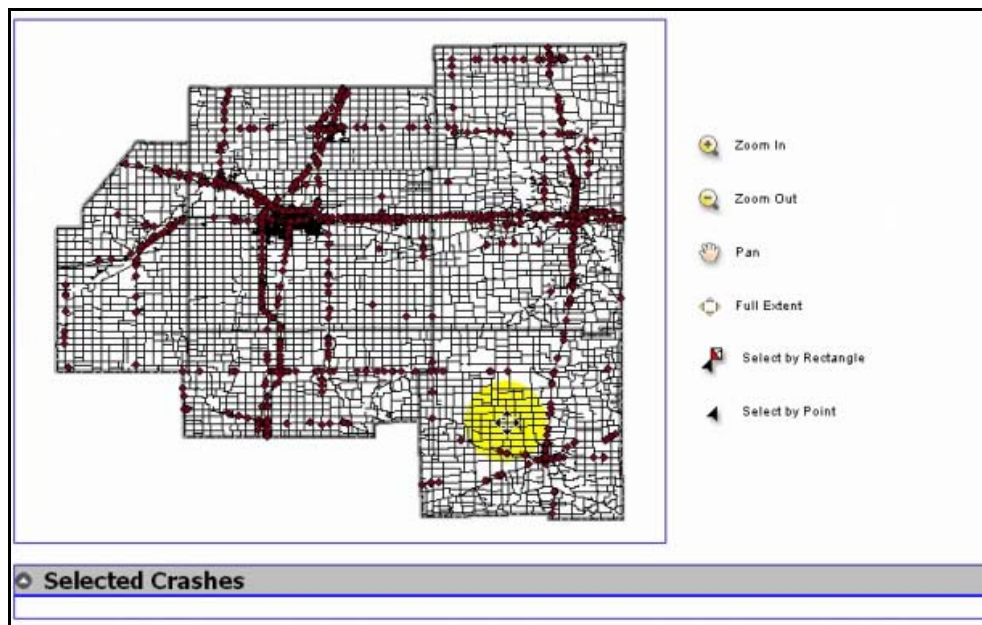
Implementation

The same implementation method as mentioned in previous modules is used for this one. One difference is that users will select the roadway segments with route name such as I-74, I-57, and so on.

Crash Query Using Interactive Map

In the case that users do not know exact road names and route numbers, they can use the “crash query using interactive map” option. Through the zoom-enabled interactive map on the screen, users can select any crashes on the road by just clicking on and dragging the mouse. This is an efficient way to identify the safety conditions of any locations, since users can directly select any locations and see crashes located on the road through the map. Also, detailed crash information is provided for each case of crashes.

As shown in Figure 23, the zoom-enabled interactive map is displayed after selecting the time range, county, and township/municipality. This map includes the Illinois roadway network within the selected jurisdiction boundary and the crashes that occurred in it. On the right side of the map, there are buttons for zoom-in, zoom-out, pan, full extent, select by rectangle, and select by point. By using these buttons, users can easily navigate through the map as well as select any crash points.



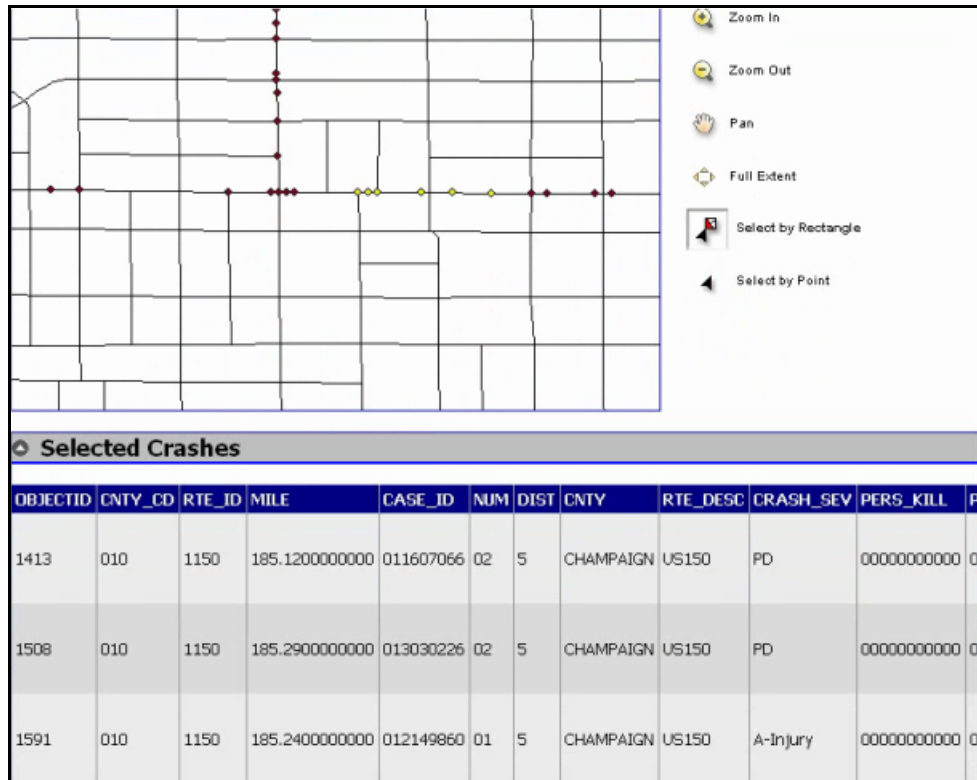


Figure 23. User-interface for crash query using interactive map.

A list of crash information types for each crash is as follows:

- CISCrashID
- ICN
- DistrictCode
- CrashReportCounty
- CrashReportCity
- TownshipName
- HighwayOrStreetName
- FunctionalClassDescription
- RouteNbr
- MileStation
- XCoordinate
- YCoordinate
- CrashDateTime
- CrashSeverityDescription
- TotalFatals
- TotalInjured
- CrashVehicleCount
- CollisionTypeDescription
- WeatherCond
- RoadSurfCond
- LightingCond
- ContribCausePrim
- ContribCauseSec

- RoadwayFeature
- TrafControlDevice
- AInjuries
- BInjuries
- CInjuries
- OInjuries
- CrashLocationIntersectionRelated

Implementation

The buffering and querying methods are the same as before. However, users can select crashes interactively on the map. If users select crashes by “select by point,” the buffers will be generated around the points where users click on the map. However, “select by rectangle” does not generate buffer, since the rectangle created by users plays the same role as buffer polygon.

3.2. SAFETY ANALYSIS SUPPORT MODULE

The safety analysis support module serves as a decision support tool to help local agencies to develop safety improvement projects effective in reducing certain types of vehicle crashes in their jurisdictions. Similar to the *SafetyAnalyst*, this module screens roadway locations within the selected jurisdiction to identify sites with high potential for safety improvements. Also, it diagnoses the sites by investigating collision types and severity types of the crashes that occurred there. Based on the diagnosis result, it recommends multiple site-specific countermeasures for safety improvement to users. Then, one or more countermeasures can be selected as possible options. Afterwards, cost-benefit analyses of selected projects are conducted and the module displays their economic appraisal results to help users to select the most cost-effective engineering solutions. This safety analysis support module consists of three sequential steps as follows:

- Network Screening
- Diagnosis and Countermeasure Generation
- Economic Evaluation

3.2.1 Network Screening

Upon receiving user’s inputs, the network screening step generates a list of hazardous sites that have the largest rooms for improvements in the selected jurisdiction. In the network screening module, an algorithm is needed to identify high-crash locations based on the crash and roadway datasets in the database. Traditionally, agencies directly use the absolute crash counts or crash rates to identify dangerous locations. However, this may cause misleading results due to two reasons. First, random fluctuations of crash counts over finite observation periods may lead to the regression-to-the-mean effect (Hauer et al., 2002); i.e., even without any safety improvements, the number of crashes at a certain location may change in future periods. Second, empirical studies (Pendleton, 1996) have shown that crash count is generally a nonlinear increasing function of risk exposure (e.g., traffic volume), e.g., a high-volume location is expected to have a higher crash count, but a lower crash rate, than a low-volume location. Hence direct comparison of crash records for different roadway locations would be inappropriate.

