Evaluation of the Iowa DOT's Safety Improvement Candidate List Process

CTRE Project 00-74

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EXECUTIVE SUMMARY

The main goal of this research project was to evaluate the current Iowa Department of Transportation (Iowa DOT) safety improvement candidate list (SICL) process. An overview of the Iowa DOT method is provided in Section 3.

A survey of 17 other state departments of transportation was conducted to determine the state of the practice in other areas. Many of the states surveyed use a variation of Crash Rate, Frequency, and Severity. The majority of the states use a combination of several different methods, as Iowa does. The most significant difference between Iowa and the other states surveyed is that Iowa uses a much longer analysis period. Three states use a 1-year analysis period. Wisconsin, Nebraska, and New York use a 2-year analysis period, and eight use a 3-year analysis period. For Pennsylvania and South Carolina, the length of the analysis period was not available. North Dakota uses both a 1-year and 3-year analysis period. Results of the state survey are detailed in Section 4.

The first objective of this research was to evaluate whether fatalities overwhelm the current Iowa DOT SICL process. Reduction of the most serious types of accidents is an important consideration in prioritizing resources for safety improvements. However, the cause and resulting severity of accidents may not be specifically related to operational or geometric characteristics of the roadway itself and over-representation of high severity locations may not necessarily lead to efficient use of resources. Section 5 discusses an analysis of the impact of fatalities on the final ranking methodology. The impact was evaluated by reassigning dollar value weights to fatalities for locations in the Iowa DOT crash database according to several different scenarios. Rather than applying a universal value for each fatality, fatalities values were reduced to the same value given to major injuries. The impact on the final ranking was evaluated for each of the following scenarios:

- All Fatalities Assigned Value Loss of a Major Injury
- The First Fatality Assigned Value Loss of a Major Injury
- Only Fatality Assigned Value Loss of a Major Injury
- Count Only One Fatality per Accident as a Fatality, Treat Additional Fatalities as Major Injuries

The main conclusion of the analysis was that the SICL process is significantly influenced by fatalities, based on the dollar value given them in the Value Loss Ranking. Of particular interest is that the process appears to be influenced by a single fatality at a location.

The second objective was to perform a sensitivity analysis to evaluate impact of the individual ranking methods (Crash Frequency, Crash Rate, and Value Loss) on the final ranking, which results in the final safety improvement candidate list. The Iowa DOT currently uses a final ranking method that gives equal weight to rankings produced by the three methods. The purpose of the sensitivity analysis was to evaluate the impact that each of the individual methods has on the final ranking and to evaluate the impact that different weightings would have.

A description of the sensitivity analysis and results and recommendations are provided in Section 6. Results indicate that the contributions of Value Loss and Crash Rate to the final Iowa DOT SICL ranking are similar. Significantly different lists than the original ranking lists result when the contribution of either is maximized. When the contribution of Crash Frequency is maximized, significantly less pronounced changes occur, suggesting that the SICL ranking process is more influenced by Crash Frequency than the other two methods.

The final stage of this research was a workshop that was held on June 7, 2002, at the Center for Transportation Research and Education. Workshop participants discussed alternative ways to rank high crash locations. It was felt that prevention of serious accidents was a priority but that major injuries may be as significant as fatalities, which are often the focus of prevention. Since Value Loss is the only mechanism in the current Iowa DOT ranking method that takes severity into account, the focus was on developing a new method to allocate severity among accident types in the Value Loss Ranking. The conclusion of the workshop were to consider different scenarios, including the following:

- Treat the first fatality as a major injury in terms of the value assigned.
- Assign values for major injures that are closer to fatalities.
- Use a range of values for the various injury types rather than a dollar value with a "possible injury" as the baseline and the following values:
  - Fatality = 200 * Possible Injury
  - Major Injury = 100 * Possible Injury
  - Minor Injury = 10 * Possible Injury
  - Property Damage Only = Possible Injury
- Use the coefficients (0.2, 0.2, 0.6) in the final ranking process to calculate the composite value. Combinations of the above recommendations were applied to determine the effect that each would have on the original re-ranked SICL.

1. INTRODUCTION

1.1. Background

One goal of transportation safety engineers is to identify roadway locations characterized by a disproportionate share or severity of crashes. Development of a safety improvement candidate list (SICL) has the two-fold objective of identifying high accident locations and evaluating which of those locations has the greatest potential for accident reduction. The candidate ranking process is necessary to ensure that safety funds are efficiently allocated to provide the maximum benefit, in terms of reduced number and severity of accidents, for the available resources. The process allows high crash locations to be identified and prioritized so that safety funds can be targeted to locations that would benefit the most from engineering, enforcement, and/or educational measures that may be used to improve safety (Hauer and Persaud, 1984). In addition, states are required by federal law to identify high crash locations on their roadway networks.

Currently, several basic methods or combination of the basic methods are used by states and other agencies to identify and prioritize high crash locations. The most widely used methods, used individually or in combination, can be classified into several categories as listed below:

- Frequency
- Crash Rate
- Severity
  - Value Loss
  - Indices
- Rate-Quality-Control
- Bayesian Analysis (Zeeger, 1986; Persuad et al., 1999; Homburger et al., 1996)

1.2. Research Objectives

The main goal of this research project was to evaluate the current Iowa Department of Transportation (Iowa DOT) process to create their safety improvement candidate list and to explore other statistical methodologies to rank candidate safety improvement locations.

The first objective was to evaluate whether fatalities overwhelm the process. Reduction of the most serious types of accidents is an important consideration in prioritizing resources for safety improvements. However, the cause and resulting severity of accidents may not be specifically related to operational or geometric characteristics of the roadway itself and over-representation of high severity locations may not necessarily lead to efficient use of resources.

The second objective was to perform a sensitivity analysis to evaluate impact of the individual ranking methods on the final ranking, which results in the final safety improvement candidate list. The Iowa DOT currently uses a final ranking method that gives equal weight to rankings produced using frequency, crash rate, and value loss. The purpose of the sensitivity analysis was to evaluate the impact that each of the individual methods has on the final ranking and to evaluate the impact different weighting would have. Crash Rate and Severity are considered by many researchers to more closely represent safety and may need to be assigned a larger contribution in the final ranking process. The contribution of Value Loss, however, may be biased towards fatalities.

2. DESCRIPTION OF COMMON IDENTIFICATION AND RANKING METHODS

The most frequently used methods to identify and prioritize candidate high crash locations include the Crash Frequency Method, Crash Rate Method, Frequency-Rate Method, Crash Severity Method, Safety Indices, Severity-Rate Method, Rate-Quality-Control Method, and Bayesian Approach. Each of these methods is explained in the following sections.

