NDOT Research Report

SafetyAnalyst Testing and Implementation

March 2009

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16. Abstract

SafetyAnalyst is a software tool developed by the Federal Highway Administration to assist state and local transportation agencies on analyzing safety data and managing their roadway safety programs. This research report documents the major tasks accomplished as well as the findings and recommendations from the research. The scope of this project was focused on the first module of the analytical tool – Network Screening. The report includes a comprehensive literature review of studies and findings related to network screening methodologies and GIS-based data processing tools. An overview of the major functions and features of SafetyAnalyst is also included in the report. Major efforts were spent on compiling a dataset based on the transportation network managed by the Regional Transportation Commission of Washoe Country. The dataset was assembled using various tools and according to the data structure required by SafetyAnalyst. Finally, summaries and future research recommendations are provided by the researchers.

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SafetyAnalyst Testing and Implementation

Final Report

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Abstract

SafetyAnalyst is a software tool developed by the Federal Highway Administration to assist state and local transportation agencies on analyzing safety data and managing their roadway safety programs. This research report documents the major tasks accomplished as well as the findings and recommendations from the research. The scope of this project was focused on the first module of the analytical tool – Network Screening. The report includes a comprehensive literature review of studies and findings related to network screening methodologies and GIS-based data processing tools. An overview of the major functions and features of SafetyAnalyst is also included in the report. Major efforts were spent on compiling a dataset based on the transportation network managed by the Regional Transportation Commission of Washoe Country. The dataset was assembled using various tools and according to the data structure required by SafetyAnalyst. Finally, summaries and future research recommendations are provided by the researchers.

Acknowledgement

1 Introduction

1.1 Background

In April 2001, Midwest Research Institute (MRI), under a contract with the Federal Highway Administration (FHWA), initiated a research project to plan and develop a software tool known as the SafetyAnalyst. SafetyAnalyst includes a set of computerized analytical tools to aid state and local transportation agencies in managing their roadway traffic safety programs. The development of SafetyAnalyst has been jointly funded by the FHWA and the participating pooled-fund states including the Nevada Department of Transportation (NDOT). The SafetyAnalyst Technical Working Group consists of representatives from 24 States participating in the SafetyAnalyst development as well as from three local agencies (1). Lead by the Midwest Research Institute, the SafetyAnalyst development team also includes iTRANS Consulting, Inc., Human Factors North, Inc., Ryerson Polytechnic University, Woodward Communications, Inc., and Dr. Ezra Hauer from the University of Toronto.

As one of the participating agencies supporting the development of SafetyAnalyst, NDOT, contracted with the University of Nevada Reno (UNR) to conduct this research project. This report documents the major tasks accomplished as well as the findings and recommendations from the study. The primary objective of the study is to ensure that the software meet NDOT's expectations and satisfy its Highway Safety Improvement Program needs. This objective is accomplished through extensive testing and evaluation of the software using a dataset assembled for the Washoe County transportation network. It is also apparent that the research team needs to be actively involved in every stage of the software development, providing feedbacks to the software development team regarding software features and functionality.

1.2 Project Scope

This study is the first Phase of the SafetyAnalyst testing and implementation, which primarily focuses on Module 1 - Network Screening of the four SafetyAnalyst modules. The main tasks of the project involve a dataset compilation based on the Washoe County roadway network and crash data, and testing the SafetyAnalyst functions using the dataset.

SafetyAnalyst requires a comprehensive dataset that follows specific data formats. The data used in SafetyAnalyst generally fall under the following categories (2,3):

- Geometric design features
- Traffic control features (Traffic operation types)
- Traffic volumes (AADT)
- Accident history

- Accident characteristics
- Safety performance functions (SPFs)

The software testing and evaluation also involved participation in the regularly scheduled Technical Working Group meetings and trainings. The research team was required to provide feedback to the software development team regarding any functionality improvement and software bug fixes.

1.3 Organization

This report is organized as follows. Following the introduction section is a literature review with a focus on network screening related research and application of GIS techniques. The next section provides an overview of the structure and major functions of the SafetyAnalyst software. The fourth section documents the process and issues related to data compilation, including data requirements, data sources and collection, data manipulation, and analysis. After the data compilation section, is the software testing section that describes the functionality of the main components of the module, and the results from the software test using the compiled dataset. Finally, a summary and future work includes findings and lessons learned throughout the project.

2 Literature Review

The literature review mainly focused on two topics in relation with SafetyAnalyst: network screening methodologies and applications for identifying high crash locations, and GIS/LRM method for data preparation.

2.1 Network Screening

Network screening identifies the high crash locations, and is the first step in state agency's safety improvement process. FHWA requires the states to submit an annual report describing not less than 5 percent of their highway locations exhibiting the most severe safety needs (4). The annual report needs to identify locations exhibiting the most severe safety issues. Additionally, the report describes the ranking and evaluation methods. The report must also include the proposed safety improvements and the associated cost estimate for each improvement. In order to search for the high crash locations based on safety ranking, the two basic issues need to be addressed:

1. What evaluation measures should be used to find safety concerns and rank them?
2. What screening method should be used to search for high crash locations?

2.1.1 Safety Ranking Measures

Each state department of transportation has the flexibility to adopt an appropriate ranking method in order to identify the most hazardous locations. The "Five-Percent Report" with the ranking method was submitted by each state firstly in August 2006. By reviewing the 2006 reports, current ranking methods used by individual states can be obtained. As a result, the ranking methods summarized in this section are generally compatible with those reported in the various states' "Five-Percent Report" available on the FHWA website (5). The Center for Transportation Research and Education at the Iowa State University suggested several common safety ranking categories that are suitable for this summary (6,7,8):

*   Crash frequency method
*   Crash density method
*   Crash rate method
*   Quality control method
*   Crash Severity method
*   Index Methods
*   Others (e.g. pattern recognition and direct diagnostics techniques)

Each of these methods has various strengths and weaknesses. Many are simple to use, while others require extensive data and are computationally complicated. The use of crash severity categories can

generally be adapted for each of the methods, though some states do not currently use this approach. Figure 1 shows the number of states and their adopting ranking methods from the review of the Five-Percent Reports. As can be seen that Crash Severity is used by the highest number of states with 17 states, and Critical Crash Frequency-Rate method is not used.
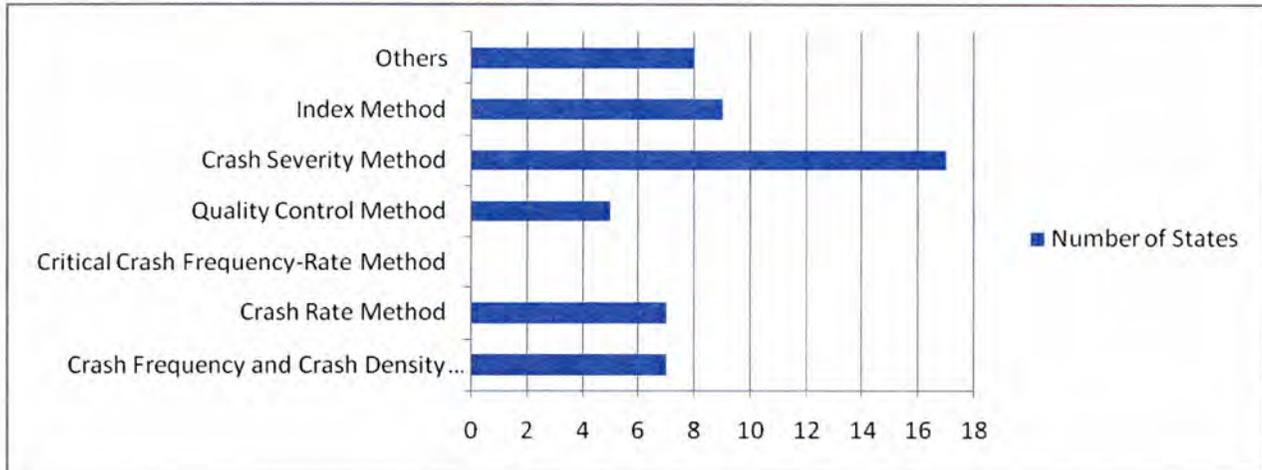
Figure 1 State Safety Ranking Methods

The safety ranking methods are different for urban and rural areas at NDOT when producing the Five-Percent Report (9). NDOT's method is considered to be in the "Others" category.

To identify the rural 5 Percent list, GIS is used to perform sliding mile analyses on all public roads outside the urban areas, counting crashes in four years (2003-2006) on these roads involving only fatalities, Type A (the most severe type) injuries , and Type B (less severe) injuries. Property Damage Only (PDO) and Type C (non-visible injury) injury crashes are not included. Hotspots have with more than 5 weighted crashes per mile are identified, using Equation 1. A 5-mile buffer is then placed around each of the hotspots to develop contiguous segments. The contiguous segments are ranked by a weighted crash density (crashes per mile) as the safety ranking measure. From this ranking a list of the top roadways that need further analysis is developed.

$$C = \frac{4f + 2A + B}{L}$$

(1)

Where:

C = Weighted Crashes per Mile

f = Number of fatal crashes

A = Number of type A injury crashes

B = Number of type B injury crashes

L = Length of Route (miles)

There are several issues regarding this Five-Percent procedure on rural routes. Firstly, the calculation does not consider Type C injury and PDO crashes, which happen more frequently and may contain useful information for identifying locations with inherent problems. However, Type C injury and PDO

crashes are used in mitigation analysis. Secondly, the method does not consider Average Annual Daily Traffic (AADT) and different roadway characteristics, which may produce inadequate ranking. For example, a minor two-lane rural road with 8 crashes per mile may be ranked lower than a major 6-lane freeway with 10 crashes per mile, but the former may have a highway potential for safety improvement. Traditional crash rate methods considering AADT may also give false high rankings on locations with very low traffic volumes. Advanced statistical analysis such as Empirical Bayes approach may have the potential of solving this issue. The final measure for safety ranking in the Five-Percent procedure is for a 5-mile segment, which is relatively long and may even out the problematic portion of the route. Finally, ramps and interchanges are not considered in the analysis, because currently, these crash data are not accurately located.

NDOT's urban Five-Percent Report is developed for only at-grade intersections in both Washoe and Clark Counties. Three years of crash data (2004-2006) are used, and intersections with 30 or more crashes of any severity within 100 feet of an intersection are further analyzed using the following equation.

(2)

$$CFI = 0.7C + 0.8FI$$

Where:
CFI = Crash/Fatality and Injury rate
C = Weighted crash rate
FI =Weighted fatality/injury rate

Below the weighted rates are calculated using crash-type weighting factors and population weighting factors multiplied by crash counts accordingly.

Where weights for Weighted Crash Count:

   Fatal Crash = 3.0

   A Injury Crash = 1.5

   B Injury Crash = 1.0

   C Injury Crashes not used in analysis

For Weighted Fatality/Injury Count:

Fatality = 4.0

Injury = 1.0

Population Weighting (100,000 pop per square mile)

Washoe County

Population = 396,000

Urban area under analysis = 289. 2 square miles

3.96/289.2= 0.0137

Clark County

Population = 1,777,000

Urban area under analysis = 520.4 square miles

17.77/520.4 = 0.0341

Raw weighting factor = 0.0137/0.0341= 0.401

The actual weighting factor used is doubled or 0.802 as the raw number had undue influence in the results. This factor is applied both to the weighted crash count and weighted fatality/injury count to create a weighted crash rate and weighted fatality/injury rate.

This calculation takes into consideration those locations that exhibit more fatalities and injuries per crash. Those High Crash Location (HCL) intersections with a Crash/Fatality and Injury rate greater than or equal to 5 yield 895 locations, the top 45 is considered as the top 5%.

Final analysis of the top 5% ranked intersections is done by applying an entering vehicle volume for each intersection to develop the severity index as the safety ranking measure. The following equations are used to calculate the severity index.

(3)

$$Im = \frac{1,000,000I}{3 \times 365 \times V}$$

$$(4)$$

$$Fm = \frac{1,000,000F}{3 \times 365 \times V}$$

$$(5)$$

$$SI = 0.8Im + 0.7Fm$$

Where:

Im = Injury crash rate per million entering vehicles

I = Number of Injury Crashes

V = Daily entering vehicles

Fm = Fatal crash rate per million entering vehicles

F = Number of fatal Crashes

SI = Severity index

For the urban Five-Percent Report, intersection rather than roadways segments in urban areas are considered. However, intersections are not analyzed in different categories based on intersection geometry and traffic control types, from which different crash rates may be expected.

All the calculations in the NDOT's Five-Percent Report require manual manipulation of ranking measures as well as GIS programming. Any changes in the parameters used for the calculations would result in a recalculation, which may take significant time and effort.

Various studies have been conducted regarding safety ranking measures. Ezra Hauer (10,11) compared five alternative ranking criteria by the cost-effectiveness of the projects for rural two-lane roads in Colorado's mountainous terrain. It was found that sites at which most crashes occur or most severity-weighed crashes are expected lead to most cost-effective projects. However this study is not definitive. The number of sites examined was not large, and factors adopted in the study such as judgments, accident modification factors, raw crash data and Empirical Bayes estimates all have some bias.

Crash frequency method has advantages over crash rate method (12,13). There are also two major types of measures of crash frequency (14), namely: expected crash frequency and expected excess crash frequency. The expected crash frequency assumes that the effect of remedial action is to reduce the

expected crash frequency and severity of target crashes by some fixed proportion. The expected excess crash frequency, on the other hand, assumes that the effect of remedial action of some kind is to reduce the excess of the expected crash frequency and severity over what is normal or over what is safest at similar sites. The later method was used by McGuigan (15) and Persaud in their research (16,17). The two options are both included by the SafetyAnalyst functionality with Empirical Bayes estimates as described next (18).

The safety of an entity (site location) is defined as "the number of accidents (crashes), or accident consequences, by kind and severity, *expected* to occur on the entity during a specified period" (13). What is 'expected' is unknown and can only be estimated by statistical analysis procedures. The Emperical Bayes (EB) method mixes two clues for the estimation: the estimated number of crashes at similar entities, $E\{k\}$, from regression relationships (i.e., safety performance functions (SPFs)), and the crash counts of the entity of interest, K. The EB method for estimation of number of crashes addresses two problems of safety estimation; it increases the precision of estimates beyond what is possible when one is limited to the use of a two to three year crashes history, and it corrects for the regression-to-the-mean bias (12). EB method has been widely used in safety analysis. The primary reason that employing EB concepts to basic network screening is considered an improvement over identifying sites for their potential for safety improvement, based strictly upon observed crash data, is because the number of crashes at a location is a random variable which fluctuates around some unknown mean. Because of this randomness, historical data (i.e., observed crashes counts) at a location are not considered an accurate reflection of a site's long-term crash characteristics. Employing an EB approach to network screening accounts for these random variations in crashes. As indicated above, with the EB approach, location-specific crash data are combined with crash predictions for similar sites to estimate a site's potential for safety improvement (i.e., an estimated value of either an expected crash frequency or an expected excess crash frequency). Several researchers have utilized EB principles for network screening, most notably Hauer. SafetyAnalyst employs the EB method in all modules of the analysis (19).

Currently, SafetyAnalyst does not have the capability of generating SPFs based upon input data for the EB calculation. A default SPF, modeled using crash data either from California, Minnesota, Ohio, or Washington, is provided within SafetyAnalyst for each site subtype. During the data import process, for each site subtype a yearly calibration factor is calculated for use with the respective default SPF. This calibration factor is calculated using the state's own crash data. An agency also has the option to input their own SPFs for whatever SafetyAnalyst site subtypes they have models for. These agency-defined SPFs have to be created outside of SafetyAnalyst. Assuming that agency-defined SPFs would have been created using a state's own data, no calibration factors would be calculated for use with these agency-defined SPFs. Regarding the site subtypes within SafetyAnalyst, currently there are 17 site subtypes for roadway segments, 12 site subtypes for intersections, and 16 site subtypes for ramps. Within SafetyAnalyst there is no capability to create new site subtypes to be analyzed. During the data import process sites are assigned to a given site subtype. When a site does not meet any of the criteria to be assigned to a specified site subtype, the site subtype for the given site is left blank in SafetyAnalyst. The site is still saved within the master SafetyAnalyst database. While creating new site lists to be analyzed, sites not assigned to any particular site subtype will possibly show up on the site list depending upon

how the site list is created. For any given analysis, if the site list to be analyzed includes a site or sites without any specified site subtype, the site or sites will simply be dropped from the analysis. In future versions of SafetyAnalyst additional site subtypes may be added.

There is also an on-going research project to produce the Highway Safety Manual (HSM) (20). Similar to the Highway Capacity Manual, the HSM will serve as a major reference and practice standard for highway safety engineers. . The purpose of a HSM is to provide the best factual information and tools in a useful and widely accepted form and to facilitate road investment and operation decisions, based upon explicit consideration of their safety consequences. This manual will greatly strengthen the role of safety in road planning, design, maintenance, construction, and operations decision making. The HSM features:

- Synthesis of validated highway research
- Procedures that are adapted and integrated to practice
- Analytical tools for predicting impact on road safety

The research project that will lead to production of the First Edition of the HSM is NCHRP project #17-36. The interim document of the Highway Safety Manual is anticipated to be available in summer of 2009.