In order to correct for such biases, statistical techniques such as safety performance function (SPF) and the empirical Bayesian (EB) method are used (MRI et al., 2002). The SPF is a statistical model that determines the expected relationship between crash intensity (number of

crashes per unit of time), roadway geometric design, traffic volume (or other risk exposure variables), crash severity, and crash type. Generally, SPF can be calibrated for various roadway types and various crash severities (e.g., fatality, incapacitating injury, and evident injury) to provide realistic and accurate predictions of crash frequencies over a roadway.

Functional forms and coefficients of the SPFs are different from each other by location type (peer group) and crash severity. Due to this reason, multiple types of the SPFs were developed according to the peer group and crash severity type in this analysis. For the location type, we categorized all Illinois roadways into twelve segment peer groups, largely consistent with the *SafetyAnalyst* guideline (Tegge 2008). However, peer groups for intersection were not included into the system, since at the moment IDOT does not have GIS intersection data for the entire state of Illinois. Therefore, this network screening step does not consider intersections and only SPFs for segments are used in this network screening.

These peer groups allow similar locations to be modeled together and as a result network, the screening can be conducted based on this peer group categorization. The peer groups used for segment SPF development are as follows:

- Rural Two-Lane Highway (Peer Group 1)
- Rural Multilane Undivided Highway (Peer Group 2)
- Rural Multilane Divided Highway (Peer Group 3)
- Rural Freeway, 4 Lanes (Peer Group 4)
- Rural Freeway, 6+ Lanes (Peer Group 5)
- Urban Two-Lane Highway (Peer Group 6)
- Urban One-Way Arterial (Peer Group 7)
- Urban Multilane Undivided Highway (Peer Group 8)
- Urban Multilane Divided Highway (Peer Group 9)
- Urban Freeway, 4 Lanes (Peer Group 10)
- Urban Freeway, 6 Lanes (Peer Group 11)
- Urban Freeway, 8+ Lanes (Peer Group 12)

If roadway segments cannot be fallen in one of the peer groups defined above due to lack of information, the road segments are categorized as “Peer Group 0.” Also, these segments are not included in the network screening. The pseudo-codes for peer group definitions are listed in Appendix F.

In terms of crash severity, only fatal crash, type-A injury crash, and type-B injury crash were considered for the purpose of SPF development. Both type-C injury crash and property damage only (PDO) crash were not used for the SPF development. As a result, this system contains SPFs for fatal crash, for type-A injury crash, and for type-B injury crash. In the system, a typical segment SPF takes on the following functional form:

$$P_{is} = (SL)_i \cdot e^{a_{sg}} \cdot (AADT_i)^{b_{sg}}, \forall i, s, g$$

where P_{is} = the predicted number of crashes at segment i (belonging to peer group g) for crash severity level s ; SL_i = length of segment i ; $AADT_i$ = annual average daily traffic at segment i ; and a_{sg} and b_{sg} are regression coefficients for severity level s and peer group g . The Illinois-specific coefficients in the SPF were estimated by negative binomial regression for each peer group and each severity. The negative binomial model also yields an overdispersion parameter which provides information on how much the variance of the crash count is larger than its mean (Savolainen and Tarko, 2005).

As shown in below tables and Appendix G, all estimated SPF parameters were then stored in the system database to compute the predicted number of crashes of each roadway location by crash severity. One important thing to note is that the SPFs were developed for a

five-year period, due to the nature of the data. This means that the results of the regression produce the expected number of crashes per five years. Dispersion parameters are also 5-year estimates.

Table 2. Segment SPF Parameters for Fatal Crashes

Peer Group	Regression Coefficients		Dispersion Parameter Per Mile
	Intercept (a)	LogAADT (b)	
Rural Two-Lane Highway	-7.249	0.521	77.886
Rural Multilane Undivided Highway	-3.925	0.068	25.776
Rural Multilane Divided Highway	-9.693	0.725	136.217
Rural Freeway, 4 Lanes	-10.575	0.881	20.675
Rural Freeway, 6+ Lanes	-33.403	2.924	87.322
Urban Two-Lane Highway	-6.899	0.423	146.043
Urban One-Way Arterial	-82.156	8.386	278.130
Urban Multilane Undivided Highway	-7.707	0.475	195.963
Urban Multilane Divided Highway	-8.865	0.606	271.873
Urban Freeway, 4 Lanes	-16.256	1.371	20.282
Urban Freeway, 6 Lanes	-6.927	0.499	23.361
Urban Freeway, 8+ Lanes	-15.855	1.247	21.943

Table 3. Segment SPF Parameters for Type-A Injury Crashes

Peer Group	Regression Coefficients		Dispersion Parameter Per Mile
	Intercept (a)	LogAADT (b)	
Rural Two-Lane Highway	-5.194	0.472	26.569
Rural Multilane Undivided Highway	-16.855	1.630	17.061
Rural Multilane Divided Highway	-6.327	0.583	42.128
Rural Freeway, 4 Lanes	-9.339	0.952	6.764
Rural Freeway, 6+ Lanes	-3.983	0.358	15.007
Urban Two-Lane Highway	-5.979	0.571	42.354
Urban One-Way Arterial	-3.398	0.302	154.099
Urban Multilane Undivided Highway	-7.786	0.728	41.662
Urban Multilane Divided Highway	-6.667	0.659	36.957
Urban Freeway, 4 Lanes	-10.045	1.013	7.582
Urban Freeway, 6 Lanes	-7.910	0.815	4.868
Urban Freeway, 8+ Lanes	-12.906	1.226	4.548

Table 4. Segment SPF Parameters for Type-B Injury Crashes

Peer Group	Regression Coefficients		Dispersion Parameter Per Mile
	Intercept (a)	LogAADT (b)	
Rural Two-Lane Highway	-5.039	0.523	19.055
Rural Multilane Undivided Highway	-17.955	2.066	20.564
Rural Multilane Divided Highway	-7.293	0.795	25.334
Rural Freeway, 4 Lanes	-4.897	0.548	4.638
Rural Freeway, 6+ Lanes	-4.274	0.452	11.678
Urban Two-Lane Highway	-6.354	0.698	26.203
Urban One-Way Arterial	-5.563	0.551	88.212
Urban Multilane Undivided Highway	-6.551	0.714	26.398
Urban Multilane Divided Highway	-7.062	0.780	23.635
Urban Freeway, 4 Lanes	-9.628	1.052	5.277
Urban Freeway, 6 Lanes	-11.567	1.235	3.353
Urban Freeway, 8+ Lanes	-12.060	1.301	2.211

The detailed algorithms of SPF estimation for the network screening are developed in ICT project R27-20.

As mentioned before, the SPF provides an “average” performance of roadway segments in a peer group which can be considered to be the *a priori* information about a given location. It can be combined with the actual (but partial) observed crash counts via the EB method (Hauer et al., 2002) to provide more objective estimations of crash counts. This is done by calculating a weighted average of the predicted and observed number of crashes,

$$m_{is} = w_{is} \cdot P_{is} + (1 - w_{is})F_{is}, \forall i, s,$$

where m_{is} = the estimated number of crashes at segment i for crash severity level s , and F_{is} = the observed number of crashes at segment i for crash severity level s . The weight w_{is} is determined from the overdispersion parameter of the SPF model, k_{is} , as follows:

$$w_{is} = \frac{1}{1 + k_{is} \cdot P_{is}}, \forall i, s.$$

The difference between m_{is} and P_{is} is the so-called potential for safety improvement (PSI), i.e.,

$$PSI_{is} = m_{is} - P_{is}, \forall i, s.$$

The PSI values indicate how much worse a roadway location performs than expected,

regarding each crash severity type. For each crash severity level s , the public agency has a relative economic measure of societal cost C_s . The GIS software uses the weighted average of PSI across crash severities, $\left\{ \sum_s PSI_{is} \cdot C_s, \forall i \right\}$, to rank high-crash sites in the network screening module.

In our system, the weights are 25 for the fatal PSI, 5 for the type-A PSI, and 1 for the type-B PSI. That is, as a result of network screening, a list of locations is displayed based on the weighted PSI values in a descending order.

