

**Configuration of SafetyAnalyst Software for Efficient and Effective Safety Management**

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## **Abstract**

Many road authorities recognize the challenges associated with a reactive approach in road safety and have adopted a proactive and systematic approach in their road safety initiatives. However, automation is a key challenge road authorities face in implementing an efficient and effective traffic safety management program. In the summer of 2009, American Association of State Highway and Transportation Officials released the first version of SafetyAnalyst software, and in 2010 published the Highway Safety Manual. The Highway Safety Manual provides road safety knowledge and tools in a practical form to facilitate improved decision making based on safety performance. The focus of the Highway Safety Manual is to provide quantitative information for decision making. SafetyAnalyst software incorporates methodologies set forth in the Highway Safety Manual for road safety management in computerized analytical tools. These tools support the identification of safety improvement needs and the decision making process for developing a system-wide program of safety improvement projects. The Ministry of Transportation of Ontario has initiated a project to configure SafetyAnalyst to meet their needs' in managing the road safety analysis of their highway network. In this initiative, all six SafetyAnalyst modules including the Network Screening Tool, Diagnosis Tool, Countermeasure Selection Tool, Economic Appraisal Tool, Priority Ranking Tool, and Countermeasure Evaluation Tool are configured for the Province of Ontario road network. As part of this initiative, the Ministry's Safety Performance Functions are being updated for road sections, interchanges, ramps, ramp terminals, and intersections. The functional forms of these safety performance functions are compatible with those of SafetyAnalyst. Moreover, the SafetyAnalyst modules are configured with Ontario's customized values. The main goal of this paper is to summarize the lessons learned in this initiative to assist other road authorities in their prospective undertakings related to SafetyAnalyst. This paper highlights challenges associated with compiling infrastructure data, traffic volume data, collision data, importing data into SafetyAnalyst while keeping the road authority's databases unchanged, Safety Performance Functions in SafetyAnalyst, and customized values for various modules in SafetyAnalyst. This paper provides solutions to address these challenges. It also recommends the necessary steps for road authorities before starting an initiative to configure SafetyAnalyst for their network.

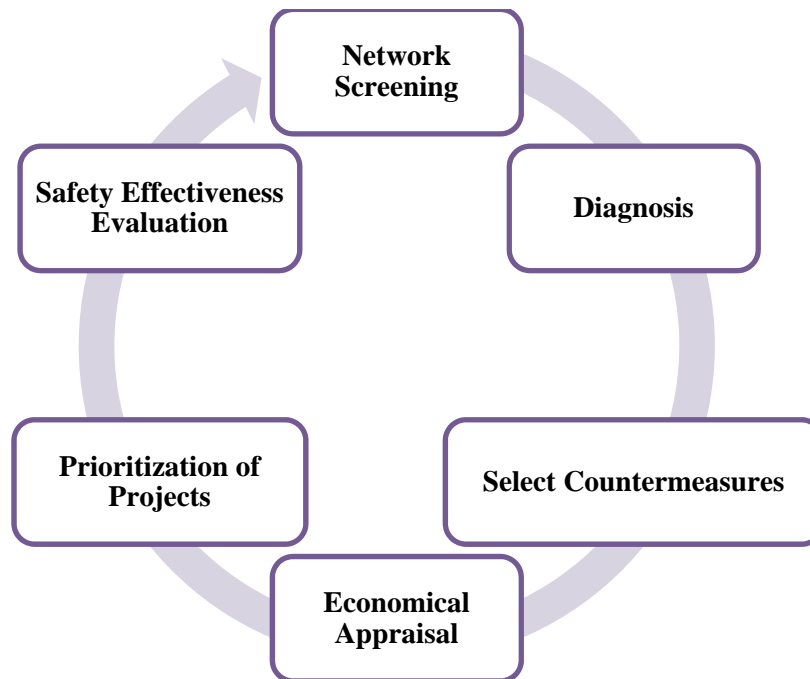
## **1 Introduction**

During the past two decades, road authorities have started to recognize the challenges associated with a highly reactive approach to road safety [1]. As a result, most municipalities have adopted a more proactive approach regarding their road safety programs. The Highway Safety Manual (HSM) [2] presents a systematic approach for a Road Safety Management process as shown in Figure 1. A road safety management process starts with Network Screening in which the main goal is to identify road locations that have poor safety performance and need safety investigation. The underlying assumption is that road design attributes often play a significant contributory role in collision occurrences.

The next step in the road safety management process is diagnosis. This step examines the contributing factors of collisions for locations identified in the Network Screening process. To complete this step, a systematic methodology, known as an "in-service road safety review", should be conducted to ensure the thoroughness and the accuracy of analysis. To conduct road safety reviews, two complementary tasks must be performed. Firstly, at least three years of historical collision data must be collected and analyzed to identify over-represented clusters of particular collision types. Secondly, location-specific data, both physical and operational, must be gathered and analyzed. This must be accompanied by consultation with local road agencies, enquiries on site traits, and observations of driver characteristics.

Countermeasure Selection and Economic Appraisal constitute the next step in the road safety management process. This step involves the selection of treatments which are potentially capable of addressing the safety problems identified in the diagnosis step. In the course of this selection process, more than one countermeasure with the potential to mitigate the problem is often identified. A subsequent

Economic Appraisal will evaluate all options for all problem locations in order to ensure that the countermeasures are economically viable. In the prioritization of countermeasure projects, the objective is to maximize benefits in terms of collision reductions subject to budget restrictions. Safety effectiveness evaluation involves monitoring implemented improvements to assess their safety effectiveness. The information obtained in this step is extremely valuable in prospective studies so that more informed decisions about the effectiveness of each countermeasure can be made.



**Figure 1: Road Safety Management Process [2]**

The road safety management process is a continuous process and demands significant resources for road authorities and particularly those jurisdictions which constitute large geographic areas (e.g. Ministries of Transportation). The process requires an extensive amount of data which should be collected annually. Consequently, road authorities have been interested in automating the road safety management process as much as possible to increase the efficiency of their road safety programs. In response to this increasing need of road authorities, American Association of State Highway Officials (AASHTO) developed and released SafetyAnalyst in 2009. SafetyAnalyst is a software package which consists of 6 modules, and these modules correspond to the six steps of the road safety management process as outlined above.