2.1.2 Screening Methods

The definition of "a site" also varies in network screening, especially for roadway segments. The difference between intersections and roadway sections is that intersections are discrete entities. However, there are issues about how to subdivide segments, how to search for peaks in crash experience within segments, and how to estimate the expected crash measures with different segment lengths (21). Ideally, a "site" should be defined as the shortest segment of a road section at which the estimate of the expected crash frequency is largest while the coefficient of variation is smaller than the chosen limiting value (14). Existing site searching methods include: using an entire road section, segments of fixed length, peak searching, and sliding window with fixed length. SafetyAnalyst uses two types of segment screening methods for its functionalities of site searching: peak searching and basic sliding window calculations (22).

Peak Searching Concepts

For a given roadway segment, the procedure starts by dividing the site (segment) into 0.1 mile windows. The windows do not overlap, with the possible exception of the last window overlapping with the previous. Expected (or excess) crash frequencies are then calculated for each window, and the results are subjected to statistical testing. If no statistically significant peak crash frequencies are found in any of the initial windows, the ending window location for each window is incrementally moved forward growing the windows to a window length of 0.2 miles, and the calculations are performed again to identify statistically significant peak crash frequencies. The algorithm continues in this fashion until a

peak is found or the window length equals the site length.   Figure 2 illustrates how a site is incrementally subdivided into windows for analysis purposes for a site 0.67 mi in length.

To further explain the peak searching process, from all of the 0.1-mi windows with the expected (or excess) crash frequencies (X_Y) greater than the user specified limit, the Coefficient of Variation (CVs) are compared to the user specified CV_{Limit}.   When at least one CV is less than CV_{Limit}, the entire roadway segment (i.e., site) is flagged.   From all windows that have a CV less than CV_{Limit} and the respective expected (or excess) crash frequency (X_Y) is greater than the user specified limit, the 0.1-mile window with the largest (peak) expected crash frequency is selected.   The entire flagged roadway segment is placed on the list of roadway segments to be ranked and the location of the window "passing the test" and the value of its expected crash frequency is included in the output.   Thus, the Potential for Safety Improvement (PSI) = Peak (X_Y).   The entire site is ranked based upon the Peak (X_Y).

Sliding Window Concepts

In the sliding window approach, a sliding window of user-specified length moves forward in increments of user-specified size along each roadway segment in the current site list.   At each location of the window, calculations are performed to determine the expected crash frequency or excess crash frequency for the segment of roadway within the boundaries of the given sliding window.   A sliding window will be comprised of a minimum of one sub-segment but may consist of multiple sub-segments, depending upon the location or placement of the window relative to the roadway segment sites. The number and length of sub-segments which comprise a given sliding window is a function of the window length, the *incremental* length by which the sliding window is moved forward along a set of contiguous sites, and the length of roadway segment sites in the site list being analyzed.

| Window Length = 0.1 mi | Window Length = 0.2 mi |
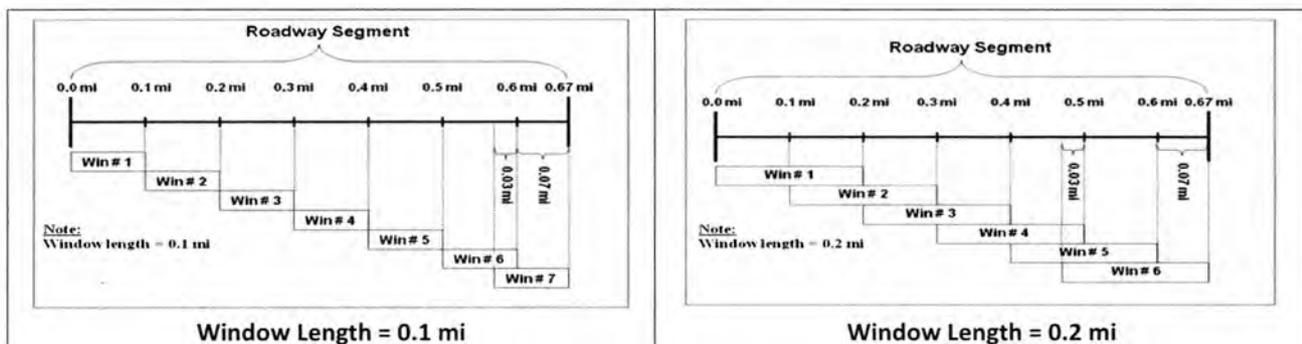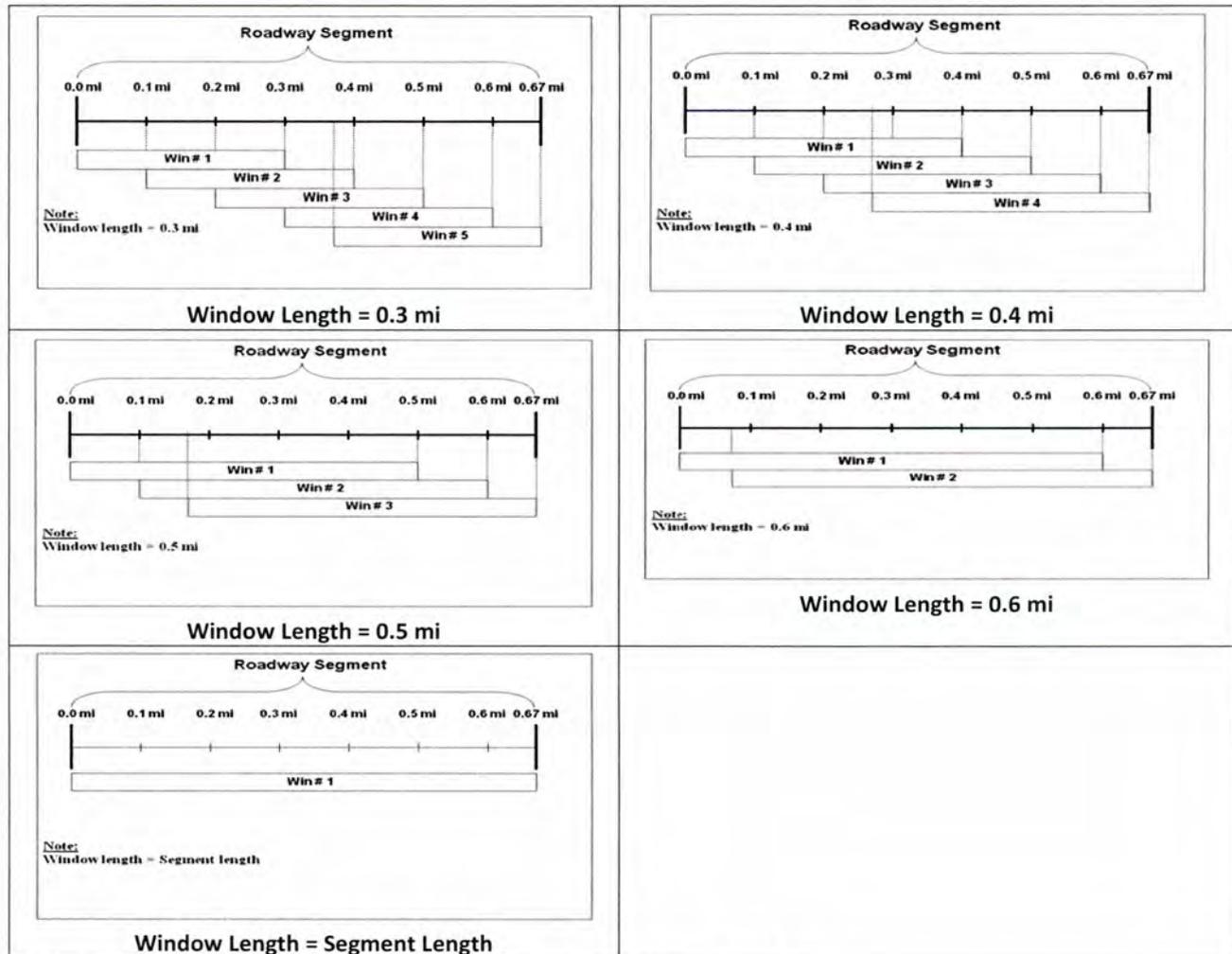
Figure 2 Peak Searching Example

For a given analysis, the beginning of the first sliding window is placed at the beginning of the first roadway segment in the current site list (i.e., the terminal of the first roadway segment with the smaller milepost value), and calculations (e.g., EB estimates of the expected or excess crash frequency) are conducted over the length of this first sliding window. The user specifies an incremental length by which the sliding window is moved forward. For example, the user might choose to specify a sliding window length of 0.3 mi (W = 0.3 mi) that moves forward in increments of 0.1 mi as seen in Figure 3. This means that the beginning of the second sliding window is 0.1 mi from the beginning of the first roadway segment. This also means that the second 0.3-mi sliding window overlaps by 0.2 mi with the first sliding window and so on, as sliding windows are moved incrementally forward along a roadway segment (see Figure 3). By default, sliding window lengths are set to 0.3 mi, and windows are moved forward in 0.1-mi increments in SafetyAnalyst. If the first sliding window is located or positioned on a roadway segment site having a length greater than the window length, the window consists of one sub-segment equal to the length of the sliding window.
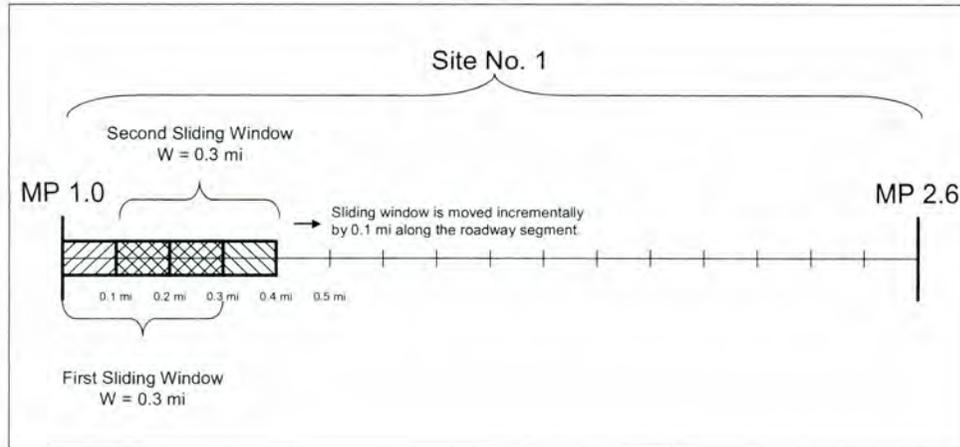
Figure 3 Sliding Window Concepts: Incremental Moves

2.1.3 Summary of Network Screening Review

It is clear from the literature that there is a substantial requirement fueled by recent federal legislation that state agencies need to develop defendable assessment strategies for their safety improvement projects. Presently, there are two major on-going research efforts at the national level: Development of the SafetyAnalyst software and Development of the Highway Safety Manual (HSM). Development of the SafetyAnalyst software is a project sponsored by the Federal Highway Administration since 2001. SafetyAnalyst incorporates a set of advanced analytical tools for traffic safety studies. The Highway Safety Manual (HSM), near completion, is a document that will serve as a tool to help practitioners make planning, design, and operations decisions based on safety. Material in Chapter 4 of HSM, pertaining to screening high collision sites, covers material similar to that covered in SafetyAnalyst.

2.2 GIS/LRM method for data preparation

Federal highway safety programs such as Highway Performance Monitoring System (HPMS) and Highway Safety Improvement Programs (HSIP) require developing roadway safety systems with local transportation data based on locations. The HPMS is a national level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the Nation's highways (23). In general, the HPMS contains administrative and extent of system information on all public roads, while information on other characteristics is represented in HPMS as a mix of universe and sample data for arterial and collector functional systems. Limited information on travel and paved miles is included in a summary form for the lowest functional systems. Also, each state is required to develop and implement HSIP on a continuing basis and has the overall objective of reducing the number and severity of crashes and decreasing the potential for crashes on all highways (24). HSIP also requires transportation data on local routes as well as on state routes. Therefore, including local data into the state safety system is a major task for most states.

Location Liner Referencing Systems is studied and used in transportation data processing. NCHRP report 460 (25) presents and describes the transportation multimodal, multidimensional location referencing system data model developed through NCHRP Project 20-27(3). The NCHRP 20-27(2) linear referencing

system data model was developed in response to a growing awareness of the need to integrate increasing amounts of linearly referenced data used by the transportation community.

In summary, federal highway safety programs such as HPMS and HSIP require state DOTs to conduct safety analysis based on crash data on all public roads. However, most states do not have sufficient crash data for local roads; analysis currently generally is applied to state owned or maintained highways rather than to all public roads as required. All of the state departments of transportation (DOTs) are aware of this requirement and have proposed to improve crash data coverage on local roads in the next several years. Local inventory and traffic data are usually available from local agencies. However, efforts are needed to accommodate the incompatibility issue of state and local data. For this project, in order to create datasets based on homogeneous segments, all linear event features need to be converted to a common topological network. Several GIS/LRS techniques need to be applied to perform the data manipulation and transformation, which can be an efficient way for the data assembling.

3 SafetyAnalyst Overview

SafetyAnalyst incorporates state-of-the-art safety management techniques utilizing Empirical Bayes method to improve state and local agency's transportation safety programs. With such an advanced analysis tool, transportation agencies can make rational decisions and to identify safety improvement needs based on the results from cost-effectiveness analyses. This software is intended to be the standard for potential improvement location analysis in support of the Federal Highway Safety Improvement Program (HSIP). SafetyAnalyst addresses site-specific safety improvement needs that involve physical modifications to the highway system. SafetyAnalyst is not intended for direct application to non-site-specific highway safety programs that can improve safety for all highway travel such as vehicle design improvements, graduated licensing, occupant restraints, or alcohol/drug use programs. However, SafetyAnalyst has the capability to identify crash patterns at specific locations and determine whether those crash types are overrepresented. In addition, SafetyAnalyst has the capability to determine the frequency and percentage of particular crash types along specified portions of the highway system. These capabilities can be used to investigate the potential need for enforcement and public education efforts in a specific area, in addition to identifying potential engineering improvements at a site.

In summary, SafetyAnalyst has been developed to:

- Address site-specific safety improvements that involve physical modifications to the highway system,
- Use state-of-the-art analysis techniques to advance the state of the practice of highway safety programs,
- Be comprehensive and include all stages of the safety management process,
- Be rigorous enough to have scientific merit, yet flexible enough to fit into diverse highway agency operating environments, and
- Draw upon knowledge and experience from previous and ongoing safety initiatives.

A general safety management process can be described in six main steps:

Step 1: Identification of sites with potential for safety improvement
Step 2: Diagnosis of the nature of safety problems at specific sites
Step 3: Selection of countermeasures at specific sites
Step 4: Economic appraisal for sites and countermeasures under consideration
Step 5: Priority rankings of improvement projects
Step 6: Safety effectiveness evaluation of implemented countermeasures

SafetyAnalyst is comprised of four modules which, when packaged together, incorporate the six main steps listed above for highway safety management:

Module 1 - Network screening
Module 2 - Diagnosis and countermeasure selection
Module 3 - Economic appraisal and priority-ranking
Module 4 - Evaluation of implemented countermeasures

While most state agencies have established procedures and policies on safety improvement projects, the decision-making process may lack the required efficiency and accuracy due to limited resources. Furthermore, there is a lack of knowledge of the state-of-the-art analysis procedures and software tools. For example, most data process and analyses are still being performed manually, such as sliding mile calculation and cost-effectiveness ratio.

The basic purpose of the network screening module in SafetyAnalyst is to:

- Use available data to review the entire roadway network under the jurisdiction of a particular highway agency,

- Identify and prioritize those sites that have promise as sites for potential safety improvements and, therefore, merit further investigation, and

- Identify sites to which the other SafetyAnalyst modules should be applied.

This network screening process will utilize the computerized analytical tool to make use of information on roadway characteristics and safety performance to identify those sites that are the strongest candidates for further investigation. The computation uses advanced statistical analysis method (Empirical Bayes) to optimize the estimation of the safety performance of a site. The software also provides automated and efficient operations to examine the sites with different characteristics.

The process of conducting detailed engineering studies of candidate improvement sites is an expensive one, even with the improvements in efficiency of such investigations that will be provided by the other SafetyAnalyst modules. Therefore, only a limited set of sites can be investigated by a highway agency in any one year. The most efficient network screening procedure is one that will best identify "sites with promise" as those sites (road sections, intersections, interchange ramps) that would most likely be the highest ranked in terms of safety cost-effectiveness among all candidate sites. This goal will govern the investigation and selection of practical approaches to network screening. The basic function of the network screening module will be to rank sites by one or more selected measures or indices based on a consideration of each site's crash history, traffic volume, and roadway characteristics.

A beta version of the software was released in 2005. Since the first beta release, the software has gone through numerous updates based on the inputs from the Technical Working Groups. There has been a number of fixes of software bugs and redesign of the interface. The results reported in this document are based on version 1.4.17, released on August 15th, 2008.

4 Dataset Compilation

This section describes the process of compiling the dataset to use for testing the SafetyAnalyst functions. The dataset needs to include sufficient information to run the SafetyAnalyst software and to perform some basic analyses using the software. The dataset should also be compatible to the format required by the software. Main tasks of the dataset compilation include identification of data requirements, data sources and collection, and data manipulation and analysis.