Figure 24 illustrates the PSI calculation method.

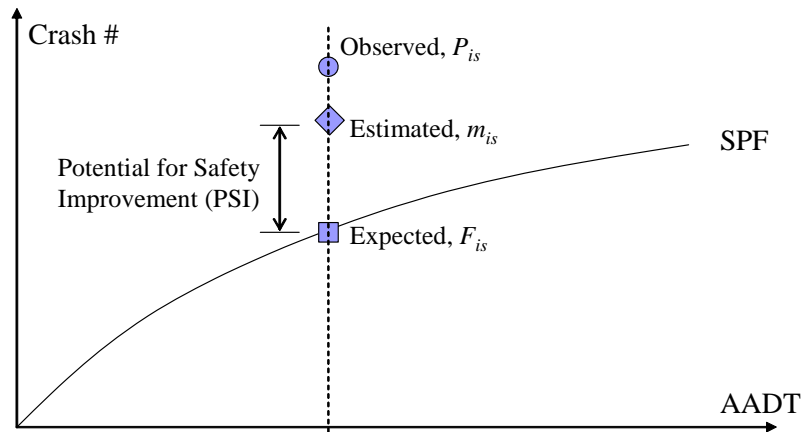


Figure 24. A graphical logic for the PSI calculation.

Example of Weighted PSI Calculation

- Roadway Functional Class: Rural Two-Lane Highway (Peer Group 1)
- Length of Segment: 10 miles
- AADT: 2000 vph
- Observed Crashes from 2001 to 2003: 20 fatal crashes, 120 type-A injury crashes, and 180 type-B injury crashes

□ By using above SPF summary tables, estimate the predicted number of crashes per year. In the above summary tables, all coefficients are based on 5-year estimates. The predicted number of crashes per year can be calculated by dividing 5-year SPF values by 5.

$$\begin{aligned}
 \text{- Fatal SPF} &= (\text{Segment Length}) \cdot \exp(-7.249) \cdot (\text{AADT})^{0.521} \\
 &= (10) \cdot \exp(-7.249) \cdot (2000)^{0.521} \\
 &= 0.373 \text{ crashes per 5 years} \rightarrow 0.075 \text{ crashes per year}
 \end{aligned}$$

$$\begin{aligned}
 \text{- Type-A injury SPF} &= (\text{Segment Length}) \cdot \exp(-5.194) \cdot (\text{AADT})^{0.472} \\
 &= (10) \cdot \exp(-5.194) \cdot (2000)^{0.472} \\
 &= 2.006 \text{ crashes per 5 years} \rightarrow 0.401 \text{ crashes per year}
 \end{aligned}$$

$$\begin{aligned}
 \text{- Type-B injury SPF} &= (\text{Segment Length}) \cdot \exp(-5.039) \cdot (\text{AADT})^{0.523} \\
 &= (10) \cdot \exp(-5.039) \cdot (2000)^{0.523} \\
 &= 3.452 \text{ crashes per 5 years} \rightarrow 0.690 \text{ crashes per year}
 \end{aligned}$$

- By using an overdispersion parameter k and P , calculate weight factors, w as follows:

$$w = \frac{1}{1 + \left(\frac{k}{5} \cdot N \cdot \text{segment_length}\right)(P \cdot N)}$$

N in the above equation is 3 years. The overdispersion parameters k in the SPF summary tables are five-year and per mile estimates. Thus, the 3-year and 10-mile overdispersion parameter k can be estimated by dividing the 5-year k value by 5 and multiplying by N (3 years) and mile length (10 miles). In addition, 3-year SPF estimates can be calculated from a SPF estimate per year multiplied by N , which is 3 years.

$$\text{- Fatal weight factor, } w = \frac{1}{1 + \left(\frac{77.886}{5} \cdot 3 \cdot 10\right)(0.075 \cdot 3)} = 0.009$$

$$\text{- Type-A injury weight factor, } w = \frac{1}{1 + \left(\frac{26.569}{5} \cdot 3 \cdot 10\right)(0.401 \cdot 3)} = 0.005$$

$$\text{- Type-B injury weight factor, } w = \frac{1}{1 + \left(\frac{19.055}{5} \cdot 3 \cdot 10\right)(0.690 \cdot 3)} = 0.004$$

- Calculate the estimated number of crashes using EB method

$$m = w \cdot P + (1 - w)F$$

where m is the estimated number of crashes in N years, w is the determined weight factor in N years, P is the number of predicted crashes in N years, and F is the total number of crashes observed in N years. Thus, 3-year m divided by 3 is the estimated number of crashes per year.

$$\begin{aligned} \text{- } m (\text{Fatal}) &= w \cdot P + (1 - w)F = (0.009 \cdot 0.075 \cdot 3) + (1 - 0.009)20 \\ &= 19.822 \text{ crashes per 3 years} \rightarrow 6.607 \text{ crashes per year} \end{aligned}$$

$$\begin{aligned} \text{- } m (\text{Type-A injury}) &= w \cdot P + (1 - w)F = (0.005 \cdot 0.401 \cdot 3) + (1 - 0.005)120 \\ &= 119.406 \text{ crashes per 3 years} \rightarrow 39.802 \text{ crashes per year} \end{aligned}$$

$$\begin{aligned} \text{- } m (\text{Type-B injury}) &= w \cdot P + (1 - w)F = (0.004 \cdot 0.690 \cdot 3) + (1 - 0.004)180 \\ &= 179.288 \text{ crashes per 3 years} \rightarrow 59.763 \text{ crashes per year} \end{aligned}$$

- Calculate the weighted PSI.

PSI per mile can be estimated as follows:

$$\text{PSI} = \frac{m - P}{\text{segment_length}}$$

$$\text{- Fatal PSI} = \frac{6.607 - 0.075}{10} = 0.653 \text{ crashes per year per mile}$$

$$\text{- Type-A injury PSI} = \frac{39.802 - 0.401}{10} = 3.940 \text{ crashes per year per mile}$$

- Type-B injury PSI = $\frac{59.763 - 0.690}{10} = 5.907$ crashes per year per mile

Therefore, the weighted PSI of the selected segment is as follows:

Weighted PSI = $0.653 \cdot 25 + 3.940 \cdot 5 + 5.907 \cdot 1 = 41.932$

User-Inputs for Network Screening

To calculate PSI values and generate a list of locations with possibilities of high crashes, the procedures explained in the previous sections should be properly defined through the user-inputs. Upon these inputs, the system can take necessary data from the database to calculate PSI values. As shown in Figure 25, six inputs should be specified for network screening.

1. Jurisdiction Type Selection

Please select one of the jurisdiction types and choose a location name from a drop-down list.

Jurisdiction Types: District County

Jurisdiction Name:

2. Location Type Selection

Please select a location type.

Segment Intersection

3. Roadway Functional Class Selection

Please select roadway functional classes.

Rural Freeway, 4 Lanes Rural Two-Lane Highway

4. Time Range Selection

Please select a time range to apply Safety Performance Functions.

From to (Format: mm/yyyy)

5. Maximum Location Display Number Selection

Please select the maximum number of locations to display.

Maximum Number to Display:

6. Safety Performance Function (SPF) Type Selection

Please select Function Type, then click the "Submit Query" button.

Level I SFP Level II SFP

Figure 25. User-interface of inputs for network screening step.

First, either an IDOT district or a county needs to be specified to select the jurisdiction for screening. If an IDOT district is needed, users can choose one of the IDOT district numbers

from the drop down list. Also, if a county is needed, the county name can be chosen from the drop down list. This input ensures the network screening to be conducted only within the selected jurisdiction. Next, users can specify the location type and roadway functional class (peer group), because different types of the SPFs are applied according to the location type (segment or intersection) and roadway functional class (twelve peer groups for segments). If a certain functional class of the segment is chosen, intersection and other types of functional classes will not be included for the network screening. However, as mentioned before, because IDOT does not have a full set of GIS intersection data at present, users can only select segments. Also, in PSI calculation using the EB method, because the numbers of predicted crashes from SPFs and historically observed crashes are both considered, it is essential to select a time range to retrieve historically observed crashes occurred during the selected time period from the databases. Currently, this system was designed to retrieve the most recent 5-year crash data automatically to calculate the PSI values. Following this time range selection, users need to choose the maximum location display number or a percentage value in order to show the top ranked locations. Since the module cannot display all locations, users need to select the maximum number of locations for display based on the descending order of PSI values. If users choose a '20' from the drop down list of the maximum number of locations, the top 20 locations with the highest values of weighted PSI are displayed on the screen. Lastly, either Level I SPF or Level II SPF needs to be selected in the SPF type selection input. In case of Level I SPF, the SPF only includes Average Annual Daily Traffic (AADT) as an independent variable. However, Level II SPF incorporates variables other than just traffic volumes, including weather conditions, roadway geometries, traffic data, and human factors to calculate crash frequencies. In current status, users can only select Level I SPF. After selecting all these inputs, users click on a "Submit Query" button to see the final result of network screening.