The jurisdiction of the Ministry of Transportation Ontario (MTO) includes more than 260,000 km of roadways. This transportation network in Ontario includes a wide range of facilities including mainline road sections, interchanges, ramps, intersections, and ramp terminals. MTO's roadways are the safest roads in North America, and they have had a road safety program in which locations with potential for safety improvements have been identified in each MTO region [3, 4, and 5].

With the advent of the SafetyAnalyst, MTO has initiated a project to configure the software. In this initiative, all six of the SafetyAnalyst modules including the Network Screening Tool, Diagnosis Tool, Countermeasure Selection Tool, Economic Appraisal Tool, Priority Ranking Tool, and Countermeasure Evaluation Tool are configured for the Province of Ontario road network.

The main objective of this paper is to summarize lessons learned in this initiative in order to assist other road authorities in their prospective undertakings related to SafetyAnalyst. This paper highlights

challenges associated with compiling infrastructure data, traffic volume data, collision data, and importing data into SafetyAnalyst while keeping the road authority's databases unchanged, and Safety Performance Functions in SafetyAnalyst. This paper provides solutions to address these challenges. The paper also recommends steps necessary for road authorities before starting an initiative to configure SafetyAnalyst for their network.

The organization of this paper is as follows: Section 2 briefly introduces the SafetyAnalyst software. This section explains analytical capabilities, data needs, and customization opportunities of SafetyAnalyst. Section 3 provides recommendations for configurations of SafetyAnalyst. This section is based on lessons learned within the Province of Ontario. This section focus primarily on the data collection and data importation, as this is the extent of the progress of the project in Ontario. Section 4 concludes the paper with an overall summary and some closing remarks.

## 2 SafetyAnalyst

SafetyAnalyst is comprised of six modules. This section introduces each module and explores opportunities for customization in each. Figure 2 shows various tools within the SafetyAnalyst software.

The Analytical Tool provides capabilities to perform all of the steps in the road safety management process. As can be seen in Figure 2, this tool includes six modules. Later in this paper, these modules will be described in more detail.

The Administrative Tool is used by a software administrator to setup the software for the road authority and to manage access to the software. This tool is used to define agency-specific values for each of the six modules within the Analytical Tool. For example, road authorities are able to use this tool to enter their own Safety Performance Functions (SPFs), collision modification factors (CMFs), or diagnostic scenarios. SafetyAnalyst is an AASHTO product. As a result, default values have been developed based on the US standards. For example, the collision table in SafetyAnalyst is based on the Model Minimum Uniform Crash Criteria (MMUCC) [6]. As a result, the collision report forms of Canadian jurisdictions are most likely different from the MMUCC. The Administrative Tool can be used to add components of road authorities' collision table to the SafetyAnalyst as required.

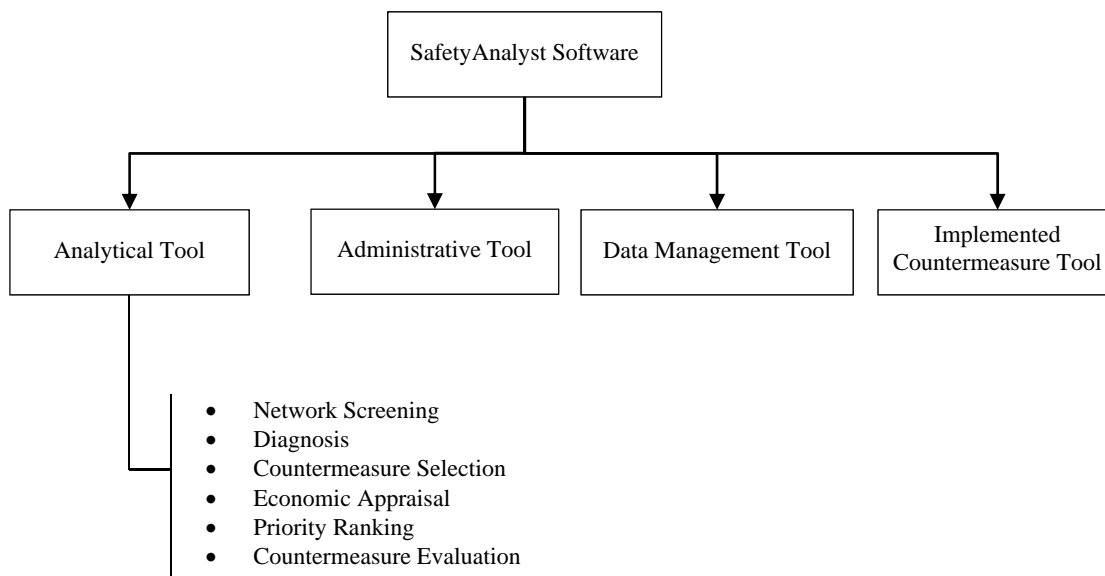


Figure 2: SafetyAnalyst Tools

The Data Management Tool provides capabilities to road authorities to create and maintain the SafetyAnalyst databases including data on collisions and the characteristics of the network elements (road sections, intersections, and ramps) [7].

The Implemented Countermeasure Tool provides capabilities to highway agencies to create and maintain a special-purpose database that documents the date, location, and nature of post physical improvements to the highway network [7].

## **2.1 Analytical Tool Modules**

### **2.1.1 Module 1: Network Screening**

The main purpose of Module 1 is to conduct Network Screening for the road authority's entire network (or a subset of the network) to identify locations with potential for safety improvement. These locations will be investigated further in the diagnosis stage of the road safety management process (Module 2 in SafetyAnalyst) to identify the contributing factors to collisions of each location. Module 1 of SafetyAnalyst is capable of conducting Network Screening for road segments, intersections, and ramps.

The analyst is able to choose from six types of methodologies for Network Screening [7]:

- Basic Network Screening (with peak searching on roadway segments);
- Basic Network Screening (with sliding window on roadway segments);
- Screening for high proportion of specific collision type;
- Sudden increase in mean collision frequency;
- Steady increase in mean collision frequency, and
- Corridor screening.