4.1 Data Requirements

Data requirements to be described in this section are with regard to Module 1: Network Screening within SafetyAnalyst. It is presented in a spreadsheet format and the information included in the spreadsheet is described blow.

- **Data Type Category**

Five types of data elements are to be obtained for SafetyAnalyst database from NDOT and other agencies. These data types include:

- Site characteristic (i.e., inventory) data for roadway segments
- Site characteristic (i.e., inventory) data for intersections
- Site characteristic (i.e., inventory) data for intersection legs
- Site characteristic (i.e., inventory) data for ramps
- Accident data

- **Data Element Name**
- **Data Element Definition**

The spreadsheet also provides the names and definitions of the mandatory data elements that are critical to the execution of Module 1 within SafetyAnalyst, and of the optional data elements that are needed for specific program features. A total of 40 data elements are mandatory for Module 1, and 10 data elements are needed for specific program features.

- **Anticipated Data Element Source**

This entry specifies the anticipated data element sources such as LRS (Linear Referencing System), HCL (High Crash Locations), HPMS (Highway Performance Monitoring System), TRINA (Traffic Information Access), PMS (Pavement Management System) from NDOT and other agencies.

- **Availability**

The availability of each data element was to indicate if the dataset is partially or completely available from the agencies, or needed to be collected other ways.

Further detailed information regarding data requirements for Module 1 can be found in Appendix A.

4.2 Data Collection

Data were collected from various sources maintained by NDOT and local agencies to create the   dataset for running the SafetyAnalyst software. After evaluation, these data sources were included: LRS, TRINA, RTC traffic demand model data, HCL, and Crash data.

LRS (Linear Referencing System)

LRS is the Linear Referencing System maintained by NDOT. LRS as in Figure 4 contains geometry and location of all routes (both state and local) in Nevada. Each route has a Route Master ID and route cumulative mileages. Therefore, Roadway Segment Location, Segment ID and Segment Length can be obtained from this data source. In addition, because LRS has detailed route geometry and location, it also serves as a base map, which other data can be applied onto using GIS functions. The data also has road name information for each roadway segment.
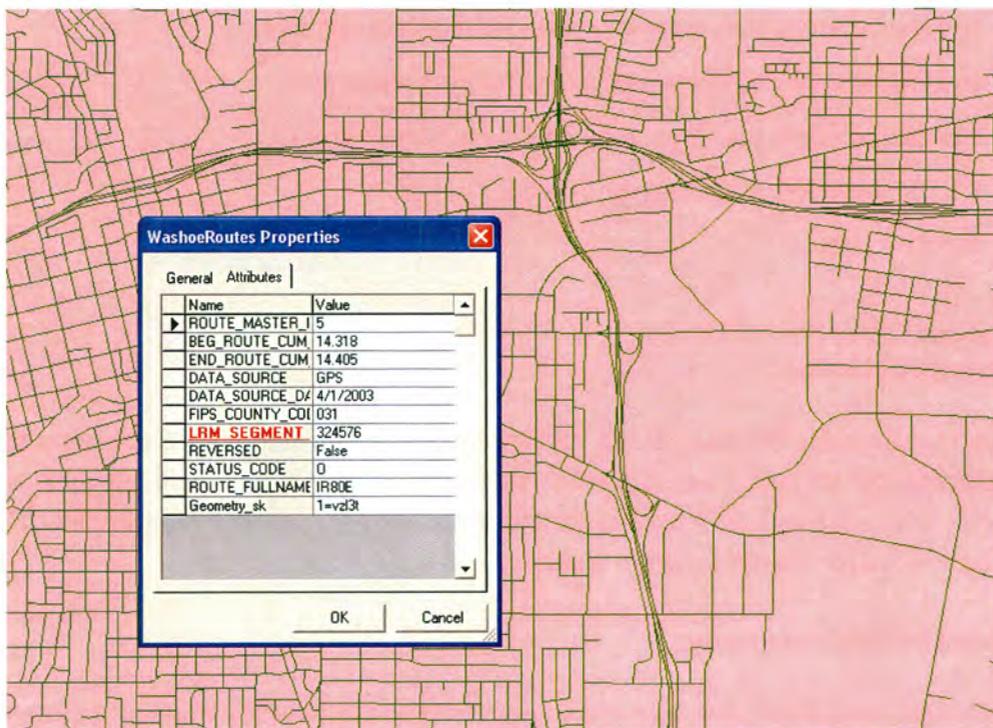
Figure 4 NDOT LRS Data

TRINA (Traffic Information Access)

TRINA, shown in Figure 5, is the traffic count database collected by NDOT. NDOT maintains traffic count stations along most major routes especially state routes in Nevada. Ideally, in order to accurately obtain traffic volume information on all streets, a traffic count station needs to be installed in each block. In Washoe County, there is an estimated number 20,571 blocks. There are a total of 737 traffic count stations in Washoe County. Assuming each station an accurate volume count for one block, the percentage of coverage is about 3.6%. However, it seems that there is sufficient data coverage for the state maintained highway system. Major streets in Reno-Sparks such as Virginia St, McCarran Blvd, Pyramid Way, and Rock Blvd are also well covered by TRINA. However, this statement is only from empirical observation. Depending on the level and accuracy of the analysis, it warrants a future investigation.

These traffic count stations are location based and geo-coded into TRINA data which contains information regarding AADT, Numbers of Lanes for both directions, Area Type, Route Type and Two-Way vs. One-Way Streets.
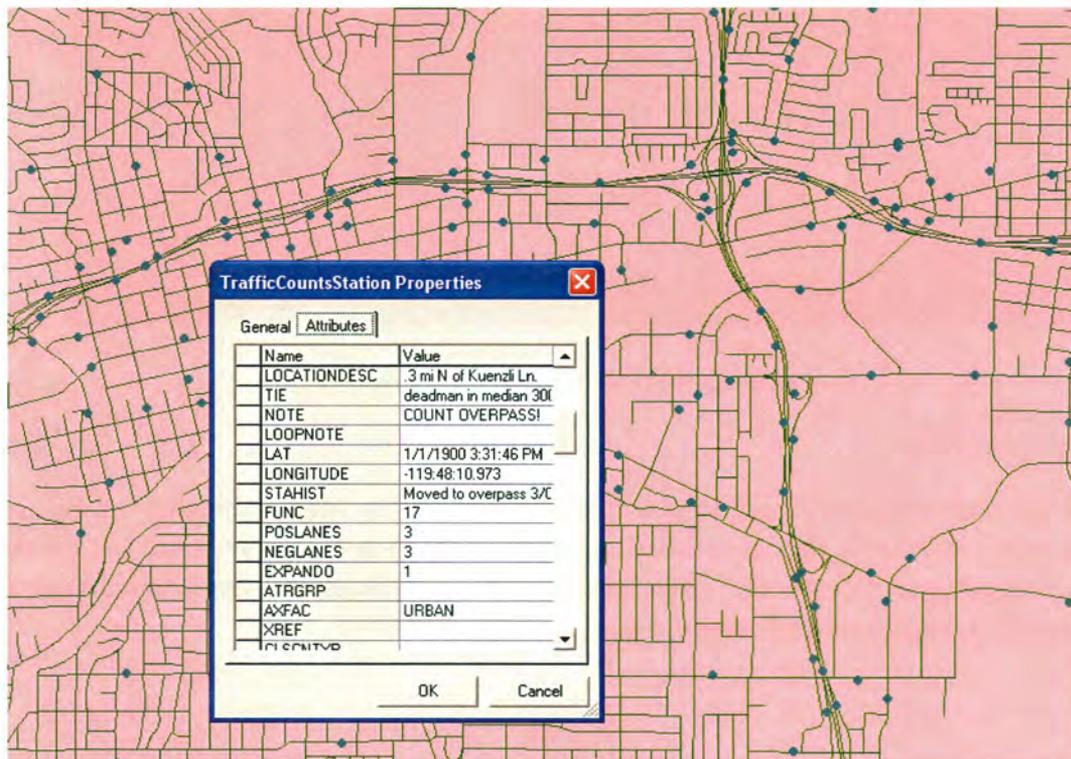
Figure 5 NDOT TRINA Data

RTC (Regional Transportation Commission of Washoe County) Travel Demand Data

RTC maintains a regional traffic demand forecasting model which contains traffic volume information along the routes that cover most of the local streets. Although the database has some geometric information about the routes, it does not have the precise geometry information as seen in Figure 6.

Also, the traffic volumes are mostly forecasted traffic demands in future years; therefore, the AADTs derived from the database are not actual counts. RTC recently calibrated the data on some major routes according to TRINA. The RTC database was mainly used to extract most of the local routes which are not covered by TRINA. The information obtained from the RTC database included AADT, Numbers of Lanes for both directions, Area Type, Route Type and Two Way vs. One Way Operation.
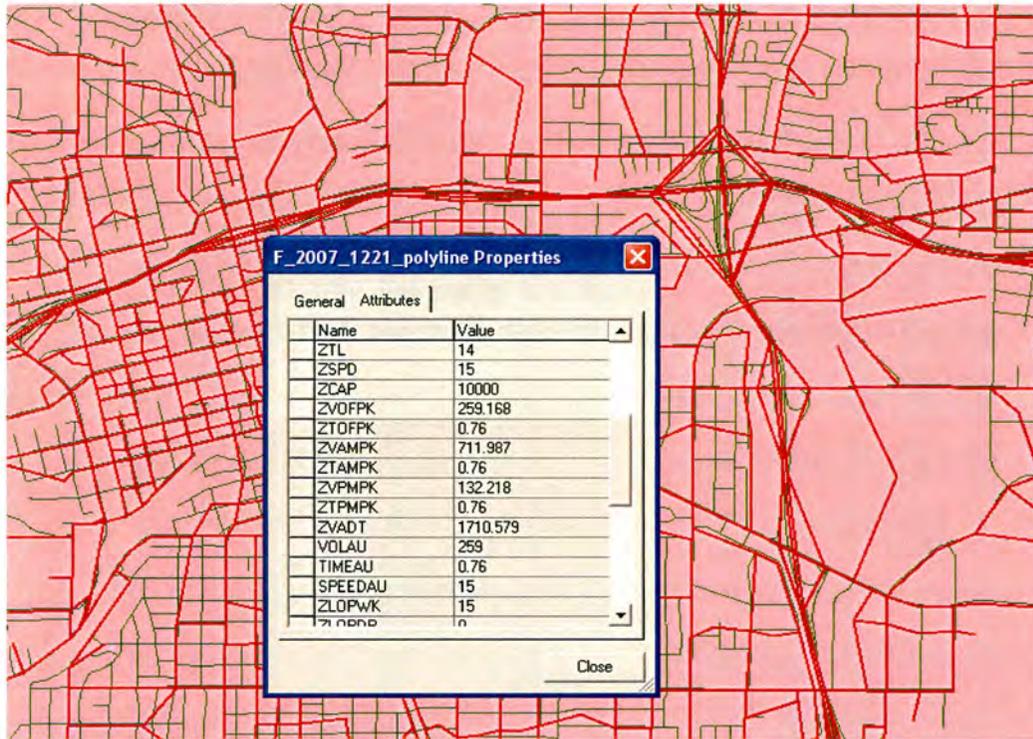
Figure 6 RTC Traffic Modeling Data

HCL (High Crash Location)

HCL (spell out) is the High Crash Location information maintained by NDOT. A number of high crash intersections were selected for the case study to be discussed later in the report. From this database, the intersections with high number of crashes were provided with most mandatory intersection data elements required by SafetyAnalyst as seen in Figure 7.

Crash Data

NDOT has a Crash database for all reported crashes on public routes. The crash data, as in Figure 8, are location based using the state's milepost system and have all the information required by crash data elements of SafetyAnalyst. The crashes were located using Dynamic Segmentation with GeoMedia. Three years data from 2003 to 2005 were used to assemble the test dataset.

Figure 7 NDOT HCL Data
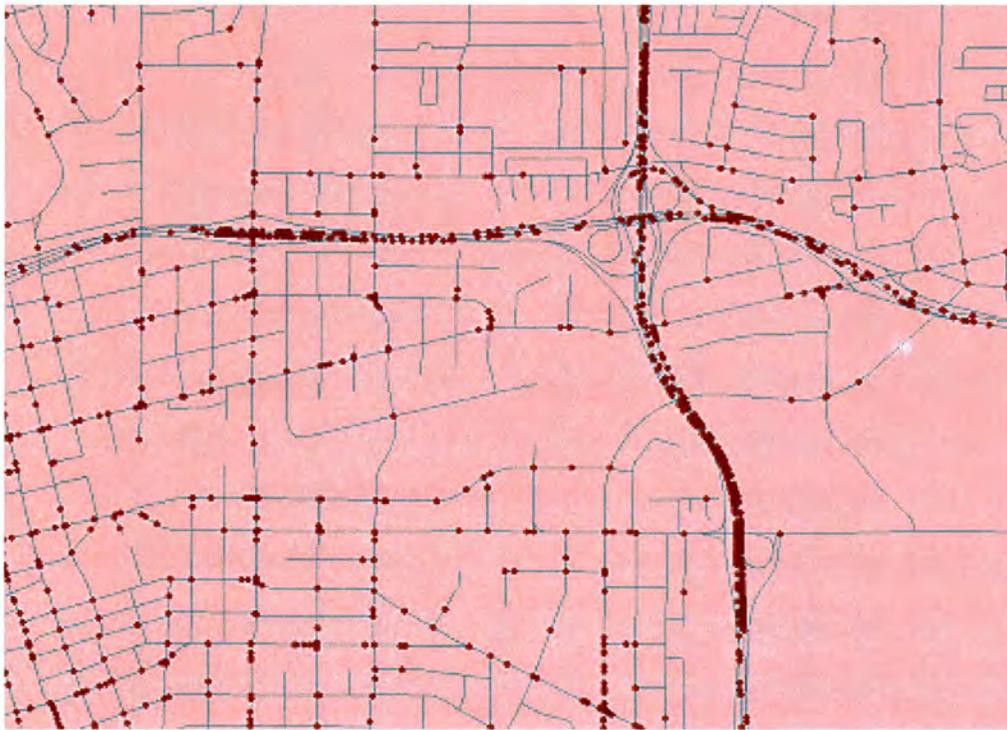
Figure 8 NDOT Crash Data

4.3 Data Manipulation and Analysis

4.3.1 Data Manipulation

Compilation of the dataset for SafetyAnalyst involved an intense data manipulation process. Before the data could be imported for analysis, data collected from many transportation agencies had different formats and can support more than one geometric representation of the network. Several issues needed to be addressed using a multilevel LRS (spell out) method.

One example was where different levels of generalization were used for different map products as shown in Figure 9. For example, with the same event, the first line has a better resolution with each unit representing 5000 units of length. Therefore, the geometric details of the line are better described. However, the third line with lower resolution appears differently with less detailed geometric information. In the figure, the lengths of the lines are not in scale. For safety data analysis, we would like to be able to use the same event data against different geometric representations depending on whether performing large scale or small scale analyses.
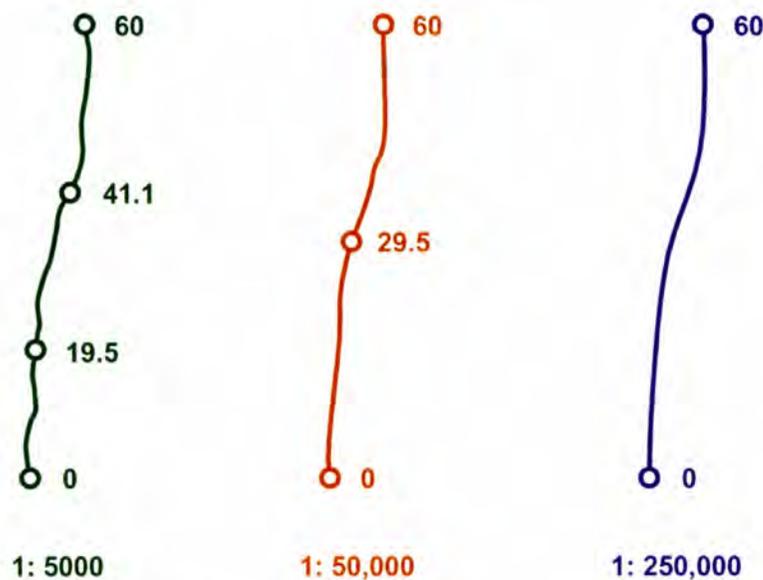
Figure 9 Segments in Different Scales and Accuracies

Multilevel LRSs allows agencies desire is to be able to easily switch back and forth between scales without worrying if scale switching will affect the validity of their analyses.

Another common case for multiple geometric representations is where some of the data comes from a regional agency and some of it comes from various local agencies. There is a considerable overlap of the data coverage, but there are also considerable roads covered by the local data that is not covered by the regional data.