Outputs of Network Screening

As shown in Figure 26, the locations with the most improvement potentials are arranged into a list in descending order of weighted PSI values. This list indicates that high potential of having expected excess frequency than predicted exists at those locations that ranked at the top portion.

Screening Results									
Geographical Area: CHAMPAIGN County Location Type: Segment SPF Type: Level I SPF									
Time Range: From 2005 To 2007 Maximum Display Number: 5									
	Rank	OBJECTID	Road Name	Func. Class	AADT	Length (Mi)	Lanes	Observed Crashes	PSI
Select	1	746245	I-74	Rural Freeway, 4 Lanes	24000	0.49	4	5	36.0170031191285
Select	2	732040	I-57	Rural Freeway, 4 Lanes	21300	1.10000002	4	4	25.9725613862611
Select	3	725601	US-45	Rural Freeway, 4 Lanes	9600	1.47000002	4	4	19.1843067763702
Select	4	746100	I-74	Rural Freeway, 4 Lanes	26900	1.37999999	4	3	16.7816983283087
Select	5	770486	I-57	Rural Freeway, 4 Lanes	20200	0.75	4	2	12.9563470552832

Figure 26. A screenshot of the network screening results.

For each segment, detailed information, including the rank, object ID, road name, roadway functional class, AADT, segment length, number of lanes, and the number of observed crashes, is also displayed together with PSI values. Moreover, by clicking on the "Select" button in the list, users can check all crashes on the segment as shown in Figure 27. A list of crash

information types for each crash is as follows:

- CISCrashID
- ICN
- DistrictCode
- CrashReportCounty
- CrashReportCity
- TownshipName
- HighwayOrStreetName
- FunctionalClassDescription
- RouteNbr
- MileStation
- XCoordinate
- YCoordinate
- CrashDateTime
- CrashSeverityDescription
- TotalFatals
- TotalInjured
- CrashVehicleCount
- CollisionTypeDescription
- WeatherCond
- RoadSurfCond
- LightingCond
- ContribCausePrim
- ContribCauseSec
- RoadwayFeature
- TrafControlDevice
- AInjuries
- BInjuries
- CInjuries
- OInjuries
- CrashLocationIntersectionRelated

Detailed Information of Crashes								
CrashDateTime	CrashYear	CrashMonth	CrashDay	CrashHour	DayOfWkCode	DayOfWk	CrashSeverityCode	CrashSeverityDescription
4/8/2005 2:46:00 PM	2005	4	8	14	6	Friday	B	Non-cras
4/8/2005 2:46:00 PM	2005	4	8	14	6	Friday	B	Non-cras
4/8/2005 2:46:00 PM	2005	4	8	14	6	Friday	B	Non-cras
6/23/2005 5:49:00 PM	2005	6	23	17	5	Thursday	B	Non-cras
12/1/2005 9:33:00 AM	2005	12	1	9	5	Thursday	A	Inca

Figure 27. A screenshot of the detailed crash information on the selected segment.

As mentioned before, all crashes here are fatal, type-A injury, or type-B injury crashes.

Implementation

The major task of this module is to get observed number of crashes. In order to get the observed number of crashes, the buffering and querying methods described in “User-Specified

Crash Information” section are used. In addition, in order to use the various equations according to the peer group, the system stores the equation parameters by peer group at a table. The steps of network screening are shown in the Figure 28 below:

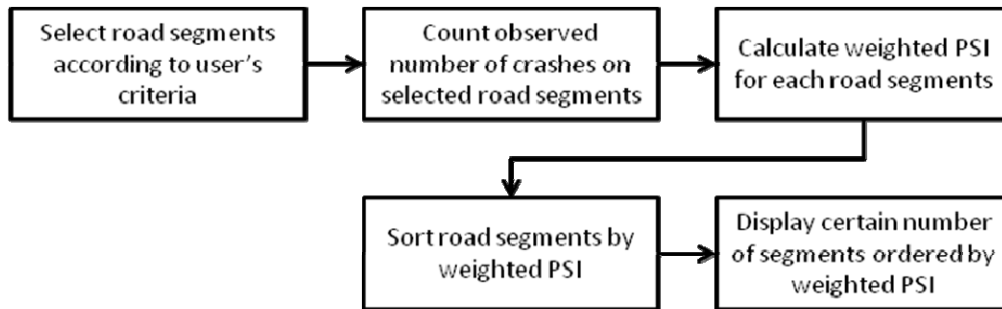


Figure 28. Steps of network screening.

3.2.2 Diagnosis and Countermeasure Generation

The diagnosis is a procedure of conducting a detailed investigation specific for each site selected by network screening. This investigation focuses on identifying what types of crashes occurred and what their degrees of severity are. Through this diagnosis step, users can understand crash patterns and safety conditions of the selected site. In addition, based on results of the diagnosis evaluation, appropriate and effective countermeasures, which are site-specific projects, are provided as possible options and users can select one or multiple projects to reduce crashes for the selected site.

Algorithms of Diagnosis and Countermeasure Generation Steps

As shown in Figure 29, when the user selects a hazardous site for detailed analysis, the diagnosis process categorizes all crashes at that site by collision type and crash severity. Based on this classification, crash frequencies are displayed in the table which has collision type information in the row and severity information in the column. Through this process, users can easily identify how many crashes occurred on the selected segment by their collision type and severity, and this process hence provides the basis for selecting safety improvement countermeasures.

Crash Diagnosis			
Collision Type			
Collision Type	Fatal	A Injuries	B Injuries
Overtuned	0	0	1
Rear end	0	1	3

Figure 29. A screenshot of the diagnosis process.

The following list shows crash severities and collision types considered in this diagnosis process. All crashes can be classified as one of the following collision types and severities.

- Crash Severity -
 - Fatal Crash
 - Type-A Injury Crash
 - Type-B Injury Crash

- Collision Type -

- Angle (AG)
- Animal (AN)
- Fixed Object (FO)
- Head-On (HO)
- Other Non-Collision (ONC)
- Other Object (OO)
- Overturned (OVT)
- Pedestrian (PD)
- Pedal cyclist (PDC)
- Parked Vehicle (PKV)
- Rear End (RE)
- Sideswipe Same Direction (SSD)
- Sideswipe Opposite Direction (SOD)
- Turning (T)
- Train (TR)

The system includes an auxiliary database that stores countermeasures that have been identified to be effective in reducing certain types of collisions. Since all countermeasures are stored together with collision type information in the database, this system can identify what types of countermeasures are effective for reducing crashes of certain collision types. This database of the countermeasures was developed from an Illinois comprehensive highway safety plan (IDOT, 2006). Table 5 shows a list of highway segment safety improvement countermeasures and collision types used in this module. As mentioned before, since the system can only screen segments of the roadway, countermeasures for intersections are not available in the database. In the table, countermeasures marked with 'Vs' indicate that they have effects on reducing crashes of corresponding collision types.