2.1. Crash Frequency Method

The Crash Frequency Method summarizes the number of crashes by location. The main advantage to this method is that it is simple to use and doesn't require additional information beyond number and location of crashes. Locations are ranked by descending crash frequency and those with more than a predetermined number of crashes are classified as high-crash locations to be further scrutinized for statistical significance (Traffic Institute, 1999; NCHRP, 1986; NCHRP, 2000; SEMCOG, 1997). It is useful initially to identify locations for further analysis and ranking. The main disadvantage is that exposure (traffic volume) is not accounted for. Without being able to account for variations in traffic volume, locations that have high crash frequency due to high traffic volumes rather than some deficiency may be misidentified as high crash locations (Homburger et al., 1996; Traffic Institute, 2000). The Crash Frequency Method tends be biased towards high traffic volume locations (Layton, 1996; McMillen, 1999).

2.2. Crash Density Method

The Crash Density Method is closely related to the crash frequency method, the crash density method summarizes the number of crashes per mile for highway sections. Sections are defined as a minimum length of roadway with consistent characteristics, with the minimum distance used frequently being one mile. Locations are ranked by descending crash density and those with more than a predetermined density of crashes are classified as high-crash locations to be further scrutinized for statistical significance (Traffic Institute, 1999; NCHRP, 1986; NCHRP, 2000; SEMCOG, 1997; Ogden, 1996).

2.3. Crash Rate Method

The crash rate method does account for both exposure and the total number of crashes. For links, crash rate is a function of the number of crashes, traffic volume, and the length of the segment. At nodes, crash rate is a function of the number of crashes and daily entering vehicles. Crash rate is typically expressed as the number of crashes per million vehicle miles traveled for road segments and number of crashes per million daily entering vehicles for intersections (Homburger et al., 1996; Traffic Institute, 2000).

The main advantage of this method is that locations with a disproportionate number of crashes in relationship to volume can be identified avoiding the bias towards high volume roadways. However, locations with only few crashes but low volumes will result in high crash rates. As a result, this method may be biased towards low volume roadways (Layton, 1996; McMillen, 1999).

2.4. Frequency-Rate Method

This method is a combination of the Crash Frequency and Crash Rate Methods. Locations are first ranked by Crash Frequency and the worst locations re-ranked using Crash Rate (Homburger et al., 1996; Traffic Institute, 2000). The rational of combining Crash Frequency and Crash Rate is to eliminate or minimize the bias of the two individual methods (Traffic Institute, 2000; McMillen, 1999). The frequency-rate method is a combination of crash frequency/crash density methods and the crash rate method. Locations are classified as high-crash locations if they have more than the prescribed minimum crash frequency or crash density and higher than the minimum crash rate. The crash frequency/crash density methods and the crash rate methods have deficiencies that limit their effectiveness. However, if these methods are combined, as they are in the frequency-rate method, it appears possible to eliminate or minimize the effects of the deficiencies (Traffic Institute, 1999; NCHRP, 1986; NCHRP, 2000; SEMCOG, 1997; Ogden, 1996).

2.5. Crash Severity Method

The Crash Severity Method accounts for monetary losses of crashes by considering and then weighting crashes at a location based on the resulting degree of injury (Layton, 1996). Fatal and injury crashes are usually weighted more heavily than possible or minor injuries and property damage only (PDO) crashes. This allows severity of accidents to be considered.

Safety agencies and the general public are often most concerned with severe crashes. The main advantage of this method it is frequently biased towards locations with major injuries and fatalities (McMillen, 1999). Targeting safety funds toward improvements to reduce the most serious accidents may result in significant benefits.

The main disadvantage is that this method is likely to rank locations with a single fatality or major injury over those with numerous but less serious accidents. A location with a single fatal crash resulting from driver error rather than roadway features would be ranked higher than a location with numerous minor injury or property damage only crashes, resulting in poor allocation of resources. Fatalities, in particular, may overwhelm the process. This method may also favor rural areas (Layton, 1996).

2.6. Safety Indices

Tamburri and Smith introduced the concept of a Safety Index. The concept is based on the idea that locations with severe crashes deserve more immediate improvement but recognizes that due to the random nature of crashes, a certain number crashes are “expected”. In this method, each road type is assigned an “expected” mix of crash severity (i.e., each roadway type is considered to have a certain percentage of fatalities, a certain percentage of injuries, and a certain percentage of PDO crashes). A weight is also assigned to each severity for each road type (Tamburri and Smith, 1970).

Taylor and Thompson (1977) have suggested a ranking approach that uses a hazard index for each location. The index is a weighted sum of the following factors: crash frequency, rate, severity, volume-to-capacity ratio, sight distance, conflicts, erratic maneuvers, and driver expectancy. The weights assigned each variable were proposed by state highway safety personnel.

2.7. Severity-Rate Method

This method combines the Crash Severity and Crash Rate methods and has been considered to be the most meaningful method by various state and local agencies. In this method, an equivalent property damage only (EPDO) number is calculated (as in crash severity method) and then divided by volume (e.g., MEV or MVM) to obtain an EPDO rate for each location (Stokes, 1996).

2.8. Rate-Quality-Control Method

The rate quality control method consists of a simple statistical test that is applied to the crash rate at a particular location (intersection/roadway) to determine whether it is significantly different (abnormally high) than the average crash rate of other similar locations (Homburger, 1996; Traffic Institute, 2000; Layton, 1996). The critical crash rate is determined using the following:

$$R_c = R_a + K\sqrt{\frac{R_a}{M}} + \frac{1}{2M} \qquad (2.1)$$

where

R_c = Critical crash rate
R_a = Average crash rate for locations of similar characteristics
M = Millions of vehicle miles (MVM) for segments or millions of total daily entering vehicles (MEV) for intersections
K = probability constant based on the desired level of significance

Equation 2.1 is based on the assumption that traffic crashes are Poisson distributed (Traffic Institute, 2000). If the actual crash rate of a location is greater than the critical crash rate, it is considered to be a high crash location (Hauer, 1996; Barbaresso et al., 1982). This method recognizes the variation in the occurrence of crashes for both low and high volume roadways (Layton, 1996). It also recognizes the importance of making a comparison to what is normal crash rate for the group being considered.

The main disadvantages are that it does not address crash severity (McMillen, 1999) and by only comparing locations to other locations with the same physical characteristics, safety problems inherent to those physical characteristics are masked.

Flak and Barbaresso (1982) recommend a variation on the method, which consists of creation of a list of crashes by type (angle, rear-end, etc.), by pavement condition (dry, wet, etc.), and so forth. The crash frequency at a location is compared to average crash frequency and standard deviation calculated for the list of similar locations. These locations with crash frequencies, a few standard deviations above the average are considered for safety remediation. Analysis of crash rates for specific crash types may improve the ability of an analyst to identify problem areas and causal factors. In this method total crashes are also considered (represented by crash frequency and crash rate).