In Figure 10, two representations are illustrated for state maintained roads only (marked Regional) and a compilation of local data for other roads (marked Local). Of course there is an overlap of roads that are included in both data sets. The LRS method can be applied to combine the information from different databases.
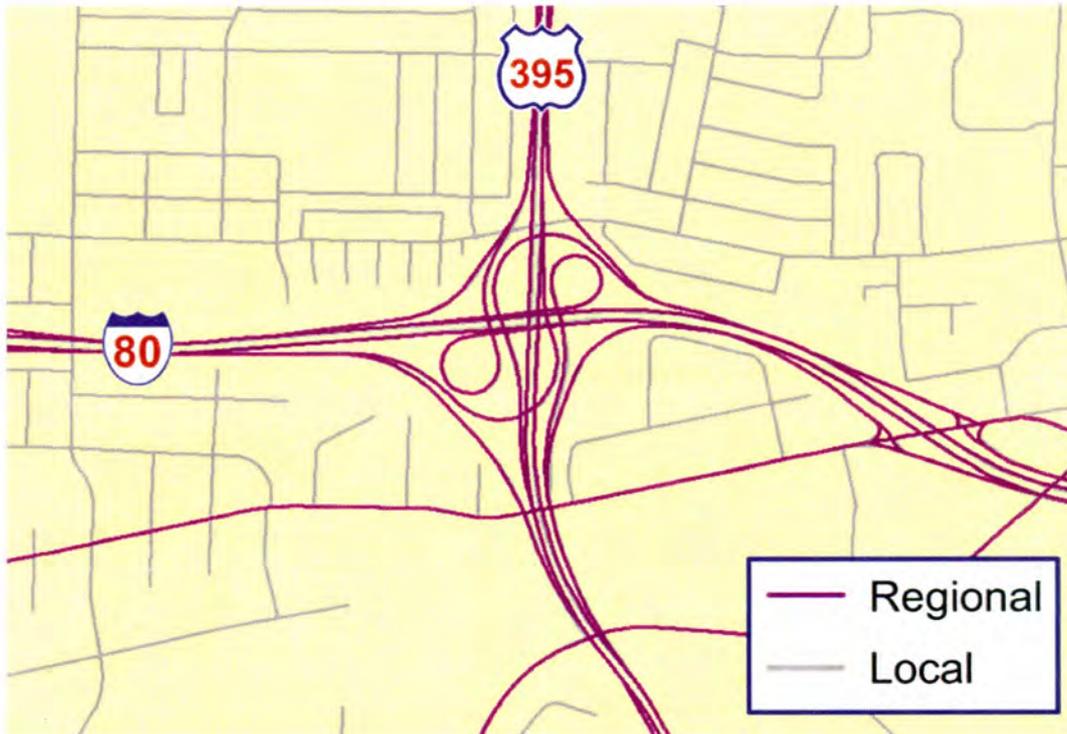
Figure 10 Datasets with Different Coverage

In addition, datasets can be represented in different feature classes. For example, as in Figure 11, traffic count stations from TRINA were provided as points with Latitude/Longitude coordinates. However, the base map LRS data were described in lines. In this case, Beginning/End Measures from both datasets were used to create an aggregation function to associate the nearest route to the count stations.

LRS conflation needed to be conducted for datasets with different spatial representations (26). As seen in Figure 12, traffic modeling data in the yellow lines with link-node format did not accurately match the geometry of the base map which is shown in the grey lines. A LRS conflation needed to be used here to apply the information from the traffic modeling dataset to the base map. The links that contained street names and nodes were located close to their corresponding intersections. Name comparison of intersection pairs were used to match intersection to intersection, where Beginning/End Measures of intersections were then applied through a dynamic segmentation.

Before Conversion   After Conversion

Figure 11 Datasets with Different Feature Classes and Aggregation Results

Figure 12 Datasets with Different Spatial Representations

The final sample dataset contained 3,868 roadway segments, covering most major routes in Washoe County. The blue lines in Figure 13 show the coverage of the final segment data according to the base LRS network, which is shown as the thinner green lines in the figure. Because of the data availability, only 8 high crash intersections were included for the intersection data. Ramp data required manual input for ramp type and ramp configuration.
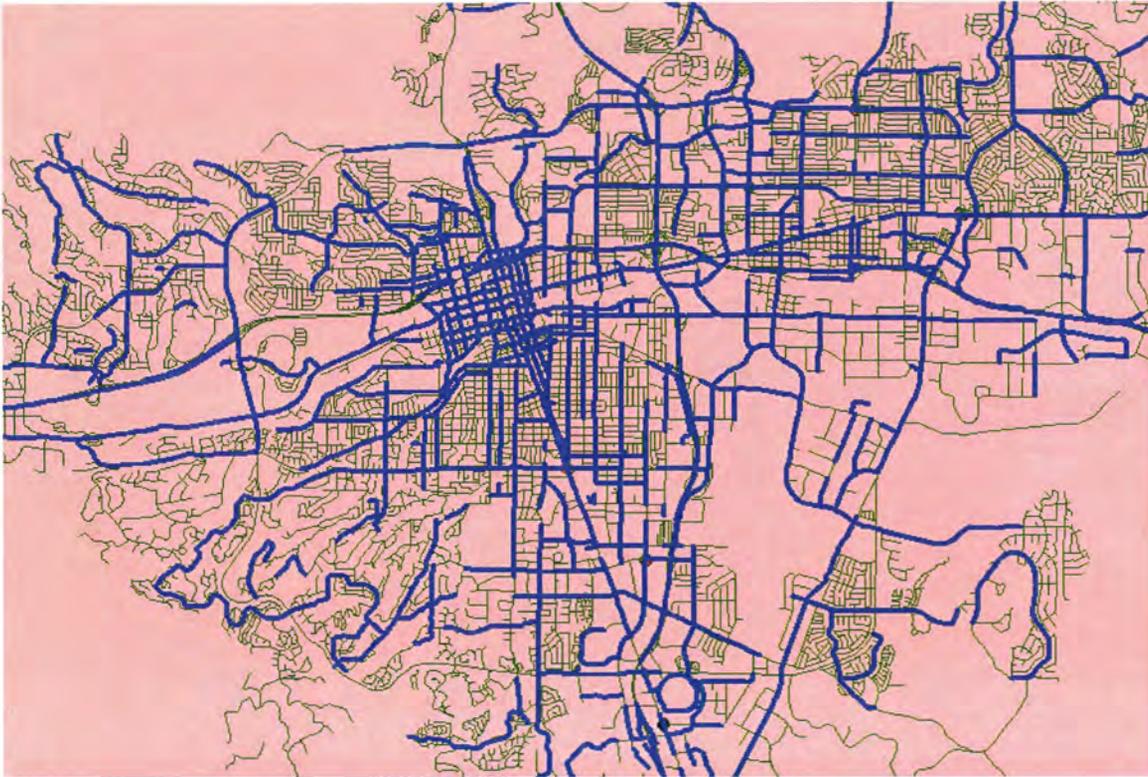
Figure 13 Segment Data for SafetyAnalyst Input

4.3.2 AADT Analysis—TRINA and RTC AADT Data

During the data progressing, several problems were found with both Annual average daily traffic (AADT) and crash data.

AADT is a major input for SafetyAnalyst and is a mandatory data element. For the project, TRINA and RTC travel demand databases were the primary sources for AADT. Several problems have been identified with the TRINA AADT data.

Firstly, some of the TRINA traffic count stations are not accurately located. In TRINA data, the cumulative route (begin mile and end mile) does not seem to be consistent with the CDS data in LRS. The traffic count stations are supposed to provide traffic information regarding the route lines close by. But as can be seen from the screen capture in Figure 14 and Figure 15, the begin and end mileages of the points from TRINA do not match the route mileages of the line routes from LRS. In order to accurately analyze how significant the problem could be, data from traffic count stations need to be checked against the segments close by. However, at the time of completing this report, the analysis was not enough to draw any decisive conclusions; there, further research is needed regarding more extensive data collection and analyses.
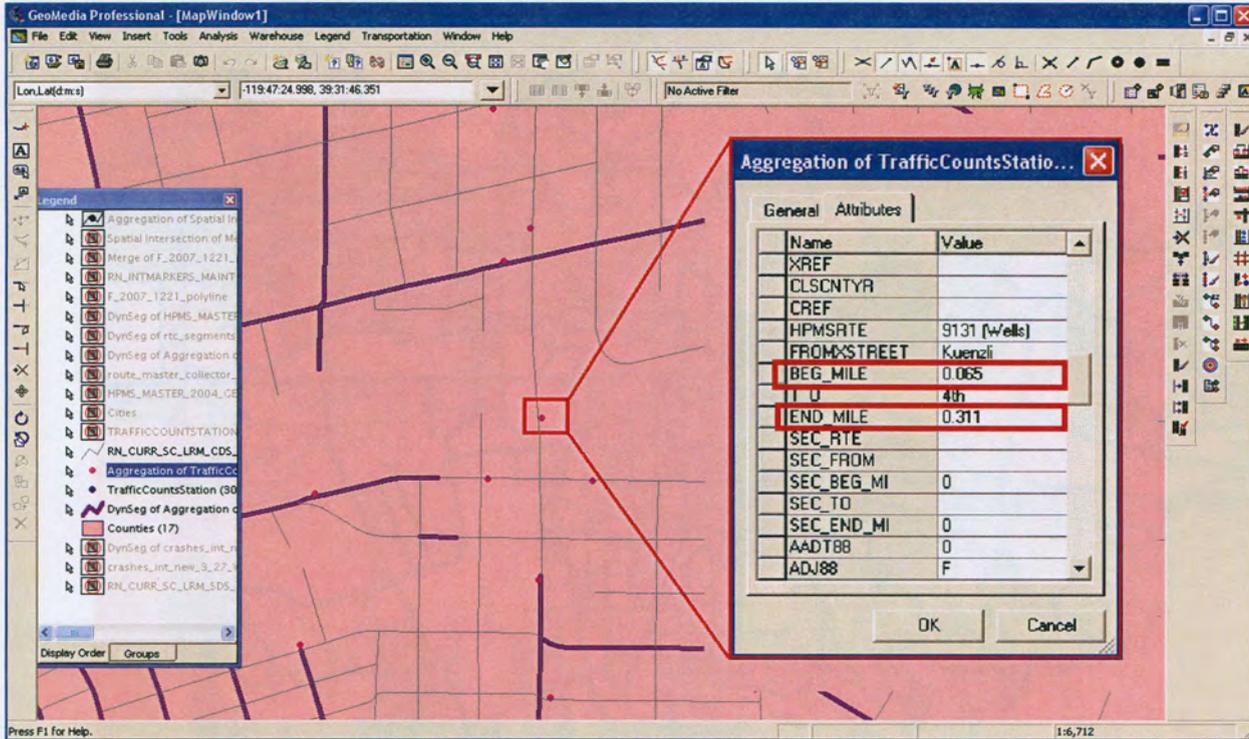
Figure 14 TRINA Begin and End Mileages
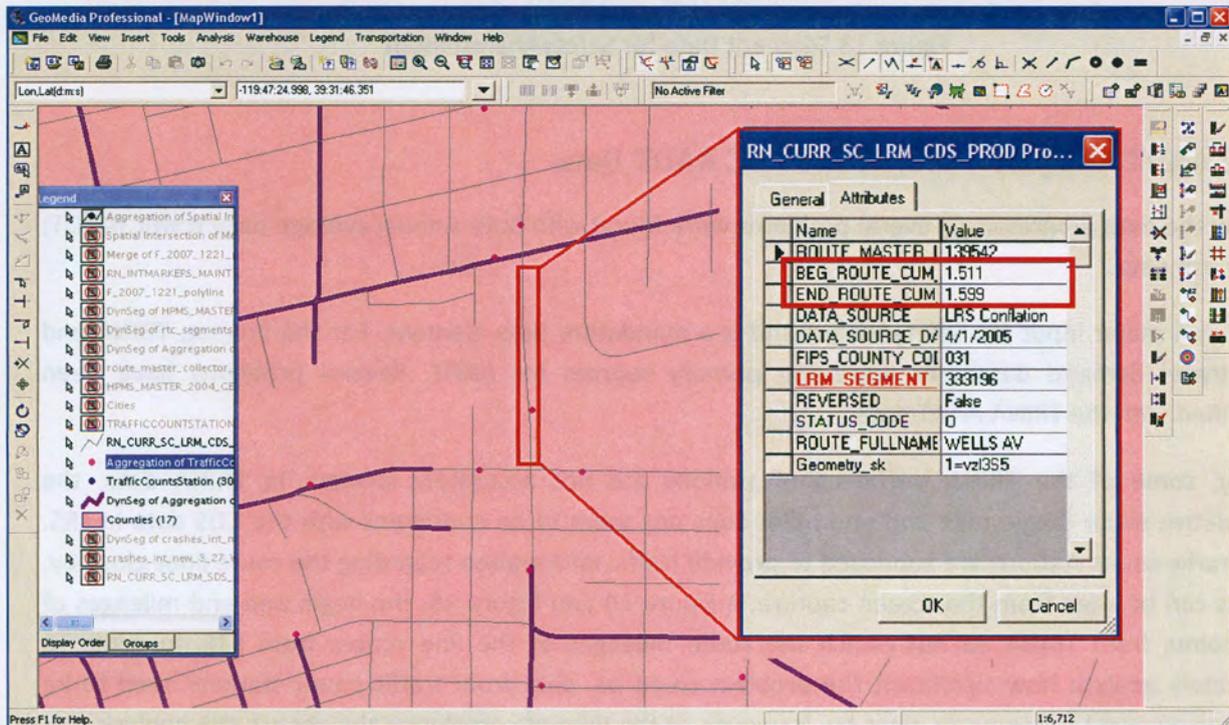
Figure 15 LRS Begin and End Mileages for the Route Close By

AADT information is very important for the Network Screening in SafetyAnalyst because the software uses EB (spell out) approach where AADT is a critical input for PSI (spell out) calculation. The above analysis shows that the locations of some traffic count stations are not accurate. This problem needs to be fixed before conducting detailed analysis. Otherwise, it will affect the results from the GIS aggregation function as well as the accuracy of AADTs.

Another problem is that TRINA assumes AADT for some entire segments, even though there are intersections in between. Therefore, the AADT might not be accurate for some locations. For the example depicted in Figure 16, according to what is described in the TRINA data attributes, there is only one traffic count station for the entire Idlewild Drive, and the highlighted traffic count station represents the traffic volume for the entire street from point A to point B. The AADT information may not be accurate, since the location where the AADT data is actually collected only represents the condition in the nearby block. However, there are many intersections along the street, where traffic volume varies because of the turning traffic. From the randomly selected 10 stations, 9 of them have this issue. However, how significantly the issue would affect the analysis results cannot be assessed within the scope of this project. Future study should be conducted on the required number of counting stations and their placement along a roadway segment for the desired accuracy.
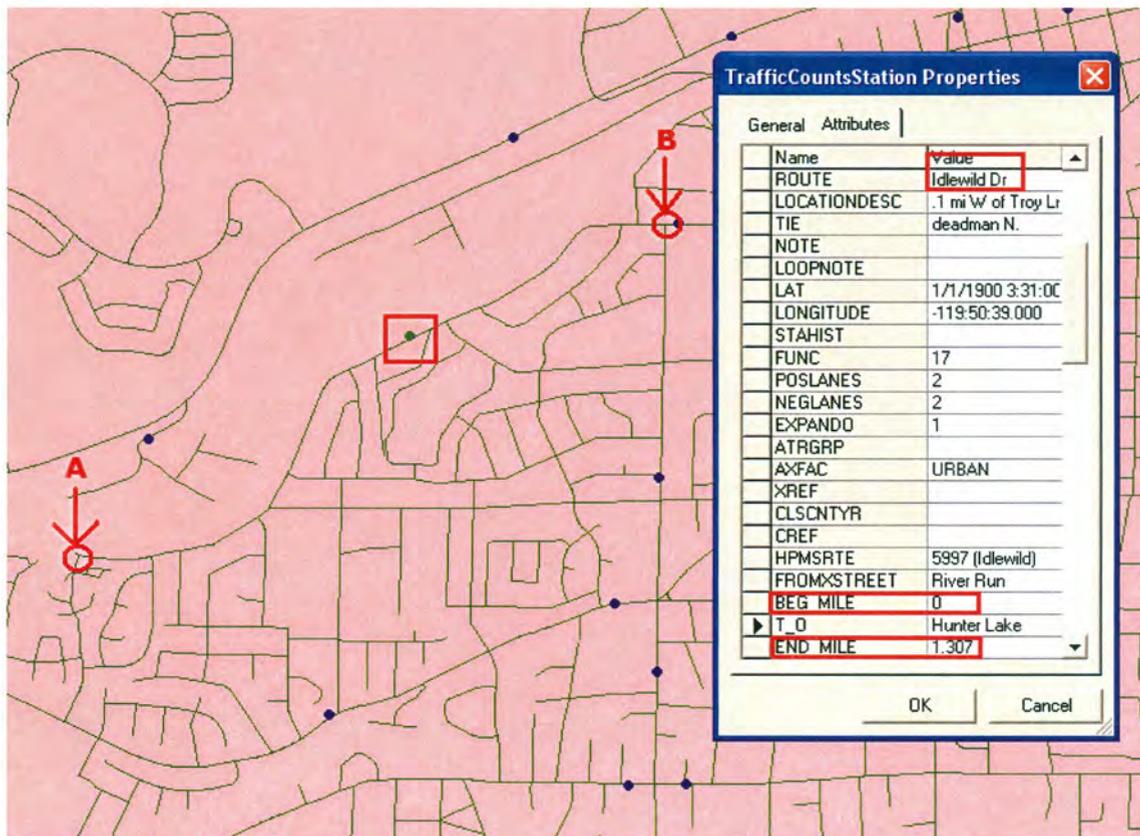
Figure 16 TRINA Referencing Routes