Table 5. A List of Highway Segment Safety Improvement Countermeasures by Collision Type

Safety Issue Type	Countermeasure	AG	AN	FO	HO	ON C	OO	OVT	PD	PDC	PKV	RE	SSD	SOD	T	TR
Alignments	Realignment/Reconstruction URBAN			V	V			V					V	V		
Lane Width	Increase Lane Width	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Shoulder Attributes	Shoulder Paving and Widening			V				V								
Rumble Strips	Install Shoulder Rumble Strips			V				V								
	Install Centerline Rumble Strips				V									V		
Pavements	Pavement Widening and Resurfacing or Widening alone	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Bridges	General Bridge Repair			V	V			V			V		V	V		
	Bridge Widening and Resurfacing			V	V			V					V	V		
	Bridge Widening			V	V			V					V	V		
	Install Bridge Frost/Ice Detector Signs			V	V			V					V	V		
	Install Bridge Frost/Ice Detector Radio			V	V			V			V		V	V		
	Install Bridge Guardrail			V				V								
	Separate Pedestrian and Vehicle Traffic			V				V	V	V						
	Install Bridge Delineators			V				V								
	Install Bridge Impact Attenuators			V				V								
	Bridge Reconstruction			V	V			V					V	V		

Table 5. A List of Highway Segment Safety Improvement Countermeasures by Collision Type (continued).

Safety Issue Type	Countermeasure	AG	AN	FO	HO	ONC	OO	OVT	PD	PDC	PKV	RE	SSD	SOD	T	TR	
Railroad Crossing	Railroad Crossing Modification			V				V				V				V	
	Install Gates			V				V				V				V	
	Install Crossbucks			V				V								V	
	Install Flashing lights			V				V				V				V	
	Install Flashing Beacons			V				V				V				V	
	Install Warning Bells																V
	Install Markings			V				V				V					V
	Install Warning Signs - Standard			V				V				V					V
	Install Warning Signs - Special			V				V				V					V
	Install Delineators			V				V									V
	Install Lighting			V				V				V					V
	Railroad Crossing Resurfacing			V				V				V					V
	Convert railroad Crossing to Grade Separation	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Remove Railroad Crossing	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Signs	Install Advance Warning Signs	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
	Install Chevrons or Delineators			V	V			V						V			
	Sign Relocation	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
	Drainage Improvement	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
Markings	General Pavement Markings	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
Guardrails and Attenuators	Install Guardrails			V				V									
	Install Impact Attenuators			V				V									
Roadside Conditions	General/Fixed Obstacle Removal			V				V									
	Curb Parking Removal			V				V			V	V					
	Utility Adjustment			V				V									
	Install Glare Shields	V		V				V					V				
	Install Fencing	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	

Based on the result of diagnosis, the system will find the most severe crashes (e.g., fatal crashes) at the specified site, and then identify the statistically dominant collision type of the crashes to retrieve the set of countermeasures in the database. For example, if a diagnosis result shows that fatal, type-A injury, and type-B injury crashes all occurred on a selected segment, the system will consider only the fatal crashes and will investigate collision types of these fatal crashes to find out the predominant collision type. Only countermeasures effective for reducing crashes of this collision type in the fatal crashes are displayed on the screen. If both type-A injury and type-B injury crashes happened on a segment, the system will display only countermeasures effective for reducing type-A injury crashes of the predominant collision type. If only crashes of one severity type occurred, the system will find the most frequent collision type of these crashes and will display countermeasures for crashes of this collision type.

The selected countermeasures will be listed as candidate options for the user to select from, while those including high crash reduction factors (CRFs) will be given priority on the list. According to users' preference, any countermeasures displayed on the screen can be selected for an economic analysis. The user-interface for this countermeasure generation step is shown in Figure 30.

After selecting countermeasures, users need to click on the "Economic Appraisal Module" button to perform the economic analysis on selected candidate countermeasures. Detailed information about algorithms of benefit-cost analysis for selected countermeasures will be provided in the next section.

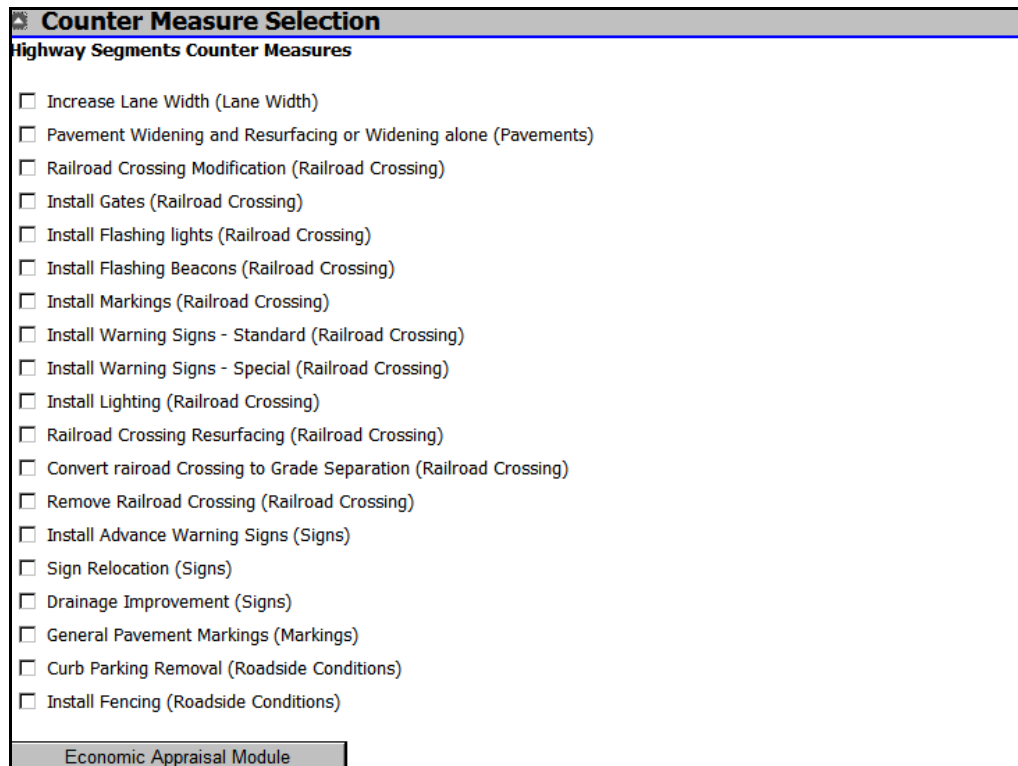


Figure 30. A screenshot of the countermeasure selection.

Implementation

This module displays the diagnosis result and countermeasures on a road segment selected by the user. The diagnosis is done via query generator and table generator. When the module displays the countermeasures, it uses the information presented in Table 5, which is stored in the database.

3.2.3 Economic Evaluation

Economic Appraisal

The economic evaluation step provides users with a means to perform an economic analysis of selected countermeasures. The expected benefits of a countermeasure (in terms of the expected reduction in number of crashes in future years) are estimated based on the SPF and CRF. A minimum attractive rate of return, which is a discount rate, and service life estimates of the selected projects are required to convert the annual benefits of safety improvement into the present monetary values. The budget requirement of each project also needs to be specified by the user. The system then conducts both benefit-cost ratio analysis and net-benefit analysis to recommend a priority ranking of cost-effective projects. In this system, the economic evaluation tool performs the economic analysis for each individual countermeasure at a selected site. Thus, the economic analysis for combinations of countermeasures is not considered in this module.

Economic Criteria

For this economic evaluation step, two economic criteria are used: benefit-cost ratio analysis and net benefit analysis.

The benefit-cost (BC) ratio is the ratio of present benefits to construction costs of a project as follows:

$$\text{BC ratio} = \frac{\textit{Benefit}}{\textit{Cost}}$$

If benefit-cost ratio is greater than 1.0, a candidate countermeasure could be economically justified (MRI et al. 2002).

The second approach used in this step is the net benefit analysis. In this case, economic appraisal of candidate improvements can be determined by benefits minus costs as follows:

$$\text{Net benefit} = \textit{Benefit} - \textit{Cost}$$

If the net benefit is positive, it can be said that the selected countermeasure is economically justified. Thus, the most desirable countermeasure for safety improvements is those with the highest net benefit (MRI et al. 2002).

To use either of these two approaches, the benefits and costs for each countermeasure should be expressed in monetary terms. In case of project costs, meaning construction or maintenance costs required to implement the countermeasures, they will be entered into the system by the user directly in terms of the present value (which is required for all selected countermeasures). These safety improvement project costs can be obtained from a variety of sources such as IDOT's or local agencies' contract databases, since they have extensive experience on the construction of transportation infrastructures. The major challenge has to do with the evaluation of safety benefits

associated with each candidate countermeasure, which rely on the long-term reduction in crash occurrence.