2.9. Empirical Bayes Method

Hauer and Persaud (1984) suggest an Empirical Bayes (EB) method for identification of high crash locations. The EB method attempts overcome the difficulties with some of the conventional techniques. The EB method controls the randomness of crash data by using an estimate of the long-term mean number of crashes at a location. This method is used for predicting crashes in the future and then ranking based on the predicted number of crashes. An estimate of the long-term mean number of crashes at a location is obtained by combining its crash count (in the most recent years) with the expected annual number of crashes at that location (based on the crash history of sites with similar characteristics) (Persuad et al., 1999). However, the method is complex and has not been tested in widespread implementation (McMillen, 1999). The main disadvantage of this method is extensive data requirements.

3. THE IOWA DOT'S METHOD FOR IDENTIFICATION AND RANKING OF HIGH CRASH LOCATIONS

The Iowa DOT annually ranks crash locations and identifies the 100 highest statewide crash locations resulting in a safety improvement candidate list. They use a combination of Crash Frequency, Crash Rate, and Value Loss (Crash Severity). A five-year analysis period is used to evaluate and rank crash data. The analysis includes both links and nodes. Links are roadway segments between adjacent nodes. Nodes are spot locations that include intersections, ramp terminals, bridges, railroad crossings, etc. A two-step process is used to identify high crash locations. First, all crash locations in the state are evaluated and only locations that meet the criteria of having at least one fatal crash, or at least four personal injury crashes, or at least eight total crashes for the five-year analysis period (1-4-8 criteria) are included in the final analysis (Nervig, 1999). Next, the set of locations meeting the minimum criteria are ranked using a combination of the Crash Frequency, Crash Rate, and Value Loss methods as described in the following sections. A schematic of the process is provided in Figure 3.1.

3.1. Crash Frequency

Crash Frequency is the total number of crashes at a location for the five-year period. Locations are sorted in descending order by the number of crashes and each location is assigned a "Crash Frequency Ranking" (Nervig, 1999). The location with the most crashes is given the rank of 1.

3.2. Crash Rate

The Crash Rate Method accounts for exposure. Crash Rate is calculated according to the following equation. Daily entering vehicles (DEV) is calculated separately for links that are greater than 0.6 miles in length and links that are less than or equal to 0.6 miles in length and spot location.

$$\text{Crash Rate} = \frac{(\text{Number of crashes}) \times (10^6)}{(\text{DEV}) \times (n \text{ years}) \times (365 \text{ days/year})} \tag{3.1}$$

where

n = analysis time period in years (5 years for the Iowa DOT)
DEV_{node} = actual daily entering vehicles for nodes and average daily traffic for road segments (for road segments up to 0.6 miles long and spot locations)
DEV_{link} = Absolute value of [(Link length/0.3) x (Actual DEV)] (for road segments 0.6 miles and longer)

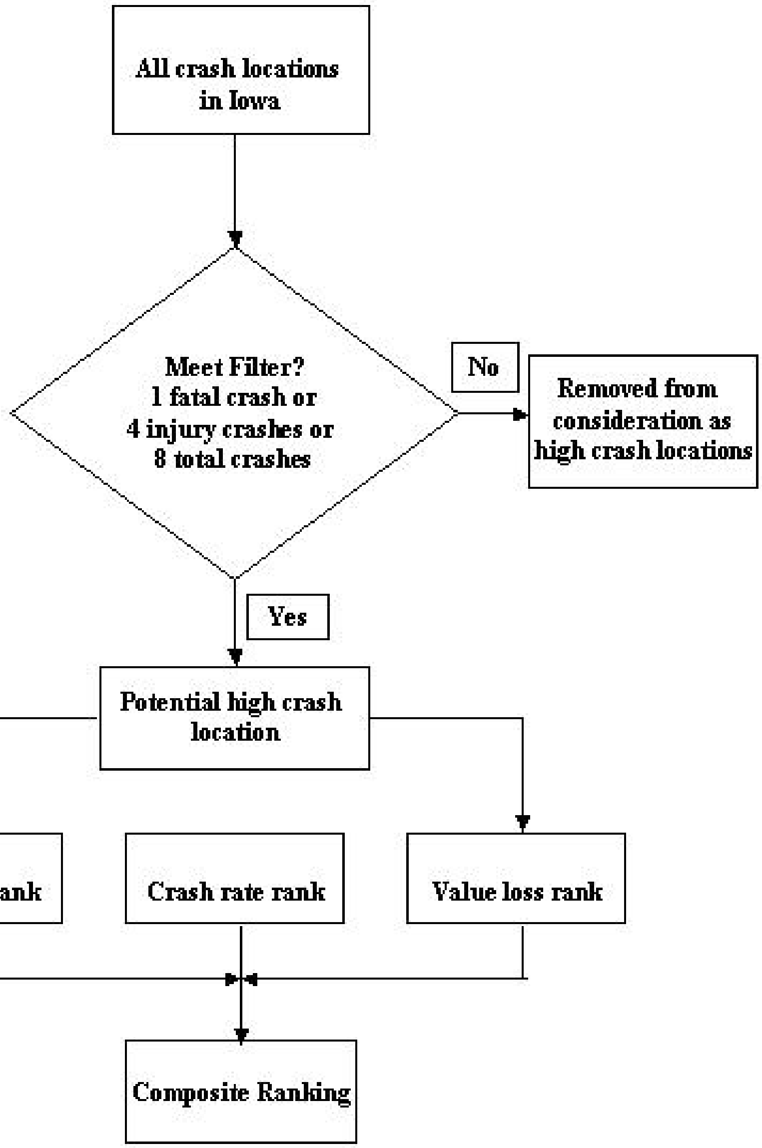

Figure 3.1. Iowa DOT Ranking Process

Traffic volume is not available for all locations, consequently Crash Rate is not calculated for those locations and a Crash Rate Ranking of “zero” is assigned to those locations, which are still considered in the final ranking process. Locations are sorted in descending order by Crash Rate and each location assigned a “Crash Rate Ranking” (Nervig, 1999). The location with the highest crash rate receives the rank of 1.

3.3. Value Loss

The Value Loss method measures cost or severity and is calculated for each location by assigning values to different injury types using the following equation:

$$\text{Value Loss (in \$)} = (\text{Value of Fatalities}) + (\text{Value of Major Injuries}) + (\text{Value of Minor Injuries}) + (\text{Value of Possible Injuries}) + (\text{Value of PDO}) \quad (3.2)$$

The values assigned to each injury or fatality is proportional according to the following:

- Value of a Fatality = 400 * (Value of a Possible Injury)
- Value of a Major Injury = 60 * (Value of a Possible Injury)
- Value of a Minor Injury = 4 * (Value of a Possible Injury)
- Value of PDO = actual value of property damage if available or equal to the value of a single possible injury

The total number of fatalities, injuries, and property damage are calculated for the five-year analysis period. The locations are sorted in descending order by value loss and each location assigned a “Value Loss Ranking” (Nervig, 1999). The location with highest value loss is given a rank of 1.