The first five methods are conducted for Network Screenings at a specific location (road segment or intersection) as opposed to the last method which is used to conduct Network Screening for a corridor consisting of intersections and road segments.

The basic Network Screening methods use the Empirical Bayes (EB) method to calculate the expected collision frequency at each location [9]. Potential for Safety Improvement (PSI) for each location is calculated as the reference between the expected collision frequency at the location obtained from the EB method and the predicted collision frequency at similar locations which is obtained from the Safety Performance Functions (SPF). SafetyAnalyst has default SPFs which have been developed based on the US data. However, road authorities can develop their own SPFs and import them into SafetyAnalyst using the Administration Tool.

Analysts are able to use the peak searching method or the sliding window method for conducting Network Screening for road sections. The peak searching method is an iterative process in which the road segment is divided into smaller subsegments and the PSI for each subsegment is calculated. The segmentation process starts with 0.1 mile segments. The size of each subsection is increased by 0.1 mile each iteration. If the PSI for any subsegment meets a certain threshold (pre-determined by the analyst) at any iteration, the search stops.

The basic Network Screening with sliding window for road segments is similar to the peak searching method. The main difference is that in the sliding window a window of a specified length is incrementally moved along the road segment and the PSI for each subsegment is calculated.

The other screening method is screening for a high proportion of specific accident types. This method is identical to "Excess Proportion of Specific Crash Type" for Network Screening in the HSM [2]. The main purpose of this method is to quantify locations with an overrepresentation of any particular collision attribute. This screening approach estimates the probability that the observed proportion of the specific

target collisions at a location is greater than expected collisions for similar locations. It should be noted that this method does not consider traffic volume.

In the event of a sudden increase in mean collision frequency, the main objective is to identify sites where the mean collision frequency increased suddenly over time to more than what can be attributed to changes in traffic or general trends [7]. The methodology for the sudden increase in mean collision frequency is based on procedures developed by Hauer [10].

In the steady increase in mean collision frequency, the objective is to identify locations which have had steady increase in collision frequency over years, but the increase is more than can be attributed to increase in traffic volume or general trend at similar locations in the study area. In this methodology a linear regression is fit to collision frequencies versus year at each location. If the slope of the fitted regression line is larger than a certain threshold, then there is concern about the safety performance of the location and the location requires further investigation.

The last screening methodology is corridor screening. A corridor may consist of road segments, intersections and ramps which are along a highway. The corridors are defined by the Administrator and analysts are not able to modify them. This screening methodology is able to rank infrastructure elements associated with the corridor in terms of their PSI.

The performance of the basic Network Screening relies on accurate SPF for each location type (e.g. rural two lane roads). SafetyAnalyst at this time only supports SPFs with the functional forms shown in Equation (1) and Equation (2):

$$\kappa_{y(TOT)} = SPF_{TOT} \{AADT\} = C_{y(TOT)} \times P_{CT(TOT)} \times e^{\alpha} \times AADT_y^{\beta_1} \quad (1)$$

$$\kappa_{y(FI)} = SPF_{FI} \{AADT\} = C_{y(FI)} \times P_{CT(FI)} \times e^{\alpha} \times AADT_y^{\beta_1} \quad (2)$$

Where,

$\kappa_{y(TOT)}$  = Predicted total number of collisions using the  $SPF_{TOT}$  at a location during year  $y$  (expressed on a per mile basis for non-intersection locations),

$\kappa_{y(FI)}$  = Predicted number of severe collisions using the  $SPF_{FI}$  at a location during year  $y$  (expressed on a per mile basis for non-intersection locations),

$C_{y(TOT)}$  = Yearly correction factor for year  $y$  relative to year 1 for total collisions,

$C_{y(FI)}$  = Yearly correction factor for year  $y$  relative to year 1 for severe collisions,

$AADT_y$  = Average Annual Daily Traffic for year  $y$ ,

$\alpha, \beta_1$  = Parameters of SPF models,

$P_{CT(TOT)}$  = Proportions of total collisions of a specified collision type to all total collisions, and

$P_{CT(FI)}$  = Proportions of severe collisions of a specified collision type to all severe collision.

As can be observed in Equation (1) and Equation (2), roadway length is not present in the equations and the SPFs predict number of collisions per mile (or km if SPFs calibrated accordingly). The other important observation in these equations is that a separate equation is not calibrated for each collision impact type. The proportion of each impact type to total collision (at a specified severity level) is used to predict number of collisions for each impact type.

SPFs developed by most Canadian jurisdictions do not conform to the above two observations. In other words, the functional forms of SPFs most likely do not match with those of SafetyAnalyst. Consequently, if road authorities would like to customize the SafetyAnalyst SPFs based on their local data, new SPFs based on the limitations of SafetyAnalyst have to be developed.

### 2.1.2 Module 2: Diagnosis and Countermeasure Selection

This module combines the second and third steps in the road safety management process shown in Figure 1. This module intends to assist the analyst in the diagnosis of safety concerns at a location and identify a set of countermeasures to mitigate the safety problems. To diagnose safety problems at a location, this module provides the following three capabilities [7]:

- Generating collision summary statistics,
- Generating collision diagrams, and
- Conducting statistical tests on collision frequencies and/or proportions.

The above capabilities will assist an analyst to identify certain patterns in collision types or other collision attributes (e.g. collisions with wild animals or icy road surface conditions).

In addition to the above three capabilities, SafetyAnalyst is equipped with an “expert” system which guides the analyst towards appropriate office and field investigations. This process includes both traditional engineering considerations as well as a strong human factors component, to help diagnose potential safety concerns at a site [7]. The main output of the expert system is an array of countermeasures for each collision pattern identified using the diagnosis capabilities described above.

The expert system consists of diagnostic scenarios. Each diagnostic scenario includes a particular title, site type, site subtype, attributes, collision pattern, vehicle maneuvers, circumstance statement, scenario background rationale, and diagnostic questions. Table 1 shows a sample diagnostic scenario. The common elements in all scenarios are shown in boldfaced font. As can be seen in the diagnostic question section of this table, depending on the answers to preceding questions, succeeding questions may be different. Also, depending on answers to questions, arrays of countermeasures are suggested by SafetyAnalyst. If answers to questions are unknown, the analyst is guided to obtain answers to the questions (e.g. conduct a site visit or measure 85<sup>th</sup> percentile speed (see ITE Traffic Engineering Handbook)).