Since RTC data is from the regional travel demand forecasting model (not from actual counts), a comparison was made between TRINA AADT and RTC model estimated AADT at some selected locations. The data are presented in the figures with x axis showing RTC data and y axis showing TRINA data from the same year. The figures are presented in three different scales regarding AADT ranges.
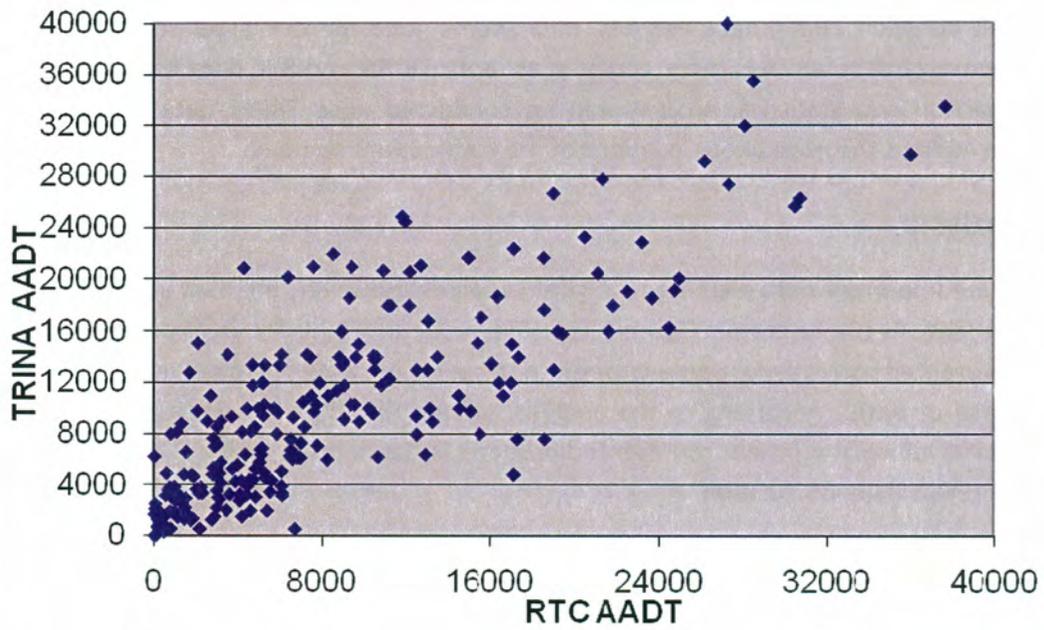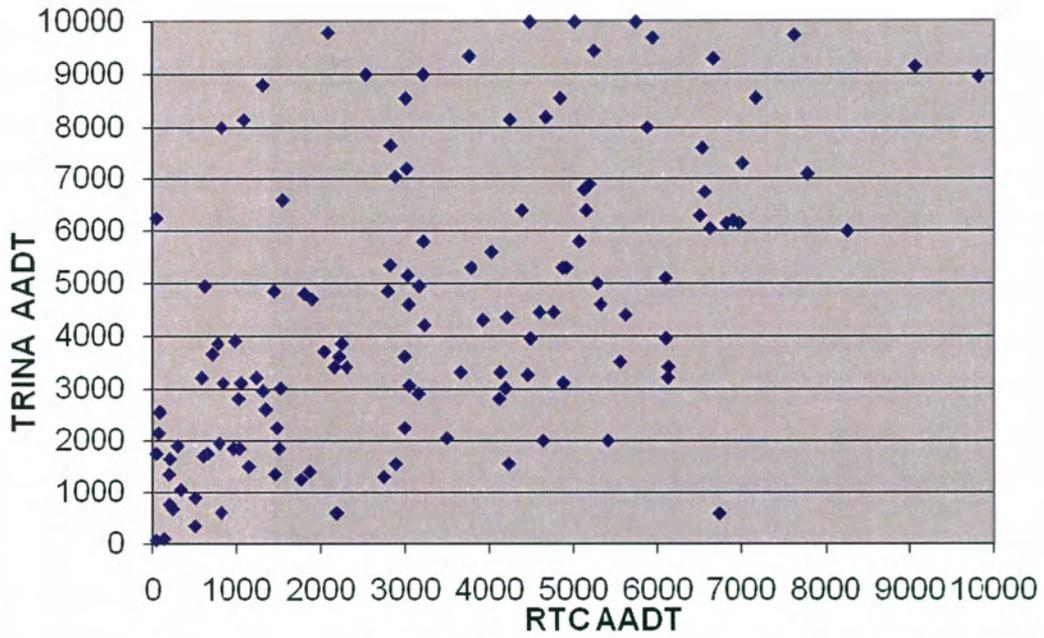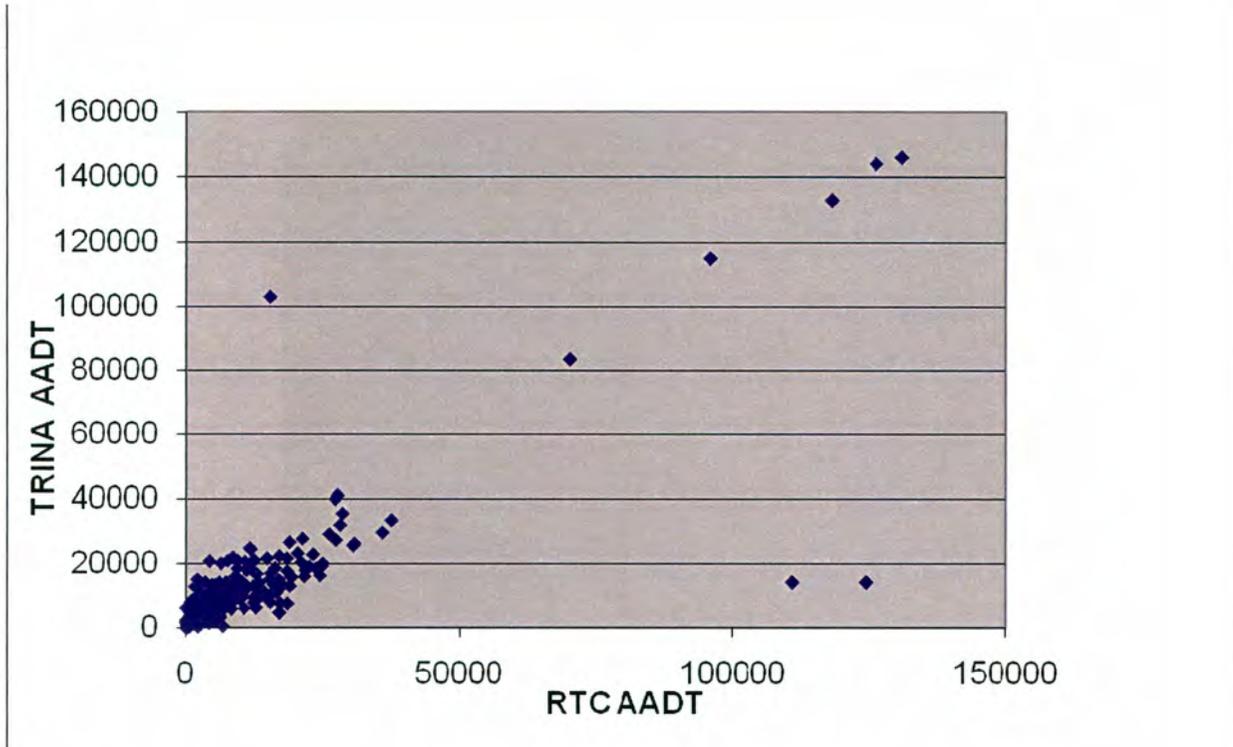
Figure 17 AADT Comparison between TRINA and RTC Model

Although the correlation between TRINA data and RTC data seems good for the larger scales, it no conclusions can be drawn regarding which is more accurate as both TRINA and RTC data have certain problems. Better comparison and statistical analysis can be conducted once TRINA data is further cleaned up, especially to address the issue about locations of the traffic count stations.

4.3.3 Crash Data Analysis

Collision data and time are important data elements for safety analysis. However, the data in the crash dataset is not correctly coded. As can be seen in Figure 18 and Figure 19, the fields for Collision Date and Collision Time are not presented correctly for some crashes. In some other cases, the data and time are coded in one field instead of both. According to the analysis, among the 27,161 crashes in Washoe County, 9,190 crashes' time information is not represented properly in the dataset, which is about 34%. 17 crashes do not have correct date information.

Figure 18 Incorrect Collision Date and Time 1

Figure 19 Incorrect Collision Date and Time 2

5 Software Testing

During the development and beta testing stages of the SafetyAnalyst software, numerous revisions and updates have occurred to address the issues and comments raised by the TWG. The latest update of SafetyAnalyst is the Pre-Public full Enterprise distribution version 1.4.17, released on August 15, 2008. The research team has also been following closely with the updates and has been conducting the testing based on different versions of the software. The results reported in this document represent those from the latest version of SafetyAnalyst at the time when the report was prepared. The software testing included two steps: data management and network screening. The data management tool in SafetyAnalyst was tested and used to import and run calibrations to make sure the data prepared meet the requirements of SafetyAnalyst. The data set was able to be imported correctly. Network screening within the analytical tool of SafetyAnalyst was tested to show the functionalities of the software.

5.1 Data Management Tool

The data management process started with creating and selecting a dataset as shown in

Figure 20. Here the dataset created was named "SAtest". Prepared input data files were then imported to the SafetyAnalyst dataset as shown in Figure 21.
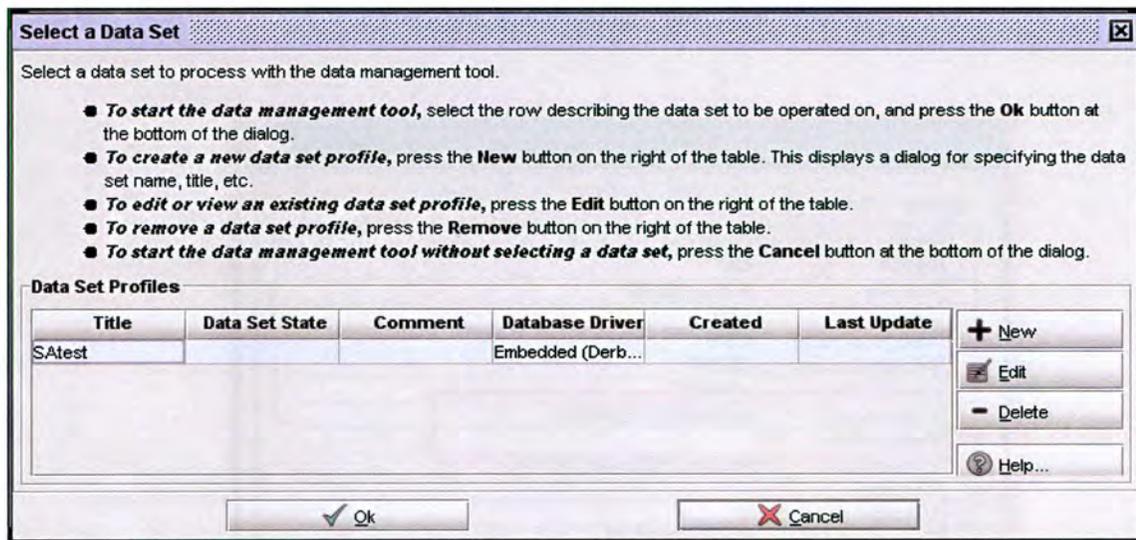
Figure 20 Dataset Selection
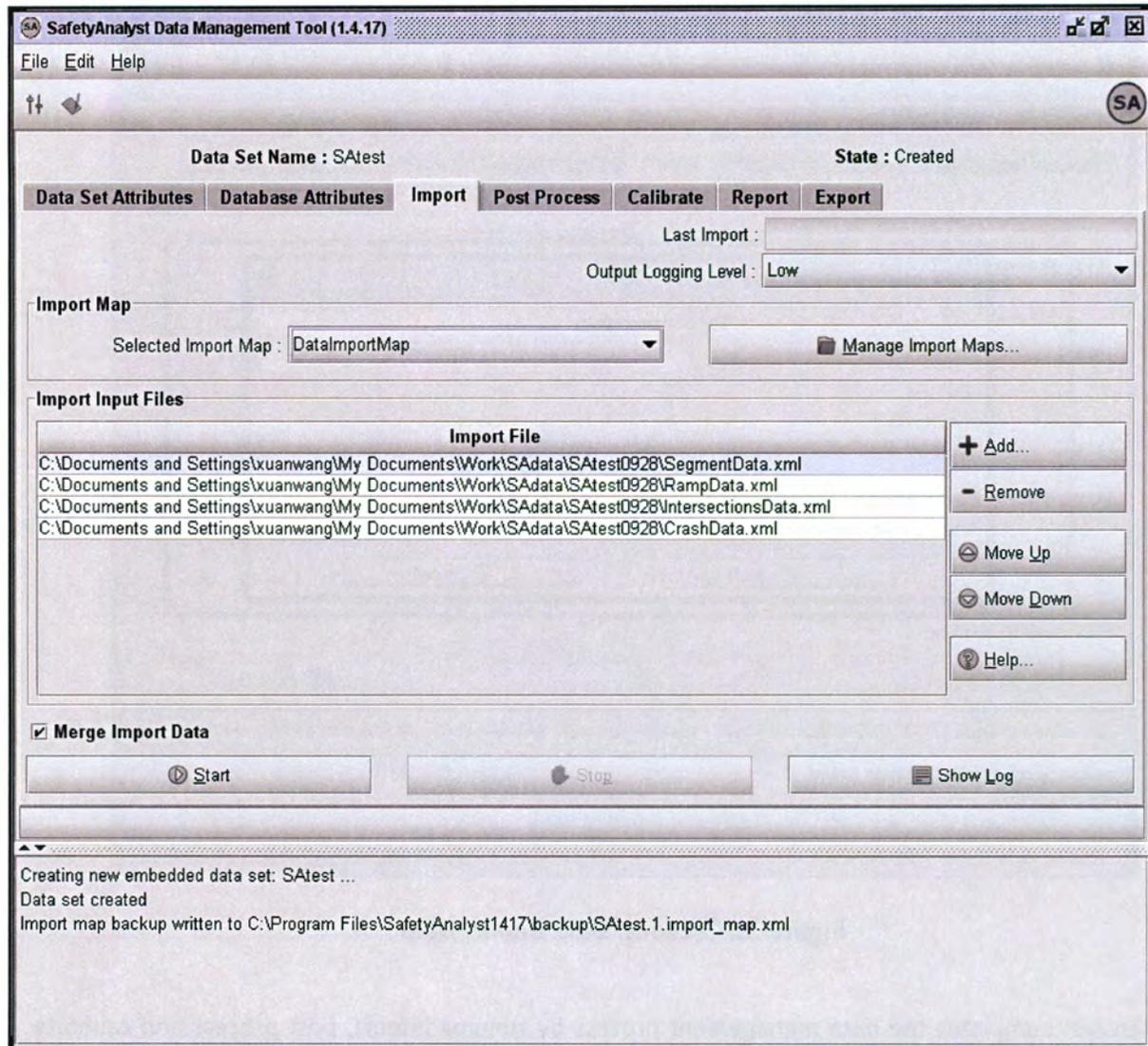
Figure 21 Import Input Files