3.4. Composite State Ranking

Once locations have been ranked by the Crash Frequency, Crash Rate, and Value Loss Methods, a composite value is calculated that gives equal weight to all three according to the following:

$$\text{Value}_{\text{composite}} = 1/3(\text{Crash Frequency Rank}) + 1/3(\text{Crash Rate Rank}) + 1/3(\text{Value Loss Rank}) \quad (3.3)$$

The composite value for a location ranked 5th by Crash Frequency, 10th by Crash Rate, and 25th by Value Loss would be calculated by the following:

$$1/3(5) + 1/3(10) + 1/3(25) = 13.3$$

Once composite values are calculated for all locations, the locations are then sorted in ascending order by the composite value and all the locations re-ranked. The location with the lowest composite value receives the rank of 1. Ties are accounted for in all of the three initial ranking and the final ranking methods. The locations ranked from 1 to 100 become the Safety Improvement Candidate List for the State of Iowa (Nervig, 1999). The top 50, top 200 locations, etc. can also be determined.

4. HIGH CRASH LOCATION METHODS USED BY OTHER STATES

Each state selects its own high crash identification and ranking methodology. Seventeen state departments of transportations (DOTs) were contacted to determine the most common methods used by their agencies. Table 4.1 summarizes the methods used by the various states. A discussion of the methods used is provided in the following sections. Most used a combination of different methods as Iowa does. The most common methods used include the following:

- Rate Quality Control
- Crash Rate
- Frequency
- Severity
- EPDO

All of the states use an analysis period that is considerably shorter than the 5-year period used by Iowa. One state uses a 1-year analysis period. Three states use a 2-year period and eight states use a 3-year analysis period. Three states uses several analysis periods and information was not available for two states. Eleven states combine locations as Iowa does, while four analyze and rank segments and intersections differently. Information was not available for the two remaining states.

4.1. Florida

According to the Florida Department of Transportation, any location experiencing an abnormal number of crashes, as determined by their ranking process, is termed as a hazardous location. The district safety engineers through citizen complaints, the Florida Highway Patrol, incident reports, fatal crash reports, and other district personnel identify hazardous locations. Once the locations are identified in this manner, the number of crashes at each location is analyzed (Florida DOT).

Florida uses their crash database of statewide crash records to rank crashes. Only locations with at least 8 crashes in a one-year period are considered in the final analysis. A safety ratio is calculated using:

$$\text{Safety Ratio} = \frac{\text{Actual Crash Rate}}{\text{Critical Crash Rate}} \tag{4.1}$$

The actual and critical crash rates are calculated using Equation 3.1 (Section 3.2), similar to the Iowa DOT. For calculation of the critical crash rate, a 95% level of significance is used for rural and 99% for urban locations. In Florida, segments are roadway sections between 0.1 and 3 miles in length and spot locations are those less than 0.1 mile in length (Florida DOT). Average crash rates are developed for each type of roadway (e.g. rural, urban, 2-lane, 3-lane, 4-lane, divided, undivided) (Cavin, 2001).

Table 4.1. Methods Used by Other States

State	High Crash Location Identification and Ranking Factors Used	Time Period of Analysis (years)	Separate Ranking for Intersections and Segments
Florida	Rate Quality Control Method	1	Yes
Georgia	Crash Frequency, Crash Rate, and Severity	3	Yes
Idaho	Crash Frequency, Crash Rate, and Severity	3	No
Illinois	Crash Frequency, Crash Rate, EPDO, and Delta Change	3	No
Kansas	Crash Rate and EPDO Rate	1, 6 months	Yes
Minnesota	Crash Cost	3	No
Missouri	Crash Rate and EPDO Rate	1, 6 months	Yes
Nebraska	Rate Quality Control Method	2	No
New York	Rate Quality Control Method	2	No
North Dakota	Crash Frequency, Crash Rate, and Weighted Severity	1, 3	No
Ohio	Crash Frequency, Crash Rate, Delta Change, EPDO, EPDO Rate, Relative Severity Index, and Density	3	No
Oregon	Crash Frequency, Crash Rate, and Crash Severity	3	No
Pennsylvania	Crash Frequency, and Severity	—	—
South Carolina	Crash Frequency, Rate Quality Control Method, and Crash Severity	—	—
South Dakota	Crash Rate and Crash Cost	3	No
Washington	Severity (Benefit/Cost Ratios)	3	No
Wisconsin	Crash Rte, Rate of Fatal/Severe Injury Crashes, Rate of Run-off-the-Road Non-Intersection Crashes, and Rate of Intersection-Related Crashes	2	No

A critical Crash Rate (K factor) of 1.645 is used for rural locations and any location above the 95% confidence interval is considered to be abnormal and is designated as a high crash location. A K factor of 3.291 is used for urban locations, with any location above the 99% confidence interval is considered to be abnormal and is designated as a high crash location (Florida DOT).

All the locations with a safety ratio greater than or equal to one are selected as high crash spots or segments (Florida DOT). The list of high crash locations is then submitted to the DOT districts and then prioritized (Thakkar, 2001).

No information was available as to why the value of 8 crashes is used as a minimum threshold. The Rate Quality Control Method is used in order to take care of variations in traffic volume (Thakkar, 2001). The statistical tests applied are based on the common assumption that crashes fit the Poisson distribution (Florida DOT).

4.2. Georgia

The Georgia DOT uses the Frequency, Rate, and Severity Methods for both intersection and segment analysis. A list of the top 150 locations for each method are developed as well as a top 150 list for a combination of the three categories. The analysis period is one year (Georgia DOT, 2001). Intersections and segments are evaluated separately.

The Department of Transportation of Gwinnett County, one of the 13 counties in the Atlanta metropolitan area, uses the frequency method and produces a list of the top 100 intersections. They use three years of crash data to avoid regression-to-the-mean errors. Only locations with at least 15 total crashes are considered for further analysis based on the crash warrant for multiway stop signs and traffic signals (Bretherton, 2001).