**Table 1: Sample Diagnostic Scenario**

|  |
|--|
| Scenario: (45) - Speeds Too High   |
| <b>Title:</b> Speeds Too High  |
| <b>Site Type:</b> Intersection   |
| <b>Site Subtype(s):</b><br>Int/Urb; 4-leg signalized   |
| <b>Attribute(s):</b><br>General  |
| <b>Accident Pattern(s):</b><br>Sideswipe, same direction   |
| <b>Vehicle Maneuver(s):</b><br>2 changing lanes<br>1 left-turn, 1 changing lanes<br>1 left-turn, 1 overtaking/passing<br>1 right-turn, 1 changing lanes<br>1 right-turn, 1 overtaking/passing<br>1 thru, 1 changing lanes<br>1 thru, 1 overtaking/passing  |
| <b>Statement:</b> Sideswipe crashes can occur due to high operating speeds or speed differentials among vehicles approaching an intersection. Drivers approaching the intersection at high speeds may be unable to avoid other drivers changing lanes. As a result, vehicles come into conflict with vehicles in adjacent lanes that are changing lanes on the intersection approach. Changing lanes is sometimes recorded as overtaking or passing. |
| <b>Rationale:</b> A wide cross-section and wide lanes contribute to a road message that high speeds are acceptable. High   |



operating speeds may occur at intersections near freeway exits or on freeway to highway transitions. Drivers from the freeway have adapted to traveling at higher speeds, and require several minutes to transition to lower speeds. Even when drivers are aware that this transition is required, it can take several minutes for drivers to adapt and reduce their speed. High operating speeds are a concern for vulnerable road users, such as pedestrians and bicyclists. Accesses near the intersection are a concern when operating speeds are high, for vehicles slowing, stopping, or turning into or out of the access.

**Diagnostic Question(s):**

**Question:** (65) - *Are there dedicated turn lanes?*

**Yes:**

Next Question: (113) - *Is this the first signalized intersection following a freeway exit?*

**No:**

Countermeasure: (93) - *Install left-turn lane*

Countermeasure: (105) - *Install right-turn lane*

Next Question: (113) - *Is this the first signalized intersection following a freeway exit?*

**Unknown:**

Procedure: (4) - *Check design or as-built plan and profile.*

Procedure: (31) - *Visit site.*

Next Question: (113) - *Is this the first signalized intersection following a freeway exit?*

**Question:** (113) - *Is this the first signalized intersection following a freeway exit?*

**Yes:**

Next Question: (114) - *Is traffic on the intersection approach coming from the freeway traveling at higher speeds than traffic not originating from the direction of the freeway?*

**No:**

Next Question: (84) - *Are operating speeds higher than desirable given the presence of pedestrians, bicyclists, or accesses?*

**Unknown:**

Procedure: (9) - *Obtain information from relevant agencies or departments.*

Procedure: (31) - *Visit site.*

Next Question: (84) - *Are operating speeds higher than desirable given the presence of pedestrians, bicyclists, or accesses?*

**Question:** (114) - *Is traffic on the intersection approach coming from the freeway traveling at higher speeds than traffic not originating from the direction of the freeway?*

**Yes:**

Countermeasure: (113) - *Install transverse pavement markings*

Countermeasure: (109) - *Install single-lane roundabout*

Countermeasure: (96) - *Install multilane roundabout*

Next Question: (84) - *Are operating speeds higher than desirable given the presence of pedestrians, bicyclists, or accesses?*

**No:**

Next Question: (84) - *Are operating speeds higher than desirable given the presence of pedestrians, bicyclists, or accesses?*

**Unknown:**

Procedure: (1) - *Measure 85th percentile speed (see ITE Traffic Engineering Handbook).*

Procedure: (31) - *Visit site.*

Next Question: (84) - *Are operating speeds higher than desirable given the presence of pedestrians, bicyclists, or accesses?*

**Question:** (84) - *Are operating speeds higher than desirable given the presence of pedestrians, bicyclists, or accesses?*

**Yes:**

Countermeasure: (171) - *Increase enforcement to reduce speed on intersection approach*

Countermeasure: (117) - *Narrow cross section by reducing number of approach lanes*

Countermeasure: (131) - *Restrict movements to right-in and right-out at the access using channelizing island*

Countermeasure: (110) - *Change streetscape to increase stimulation of peripheral vision*

Countermeasure: (126) - *Reduce speed limit on approaches*



Next Question: (EOS) - End of Scenario

**No:**

Next Question: (EOS) - End of Scenario

**Unknown:**

Procedure: (31) - Visit site.

Procedure: (1) - Measure 85th percentile speed (see ITE Traffic Engineering Handbook).

Next Question: (EOS) - End of Scenario

It should be noted that a total of 393 diagnostic scenarios have been incorporated into SafetyAnalyst. The existing scenarios do not include any scenarios for freeways or ramps.

One of the important characteristics of this module is that the diagnosis scenarios are completely customizable. Scenarios can be deleted, new scenarios can be added, and the content of scenarios can be modified by each road authority.

### **2.1.3 Module 3: Economic Appraisal and Priority Ranking**

This module intends to conduct an Economic Appraisal for one or a combination of countermeasures for a site to identify whether a countermeasure is cost effective or not. Also, this module is able to develop a ranked list of alternative countermeasures for a site in terms of net benefit in dollars or number of collisions reduced. In case of any budget constraint, SafetyAnalyst is capable of solving an optimization problem to identify the best countermeasures which are able to maximize benefits subject to the budget constraints.

In order to conduct any economic analysis, SafetyAnalyst requires Collision Modification Factor (CMF), service life, and construction costs associated with each countermeasure. Fortunately, the information for most of the countermeasures has been incorporated into SafetyAnalyst. The societal costs of collisions and attractive rate of return for each jurisdiction is obviously required.