The input files were mapped with "Data Import Map" created by the user to connect the user defined data attributes to SafetyAnalyst's data formats as shown in Figure 22. The software operation should be relatively easy based on some training. The map was edited within SafetyAnalyst for each mandatory data element. For an example shown in Figure 23, "Intersection ID" (A unique ID for each intersection required by SafetyAnalyst) was imported from ID1 in the input file "IntersectionData". All mandatory data elements were mapped so that SafetyAnalyst was able to import each data element accordingly from the input data files. The software testing used only the XML format map type. Database to database mapping function was completed and added to SafetyAnalyst recently after we started this report preparation. This function will be tested in a future task.
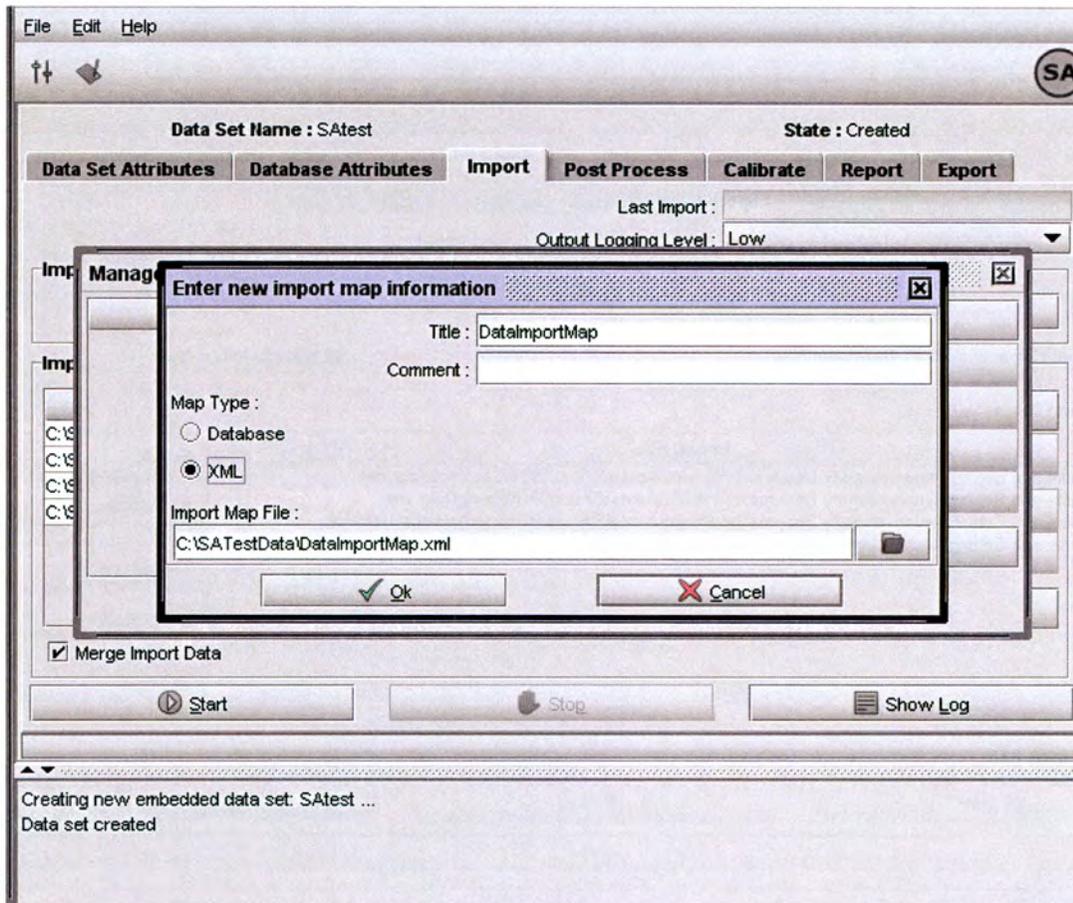
Figure 22 Creating Data Import Map

SafetyAnalyst completes the data management process by running import, post process and calibrate functions. The import datasets were finally calibrated within SafetyAnalyst, and were ready to be analyzed by the Analytical Tool of SafetyAnalyst. The import function includes a Merge Import Data option. This option allows the newly added data to be merged into the data that has already been imported. For the post process, homogeneous segments are created to connect routes with similar geometry and traffic volume. Threshold parameters can be edited by the user to define what are considered to be homogeneous segments.
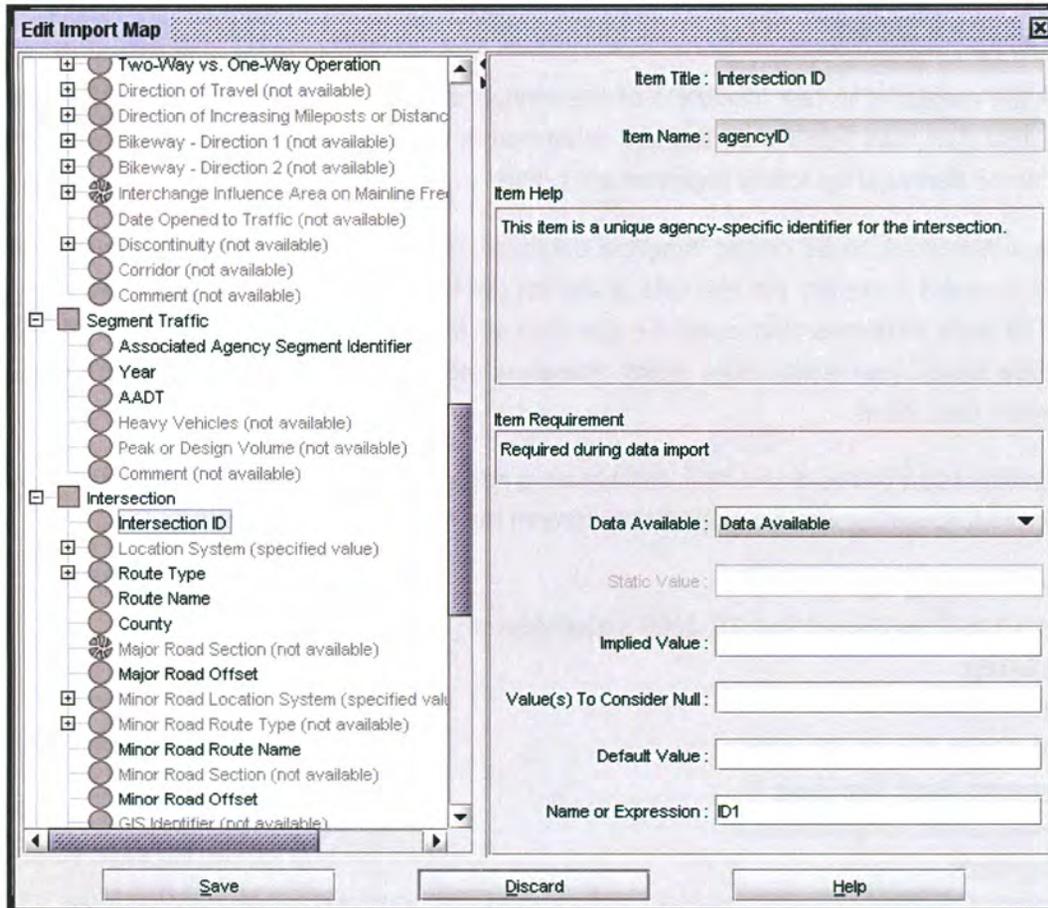
Figure 23 Data Map Editing

The ramp data was not able to be imported into SafetyAnalyst. The software gave error messages regarding the ramp data import, but the information was not specific enough to indicate what the reason was. The error messages are shown in Figure 24.

Figure 24 Data Import Error

The research team had contacted the SafetyAnalyst development group for resolution of this issue, but the reason has not been found by the time the report was prepared.

5.2 Analytical Tool

The scope of the project is to test Module 1 of the Analytical Tool – Network Screening. The module analyzes the data that have been imported and calibrated in the data management and gives a list of sites ranked by the Potential for Safety Improvements (PSI).

After creating a Workbook based on the imported database, the user can use the query function in the analytical tool to select a site list. For example, a site list can be developed to include all the rural two-lane roads. The data attributes that could be specified to form the query are based on geographic description data items, intersection data items, inventory element data items, ramp data items, and roadway segment data items.

The following discussion shows a test that completed a network screening with all the rural two-lane roads. The network screening was developed according to the following specifications:

Basic Network Screening
SafetyAnalyst: v1.4.17, packaged: Aug 15, 2008 3:12 PM on sa_dev.ittsystems.com
Dataset title: SAtest
Dataset comment: null
Dataset created: Sun, Sep 28, 05:36PM
Roadway Segments: Peak Searching
Accident Severity Level: Total accidents
Site Types: Segments
Screening Attribute: Accident Month = January; February; March; April; May; June; July; August; September; October; November; December
Potential for Safety Improvement Using: Expected accident frequency
Analysis Period: From 2003 To 2005
Exclude years prior to major reconstruction: true
CV limit (roadway segments): 0.5
Area Weights (Rural): 1.0
Area Weights (Urban): 1.0
Limiting Value (Roadway Segments): 1.0 acc/mi/yr

Based on the input data, the analytical tool calculates various measures including the PSI which is used to rank all the sites. The network screening report contains a table documenting the measures regarding the network screening procedure. The measures are:

Average Observed Accidents for Entire Site - this measure is the average crash density (i.e., crash/mi/yr) for the entire section identified by the network screening criteria, taking into consideration an ADT growth factor to scale the observed crash frequency to the final year of the analysis period. Most analyses within SafetyAnalyst look at individual sites. A site is a single record in the site characteristic files in the master SafetyAnalyst database, which basically includes all the relevant geometric design, traffic control, traffic volume, and crash data available for the respective location. Basically, there are three types of sites within SafetyAnalyst: roadway segments, intersections, and ramps. For roadway

segments and ramps, a site extends over a specified length and all of the site characteristics are homogeneous over the length of the site.

Average Observed Accidents - the measure is a projection (to crash/mile/yr) of the highest crash location for that portion of the site which is used to flag for having the greatest potential for safety improvement. Only those observed crashes reported to have occurred between the limits as specified in Columns 13 and 14 (Start Location and End Location) of the report are included in this calculation. Again, the average observed crash frequency is scaled to the final year of the analysis period so that the observed, predicted, and expected crash frequencies are directly comparable. This calculation only considers observed crash frequencies and growth in ADT.

Predicted Accident Frequency - This is the predicted crash frequency for that portion of the site which is flagged for having the greatest potential for safety improvement. This predicted value is calculated directly from safety performance functions. This calculation does not consider "observed" crashes at the site. This is essentially a preliminary calculation in the Empirical Bayes methodology. Again the predicted crash frequency is for the final year of the analysis period considering the ADT growth factor.

Expected Accident Frequency - This is the expected crash frequency for that portion of the site which is flagged for having the greatest potential for safety improvement. This expected value is calculated from safety performance functions and observed crash data. This is essentially the final output from the EB calculations. Again, the expected crash frequency is for the final year of the analysis period. The value of the "Expected Accident Frequency" is always between the values for the "Average Observed Accident" and the "Predicted Accident Frequency". The "Expected Accident Frequency" is the measure used to rank the sites for their potential for safety improvement. Sites with higher "Expected Accident Frequencies" have greater potential for safety improvement.

The reporting table also includes another two measures- Number of Expected Fatalities and Number of Expected Injuries. However these two measures were not calculated in SafetyAnalyst of the tested version.

The testing report is attached in Appendix B with ranking of all the sites that were analyzed based on the Expected Accident Frequency as the Potential for Safety Improvement.

The software was completed shortly before the report was prepared. Therefore, the analysis and validation of the results were not performed due to the time restriction. A comparison should be needed in future studies between the output from the software and a manual calculation on several selected locations.

The operation of the software is relatively easy and straightforward, but some features need to be improved. For example, some error messages do not specify the potential problems as seen in Figure 24. The query function to create or edit a site list is also not very user friendly compared to other database software tools. From the query wizard, the user will need to edit a query using the same three dialogue windows repeatedly with certain logic operators (Union, Intersection, or Complement). This function is usually within one dialogue window in other software packages, such as MS Access and GeoMedia.

However, the major concern with the software is still the data preparation to have all the data required by SafetyAnalyst.

5.3 Software Updates and Fixes

The research team was actively involved in every stage of the software development and testing. Several software bugs were identified and reported to the SafetyAnalyst development group. The group has adopted most of our suggestions on improving the functionality of the software. Such an effort improved the applicability of the software in proper functionality and actual transportation safety practice. Some major recommendations adopted by the Technical Working Group include:

- The intersection data were not able to be imported properly. Based on what was experienced from Nevada, TWG updated the software with a JAR file with modified leg post processing code. If no leg data is available at the intersection, a set of leg stubs will be created based on the value of the *intersectionType1* value for the leg. (November, 2007)

- The software was updated to address the issues related to incorrect number of imported segments. For the Washoe county network, there should be a total of 1131 segments after aggregation, but only 990 were inserted into the database table because of a database error. Thus, 141 aggregated segments were missing. TWG fixed the database error and updated the software. (December, 2007)

- When trying to import data with the 1.4.12 version, the software produced error messages and the calibration could not get through. The older version of the software was able to calibrate the data with the same input files. Based on the report, the problem was identified and solved by TWG. (June, 2008)

- Ramp data were rejected from importing. When sites were rejected (ramps in Nevada and intersections in Michigan) their IDs were not removed from the lists used for accident location matching. Thus, some accidents were assigned to the rejected sites, and this caused a program exception to occur. The problem was fixed in the updated version. (October, 2008)

6 Summary and Recommendations

One of the primary functions of the Safety Management System in state DOTs is to identify and prioritize locations where future funding can be effectively spent for safety improvement. The SafetyAnalyst software was specifically developed for assisting state DOTs and transportation agencies to improve their Safety Management Systems. This report describes an effort on testing and evaluation of the software using a dataset compiled based on the transportation network in Washoe County, Nevada.

Major efforts described in this report include sections of literature review and overview of the SafetyAnalyst software functions; the dataset compilation process; and testing of the software using the assembled dataset. Data in different formats were collected from both state and local agencies to create a database for all the public roads within the Washoe County limit. A significant effort was involved with assembling the dataset for SafetyAnalyst. Several GIS/LRS techniques were applied to perform the data manipulation and transformation, which proved to be an efficient way for the data assembling. Testing of the software primarily focused on Module 1-Network Screening of SafetyAnalyst. The final software, including all four modules, was completed in early October 2008. However, improvements are still needed as the testing goes on. As a "pool" member, NDOT will receive the completed SafetyAnalyst software for testing and implementation.

Major findings and recommendations from this research are provided next.

Findings

- SafetyAnalyst has a much greater demand for data, and correspondingly carries a greater expense to operate. NDOT needs to have a better understanding of the significance of utilizing SafetyAnalyst, as opposed to using traditional techniques.

- It is anticipated that more state DOTs, including NDOT, will adopt SafetyAnalyst as a major tool in their traffic safety programs. Therefore, it is critical that the software be equipped with all the necessary features and functions needed by NDOT's safety programs.

- Several critical areas related to data quality and data collection needs were identified. One such example is the lack of reliable traffic volume counts at key roadway locations in Nevada's urban areas. Without a high quality data, valid analysis results could not be achieved.

- More effort is needed to review the AADT from RTC and NDOT. From a research standpoint, there ought to be better method to analyze, merge, and extrapolate traffic count information across the network.

- In many cases, major discrepancies were found in baseline year data between NDOT's TRINA database and RTC's travel demand model. From a policy standpoint, it is clear that better cooperation needs to occur between the state and local agencies regarding the traffic volume data.

Recommendations

- A major research need is to examine the sensitivity of traffic volume in the safety models. The state-provided data (TRINA) appears to be driven by the federal Highway Performance Management Systems (HPMS) requirements. Typically the requirements for the HPMS appear to only require one count per HPMS section. In urban areas, significant changes within the HPMS section may be occurring, and may be unaccounted for in the data. This should be further examined in future research to better understand the level of sensitivity.

- A complete evaluation of all the SafetyAnalyst modules is necessary to truly assess its feasibility and benefit-cost. Prior to formally adopt SafetyAnalyst, further testing is needed as it is clear from this project that bugs still exist and software revision will continue for some time.

- Calibration of Safety Performance Functions based on Nevada's conditions is necessary as safety performance functions provided by SafetyAnalyst are generalized for the US. Calibration needs to be accomplished in a pilot setting prior to doing it over a broader scale. It seems logical after the software has been fully tested to perform calibration in order to achieve the best results from the process.