4.3. Idaho

The Idaho program evaluates intersections and roadway segments separately, and considers all crashes in which either a fatality or injury occurs or property damage is greater than $750 (Idaho DOT). A location must also have at least four crashes over the 3-year analysis period (Elmer, 2001). Locations meeting these criteria are further analyzed using a combination of Crash Frequency, Crash Rate, and Severity. The locations are first ranked by each method and the Frequency, Rate, and Severity rankings are then combined into a single listing to obtain the final ranking. Each of the three rankings is weighted before they are combined (Idaho DOT). The weighted score is calculated by the following:

$$\text{Weighted Score} = 0.25FR + 0.25RR + 0.50SR \tag{4.2}$$

where

FR = Frequency Rank
RR = Rate Rank
SR = Severity Rank

By combining Frequency, Severity and Crash Rate and weighting them according to the coefficients in Equation 4.2, the Idaho DOT tries to strike a balance between Crash Frequency and Crash Severity. By using more than three years of data, Idaho DOT believes that more problems will be encountered in relation to physical changes in the roadway, and even changes in the collision database format. Although, they consider fatalities to be important, they try to avoid bias towards locations where only fatal crashes have occurred. Rather, their procedure is intended to identify areas prone to severe types of crashes or predict where severe crashes would happen in the future (Elmer, 2001).

4.4. Illinois

Illinois uses a computerized system called the High Accident Location System (HALIS) for the identification of high crash locations in Illinois. HALIS uses the following five steps to identify high crash locations:

- Step 1—organize the data for analysis.
- Step 2—perform initial analysis, determine statewide statistics, and identify possible candidate locations.
- Step 3—compare possible candidate locations with statewide statistics and identify high crash locations.
- Step 4—provide a ranking and listing of high crash locations.
- Step 5—provide collision diagram printouts/plots for each location (Illinois DOT).

HALIS uses three years of crash data and the identification and ranking is performed only for the following roadway features:

- segments
- signalized intersections
- non-signalized intersections
- bridges
- railroad crossings
- ramps

Sixty roadway categories (by urban or rural, type of street, and type of location) are defined and used in the analysis. Each of the categories is also separated by number of lanes. For each roadway category, the crash data are summarized by vehicle-miles-traveled (VMT), total crashes (Frequency), Crash Rate, EPDO (calculated by Equation 4.3), and delta change (determined by analyzing crashes by quarter for a three-year period and establishing a slope of the trend line of crashes by quarter) (Illinois DOT).

$$\text{EPDO} = \frac{(10)(\text{FA}) + (9)(\text{AA}) + (5)(\text{BA}) + (2)(\text{CA}) + (\text{PDO})}{(\text{Total Accidents})} \tag{4.3}$$

where

FA = fatal crashes
AA = number of crashes where the most severe injury is an A (major) injury
BA = number of crashes where the most severe injury is a B (minor) injury
CA = number of crashes where the most severe injury is a C (possible) injury

The actual Crash Frequency for each location is compared to minimum values established by a user task force. In order to qualify as a possible candidate high crash location, the Crash Frequency of any location must exceed these minimum values. Minimum Crash Frequency values are established for segments and intersections (signalized and non-signalized) as well as bridges, railroad crossings, and ramps. Minimum crash densities (crashes per mile) are also established for one way, two-way, divided, bi-directional, and freeway types of roadways for both urban and rural locations. A segment must exceed all the three minimum crash values (frequency, length, and density) to qualify as a possible high crash segment. For the identification of high crash locations, separate statewide averages are determined for intersections with similar characteristics such as land use, number of lanes.

The identification of high crash spot locations (from the list of possible candidate locations) requires two steps. First, critical values are established for each of the three measures (i.e., frequency, rate, and EPDO). For frequency, the average is calculated and two standard deviations are added to the average to establish the critical value. In case of crash rate, critical values are obtained by adding one standard deviation to the average rate. The critical value for EPDO is calculated similar to that for crash rate. One standard deviation is added to the average EPDO value. In case of non-signalized intersections, the critical values for frequency, rate, and EPDO are doubled.

In the second step, the ratio of the actual crash value to the critical value is determined for each location for each of the three selection methods. The candidate locations with any of the three ratios greater than 1.0 remain as possible high crash locations. Finally, for each possible candidate location, a priority index value (PIV) is calculated using the following:

$$\text{PIV} = \frac{\text{F}}{(\text{FW})(\text{Critical F})} + \frac{\text{R}}{(\text{RW})(\text{Critical R})} + \frac{\text{EPDO}}{(\text{EPDOW})(\text{Critical EPDO})} + (\text{DCW})\,(\text{DCV}) \tag{4.4}$$

where

F = Crash Frequency
FW = Frequency Weight
R = Crash Rate
RW = Rate Weight,
EPDOW = EPDO Weight
DCV = Delta Change Value
DCW = Delta Change Weight

The weighting factors are variable and based on the PIV all the candidate locations are ranked.

The minimum thresholds for potential high crash locations are varied based on the type of location (segment, signalized intersection, etc.) and also whether the location is in one of the counties in the Chicago area. HALIS was designed to use all four-selection criteria in order to include locations that might not be considered potential if only one factor was used. The delta change factor is considered to be useful to determine if a location has an increasing or decreasing crash trend (Magee, 2001).

4.5. Minnesota

Minnesota DOT (Mn/DOT) uses separate ranking lists for intersections and road segments. The top 200 intersections and the top 150 segments in the state are identified for safety analysis using a 3-year analysis period (Hill, 2001). The following methods are considered in the ranking of intersections or segments:

- Total Crashes (for intersections) or Crashes per Mile (for segments).
- Crash Rate —crashes per million vehicles (for intersections) and crashes per million vehicle miles (for segments).
- Severity Rate—an index similar to crash rate where fatal crashes have a weight of 10, injury crashes have a weight of 4, and property damage have a weight of 1.
- Crash Cost —each crash is multiplied by its monetary cost, and the total sum for all crashes is calculated. The final number is total cost for intersections and cost per mile for segments.
- Sum of Ranks—all the intersections are ranked using the four previous indices, the values are summed, and then ranked by this value (Hill, 2001b).

Crash Cost is the index that is considered the most useful by Mn/DOT. Crash cost is used since Mn/DOT performs a benefit/cost analysis for all locations, where the benefit is the anticipated reduction in crashes after a safety recommendation is made. Existing crash cost values are based on the average cost of crashes obtained from the four largest insurance carriers in Minnesota. The current values are $500,000 per fatal crash, $30,500 per injury crash, and $2,700 per PDO crash. Values of $3,400,000 per fatal crash, $260,000 per severity A crash, $56,000 per severity B crash, $27,000 per severity C crash, and $4,000 per property damage only crash have been proposed (Rasmussen, 1999).