### **2.1.4 Module 4: Countermeasure Evaluation**

The countermeasure evaluation provides an opportunity for road authorities to evaluate the safety effectiveness of implemented countermeasures. This module uses the observational before-after techniques using the EB method to evaluate safety effects of a countermeasure at a specified site, a group of countermeasures at a site or a group of sites. This module can be used to obtain local knowledge about the safety effects of a countermeasure to see whether it is appropriate for the prospective projects. The results of the module can be utilized to justify funding for future road safety projects in other locations.

## **2.2 Data Needs**

The required input data for SafetyAnalyst are categorized into three groups:

1. Infrastructure characteristics data;
2. Historical traffic volume data, and
3. Historical collision data.

There are two types of data for each of the above data groups: required data and optional data. The required data are minimum data requirements to configure and use the SafetyAnalyst software. The optional data can provide additional services to the user if provided (e.g. display or data queries).

The infrastructure elements which can be imported into SafetyAnalyst include road sections, intersections, and ramps. The required characteristics data for each of these infrastructure elements are shown in Table 2.

Table 2: Minimum Required Infrastructure Characteristics Data for SafetyAnalyst [7]

| Infrastructure Element | Required Characteristic Data  |
|------------------------|---|
| <b>Road Segment</b>    | <ul style="list-style-type: none"> <li>• Segment Number</li> <li>• Segment Location (in a form that can be linked to the collision data)</li> <li>• Segment Length</li> <li>• Area Type (i.e. rural or urban)</li> <li>• Number of through Traffic Lanes (per direction)</li> <li>• Median Type (i.e. divided or undivided)</li> <li>• Road Functional Classification (e.g. Freeway, Arterials, Collector, etc.)</li> </ul> |
| <b>Intersection</b>    | <ul style="list-style-type: none"> <li>• Intersection Number</li> <li>• Intersection Location (in a form that can be linked to the collision data)</li> <li>• Area Type (i.e. rural or urban)</li> <li>• Number of Intersection Legs</li> <li>• Intersection Traffic Control Device</li> </ul>  |
| <b>Ramp</b>            | <ul style="list-style-type: none"> <li>• Ramp Number</li> <li>• Ramp Location (in a form that can be linked to the collision data)</li> <li>• Area Type (i.e. rural or urban)</li> <li>• Ramp Length</li> <li>• Ramp Type (i.e. on-ramp, off-ramp, freeway to freeway ramp)</li> <li>• Ramp Configuration (e.g. full diamond, full diamond split, Parclo loop, etc.)</li> </ul>   |

The historical traffic volume data for road segments and ramps are to be in the form of Average Annual Daily Traffic (AADT) and for intersections in the form of the AADT of major roads and minor roads.

The other required data for the Analytical Tool of SafetyAnalyst is collision data. The minimum required collision data for Network Screening and limited diagnosis include:

- Collision location;
- Date;
- Collision Impact Type (e.g. Read-End, Angle, Sideswipe, etc.);
- Severity (e.g. Fatal Injury, Severe Injury, Non-Capacitated Injury, Possible Injury, and Property Damage Only);
- Relationship to Junction (e.g. Non-Junction, At-Intersection, Intersection Related, etc.), and
- Maneuvers by Involved Vehicles (e.g. Straight Ahead, Backing, Changing Lanes, etc.).

The above minimum set of data elements are needed to (a) assign collisions to infrastructure elements; (b) determine subtype for each infrastructure element to assign an appropriate SPF; (c) compute the expected collision frequency for each network entity (each ramp, road section, and intersection) using the SPF for the appropriate subtype; and (d) characterize the collision experience of each entity by collision type, manner of collision, severity, and location.

### 2.3 Customization Opportunities in SafetyAnalyst

The SafetyAnalyst software provides opportunities for road authorities to customize the software based on their local data. These data are categorized into two groups. The first group which are referred to as agency-defined data are those that are added to the infrastructure characteristics tables or collision table. For example, a road authority may add seatbelt usage to each collision record if such information is being collected as part of their collision reports. As another example, angled and turning movement collisions in Ontario are recorded separately. However, both collision types are categorized as 'angle' in SafetyAnalyst. Therefore in this project, two new collision impact types were added to the SafetyAnalyst collision table; Angle-Ontario and Turning Movement-Ontario. Road authorities can change the titles, descriptions, and enumeration values for many of the data elements within the SafetyAnalyst using the Administration Tool [8]. For example, the default title for the field in the SafetyAnalyst collision table is

“Accident Type and Manner of Collisions.” This data field has a number of enumeration values including ‘collision with parked motor vehicle’, ‘collision with railroad train’, ‘overturn’, ‘rear-end’, etc. All of the enumeration values can be modified, i.e., ‘overturn’ can be modified to ‘rollover’. It should be noted that the agency-defined data and the opportunity to adjust the existing data fields provides a great deal of flexibility for road authorities to customize the software based on their jurisdiction.

It should be noted that the diagnosis scenarios which were described in Module 2 have been developed based on the default data fields of SafetyAnalyst (particularly collision types). As a result, extra care should be taken in introducing agency-defined data to ensure that the diagnosis scenario will not be adversely affected.

The other data group that can be customized in SafetyAnalyst is the global default values. The global default values are system-wide values which can only be changed by the SafetyAnalyst Administrators through the Administration Tool. These global values include:

- SPF coefficients;
- Societal cost of collisions;
- Countermeasures;
- Implementation costs and service lives of countermeasures, and
- CMF associated with countermeasures.

### **3 Configurations of SafetyAnalyst**

This section summarizes the steps taken thus far to configure SafetyAnalyst for road safety management in the Province of Ontario. These steps are not unique to Ontario and can be used by other road authorities.