Appendix A: Data Requirements

Type	Data element	Definition	Data Source	Coverage	Currency	Quality	Effort	How to Create	Steps	Comment
Segment	Segment Number	A unique identifier that identifies a section of roadway.	LRS	All routes	2005	Accurate,consistent	Minor	Use the segment id from LRS as the segment id number. Tool: Aggregation 417-99999 ramp full name RM	Output feature class: LRS for Washoe County. Build base segments. Use ID generated from base geometry generation.	
Segment	Roadway Segment Location(b)	The location of the roadway segment. Typically the locations of the beginning and end points of the segment will be specified in one of the six location identifier systems available in SafetyAnalyst.	LRS	All routes	2005	Accurate,consistent	Minor	From LRS.	ROUTE_MASTER_ID, BEGIN_ROUTE_CUM, END_ROUTE_CUM	
Segment	Segment Length	Length of the segment in miles.	LRS	All routes	2005	Accurate,consistent	Minor	Calculated from begin milelage and end milelage.	END_ROUTE_CUM - BEGIN_ROUTE_CUM	
Segment	Area Type	The character of the area in which the roadway section is located, based on FHWA urban area maps or equivalent state criteria.	TRINA	Routes close to traffic counts stations	2005	Accurate	Minor	In Trina, area types are Urban and One(rural?). Other methods may be considered to derive	From Trina, Urban, One and other coding. Need coding information.	U—Urban R—Rural N—Not applicable X—Unknown

Segment	Number of Through Lanes- Direction 1	Total number of through lanes in this direction of travel. Turn lanes and auxiliary lanes are not to be included in this count.	TRINA/RTC/HPMS	Routes close to traffic counts stations/most routes in Reno,Sparks area/state routes	2005/2005/2004	Accurate/minor error/accurate				
								area type data, such as census map.Areas with a population of 50,000.		
								Trina: Query for routes that are within 50ft of the traffic count stations in Trina data, then use Dyseg methord to get information from Trina to CDS routes. The direction of the lanes are put as Positive lanes and Negative lanes in Trina data. RTC: Transformed RTC data. The process was as follows: 1 Use analytical merge on rtc data to make longer segments 2 Use spatial intersection on itself to produce	From Trina RTC(total)	increasing milepost

							segment nodes with segment attribution 3 Perform a intersection to intersection matching route to match rtc nodes to LRS Intersection markers (routine developed by IT IS) 4 Use aggregation based upon intersections with 100ft with attribute matching between route master pairs to acquire intersection marker location, and route cum value 5 Converted node point event to duration event using a spreadsheet. 6 Dynsegged table The number of lanes information are put as		

								total number of lanes and lanes of the directional lane. Number of lanes of the other direction can be calculated then. HPMS: It has only the total number of lanes.		
Segment	Number of Through Lanes- Direction 2	Total number of through lanes in this direction of travel. Turn lanes and auxiliary lanes are not to be included in this count.	TRINA/RTC/HPMS	Routes close to traffic counts stations/most routes in Reno,Sparks area/state routes	2005/2005/2004	Accurate/minor error/accurate	Minor	Same as above	From Trina RTC(total)	Got from HPMS. Need Coding information. Also available in RTC: POLICYACES RTP access control classification of street for future years (1=freeway, 2=high access control, 3=moderate access control, 4=low access control, 5=ultra-low access control, 6=collector, 7=rural highway, 8=freeway ramp, 9=zone connector) In SA: 1—Full Access Control 2—Partial access Control 3—No Access

										Control 98—Not applicable 99—Unknown
Segment	Median Type Level 1	Indication of the type and characterization of the area separating opposing traffic lanes.	HPMS	State routes	2004	Accurate	Minor	HPMS has median type data which is coded. Need coding information.	Got from HPMS. Need Coding information.	In SA:1—Rigid barrier system (i.e., concrete) 2—Semi-rigid barrier system (i.e., box beam, W-beam strong post, etc.) 3—Flexible barrier system (i.e., cable, W-beam weak post, etc.) 4—Raised median with curb 5—Depressed median 6—Flush paved median [at least 4 ft in width] 7—HOV lane(s) 8—Railroad or rapid transit 9—Other divided 0—Undivided 98—Not applicable 99—Unknown
Segment	Access Control	The degree that access to abutting land in connection with a highway is fully, partially, or not controlled by public authority.	HPMS	State routes	2004	Accurate	Minor	Need coding information.	Got from HPMS. Need Coding information. Also available in RTC: POLICYACES RTP access control classification of street for future years (1=freeway, 2=high access control, 3=moderate access control, 4=low access control, 5=ultra-low	

									access control, 6=collector, 7=rural highway, 8=freeway ramp, 9=zone connector) In SA: 1—Full Access Control 2—Partial access Control 3—No Access Control 98—Not applicable 99—Unknown	
Segment	Annual Average Daily Traffic	The average number of vehicles passing a point on a roadway in a day from both directions, for all days of the year, during a specified calendar year, expressed in vehicles per day.	TRINA/RTC/HPMS	Routes close to traffic counts stations/most routes in Reno,Sparks area/state routes	2005/2005/2004	Accurate/minor error/accurate	Minor	Same as Number of Through Lanes-Direction 1	Trina RTC average Multiplied 2 for two way street consideration. Need configuration for one way streets.	
Segment	Two-Way vs. One-Way Operation	Indication of whether or not a roadway serves one-way or two-way traffic.	TRINA/RTC	Routes close to traffic counts stations/most routes in Reno,Sparks area	2005	Accurate/minor error		In Trina, TVO can be derived from: if number of P or N lanes is 0. In RTC data, can be derived by comparing total number of lanes and number of directionl lanes.	Query in Access	
Segment	Interchange Influence Area on Mainline	Indication of whether or not a roadway is	TRINA	Routes close to traffic counts	2005	Minor error		TRINA has a ramp identifier.		

	Freeway	within an interchange influence area.		stations				Area is defined by: 0.3 miles upstream from gore point of first off-ramp to 0.3 miles downstream from gore point of last on-ramp entrance.		
Intersection	Intersection Number	A unique number that identifies the intersection.	LRS	All routes	2005	Accurate,consistent	Minor	Publish		
Intersection	Intersection Location (b)	The location of the intersection. Specified using one of the six location identifier systems available in SafetyAnalyst.	LRS	All routes	2005	Accurate,consistent	Minor	Publish		
Intersection	Minor Road Location Identifier	Location identifier information for the intersection with reference to the minor road (as opposed to the major-road information in F.1.7 "Intersection Location". Specified using one of six location identifier systems used in SafetyAnalyst)	TRINA/RTC/HPMS	Routes close to traffic counts stations/most routes in Reno,Sparks area/state routes	2005/2005/2004	Accurate/minor error/accurate	Minor	Derived from AADT. Minor road is usually determined from the traffic volume occurring at the intersection.		

Intersection	Area Type	The character of the area in which the intersection is located, based on FHWA urban area maps or equivalent state criteria.	TRINA	Routes close to traffic counts stations	2005			In Trina, area types are Urban and One(rural?). Other methords may be considered to derive area type data, such as census map.		
Intersection	Intersection Type Level 1	The type of intersection at which two or more roadways intersect at grade.	LRS	All routes	2005	Accurate,consistent		By using Azimuth values provided by LRS.		SA: 1—Tee intersection (Can be Tee and Y) 2—Y intersection 3—Four-leg intersection 4—Traffic circle/roundabout 5—Multileg intersection, five or more legs 0—Other 99—Unknown
Intersection	Traffic Control Type at Intersection Level 1	Type of traffic control device at intersection.	RTC-Synchro files	Major arterials in Reno Sparks area	2005			Manually extract information from Synchro report.		Synchro files are available from RTC for major arterials that are running coordination.
Ramp	Ramp Number	A unique identifier that identifies a ramp.	LRS/TRINA	All routes	2005			Publish		
Ramp	Ramp Location	The location of the ramp. Specified using one of the six location identifier systems available in SafetyAnalyst. Often the milepost or	LRS/TRINA	All routes	2005	Accurate,consistent	Minor	Publish		

		distance specified as a ramp location refers to the location of the gore area for the ramp. Some states identify ramps by a ramp number (equivalent to a segment number), even though the mainline locations are identified with a milepost system.							
Ramp	Area Type	The character of the area in which the ramp is located, based on FHWA urban area maps or equivalent state criteria.	TRINA	Routes close to traffic counts stations	2005	Accurate	Minor	In Trina, area types are Urban and One(rural?). Other methords may be considered to derive area type data, such as census map.	
Ramp	Ramp Type	Indicates whether the ramp is used to enter or exit a freeway or connect two freeways.						On ramp or off ramp or free way to free way ramp	

Ramp	Ramp Configuration	The characterization of the design of the ramp.									1—Diamond 2—Parclo loop 3—Free-flow loop 4—Free-flow outer connection 5—Direct or semi-direct connection 6—C-D road or other connector 0—Other 99—Unknown
Ramp	Ramp Average Annual Daily Traffic	The average number of vehicles traversing this ramp in a day, for all days of the year, during a specified calendar year, expressed in vehicles per day.	TRINA	Routes close to traffic counts stations	2005	Accurate		Identify segment as ramp when the value of Ramp is True, then apply the AADT.			TRINA has a ramp identifier
Accident	Accident Location	The location of the accident. Typically the point location of the accident will be specified in one of the six location identifier systems available in SafetyAnalyst.									
Accident	Accident Date	The date(year, month, and day) on which an accident occurred.									

Accident	Accident Type and Manner of Collision	The type of first harmful event in a single-vehicle accident or, in a multiple-vehicle collision, manner in which two vehicles in transportation initially came together without regard to the direction of force, or the type of object with which a single vehicle collided.								
Accident	Accident Severity Level 1	The severity of an accident based on the most severe injury to any person involved.								
Accident	Accident Severity Level 2 (derived)	The severity of an accident based on the most severe injury to any person involved, with all non-fatal injury categories combined into a single level(derived from H.1.22 'Accident Severity Level 1' in many cases.)								
Accident	Vehicle Turning Movements (derived)	Characterization of accidents where any								

		involved vehicle was performing a turning maneuver prior to impact.									
Accident	Roadway Segment Number (derived)	A unique identifier that identifies the section of roadway on which the accident occurred.									
Accident	Intersection Number (derived)	A unique number that identifies the intersection on which the accident occurred.									
Accident	Ramp Number (derived)	A unique number that identifies the ramp on which the accident occurred.									
Vehicle	Vehicle Maneuver/Action	Controlled maneuver that the vehicle was doing prior to the first event in the sequence of events for this vehicle.									

Appendix B: Network Screening Report

Basic Network Screening
SafetyAnalyst: v1.4.17, packaged: Aug 15, 2008 3:12 PM on sa_dev.ittsystems.com
Data set title: SAtest
Data set comment: null
Data set created: 4:57 PM
Roadway Segments: Peak Searching
Accident Severity Level: Total accidents
Site Types: Segments
Screening Attribute: Accident Month = January; February; March; April; May; June; July; August; September; October; November; December
Potential for Safety Improvement Using: Expected accident frequency
Analysis Period: From 2003 To 2005
Exclude years prior to major reconstruction: true
CV limit (roadway segments): 0.5
Area Weights (Rural): 1.0
Area Weights (Urban): 1.0
Limiting Value (Roadway Segments): 1.0 acc/mi/yr

ID	Site Type	Site Subtype	County	Route	Site Start Location	Site End Location	Average Observed Accidents for Entire Site*	Location with Highest Potential for Safety Improvement								Rank	Additional Windows of Interest
								Average Observed Accidents*	Predicted Accident Frequency*	Expected Accident Frequency*	Variance**	Start Location	End Location	No. of Expected Fatalities	No. of Expected Injuries		
																	0.2 - 0.3
																	0.4 - 0.5
																	0.5 - 0.6
																	0.6 - 0.7
1659	Segment	Seg/Rur; 2-lane	31	L123209	0	0.721	16.9769	87.4312	2.2758	58.5865	22.5814	0	0.1	-	-	1	0.621 - 0.721
650...649	Segment	Seg/Rur; 2-lane	31	L109904	0.402	0.412	58.7944	58.7944	3.1554	43.6891	18.7131	0.402	0.412	-	-	2	
																	0.0 - 0.1
2234	Segment	Seg/Rur; 2-lane	31	L130765	0	0.22	27.6231	55.2461	3.8036	43.6663	18.6936	0.12	0.22	-	-	3	0.1 - 0.2
2983	Segment	Seg/Rur; 2-lane	31	L138907	4.57	4.633	53.1595	53.1595	3.3264	40.6376	16.9832	4.57	4.633	-	-	4	
1378	Segment	Seg/Rur; 2-lane	31	L120470	0.632	0.747	43.8313	44.8053	4.5474	36.8488	16.5589	0.647	0.747	-	-	5	0.632 - 0.732
2304...2302	Segment	Seg/Rur; 2-lane	31	L132850	0.042	0.506	15.674	50.3496	2.4642	35.3965	13.6186	0.406	0.506	-	-	6	0.242 - 0.342
4122...4117	Segment	Seg/Rur; 2-lane	31	SR99	12.96	17.212	7.1452	49.715	2.4087	34.8398	13.1936	13.86	13.96	-	-	7	12.96 - 13.06
																	13.06 - 13.16

	13.16 - 13.26
	13.76 - 13.86
	13.96 - 14.06
	14.06 - 14.16
	14.16 - 14.26
	14.26 - 14.36
	14.86 - 14.96
	14.96 - 15.06
	15.16 - 15.26
	15.26 - 15.36
	15.76 - 15.86
	15.96 - 16.06
	16.16 - 16.26
	16.36 - 16.46

																		16.66 - 16.76
																		16.76 - 16.86
																		16.86 - 16.96
																		16.96 - 17.06
																		17.112 - 17.212
2133	Segment	Seg/Rur; 2-lane	31	L129888	0.189	0.261	38.1448	38.1448	2.8523	28.3314	11.2348	0.189	0.261	-	-	8	
648	Segment	Seg/Rur; 2-lane	31	L109904	0.579	1.035	9.3262	36.4523	2.6089	25.6985	10.6518	0.935	1.035	-	-	9	0.679 - 0.779
																	1.684 - 1.784
																	1.984 - 2.084
																	2.084 - 2.184
917...928	Segment	Seg/Rur; 2-lane	31	L115166	1.584	2.517	6.5949	27.9684	3.4358	21.9424	9.259	2.417	2.517	-	-	10	2.184 - 2.284
																	0.506 - 0.606
2298...2295	Segment	Seg/Rur; 2-lane	31	L132850	0.506	0.893	11.6309	28.1323	2.6557	20.5499	8.1212	0.706	0.806	-	-	11	0.606 - 0.706
3806	Segment	Seg/Rur; 2-lane	5	SR57	5.158	7.642	3.0362	26.9357	2.0662	18.412	6.5192	7.158	7.258	-	-	12	5.658 - 5.758

																		6.058 - 6.158
																		6.158 - 6.258
																		6.458 - 6.558
																		6.558 - 6.658
																		7.258 - 7.358
																		7.358 - 7.458
																		7.458 - 7.558
4083...4119	Segment	Seg/Rur; 2-lane	31	SR99	0	11.452	4.0635	26.7446	1.8758	17.7129	6.0336	0	0.1	-	-	13	0.2 - 0.3
																		1.0 - 1.1
																		1.5 - 1.6
																		1.6 - 1.7
																		2.0 - 2.1
																		2.2 - 2.3
																		2.4 - 2.5
																		2.6 - 2.7
																		2.9 - 3.0
																		3.4 - 3.5
																		4.1 - 4.2
																		4.2 - 4.3
																		4.4 - 4.5
																		4.6 - 4.7
																		4.9 - 5.0

5.0 - 5.1	6.0 - 6.1	6.1 - 6.2	6.2 - 6.3	6.4 - 6.5	6.6 - 6.7	6.8 - 6.9	7.0 - 7.1	7.6 - 7.7	7.9 - 8.0	8.0 - 8.1	8.1 - 8.2	8.2 - 8.3	8.3 - 8.4	8.4 - 8.5	8.8 - 8.9	8.9 - 9.0	9.0 - 9.1	9.1 - 9.2	9.2 - 9.3	9.3 - 9.4	9.4 - 9.5	9.5 - 9.6	10.0 - 10.1	10.4 - 10.5

| 3808...3807 | Segment | Seg/Rur; 2-lane | 31 | SR57 | 11.439 | 14.197 | 4.4627 | 21.4052 | 2.8352 | 16.3162 | 6.3385 | 12.139 | 12.239 | - | - | 14 | 11.739 - 11.839 |

| | 10.6 - 10.7 |
| 10.8 - 10.9 |
| 10.9 - 11.0 |
| 11.0 - 11.1 |
| 11.1 - 11.2 |
| 11.2 - 11.3 |
| 11.352 - 11.452 |
| 12.039 - 12.139 |
| 12.239 - 12.339 |
| 12.339 - 12.439 |
| 12.539 - 12.639 |
| 12.639 - 12.739 |
| 13.039 - 13.139 |

																		13.139 - 13.239
																		13.239 - 13.339
																		13.339 - 13.439
																		13.439 - 13.539
																		13.639 - 13.739
																		14.097 - 14.197
																		0.2 - 0.3
																		0.4 - 0.5
																		0.5 - 0.6
716...712	Segment	Seg/Rur; 2-lane	31	L111628	0	0.847	14.3852	79.1979	0.2902	15.4673	1.8124	0	0.1	-	-	15	0.6 - 0.7
																		0.5 - 0.6
																		0.6 - 0.7
3057...3054	Segment	Seg/Rur; 2-lane	31	L139491	0	0.94	4.7632	22.3869	2.0014	15.075	5.4108	0.4	0.5	-	-	16	0.8 - 0.9
3500...3502	Segment	Seg/Rur; 2-lane	31	L319	0.07	0.174	21.123	21.9679	1.857	14.4936	5.0015	0.07	0.17	-	-	17	0.074 - 0.174
																		0.121 - 0.221
2665...2663	Segment	Seg/Rur; 2-lane	31	L135758	0.121	0.568	8.6684	16.6062	3.6971	13.6314	5.8067	0.468	0.568	-	-	18	0.221 - 0.321
293	Segment	Seg/Rur; 2-lane	31	L101803	6.867	7.005	12.0677	16.6534	3.1107	13.0913	5.3557	6.905	7.005	-	-	19	
3823...3819	Segment	Seg/Rur; 2-lane	31	SR57	14.197	16.16	3.3081	16.2347	3.1756	12.9152	5.2125	14.197	14.297	-	-	20	14.297 - 14.397

																	14.497 – 14.597
																	15.097 – 15.197
																	15.597 – 15.697
																	15.797 – 15.897
																	15.997 – 16.097
																	16.06 – 16.16
																	0.968 – 1.068
2664...2666	Segment	Seg/Rur; 2-lane	31	L135758	0.568	1.307	3.7558	16.6533	2.8578	12.7934	5.1147	1.207	1.307	-	-	21	1.168 – 1.268
																	6.142 – 6.242
295	Segment	Seg/Rur; 2-lane	31	L101803	5.842	6.349	4.3662	16.6023	2.7927	12.6827	5.0266	6.249	6.349	-	-	22	6.242 – 6.342
1031	Segment	Seg/Rur; 2-lane	31	L116962	0.197	1.407	3.6839	16.7157	2.6346	12.53	4.9063	1.307	1.407	-	-	23	0.197 – 0.297
																	0.497 – 0.597
																	0.797 – 0.897
																	0.997 – 1.097