4.6. Missouri

Missouri DOT (MoDOT) uses Crash Frequency and Crash Rate for initial analysis and both number-rate and severity-rate methods for the final selection of high crash locations. MoDOT performs an annual citywide analysis (using 1 to 3 years of data), and an early warning analysis (which uses either 3 or 6 months of crash data). In both analyses, a factor of six is applied to the number of fatal and injury crashes at each location. The weighted numbers for fatal and injury crashes are then added to the number of PDO crashes to obtain an EPDO. Crash Rate and EPDO Rate are calculated for both intersections and mid-block sections as shown in Equation 4.5. For intersections, the Crash Rate is per million entering vehicles, and the EPDO Rate is per million vehicles. For mid-block sections, the Crash Rate is per 100 million vehicle miles driven on the section, and the EPDO Rate is per 100 million (Missouri DOT, 1990).

$$\text{EPDO Rate} = \frac{(\text{EPDO Number}) \times (1\,\text{million})}{\text{Exposure}} \qquad (4.5)$$

MoDOT recommends a benefit/cost ratio for selecting high crash location countermeasures. Furthermore, MoDOT considers the benefit/cost ratio to be a straightforward procedure with its results meaningful to government officials. The crash costs used by Missouri for benefit-cost analysis are: $1,900,000 for fatal crash, $21,100 for injury crash, and $4,000 for PDO.

4.7. Kansas

The procedure adopted by Kansas is similar to Missouri's, as discussed in the previous section. The high accident location identification and ranking system adapted by Kansas was originally prepared for smaller communities in Missouri. The only difference between Kansas and the Missouri processes is the value of crash costs used for benefit-cost analysis. The crash costs used in Kansas are $61,500 for both fatal and injury crashes, and $3,500 for PDO (Russell and Mulinazzi, 1994).

4.8. Nebraska

The Highway Safety Division of the Nebraska Department of Roads (NDOR) collects and maintains crash, traffic, and highway data. According to state statute, all crashes involving personal injury or individual property damage in excess of $500 must be reported. Traffic data are collected throughout Nebraska and used to calculate crash rates for each type of roadway and for the system. The highway-related information collected by NDOR includes number of lanes, location type, and the engineering district (Nebraska DOT, 1990).

Nebraska uses the Rate Quality Control Method to identify hazardous locations on the state highway system. Intersections, clusters, and sections are analyzed as part of the identification process. Intersections are junctions of two or more state highways, clusters are defined as floating spot locations where three or more crashes occur within a selected cluster length (usually 0.1 mile), and sections are long stretches of roadway with similar characteristics.

The intersections, clusters, and sections are divided into eight categories. They are grouped by lane characteristics (2-lane, 4-lane, one-way, and interstate standard) and by land use (rural and urban). For each of these categories, a statewide average crash rate is computed and the individual crash rate for each intersection, cluster, and section compared to the statewide average rate of the appropriate highway category. All locations with a crash rate greater than the comparable statewide average rate are of interest and prioritized on the basis of crash severity. A Severity Index is used to assign a value representing average dollar loss per crash to each crash type. For each significant location, the cost of the crashes is summed and the totals used to rank the locations. The analysis is done every six months and uses two years of data for every analysis. Nebraska considers the two-year period short enough to allow sudden changes in crash numbers at any specific location to be identified, and long enough to improve the reliability of the location selection process.

The top one-third of the locations identified within each highway-engineering district (ranked by severity), are provided to the Department of Roads Safety Committee for review. A listing of the historical ranking for all the selected locations is also provided annually to the committee. The two lists are used to determine locations that require further study.

4.9. New York

The New York State Department of Transportation (NYSDOT) uses the Rate Quality Control Method to identify and rank high crash locations, also called as priority investigation locations (PILs). A two-year crash history is used to calculate crash rates. Each location must also have a minimum of 12 crashes for rural locations and 20 crashes in urban locations to be considered. In order to be considered as a high crash location, the crash rate at a location must be three standard deviations (99.9% level of significance) above the mean for similar segments. The locations are then ranked by a factor comprised of the number of crashes and the severity of crashes occurring at the identified location. However, NYSDOT does not use dollar values to determine severity (Terry, 2001).

A listing of possible high crash location is also produced using lower threshold values of six crashes in a 2-year period and a 90 percent level of significance. This listing is used to help identify locations on highways where possible highway safety problems may exist in the future.

A two-year analysis period was adopted because NYSDOT determined that a 1-year period was too short for safety analysis. It was also felt that random fluctuations in the occurrence of crashes can cause a location to appear in the final listing of high crash locations based on short time frames. They also believe that a time period longer than 2 years makes it harder for an emerging problem location to be identified.

4.10. North Dakota

North Dakota Department of Transportation (NDDOT) produces a list of locations with the highest crash severity annually. A list is produced for both urban locations and rural state highways (Kautzman, 2001).

Crash statistics are calculated for 13 major cities in North Dakota (i.e., 5,000 population or more) for the most recent one-year period and crash statistics for the most recent three-year period are calculated for rural state highway locations. All roadway segments and intersections are ranked by Crash Frequency, Crash Rate, and Weighted Severity. Weighted Severity is calculated using the following:

$$\text{Weighted Severity} = (F \times 12) + (I \times 3) + \text{PDO} \tag{4.6}$$

where

F = number of fatalities
I = number of injuries
PDO = property damage only

Locations with a weighted severity of 15 or more are considered for further analysis. The identified locations from the filter represent a preliminary list of possible high crash locations but are not the final ranking. The locations in the list are first ranked by Crash Frequency, then by Crash Rate and then Severity. A composite ranking is obtained by adding the three ranks (Wetsch, 2001).

4.11. Ohio

As part of their highway safety program, Ohio DOT uses a high crash location identification and ranking system called the High Crash Location Identification System (HCLIS). HCLIS allows minimum section length, crash count thresholds, time period, and crash types to be specified. Also, HCLIS allows a user to define the rules for selecting and ranking high crash locations (Ohio DOT, 2000).

The time period considered for crash analysis in Ohio is 3 years. Crash data are linked to the operational characteristics of each location, which include current traffic signal data, volume information, and geometrics. Each intersection or intersection- related crash is examined to ensure that it is correctly identified (e.g., correct priority roadway, and cross-road name).

The initial list of crash locations is evaluated using the following minimum criteria:

- Crash Frequency—The frequency thresholds are determined from statewide statistics and are calculated for similar locations. The frequency threshold value is equal to the statewide mean frequency plus three standard deviations.
- Crash Rate—The crash rate thresholds are determined from statewide statistics and are calculated for similar locations. The crash rate threshold value is equal to the statewide mean crash rate plus three standard deviations.
- Delta-Change—This is the slope of a regression line obtained from a plot of crashes per quarter and time. The threshold value used is 0.091.
- EPDO—The EPDO value is calculated by using weights of 292.9 for fatalities, 6.9 for injuries, and 1 for PDO crashes. The threshold value is 65.
- EPDO Rate—EPDO rates per million VMT are calculated. The threshold value used is 89.
- Relative Severity Index (RSI)—The RSI is obtained by obtaining the relative cost of each crash and dividing it by the total number of crashes at that location. The threshold value is 2253.
- Density—Crash density is the number of crashes per mile. For intersections, the density defaults to a value of zero. There is no threshold value in Ohio for density.