#### **3.1 Data Collection**

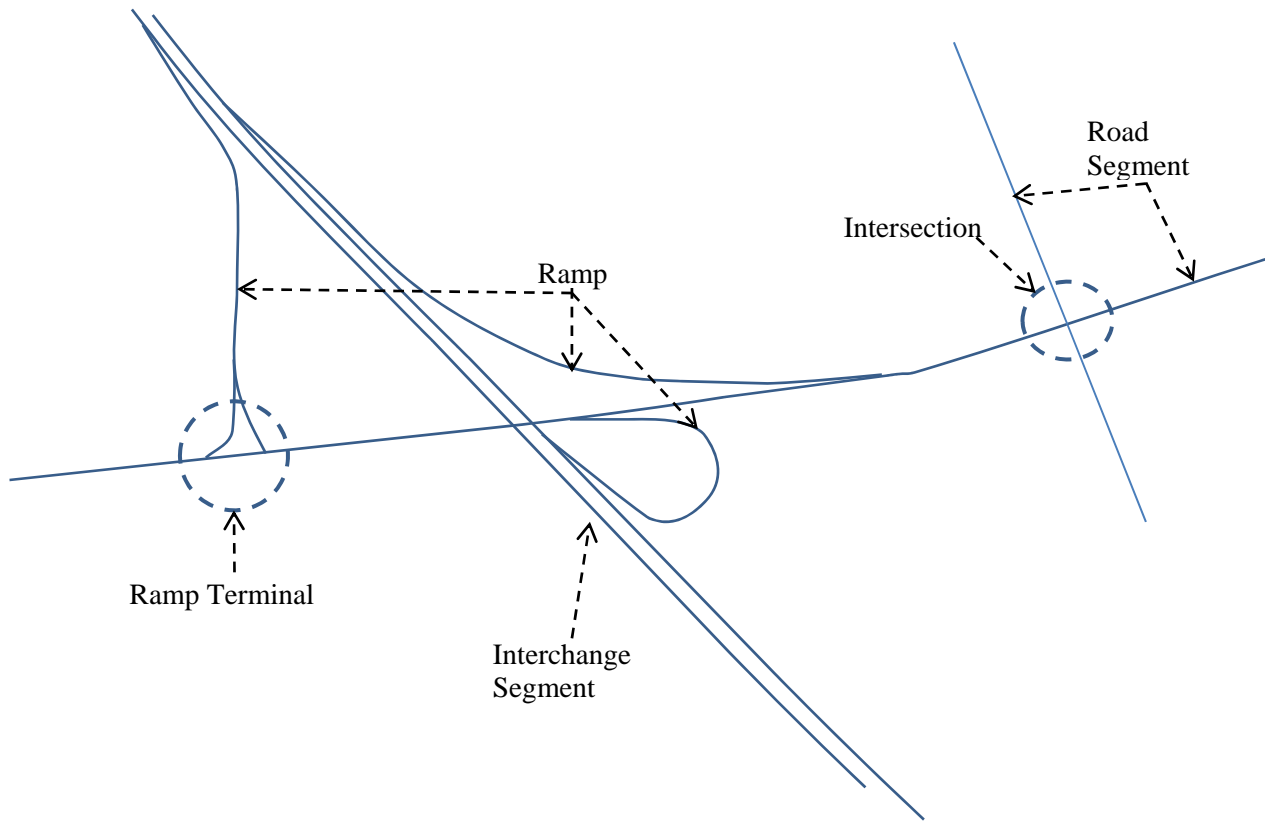
The magnitude of data collection depends on whether the road authority will be configuring all modules or only Module 1 at the outset. In Ontario, MTO initiated the project to configure all four modules. As a result the data collection involved not only the required data but also any other data requirement for maximum utilization of SafetyAnalyst capabilities.

The data collection or compilation is the most labour intensive and challenging task for configuration of SafetyAnalyst. Infrastructure characteristic data and AADT data are often more difficult to produce than the collision data.

##### **3.1.1 Infrastructure Characteristic Data**

Figure 3 shows the infrastructure elements which were used in Ontario. It should be noted that ramp terminals are similar to intersections. However, safety performance of ramp terminals is different than similar intersections. As a result, separate SPFs have been historically developed for ramp terminals. Interchange segments are freeway segments within an interchange. The characteristics collected for interchange segments are similar to roadway segments. However, because safety performances of these segments are different from similar freeway sections with similar AADT (due to lane changing, merging, etc.) separate SPFs are developed for these segments. Road authorities should define interchange segments for their jurisdictions. SafetyAnalyst data import references suggest that an interchange segments is a freeway mainline segment within interchange area which extends approximately 0.3 mile upstream from the gore (i.e. painted nose of the gore area) of the first ramp to approximately 0.3 mile downstream from the gore of the last ramp [8]. However, in Ontario historically an interchange influence segment is defined as one kilometer on either side of the interchange. However, where two interchanges were closely spaced (less than 2 kilometers), the influence length for each is taken as one half of the

distance between them [4]. It is important to note that freeway-to-freeway interchanges have two interchange segments.



**Figure 3: Infrastructure Elements in SafetyAnalyst**

If a road authority does not have infrastructure characteristic data or the database is not complete, the first step is to develop a list of all road segments (including freeway segments), ramps, and intersections. If the list of ramps and road segments are cross referenced with each other, lists of ramp terminals and interchanges segments can be developed. It should be noted that a lot of efforts is required to develop absolute complete lists of all infrastructure elements. But, AADT databases and collision databases often can assist in completing the missing infrastructure entities. As a result, the process of completing the infrastructure characteristic data is an iterative process.

Once the lists of infrastructure elements have been developed in separate databases, all of the characteristic data should be compiled. In most jurisdictions, departments responsible for asset management have some of the infrastructure characteristic data required for SafetyAnalyst (e.g. lane widths, shoulder type, median width, etc.). It is important to restate that SafetyAnalyst required data were presented previously in this paper. However, SafetyAnalyst diagnosis and Countermeasure Selection module uses a number of other characteristic data which are optional but can assist in better diagnosis and countermeasure selection. A list of all of the data elements can be found in the SafetyAnalyst Data Import Reference [8]. To complete the missing infrastructure characteristic data, Google Earth was utilized in Ontario. Each infrastructure element in Ontario is geocoded with a Linear Highway Referencing System (LHRS). Each LHRS has a longitude and latitude in the MTO GIS map. As a result, LHRS numbers and their coordinates were converted into the Google Earth KMZ format. This layer of information in Google Earth significantly expedited the locating of each infrastructure element.