Countermeasure Benefit Evaluation

The estimated safety benefits must be expressed on either an annual or a present-value basis by using an estimate of the service life of the countermeasure and a specified minimum attractive rate of return (MRI et al., 2002). In this economic evaluation step of the system, the present-value basis is used, instead of the annual basis. That is, the benefits associated with the expected crash numbers reduced in future period are converted to a present value and this value is compared to the countermeasure construction cost as a present value. This present-value basis is necessary for comparing countermeasures with different service lives and countermeasures in which the accident reduction benefits are not uniform over time (MRI et al. 2002).

As shown in Table 6, the GIS system contains a database that stores the CRF and service life information of all possible countermeasures for the selected segment. This table is based on a report, Highway Safety Improvement Program: Benefit-Cost Tool Users Guide (IDOT, 2006).

Table 6. CRF and Service Life by Highway Segment Safety Improvement Countermeasures

Safety Issue Type	Countermeasure	Service Life	CRF
Alignments	Realignment/Reconstruction URBAN	15	35%
Lane Width	Increase Lane Width	15	10%
Shoulder Attributes	Shoulder Paving and Widening	5	10%
Rumble Strips	Install Shoulder Rumble Strips	3	30%
	Install Centerline Rumble Strips	3	20%
Pavements	Pavement Widening and Resurfacing or Widening alone	15	25%
Bridges	General Bridge Repair	10	15%
	Bridge Widening and Resurfacing	15	15%
	Bridge Widening	15	15%
	Install Bridge Frost/Ice Detector Signs	10	25%
	Install Bridge Frost/Ice Detector Radio	10	25%
	Install Bridge Guardrail	10	15%
	Separate Pedestrian and Vehicle Traffic	15	95%
	Install Bridge Delineators	4	15%
	Install Bridge Impact Attenuators	3	70%
	Bridge Reconstruction	20	50%

Table 6. CRF and Service Life by Highway Segment Safety Improvement Countermeasures (continued)

Safety Issue Type	Countermeasure	Service Life	CRF
Railroad Crossing	Railroad Crossing Modification	15	50%
	Install Gates	15	60%
	Install Crossbucks	15	60%
	Install Flashing lights	15	60%
	Install Flashing Beacons	15	60%
	Install Warning Bells	15	50%
	Install Markings	2	30%
	Install Warning Signs - Standard	2	40%
	Install Warning Signs - Special	5	40%
	Install Delineators	4	40%
	Install Lighting	15	50%
	Railroad Crossing Resurfacing	10	25%
	Convert railroad Crossing to Grade Separation	20	100%
	Remove Railroad Crossing	20	50%
Signs	Install Advance Warning Signs	5	20%
	Install Chevrons or Delineators	4	40%
	Sign Relocation	15	45%
	Drainage Improvement	10	10%
Markings	General Pavement Markings	1	30%
Guardrails and Attenuators	Install Guardrails	10	40%
	Install Impact Attenuators	3	70%
Roadside Conditions	General/Fixed Obstacle Removal	20	50%
	Curb Parking Removal	20	50%
	Utility Adjustment	15	45%
	Install Glare Shields	10	15%
	Install Fencing	10	15%

For a certain countermeasure k , the CRF value R_k indicates the expected percent decrease in crash frequencies due to the countermeasure implementation. This CRF is a measurement of the effectiveness of an improvement in reducing the number of crashes at a location, or a group of locations of the same improvement type. In addition, these crash reduction factors can be used to optimize the use of safety funds through rational prioritization of improvement alternatives.

As mentioned before, the benefits associated with each safety improvement project depend on the expected crash reduction. The expected number of crashes reduced as a result of the implementation of countermeasures is estimated by using SPFs in EB framework and CRF.

The expected annual monetary safety benefits equals $R_k \cdot \sum_s m_{is} C_s$, i.e., the product of the CRF, the expected number of crashes from the EB method, and the monetary cost of each crash by severity type (fatality, type-A injury and type-B injury). Suppose the service life of countermeasure k is n_k , the annual safety benefits will be received in every one of the n_k future years. The present value of safety benefits that will result from countermeasure k is given by the following formula:

$$PSB_{ik} = [R_k \sum_s m_{is} C_s] \frac{(1+r)^{n_k} - 1}{r(1+r)^{n_k}},$$

where PSB_{ik} = present value of safety benefits of countermeasure k at segment i , and r = minimum attractive rate of return, expressed as a decimal fraction.

In above equation, the monetary cost of each crash by severity type stored in the database is as follows:

- Fatality (K) = \$4,008,900/fatal crash
- Type-A Injury (A) = \$216,000/ type-A injury crash
- Type-B Injury (B) = \$79,000/ type-B injury crash

These costs came from an IDOT report, Highway Safety Improvement Program: Benefit-Cost Tool Users Guide (IDOT, 2006).

User-Inputs for Economic Evaluation

Based on previous algorithms, benefits and costs of selected countermeasures can be estimated with two user-inputs. As shown in Figure 31, users need to specify a minimum attractive rate of return and a construction cost for each selected countermeasure. This system was set up to use 0.04 (4%) as a default value of the minimum attractive rate of return. Other information required for the economic evaluation automatically comes from system's database.

Enter Minimum Attractive Rate of Return
 Minimum attractive rate of return: 0.04

Select Highway Segments Counter Measures and Enter Cost

Counter Measures	Cost
<input checked="" type="checkbox"/> Increase Lane Width (Lane Width)	30000
<input checked="" type="checkbox"/> Pavement Widening and Resurfacing or Widening alone (Pavements)	75000
<input checked="" type="checkbox"/> Convert railroad Crossing to Grade Separation (Railroad Crossing)	54300
<input type="checkbox"/> Remove Railroad Crossing (Railroad Crossing)	0
<input type="checkbox"/> Install Advance Warning Signs (Signs)	0
<input checked="" type="checkbox"/> Sign Relocation (Signs)	234000
<input type="checkbox"/> Drainage Improvement (Signs)	0
<input type="checkbox"/> General Pavement Markings (Markings)	0
<input type="checkbox"/> Install Glare Shields (Roadside Conditions)	0
<input type="checkbox"/> Install Fencing (Roadside Conditions)	0

Perform Economic Appraisal

Figure 31. A screenshot of user-inputs for economic appraisal.

Economic Evaluation Results

After selecting countermeasures and two input values, the system displays results of the economic evaluation based on the two criteria, benefit-cost ratio analysis and net benefit analysis. The countermeasures with high values of benefit-cost ratio and net benefit will have priority in the list. Having seen the economic evaluation results on the screen, users can select one or multiple countermeasures for implementation considerations, or repeat the whole process (from network screening to economic evaluation) to screen other sites and to select new countermeasures. Figure 32 shows one example of the economic evaluation results.

Counter Measure	Benefit-Cost Ratio (PSB/Cost)	Net-Benefit (PSB-Cost, \$)
Increase Lane Width (Lane Width)	15.4186387543689	432559.162631068
Pavement Widening and Resurfacing or Widening alone (Pavements)	15.4186387543689	1081397.90657767
Convert railroad Crossing to Grade Separation (Railroad Crossing)	104.125126180036	5599694.35157598
Sign Relocation (Signs)	8.89536851213591	1847516.2318398

Figure 32. A screenshot of the economic appraisal results.

Implementation

The service life information and CRF values of selected countermeasures are also stored in the table mentioned in previous sections. The system uses these parameters to perform the economic appraisal.

3.3. EDUCATION MODULE

An important feature of the safety program is the provision of educational materials to local agencies. This education module includes space for uploading such materials and

allows users to easily access these materials. The material types may fall into the following two categories:

- Tutorial on statistical analysis methods
- Research reports and documentation of safety improvement projects

The tutorial on statistical analysis can be distributed in the form of white papers (as those on the *SafetyAnalyst* website: <http://www.safetyanalyst.org/docs.htm>), or in the form of user and technical manuals. We hope that local agencies will gradually gain expertise in safety analysis and learn the skills by using this program.