A location must meet at least one of the above criteria for further consideration. A rank is assigned for each of the seven characteristics involved. A hazard index is then calculated by weighting the value from each of the seven rankings. The hazard index for each location is the sum of the products of the weighted ranks.

4.12. Oregon

The Oregon Department of Transportation (ODOT) uses the safety priority index System (SPIS) to identify high crash locations on state highways. The SPIS index values are based on three years of crash data and consider Frequency, Crash rate, and Crash Severity for segments that are 0.10 miles. Any location that experiences either three or more crashes or one or more fatal crashes over the three-year analysis period qualifies as a SPIS site (Oregon DOT, 2001).

SPIS uses indicators for Crash Frequency, Crash Rate, and Crash Severity. The Crash Frequency indicator is a value between 0 and 25 determined by a logarithmic distribution of total crashes over a three-year period. The Crash Rate indicator is also a value between 0 and 25 determined by a logarithmic distribution of crash rates over a three-year period. The Crash Severity indicator is a value between 0 and 50 that is linear distributive of severity scores of 100 for fatalities, 100 for severe injuries, 10 for moderate injuries, 10 for minor injuries, and one for PDO crashes. The Crash Frequency indicator, Crash Rate indicator, and Crash Severity indicator are added together to calculate the SPIS value.

The current SPIS process is more likely to select intersections with the most crashes. ODOT's other tool called the Safety Improvement Program (SIP) looks at highways in five-mile segments and considers only frequency of "A" severity and fatal crashes. These tools together help ODOT program safety improvements. ODOT uses three years as time period for analysis as it believes that multiple years of data should be used for safety analysis (Monsere, 2001). Although high crash locations are identified they are not necessarily ranked. For example, the location with the highest SPIS score doesn't automatically go to the top of the list for funding. The decision on which projects are to be funded is not based entirely on just the safety aspects of the projects.

4.13. Pennsylvania

The Pennsylvania Department of Transportation (PennDOT) considers Severity and Frequency for identification and ranking of high crash locations (Taylor, 2001).

4.14. South Carolina

South Carolina DOT uses the Crash Frequency, Rate Quality Control, and Crash Severity Methods for identification and ranking of high crash locations. Improvements to these locations are scheduled after consideration of available funding, the net annual benefit of the selected countermeasure, and the calculated benefit/cost ratio (Harrelson, 2001).

4.15. South Dakota

The South Dakota Department of Transportation (SDDOT) has a hazard elimination and safety (HES) program as part of its safety management system. The primary purpose of HES is to identify high crash locations on all public roads in South Dakota. Crash maps generated from the crash database are used to identify crash locations and the period considered is three years. For each identified location, a crash record search is done and the number and type of crashes determined. Based on the number of crashes and the traffic volume, a crash rate is then calculated for each location. For every location with a crash rate above a pre-determined level, the cost of crashes are compared to the cost of an effective countermeasure. The benefit/cost (B/C) ratio must be 1:1 or greater for the location to be further studied by a field review team (SDDOT).

4.16. Washington

Washington only uses Frequency to identify high crash locations. Locations are sorted by total number of crashes and a list of 100 high crash locations and 50 high crash road segments is generated. The time period of analysis is three years and the locations prioritized using benefit/cost ratios. For crash costs, the following values are used: fatality $800,000, disabling injury $800,000, evident injury $62,000, possible injury $33,000, and PDO $5,800 (Perrin, 2001).

4.17. Wisconsin

The Wisconsin Department of Transportation (WisDOT) uses two different methods to identify locations in need of safety improvement. One method uses statistical process control algorithms to identify roadways or groups of roadways with extraordinarily high crash rates or severity. The second method compares the existing road segment geometrics to engineering design standards or benchmarks. Locations with inadequate geometrics are evaluated further. The problem identification algorithms used in the first method employ statistical process control theory of disproportionate crash rate (DCR) modeling (WisDOT, 1997).

The DCR modeling methodology groups' highway segments by user-defined characteristics, and calculates baseline crash rates and types for highway categories and for individual segments. It also applies data-defined statistical upper and lower control limits, and allows road improvement needs to be categorized based on severity and type of crash. Two years of crash data are used for analysis and the crash data are aggregated by highway segment and then associated with the deficiency file roadway inventory data. The DCR model calculates and compares crashes for highway segments for nine roadway sub-categories (defined by cross-section type, functional classification, or average daily traffic [ADT]).

If a highway segment has a crash rate (or fatal/injury crash rate or ROR non-intersection crash rate or intersection crash rate) that is disproportionately high relative to its subcategory (i.e., at least 1.65 standard deviations higher than the subcategory mean crash rate), then it is flagged as a problem location. Segments with disproportionately high severity outcome rates are more closely examined to determine if an engineering remedy is warranted. The model also measures the clustering of crashes at intersection and non-intersection spots.

4.18. Comparison of the Iowa Method to Other States' Method

Many of the states surveyed use a variation of Crash Rate, Frequency, and Severity. The majority of the states use a combination of several different methods, as Iowa does, although the amount of weight that each method has in the final SICL process is different. The most significant difference between Iowa and the other states surveyed is that Iowa uses a much longer analysis period than the others. Three states used a 1-year analysis period. Wisconsin, Nebraska, and New

York use a 2-year analysis period and eight use a 3-year analysis period. For Pennsylvania and South Carolina, the length of the analysis period was not available. North Dakota uses both a 1-year and 3-year analysis period.

In addition, 11 states combine locations as Iowa does, while four analyze and rank segments and intersections differently. Information was not available for the two remaining states.

5. EVALUATION OF THE CONTRIBUTION OF FATALITIES

One of the main objectives of this research was to evaluate the impact of fatalities on the Iowa DOT safety improvement candidate location methodology. Fatalities and severe accidents are often targeted for reduction. Alternatively, crashes are random events and a fatal accident at a location may be a result of factors other than those that can be mitigated by improvements to roadway geometry or operation. For instance, drivers may be speeding or under the influence of alcohol. However, with the current ranking method, even a single fatality may have a significant influence on the final ranking process. The Value Loss Method weights crashes according to severity with significant weight given to fatal accidents as shown in Equation 5.1. The significantly heavier weight placed on fatalities results in relatively high value loss numbers with even a low number of fatalities. Regardless of the cause, a location with a single fatality would receive a value loss 400 times the value of a possible injury. Another location would require 7 major injury or 100 minor injury crashes before it received the same value loss as a single fatality.