As part of the intersection characteristic data, detailed information for each intersection leg should be collected including number of lanes allocated for each movement and any turn prohibition. To collect this information, a template shown in Table 3 was developed. This sample only shows northbound and southbound legs. In this table, numbers of lane designations for each leg of intersections are entered. In this example, Intersection 126, has 2 lanes for northbound through movement and two individual separate lanes for northbound left turn and northbound right turn lanes. Using this template, the required information for each leg can be easily collected and then translated into SafetyAnalyst import data using utility software which will be discussed in the next section.

**Table 3: Sample Template for Intersection Leg Data Collection**

| Intersection ID | North Bound Leg |            |            |             |           |            |           | South Bound Leg |            |            |             |           |            |           |
|-----------------|-----------------|------------|------------|-------------|-----------|------------|-----------|-----------------|------------|------------|-------------|-----------|------------|-----------|
|                 | NBL Lanes       | NBTL Lanes | NBLR Lanes | NBLTR Lanes | NBT Lanes | NBTR Lanes | NBR Lanes | SBL Lanes       | SBTL Lanes | SBLR Lanes | SBLTR Lanes | SBT Lanes | SBTR Lanes | SBR Lanes |
| 123             |                 |            |            |             |           |            |           |                 |            | 1          |             |           |            |           |
| 124             |                 | 1          |            |             |           | 1          |           |                 |            |            | 1           |           |            |           |
| 125             |                 |            |            |             |           |            |           |                 |            | 1          |             |           |            |           |
| 126             | 1               |            |            |             | 2         |            | 1         | 1               |            |            |             | 1         | 1          |           |

In the infrastructure characteristic data collection, it is important to track network improvements for two reasons: (1) the safety performance of infrastructure elements during construction is different from normal conditions and (2) improvements change the infrastructure type which may change the corresponding SPF for the road entity (e.g. SPF of a stop controlled intersection is different from SPF for a signalized intersection). One of the challenges facing road authorities including in the Province of Ontario, is the tracking of these road improvement projects (the start and finish dates as well as the nature of improvements). MTO identified that the best source is the data collected by asset management departments (for example departments dealing with pavement management). It is important that jurisdictions develop a mechanism to easily obtain such information for annual or periodical update of SafetyAnalyst.

### 3.1.2 Traffic Volume Data

In order to conduct Network Screening and develop SPFs (if a road authority so chooses), traffic volumes for road sections and intersections in the form of AADT are required. It is recommended that 5 years of collision data be used for Network Screening. As a result, corresponding AADT for each year is also required. Most road authorities have traffic count programs. However, given limited available resources, only a portion of networks are annually counted. As a result, road authorities should have accurate methodologies in place to estimate or predict AADT for road sections, ramps, and intersections for missing years before attempting to configure SafetyAnalyst. If two years or more of AADT data are available, a linear regression model is fitted to the data to predict missing AADTs in many jurisdictions. If only one AADT is available, a growth rate for the area or a close location is most often used for AADT predictions.

### 3.1.3 Collision Data

Collision data are particularly important in configuration of SafetyAnalyst because the diagnosis and Countermeasure Selection module in SafetyAnalyst is based on the characteristics of a location and collision patterns at the location. As previously stated, the SafetyAnalyst default collision table may not be in accordance with jurisdictions' collision database. As a result, customization may be applied with care to ensure that the diagnostic scenarios will work. The other approach is to modify the SafetyAnalyst

collision table and modify diagnostic scenarios accordingly. The latter approach is not recommended. The fields in the jurisdiction’s collision database should be mapped into the SafetyAnalyst default collision table. Table 4 shows a sample of such mapping developed in this study for Ontario. The first column in this table shows “Accident Severity Level” field in the SafetyAnalyst collision table which may accept 6 values (K-Fatal Injury, A-Severe Injury, etc.). In the Ontario collision database, one single data field cannot be used to determine values for the “Accident Severity Level” field in SafetyAnalyst. Consequently, two data fields of clasac and DInjury in the Ontario database were used to determine the value of the field in SafetyAnalyst. The third column in this table shows the mapping rule.

**Table 4: Sample Mapping Table for Collisions**

| <b>SafetyAnalyst Data Field</b>  | <b>Ontario Collision Database</b>  | <b>Mapping Rules</b>   |
|--|--|--|
| Accident Severity Level<br>K-Fatal Injury<br>A-Severe Injury<br>B-Non-incapacitated Injury<br>C-Possible Injury<br>P-Property Damage Only<br>X-Unknown | clasac<br><ul style="list-style-type: none"> <li>• Fatal</li> <li>• Injury</li> <li>• PDOnly</li> <li>• NonRPT</li> <li>• OtherCI</li> </ul> DInjury<br><ul style="list-style-type: none"> <li>• No Injury</li> <li>• Minimal</li> <li>• Minor</li> <li>• Major</li> <li>• Fatality</li> </ul> | K-Fatal Injury ← If clasac = Fatal<br>A-Severe Injury ← If clasac = Injury and DInjury = Major<br>B-Non-incapacitated Injury ← If clasac = Injury and DInjury = Minor<br>C-Possible Injury ← If clasac = Injury and DInjury = Minimal<br>P-Property Damage Only ← PDO<br>X-Unknown ← Non-Reportable and Other. |

### **3.2 Data Import**

Infrastructure characteristic data (for road segments, intersections, intersection legs, and ramps), AADT data, and collision data can be entered directly into SafetyAnalyst databases. Another method is to format the input data in accordance with the SafetyAnalyst standard input files and then import them into SafetyAnalyst. Most jurisdictions prefer the second approach because they already have prepared data in databases such as MS-Access or MS-Excel.. The standard SafetyAnalyst input files can be either in comma separated format (CSV) or Extensible Markup Language (XML). The developers of the software strongly suggest using CSV files because the sizes of the XML files tend to be very large which slows down the import process.

In order to generate input files in accordance with the SafetyAnalyst standards, a Utility Tool was developed. This Utility Tool is able to generate input files for infrastructure characteristic data, traffic volume data, and collision data. Figure 4 shows a view of the tool developed for MTO. This tool is capable of incorporating all of the mapping rules explained previously in the collision data section.