It is also helpful to list ongoing and completed safety projects conducted by local agencies in Illinois (similar to those listed on the Iowa DOT's ITSDS website: <http://www.ctre.iastate.edu/itsds/projects.cfm>). Each project list entry will include a project title, PI, a brief description, and any reports or outcome. This will be helpful to local agencies by providing details and past experiences on various safety projects.

CHAPTER 4 FINAL REMARKS AND RECOMMENDATIONS

This report describes an Internet-based, GIS-compatible software tool for Illinois local road crash analysis. This tool is capable of performing crash information query, trend analysis, statistical analysis, color-coded mapping, and other safety information display within a GIS environment. This system helps the state and local transportation agencies in Illinois to screen dangerous highway segments, diagnose safety performance of the selected roads, and identify the most cost-effective countermeasures for safety improvements. Through this decision-support process, local agencies can evaluate current safety conditions effectively and utilize available safety funds economically to reduce fatalities and severe injuries.

Section 4.1 below explains several technical issues that became apparent during the development of this GIS system. Section 4.2 discusses update and maintenance of the system.

4.1. CURRENT KNOWN ISSUES

The following list contains known technical issues and requests that have not been addressed due to reasons such as requiring database schema changes (DC), requiring code changes (CC), requiring significant user interface changes (UC), and requiring further new research (NR). Some of the listed items were suggested during the project testing and review phase. Given the time limit of this project, these issues are listed and possible solution approaches for possible future system upgrades are suggested.

- In the current system, a month and year (mm-yyyy) format is used to select a time range for querying crash information. IDOT requests that the format be changed to a day-month-year based range such as “dd-mm-yyyy.” To implement this request, the major requirement is to change the database schema, with some minor code change and user interface change. (DC, CC, UC)
- In the general crash information sub-module, crash information by day of week is not sorted by the order of day. To implement this request, the major requirement is to change the database schema, with some minor user interface change. (DC, UC)
- Numbers in the tables as a query result of crash information are not formatted with a comma (e.g. 1,000). The current format is the ArcGIS default. To implement this request, the major requirement is to change the code based on knowledge on ArcGIS formatting. (CC, NR)
- The total numbers at the bottom of table are not available with the table format. Displaying the values is not technically challenging, but displaying them in the table with other data is challenging. The authors wonder if the IDOT GIS experts will be able to address this issue. (CC, UC)
- In the general crash information sub-module, information on unknown collision type crashes is displayed as "nown" in the table. This problem is due to the incorrect data coding (“nown”) in the SQL crash information database.
- A printing function on the web screen is not currently available. Printing a current displayed page can be done by a browser’s print function. However, printing a summary page of the query result requires significant additional work. (CC, UC)
- It is not possible to wrap text in the tables of the queries. Wrapping text causes a

number to wrap into multiple lines. In order to preserve the value in readable format, wrapping text is not recommended. The authors wonder if the IDOT GIS experts will be able to address this issue.

- Sometimes, in the Windows XP environment, a scroll bar located in the detailed crash information table does not appear. The scroll bar issue may have something to do with the Windows OS environment and ArcGIS compatibility. We wonder if the IDOT GIS experts will be able to address this issue.
- Displaying the crashes with different color or symbol by the crash type such as fatal, A, B, C, property is not available since the information, the type of crash, is stored in DataMart database not in GIS data (crash location table). Because of this issue, GIS system cannot draw the crashes based on the crash type. Once the data format is improved, crash types can be easily displayed. (DC, CC, UC)
- Preprocessing mechanism for finding crashes on each roadway link has not been implemented. It requires the programming work with ArcGIS desktop not with ArcGIS server. It will take a significant amount of time. (CC)
- The location of color selection buttons in the color-coded map is offset depending on the size of the window and the kind of web browser. This bug belongs to the web control used for the color selection not to this system. Therefore it cannot be fixed by the authors.
- The “Back” button is not available in network screening and economic appraisal modules because it is technically challenging to manage the data (or variables) that need to be transferred between pages.

4.2. SYSTEM UPDATE AND MAINTENANCE

As described before, since the system was designed to access the crash information database and GIS road network database (when the system is deployed at IDOT, the database connections need to be properly set), the update of the databases is very important. In other words, the system does not need the updates in terms of data, but tables with settings or parameters may need to be updated when the mathematical model or configuration are changed.

Since access to the roadway and crash databases are separated, the system performance is relatively slow. In order to improve the performance, some changes to architecture and database design may be necessary. One possibility is to reconfigure the underlying databases into relationship database format (rather than having two huge tables) such that SQL queries can be processed much more efficiently.

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APPENDIX A

- A List of GIS Crash Location Data Fields

OBJECTID
CASE_ID
CASE_ID2

APPENDIX B

- A List of SQL Crash Information Data Fields

CISCrashID	CollisionTypeDescription
ICN	WeatherCondCode
DistrictCode	WeatherCond
CrashReportCountyCode	RoadSurfCondCode
CrashReportCounty	RoadSurfCond
CrashReportCityCode	LightingCondCode
CrashReportCity	LightingCond
TownshipIRISCode	ContribCausePrimCode
TownshipName	ContribCausePrim
HighwayOrStreetName	ContribCauseSecCode
FunctionalClassCode	ContribCauseSec
FunctionalClassDescription	RoadwayFeatureCode
RouteNbr	RoadwayFeature
MileStation	TrafControlDeviceCode
XCoordinate	TrafControlDevice
YCoordinate	AInjuries
CrashDateTime	BInjuries
CrashYear	CInjuries
CrashMonth	OInjuries
CrashDay	CrashYearMonth
CrashHour	CrashLocationIntersectionRelated
DayOfWkCode	PDO
DayOfWk	cfatal
CrashSeverityCode	ca_inj
CrashSeverityDescription	cb_inj
TotalFataIs	cc_inj
TotalInjured	
CrashVehicleCount	
CollisionTypeCode	

APPENDIX C

- A List of SQL Vehicle Information Data Fields

CISCrashID	TotalFatals
ICN	TotalInjuries
CrashReportUnitNbr	AInjuries
VehTypeCode	BInjuries
VehType	CInjuries
VehUseCode	DriverAgeAtCrash
VehUse	DriverCondCode
VehDefectsCode	DriverCond
VehDefects	
VehManeuverPriorCode	
VehManeuverPrior	
DirectionPriorTravelCode	
DirectionPriorTravel	
IsVehInsured	
IsCommercial	
VehPointOfFirstContactCode	
VehPointOfFirstContact	
CrashEvent1Code	
CrashEvent1	
Event1LocCode	
Event1Loc	
CrashEvent2Code	
CrashEvent2	
Event2LocCode	
Event2Loc	
CrashEvent3Code	
CrashEvent3	
Event3LocCode	
Event3Loc	

APPENDIX D

- A List of GIS Roadway Data Fields

OBJECTID_1	FAULT_WITH	MED_WTH	RUT_WITH
OBJECTID	FC	MNT_1	SEG_LENGTH
INVENTORY	GAP	MNT_2	SP_LIM
BEG_STA	HCV	MNT_DIST	SPEC_SYS
END_STA	HCV_MU_YR	MNT_SECT	SU_VOL
AADT	HPMS_SECT	MRK_RT_TY2	SURF_TYP
AADT_YR	I_SHD1_TYP	MRK_RT_TY3	SURF_WTH
ACC_CNTL	I_SHD1_WTH	MRK_RT_TY4	SURF_YR
ANN_BK_NBR	I_SHD2_TYP	MRK_RT_TYP	TOLL
BLT	I_SHD2_WTH	MU_VOL	TRK_RT
CH	INV_CO	MUNI	TWP
CO_ADJ	IRI_LOW	MUNI_ADJ	TWP_ADJ
CONG	IRI_OPP	NHS	URB_LOC
CONG_ADJ	IRI_WITH	NON_ATTAIN	URBAN
CRS_LOW	KEY_RT_NBR	O_SHD1_TYP	LABELR
CRS_OPP	KEY_RT_SEG	O_SHD1_WTH	CLASSIFY
CRS_WITH	KEY_RT_SUF	O_SHD2_TYP	CNTYMAPSYM
CRS_YR	KEY_RT_TYP	O_SHD2_WTH	FC_TEXT
JUR_1	LABEL_1	OP_1_2_WAY	CTY_TEXT
JUR_2	LN_SPC	PL_AGY	TWP_TEXT
JUR_TYPE	LN_SPC_NBR	PL_AGY_ADJ	DIVIDER
K2	LN_SPC_WTH	PRK_LT	DIR_TRAVEL
KEY_RT_APN	LN_WTH	PRK_RT	Urban_Rura
KEY_RT_APP	LNS	REP	RoadType
DIST	MAINT_TYPE	REP_ADJ	PeerGroup
DTRESS_OPP	MARKED_RT	ROAD_NAME	Divided
DTRESS_WTH	MARKED_RT2	ROW	SURFACE1
FAULT_LOW	MARKED_RT3	ROW_AVL	
FAULT_OPP	MARKED_RT4	RUT_LOW	
	MED_TYP	RUT_OPP	