																		Range
																		1.297 - 1.397
																		7.643 - 7.743
																		8.643 - 8.743
																		9.043 - 9.143
																		9.243 - 9.343
																		9.443 - 9.543
																		9.843 - 9.943
3805	Segment	Seg/Rur; 2-lane	31	SR57	7.643	10.083	2.1855	15.9978	2.1113	11.3374	4.0168	9.983	10.083	-	-	24	9.943 - 10.043
3037...3043	Segment	Seg/Rur; 2-lane	31	L139485	1.211	1.402	17.0389	16.2721	2.0294	11.3107	3.9979	1.211	1.311	-	-	25	1.302 - 1.402
3836	Segment	Seg/Rur; 2-lane	31	US6	66.085	66.398	3.5257	11.0353	8.9566	10.8073	5.309	66.185	66.285	-	-	26	
741...720	Segment	Seg/Rur; 2-lane	31	L111779	8.202	10.272	1.0517	16.3279	1.7424	10.7196	3.5909	10.172	10.272	-	-	27	9.602 - 9.702
291...294	Segment	Seg/Rur; 2-lane	31	L101803	4.179	5.842	2.3297	16.6043	1.5388	10.3012	3.3161	4.179	4.279	-	-	28	4.679 - 4.779
																		4.779 - 4.879
																		4.879 - 4.979

																	4.979 - 5.079
3876	Segment	Seg/Rur; 2-lane	31	US6	38.101	38.251	11.4421	11.4421	5.0341	10.2553	4.7805	38.101	38.201	-	-	29	38.151 - 38.251
																	0.463 - 0.563
811...812	Segment	Seg/Rur; 2-lane	31	L113339	0.463	0.97	4.3903	11.1294	2.7645	8.7284	3.4629	0.763	0.863	-	-	30	0.87 - 0.97
856...860	Segment	Seg/Rur; 2-lane	31	L113900	0.467	0.718	4.378	10.9887	2.7521	8.6385	3.392	0.467	0.567	-	-	31	
																	0.0 - 0.1
2360...2362	Segment	Seg/Rur; 2-lane	31	L132867	0	0.648	4.3167	11.1888	2.4642	8.4644	3.2566	0.2	0.3	-	-	32	0.4 - 0.5
2312...2306	Segment	Seg/Rur; 2-lane	31	L132850	0.893	1.625	1.5137	11.08	2.1993	8.1048	2.9858	0.993	1.093	-	-	33	
																	1.14 - 1.24
																	1.24 - 1.34
																	1.34 - 1.44
3056...3053	Segment	Seg/Rur; 2-lane	31	L139491	0.94	1.47	5.2018	11.0279	2.1881	8.0656	2.957	1.04	1.14	-	-	34	1.37 - 1.47
1903...1902	Segment	Seg/Rur; 2-lane	31	L127394	0	1.45	0.7547	10.9427	2.1203	7.9395	2.8652	0	0.1	-	-	35	
																	0.847 - 0.947
713...718	Segment	Seg/Rur; 2-lane	31	L111628	0.847	1.6	2.1932	11.0097	2.0212	7.8402	2.794	0.947	1.047	-	-	36	1.147 - 1.247

164…101	Segment	Seg/Rur; 2-lane	31	SR101	8.241	30.086	0.9164	11.1213	1.8051	7.5697	2.6045	8.641	8.741	-	-	37	8.341 - 8.441
																	8.441 - 8.541
																	8.741 - 8.841
																	9.841 - 9.941
																	9.941 - 10.041
																	10.041 - 10.141
																	10.241 - 10.341
																	12.741 - 12.841
																	12.941 - 13.041
																	13.741 - 13.841
																	13.841 - 13.941
																	14.141 - 14.241
																	15.141 - 15.241
																	16.041 - 16.141

																				16.741 - 16.841
																				16.941 - 17.041
																				17.041 - 17.141
																				17.941 - 18.041
																				19.141 - 19.241
																				22.041 - 22.141
																				22.841 - 22.941
																				23.741 - 23.841
																				24.541 - 24.641
																				24.641 - 24.741
																				24.741 - 24.841
																				24.941 - 25.041
																				25.141 - 25.241
																				25.641 - 25.741

																		25.741 – 25.841
																		25.941 – 26.041
																		29.041 – 29.141
																		0.819 – 0.919
																		1.119 – 1.219
2638...2629	Segment	Seg/Rur; 2-lane	31	L135582	0.719	1.436	3.2102	11.5085	1.6555	7.468	2.535	1.336	1.436	-	-	38	1.319 – 1.419
																		10.183 – 10.283
																		10.583 – 10.683
																		11.083 – 11.183
3818...3815	Segment	Seg/Rur; 2-lane	31	SR57	10.083	11.439	2.7317	10.5833	1.8858	7.4568	2.5274	10.283	10.383	-	-	39	11.183 – 11.283
																		0.2 - 0.3
																		0.3 - 0.4
																		0.6 - 0.7
																		0.7 - 0.8
2124...2125	Segment	Seg/Rur; 2-lane	31	L129886	0	2.128	1.5375	10.9062	1.774	7.4293	2.5089	0	0.1	-	-	40	1.7 - 1.8
732...736	Segment	Seg/Rur; 2-lane	31	L111779	5.812	7.976	0.5057	10.9427	1.4684	6.8972	2.1623	7.876	7.976	-	-	41	
625...631	Segment	Seg/Rur; 2-lane	31	L109033	2.054	2.826	4.4176	11.3679	1.3128	6.7017	2.0415	2.054	2.154	-	-	42	2.454 – 2.554

																2.726 - 2.826
																2.4 - 2.5
																4.1 - 4.2
																5.5 - 5.6
																6.9 - 7.0
																10.2 - 10.3
																10.3 - 10.4
328...327	Segment	Seg/Rur; 2-lane	31	SR103	0	16.921	0.2877	10.8163	1.059	5.886	1.5748	12.8	12.9	-	-	43	11.8 - 11.9
																0.227 - 0.327
																1.927 - 2.027
3953...3963	Segment	Seg/Rur; 2-lane	31	SR97	0.027	2.065	1.0441	10.6396	1.0754	5.883	1.5731	1.727	1.827	-	-	44	1.965 - 2.065
3950	Segment	Seg/Rur; 2-lane	31	SR97	3.596	4.515	1.1829	10.8705	1.0138	5.7703	1.5135	3.596	3.696	-	-	45	
3858...3831	Segment	Seg/Rur; 2-lane	31	US6	40.555	40.97	1.3786	5.7211	5.0261	5.5922	2.606	40.655	40.755	-	-	46	
4025	Segment	Seg/Rur; 2-lane	31	SR98	9.524	9.689	3.451	5.6941	4.0199	5.3245	2.3625	9.524	9.624	-	-	47	
																0.2 - 0.3
652...651	Segment	Seg/Rur; 2-lane	31	L109904	0	0.325	3.4782	5.652	3.0756	4.9596	2.0498	0.1	0.2	-	-	48	0.225 - 0.325
292	Segment	Seg/Rur; 2-lane	31	L101803	6.349	6.867	3.2149	5.5511	3.1107	4.9092	2.0084	6.349	6.449	-	-	49	6.449 - 6.549

																	6.549 - 6.649
																	6.767 - 6.867
1032...1033	Segment	Seg/Rur; 2-lane	31	L116963	0	0.9	0.6184	5.566	2.679	4.7185	1.8553	0.4	0.5	-	-	50	
																	1.502 - 1.602
3035...3030	Segment	Seg/Rur; 2-lane	31	L139485	1.402	2.135	2.2568	5.5142	2.6064	4.6497	1.8016	1.402	1.502	-	-	51	1.902 - 2.002
919...918	Segment	Seg/Rur; 2-lane	31	L115166	2.521	3.51	0.5657	5.5944	2.4642	4.6169	1.7763	2.621	2.721	-	-	52	
3105...3101	Segment	Seg/Rur; 2-lane	31	L139873	1.131	3.652	0.4371	5.5093	2.5226	4.6013	1.7643	1.831	1.931	-	-	53	2.131 - 2.231
3501	Segment	Seg/Rur; 2-lane	31	L319	0.174	0.444	2.0405	5.5093	2.5226	4.6013	1.7643	0.274	0.374	-	-	53	
258	Segment	Seg/Rur; 2-lane	31	L135179	0	0.448	1.3546	6.0686	1.9949	4.5276	1.7083	0	0.1	-	-	55	
385	Segment	Seg/Rur; 2-lane	31	L105124	0	0.183	3.1169	5.704	2.1113	4.4438	1.6456	0	0.1	-	-	56	
																	9.785 - 9.885
																	10.585 - 10.685
																	10.985 - 11.085
2939...2976	Segment	Seg/Rur; 2-lane	31	L138887	6.685	11.284	0.6113	5.6224	2.1024	4.3958	1.6102	9.685	9.785	-	-	57	11.184 - 11.284

3916	Segment	Seg/Rur; 2-lane	31	SR94	2.063	3.413	0.4147	5.5979	1.8752	4.2061	1.4743	2.363	2.463	-	-	58	
1393...1395	Segment	Seg/Rur; 2-lane	31	L120517	1.045	1.668	0.9617	5.9913	1.6708	4.1869	1.4608	1.245	1.345	-	-	59	
261	Segment	Seg/Rur; 2-lane	31	L135179	0.448	0.888	4.1537	12.1843	0.549	4.1633	0.7879	0.788	0.888	-	-	60	0.748 - 0.848
2877...2886	Segment	Seg/Rur; 2-lane	31	L138771	1.159	1.418	2.1047	5.4511	1.8758	4.137	1.4262	1.259	1.359	-	-	61	
3102	Segment	Seg/Rur; 2-lane	31	L139873	0.177	1.024	0.673	5.7003	1.686	4.0809	1.3878	0.477	0.577	-	-	62	
2762...2763	Segment	Seg/Rur; 2-lane	31	L137147	2.369	4.385	0.5452	5.4954	1.7635	4.0625	1.3754	2.869	2.969	-	-	63	3.769 - 3.869
3446...3455	Segment	Seg/Rur; 2-lane	31	SR151	0	1.064	1.0447	5.558	1.6332	3.9685	1.3124	0.7	0.8	-	-	64	0.964 - 1.064
1773...1777	Segment	Seg/Rur; 2-lane	31	L124241	0	0.621	1.7218	5.3463	1.6332	3.8771	1.2527	0.1	0.2	-	-	65	0.521 - 0.621
3275...3276	Segment	Seg/Rur; 2-lane	31	L141088	0	2.144	0.2427	5.2043	1.6886	3.8636	1.2439	1.1	1.2	-	-	66	
3451...3466	Segment	Seg/Rur; 2-lane	31	SR151	2.398	2.909	1.0729	5.4826	1.4684	3.7665	1.1822	2.498	2.598	-	-	67	
2880...2887	Segment	Seg/Rur; 2-lane	31	L138771	0	1.159	1.4141	5.4632	1.4684	3.7589	1.1774	0	0.1	-	-	68	0.4 - 0.5 / 0.5 - 0.6
3918	Segment	Seg/Rur; 2-lane	31	SR94	0	0.233	2.33	5.429	1.456	3.7318	1.1605	0	0.1	-	-	69	
628...620	Segment	Seg/Rur; 2-lane	31	L109033	0	0.536	1.0368	5.5575	1.3926	3.7088	1.1462	0.436	0.536	-	-	70	
677...674	Segment	Seg/Rur; 2-lane	31	L110349	0	1.27	0.8684	5.5147	1.4054	3.7078	1.1457	0	0.1	-	-	71	0.9 - 1.0

3467...3449	Segment	Seg/Rur; 2-lane	31	SR151	1.064	2.398	0.4194	5.5949	1.3399	3.6585	1.1154	1.464	1.564	-	-	72	
630...622	Segment	Seg/Rur; 2-lane	31	L109033	0.787	1.78	1.1448	5.684	1.3128	3.6555	1.1135	0.787	0.887	-	-	73	1.487 - 1.587
2483	Segment	Seg/Rur; 2-lane	31	L133972	1.386	1.51	4.553	5.6457	1.2352	3.5394	1.044	1.41	1.51	-	-	74	
3937...3929	Segment	Seg/Rur; 2-lane	31	SR96	1.468	3.024	0.353	5.4926	1.2713	3.5359	1.0419	2.268	2.368	-	-	75	
3959...3940	Segment	Seg/Rur; 2-lane	31	SR97	6.748	7.71	0.5744	5.5253	1.1959	3.446	0.9896	6.748	6.848	-	-	76	
1283...1282	Segment	Seg/Rur; 2-lane	31	L119934	1.193	2.094	1.2355	5.5659	1.1819	3.4396	0.9859	1.593	1.693	-	-	77	1.993 - 2.093 / 1.994 - 2.094
1016...1013	Segment	Seg/Rur; 2-lane	31	L116868	0	2.475	0.4389	5.4311	1.1388	3.3357	0.9272	0.6	0.7	-	-	78	1.5 - 1.6
727...740	Segment	Seg/Rur; 2-lane	31	L111779	0	5.812	0.1869	5.4316	1.0754	3.2424	0.8761	0.6	0.7	-	-	79	2.1 - 2.2
3928...3931	Segment	Seg/Rur; 2-lane	31	SR96	0.04	1.468	0.7778	5.5532	1.0255	3.1991	0.8529	1.04	1.14	-	-	80	1.24 - 1.34
2747...2743	Segment	Seg/Rur; 2-lane	31	L136835	0	0.732	1.5277	5.5915	1.0117	3.1869	0.8464	0.1	0.2	-	-	81	0.2 - 0.3
2479	Segment	Seg/Rur; 2-lane	31	L133972	1.51	1.779	2.032	5.4661	1.0046	3.1411	0.8222	1.679	1.779	-	-	82	
1286...1287	Segment	Seg/Rur; 2-lane	31	L119934	0.958	1.193	2.3718	5.5737	0.9765	3.1232	0.8129	0.958	1.058	-	-	83	
3475...3474	Segment	Seg/Rur; 2-lane	31	L160753	0.519	1.27	0.7485	5.6212	0.9256	3.0459	0.7731	0.619	0.719	-	-	84	

840...843	Segment	Seg/Rur; 2-lane	31	L113751	0	1.084	0.5129	5.5596	0.9186	3.0182	0.7591	0.8	0.9	-	-	85	
373	Segment	Seg/Rur; 2-lane	31	L104692	0	0.1	5.6768	5.6768	0.866	2.9477	0.7241	0	0.1	-	-	86	
3962	Segment	Seg/Rur; 2-lane	31	SR97	4.997	6.748	0.5955	5.2132	0.8805	2.8641	0.6836	5.797	5.897	-	-	87	6.497 - 6.597
2439	Segment	Seg/Rur; 2-lane	31	L133631	2.092	2.387	1.8671	5.5081	0.8265	2.8333	0.6689	2.092	2.192	-	-	88	
2130...2140	Segment	Seg/Rur; 2-lane	31	L129888	2.396	5.698	0.1683	5.557	0.8192	2.8296	0.6672	4.296	4.396	-	-	89	
3510...3512	Segment	Seg/Rur; 2-lane	31	L323	0	1.948	0.2934	5.7164	0.7692	2.759	0.6343	1.4	1.5	-	-	90	
1873...1874	Segment	Seg/Rur; 2-lane	31	L127119	0	0.526	1.0045	5.2834	0.7779	2.6884	0.6023	0.4	0.5	-	-	91	0.426 - 0.526
3960...3947	Segment	Seg/Rur; 2-lane	31	SR97	2.405	3.596	0.456	5.4315	0.7051	2.5655	0.5485	3.496	3.596	-	-	92	
326	Segment	Seg/Rur; 2-lane	31	SR103	64.708	71.803	0.1573	5.5788	0.6912	2.5607	0.5464	65.908	66.008	-	-	93	70.608 - 70.708
296	Segment	Seg/Rur; 2-lane	31	SR102	0	13.121	0.0821	5.3882	0.6815	2.5048	0.5228	2.4	2.5	-	-	94	11.3 - 11.4
3915	Segment	Seg/Rur; 2-lane	31	SR94	1.234	1.879	1.7812	5.7442	0.5716	2.2901	0.437	1.234	1.334	-	-	95	1.334 - 1.434
325...332	Segment	Seg/Rur; 2-lane	31	SR103	71.803	74.689	0.3548	5.12	0.5934	2.2542	0.4234	72.003	72.103	-	-	96	72.203 - 72.303
2739	Segment	Seg/Rur; 2-lane	31	L136835	1.384	1.502	4.745	5.599	0.4388	1.8915	0.2981	1.402	1.502	-	-	97	
573...575	Segment	Seg/Rur; 2-lane	31	L107433	0	1.225	0.4419	5.4128	0.4148	1.7993	0.2698	1.1	1.2	-	-	98	1.125 - 1.225

3470	Segment	Seg/Rur; 2-lane	31	L160108	0	0.44	1.3846	6.0921	0.2902	1.4061	0.1648	0	0.1	-	-	99	
1399...1396	Segment	Seg/Rur; 2-lane	31	L120517	1.792	2.292	2.4369	12.1843	0.113	1.1378	0.0588	1.992	2.092	-	-	100	

* - Units for Observed, Predicted and Expected Accident Frequency

   - Roadway Segments (acc/mi/yr)

   - Intersections (acc/yr)

   - Ramps (acc/mi/yr)

** - Units for Variance

   - Roadway Segments (acc/mi**2/yr)

   - Intersections (acc/yr)

   - Ramps (acc/mi**2/yr)

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