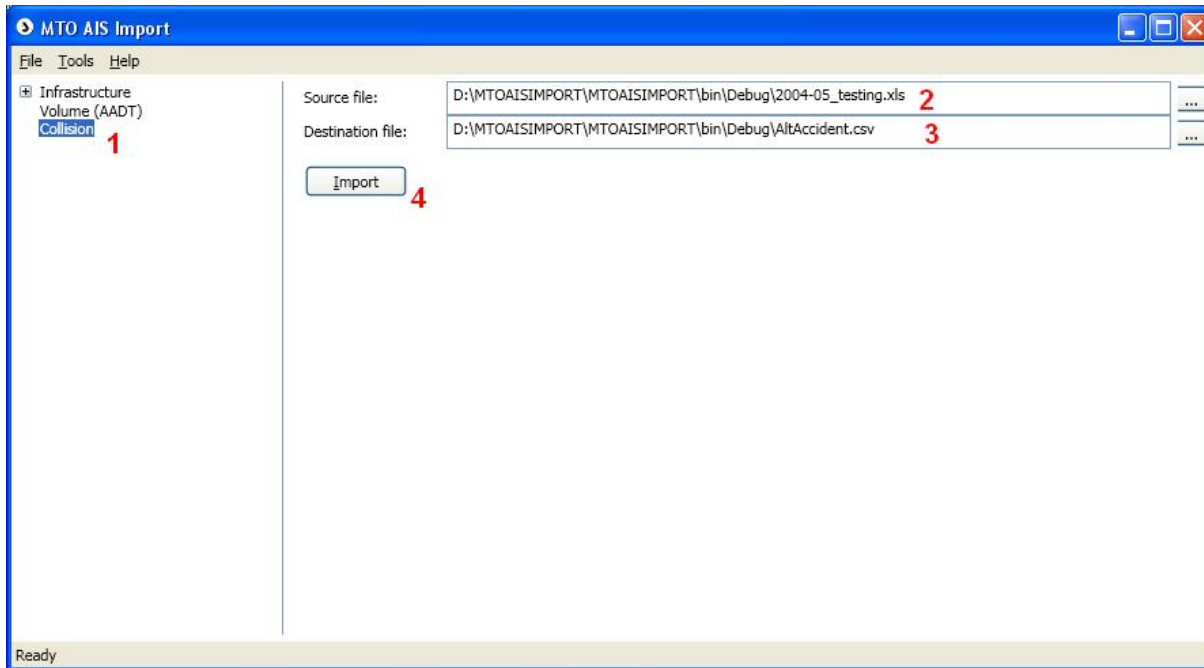


Figure 4: Data Import Utility Tool

### 3.3 Access to SafetyAnalyst

Most jurisdictions have been using SafetyAnalyst as a desktop application. However in Ontario, regions are responsible for their own road safety programs and as a result, each region needs to access SafetyAnalyst. In order to make sure that the SafetyAnalyst databases are kept unique for the entire province and also to facilitate access to the software, the software and its databases were hosted on the Cloud and access to the software was provided to the various MTO offices.

### 3.4 Annual Update of SafetyAnalyst

Infrastructure characteristic data, traffic volume data, and collision data should (preferably) be updated annually. This will ensure that the results of safety analyses are consistent with the transportation network. Larger municipalities in which more than one office is responsible for data collections (e.g. regional municipalities with their own area municipalities or Ministries of Transportation), should designate a SafetyAnalyst champion who is responsible for collecting data for any SafetyAnalyst update.

## 4 Conclusions

Automation of a road safety management process to proactively address potential safety concerns in a jurisdiction is a challenge for most municipalities. With the arrival of SafetyAnalyst, municipalities have the opportunity to compile their detailed infrastructure characteristics, traffic volumes, and collisions in one location. SafetyAnalyst is capable of conducting analyses related to all steps of the road safety management process. The main objective of this paper was to briefly review the capabilities of SafetyAnalyst and outline the various lessons learned thus far in an initiative by MTO to configure SafetyAnalyst for the Province of Ontario. The lessons learned in this project may assist other jurisdictions to configure the software more efficiently.



The most important and labour intensive task in the configuration of SafetyAnalyst is the data collection and compilation. As previously outlined, it is critical to first develop a (rather) complete list of infrastructure characteristics data. Google Earth functionalities can be very valuable in quickly finding each infrastructure entity to extract required information.

SafetyAnalyst provides customization opportunities to the users to match the SafetyAnalyst databases with the jurisdiction's databases. However, some of the functionalities of SafetyAnalyst (especially diagnosis scenarios) have been developed based on the default SafetyAnalyst database.

A Utility Tool was developed by MTO for importing data into SafetyAnalyst. This Utility Tool is able to generate standard SafetyAnalyst input files from the agency's databases. The advantages of using such a tool are; (1) road authorities can use their legacy infrastructure characteristic, traffic volume, and collision databases with minimal change; (2) annual update of SafetyAnalyst is facilitated if the agency's databases are updated; and (3) the Utility Tool can combine multiple columns of agency's databases to generate SafetyAnalyst's input files. The last item is particularly important for Canadian jurisdictions for which collision databases are often different from the US MMUCC.

It is recommended that jurisdictions allocate SafetyAnalyst champions to ensure that SafetyAnalyst databases are kept updated. The champions should keep track of new infrastructure elements and network improvement projects. They may also give advice to staff in charge of traffic volume collection to ensure that the infrastructure elements with no volume observations are included in the annual traffic count programs.

Once the data is imported into SafetyAnalyst, the next steps are to:

- Configure of the Network Screening module
  - Develop SPF based on local data
- Configure the diagnosis and Countermeasure Selection module
  - Review the existing diagnosis scenarios and countermeasure
  - Review societal costs of collisions
  - Customize collision modification factors based on the agency's past history
  - Add any new diagnostic scenarios, especially for ramps and freeways for which SafetyAnalyst does not have any diagnostic scenario
- Configure Economic Appraisal and Priority Ranking
  - Review construction costs of countermeasures

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