APPENDIX E

- A List of GIS Jurisdiction Data Fields

NC4_
NC4_ID
FIPS_CO
STATE_CODE
TOTALPOP
NAME_LC
DISTRICT
COUNTY_NAM
area

APPENDIX F

- Peer Group Definition for Roadway Segments

Group 1: Rural Two-Lane Highway

if (Fc <= 60) and (Lns <= 2) and (Urban = 0) then classification = 1;

Group 2: Rural Multilane Undivided Highway

if (Fc = 30 or Fc = 40 or Fc = 50 or Fc = 55 or Fc = 60) and (Lns > 2) and (Med_typ = 0) and (Urban = 0) then classification = 2;

Group 3: Rural Multilane Divided Highway

if (Fc = 30 or Fc = 40 or Fc = 50 or Fc = 55 or Fc = 60) and (Lns > 2) and (Med_typ ne 0) and (Urban = 0) then classification = 3;

Group 4: Rural Freeway, 4 Lanes

if (Fc <= 20) and (Urban = 0) and (Lns = 4 or Lns = 3) then classification = 4;

Group 5: Rural Freeway, 6+ Lanes

if (Fc <= 20) and (Lns >= 5) and (Urban = 0) then classification = 5;

Group 6: Urban Two-Lane Highway

if (Fc <= 30 or Fc >= 70) and (Lns <= 2) and (Urban ne 0) and (Op_1_2_way = 2) then classification = 6;

Group 7: Urban One-Way Arterial

if (Fc <= 30 or Fc >= 70) and (Urban ne 0) and (Op_1_2_way = 1) then classification = 7;

Group 8: Urban Multilane Undivided Highway

if (Fc = 30 or Fc = 70 or Fc = 80 or Fc = 90) and (Lns > 2) and (Med_typ = 0) and (Urban ne 0) and (Op_1_2_way = 2) then classification = 8;

Group 9: Urban Multilane Divided Highway

if (Fc = 30 or Fc = 70 or Fc = 80 or Fc = 90) and (Lns > 2) and (Med_typ ne 0) and (Urban ne 0) and (Op_1_2_way = 2) then classification = 9;

Group 10: Urban Freeway, 4 Lanes

if (Fc <= 20) and (Lns = 3 or Lns = 4) and (Urban ne 0) and (Op_1_2_way = 2) then classification = 10;

Group 11: Urban Freeway, 6 Lanes

if (Fc <= 20) and (Lns = 5 or Lns = 6) and (Urban ne 0) and (Op_1_2_way = 2) then classification = 11;

Group 12: Urban Freeway, 8+ Lanes

if (Fc <= 20) and (Lns >= 7) and (Urban ne 0) and (Op_1_2_way = 2) then classification = 12

APPENDIX G

- A List of Illinois Segment SPF Equations

Peer Group	Crash Type	Safety Performance Function (Expected Number of Crashes per Five Years)
Rural Two-Lane Highway	Fatal	$(\text{Segment Length}) \cdot \exp(-7.249) \cdot (\text{AADT})^{0.521}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-5.194) \cdot (\text{AADT})^{0.472}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-5.039) \cdot (\text{AADT})^{0.523}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-4.435) \cdot (\text{AADT})^{0.525}$
Rural Multilane Undivided Highway	Fatal	$(\text{Segment Length}) \cdot \exp(-3.925) \cdot (\text{AADT})^{0.068}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-16.855) \cdot (\text{AADT})^{1.630}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-17.955) \cdot (\text{AADT})^{2.066}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-3.005) \cdot (\text{AADT})^{0.259}$
Rural Multilane Divided Highway	Fatal	$(\text{Segment Length}) \cdot \exp(-9.693) \cdot (\text{AADT})^{0.725}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-6.327) \cdot (\text{AADT})^{0.583}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-7.293) \cdot (\text{AADT})^{0.795}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-7.767) \cdot (\text{AADT})^{0.923}$
Rural Freeway, 4 Lanes	Fatal	$(\text{Segment Length}) \cdot \exp(-10.575) \cdot (\text{AADT})^{0.881}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-9.339) \cdot (\text{AADT})^{0.952}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-4.897) \cdot (\text{AADT})^{0.548}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-6.687) \cdot (\text{AADT})^{0.804}$
Rural Freeway, 6+ Lanes	Fatal	$(\text{Segment Length}) \cdot \exp(-33.403) \cdot (\text{AADT})^{2.924}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-3.983) \cdot (\text{AADT})^{0.358}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-4.274) \cdot (\text{AADT})^{0.452}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-7.406) \cdot (\text{AADT})^{0.872}$
Urban Two-Lane Highway	Fatal	$(\text{Segment Length}) \cdot \exp(-6.899) \cdot (\text{AADT})^{0.423}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-5.979) \cdot (\text{AADT})^{0.571}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-6.354) \cdot (\text{AADT})^{0.698}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-3.557) \cdot (\text{AADT})^{0.462}$
Urban One-Way Arterial	Fatal	$(\text{Segment Length}) \cdot \exp(-82.156) \cdot (\text{AADT})^{8.386}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-3.398) \cdot (\text{AADT})^{0.302}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-5.563) \cdot (\text{AADT})^{0.551}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-5.495) \cdot (\text{AADT})^{0.689}$
Urban Multilane Undivided Highway	Fatal	$(\text{Segment Length}) \cdot \exp(-7.707) \cdot (\text{AADT})^{0.475}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-7.786) \cdot (\text{AADT})^{0.728}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-6.551) \cdot (\text{AADT})^{0.714}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-4.876) \cdot (\text{AADT})^{0.647}$

	Injury	
Urban Multilane Divided Highway	Fatal	$(\text{Segment Length}) \cdot \exp(-8.865) \cdot (\text{AADT})^{0.606}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-6.667) \cdot (\text{AADT})^{0.659}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-7.062) \cdot (\text{AADT})^{0.780}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-6.206) \cdot (\text{AADT})^{0.761}$
Urban Freeway, 4 Lanes	Fatal	$(\text{Segment Length}) \cdot \exp(-16.256) \cdot (\text{AADT})^{1.371}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-10.045) \cdot (\text{AADT})^{1.013}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-9.628) \cdot (\text{AADT})^{1.052}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-10.369) \cdot (\text{AADT})^{1.201}$

Urban Freeway, 6 Lanes	Fatal	$(\text{Segment Length}) \cdot \exp(-6.927) \cdot (\text{AADT})^{0.499}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-7.910) \cdot (\text{AADT})^{0.815}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-11.567) \cdot (\text{AADT})^{1.235}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-13.022) \cdot (\text{AADT})^{1.425}$
Urban Freeway, 8+ Lanes	Fatal	$(\text{Segment Length}) \cdot \exp(-15.855) \cdot (\text{AADT})^{1.247}$
	A-Injury	$(\text{Segment Length}) \cdot \exp(-12.906) \cdot (\text{AADT})^{1.226}$
	B-Injury	$(\text{Segment Length}) \cdot \exp(-12.060) \cdot (\text{AADT})^{1.301}$
	Fatal and Injury	$(\text{Segment Length}) \cdot \exp(-0.508) \cdot (\text{AADT})^{1.228}$