The impact of fatalities on the final ranking methodology was evaluated by reassigning dollar value weights to fatalities for locations in the Iowa DOT crash database according to several different scenarios. Rather than applying a universal value for fatalities, fatalities values were reduced to the same value given to major injuries (60 times the value of a possible injury). The impact on the final ranking was evaluated for each of the scenarios, which are described in the following sections. The scenarios evaluated included consideration of the following:

- All Fatalities Assigned Value Loss of a Major Injury
- The First Fatality Assigned Value Loss of a Major Injury
- An Only Fatality Assigned Value Loss of a Major Injury
- Count Only One Fatality per Accident as a Fatality, Treat Additional Fatalities as Major Injuries

A significant change in Value Loss may influence value loss rankings and ultimately the final ranking process. Value Loss is calculated according to the following with adjustments to fatalities as indicated for each scenario:

Value Loss (in $) = (Value of Fatalities) + (Value of Major Injuries) + (Value of Minor Injuries) + (Value of Possible Injuries) + (Value of PDO) (5.1)

The values assigned to each injury or fatality are proportional according to the following:

- Value of a Fatality = 400 * (Value of a Possible Injury)
- Value of a Major Injury = 60 * (Value of a Possible Injury)
- Value of a Minor Injury = 4 * (Value of a Possible Injury)
- Value of PDO = actual value of property damage if available or equal to the value of a single possible injury

5.1. Description of Data

The crash database used in the analysis was the statewide Iowa DOT crash database with crashes that occurred from 1995 to 1999. A total of 10,534 crash locations in Iowa were included in the list. The data set represented crash locations after the 1-4-8 initial screening process had been applied (see Section 3). Of the 10,534 locations, 2,692 were removed since no traffic volume data were available for those locations and locations without volume data could not be re-ranked using accident rate. Only the remaining 7,842 locations were used in the evaluation process. None of the 2,692 locations that were removed were included in the top 200 safety improvement candidate list. The Iowa DOT does have a methodology to deal with locations that have no recorded volume so that they can be evaluated. However, that methodology could not be applied in this study so zero volume locations were removed.

After locations with missing volumes were removed, the remaining locations were re-ranked for each of the three methods (Value Loss, Frequency, and Crash Rate). For example, if the location ranked 947th had no volume information, it would have been removed and the location ranked 948th would then have been ranked 947th. Ties were accounted for and included. Two or more locations with the same value received identical ranks. Once the Value Loss, Frequency, and Crash Rate were re-ranked, the composite value was recalculated using the following:

$$\text{Adjusted Composite Value} = 1/3(\text{Re-ranked Value Loss}) + 1/3(\text{Re-ranked Frequency}) + 1/3\,(\text{Adjusted Crash Rate}) \tag{5.2}$$

The composite value was sorted and then re-ranked. Locations were re-ranked to provide an “adjusted original list” that could be used for comparison.

5.2. Methodology and Results

For each of the three scenarios, the dollar value assigned to fatalities was reassigned and Value Loss recalculated for all locations according the scenario. The resulting Value Loss value was used to re-rank locations. Locations were sorted in descending order and the location with the highest Value Loss was given the rank 1 and the location with the lowest Value Loss was given a rank of 7,842. The updated value loss rank was then used to recalculate the final composite score using Equation 5.2, which lead to an updated final ranking. Changes between the “original” ranking list and that generated as a result of the different scenarios was evaluated and is reported in the following sections.

5.2.1. First Fatal Assigned Value of Major Injury

For this scenario, the first fatality was reassigned the weight of a major injury (60 times the value of a possible injury). This allows any single occurrence of a fatality to be treated as a random event and decreases its impact in the ranking process. For example, the Value Loss for a location with 3 fatalities and 2 major injuries would be calculated in terms of equivalent possible injury:

$$\text{Value Loss}_{\text{scenario1}} = (2 \times 400)_{\text{fatalities}} + (3 \times 60)_{\text{major injuries}} + (0 \times 4)_{\text{minor injuries}} + (0 \times 1)_{\text{possible injuries}} + (0)_{\text{PDO}} = 980 \text{ times the value of a possible injury}$$

The same location in the original list would have received the following:

Value $Loss_{original} = (3 \times 400)_{fatalities} + (2 \times 60)_{major\ injuries} + (0 \times 4)_{minor\ injuries} + (0 \times 1)_{possible\ injuries} + (0)_{PDO}$ = 1,320 times the value of a possible injury

Once Value Loss was recalculated as shown, locations were then re-ranked using the new Value Loss values. A new composite value was computed using the new Value Loss rank and the adjusted original Crash Frequency and Crash Rate rankings using the following:

$$Value_{composite} = 1/3(\text{Original Adjusted Crash Frequency Rank}) + 1/3(\text{Original Adjusted Crash Rate Rank}) + 1/3(\text{New Value Loss Rank}) \quad (5.3)$$

Table 5.1 illustrates the changes from the top ranked positions from the Iowa DOT’s re-ranked original ranking that occurred using each of the three scenarios. The remaining two scenarios are presented in the following sections. The number of locations dropped from the original list of the top ranked 50, 100, 150, and 200 positions are shown. When the first fatality was reassigned a value of a major injury, 16 (32%) of the locations that were ranked in the original top 50 were ranked lower than 50th and 22 (22%) of the locations in the original top 100 list would no longer have been included in that list. For locations ranked in the original top 150 positions, 20 (13%) were ranked lower than 150 after reassigning the value of the first fatality and 24 (12%) of the locations ranked in the top 200 positions dropped from the top 200.

Table 5.2 provides the original DOT rankings compared against the rankings resulting from reassigning the value of the first fatality for the original top 100 positions. Shown are the changes in position for individual locations. For example, the top location from the original list remained in the first position, while the location ranked 9th fell to the 25th position. The same information is provided graphically in Figures 5.1 and 5.2. As shown, more significant changes occurred for positions 26 to 50 than for positions 1 to 25.

Table 5.1. Locations Dropped from the Original SICL For Different Scenarios

Scenario	**Top 50**	**Top 100**	**Top 150**	**Top 200**
First Fatality Reassigned Value of a Major Injury	16 (32%)	22 (22%)	20 (13%)	24 (12%)
Only Fatality Reassigned Value of a Major Injury	20 (40%)	23 (23%)	22 (15%)	24 (12%)
All Fatals Reassigned Value of a Major Injury	18 (36%)	22 (22%)	20 (13%)	25 (13%)

Table 5.2. Original Rankings Versus Ranking From When First Fatality is Treated as a Major Injury

Original	First to Major		Original	First to Major		Original	First to Major
1	1		35	31		68	141
2	2		36	84		69	24
3	3		37	86		70	62
4	6		38	56		70	233
5	9		39	65		72	211
6	5		40	45		73	112
7	4		41	94		74	15
8	8		42	115		75	16
9	25		43	54		76	71
10	14		44	72		77	310
11	10		45	27		78	108
12	11		46	66		79	76
13	13		47	36		79	73
14	17		48	68		81	66
15	20		49	58		82	177
16	29		50	22		83	178
17	7		51	80		84	95
18	21		52	36		85	98
19	38		53	79		86	167
20	19		54	34		87	119
21	90		55	57		88	311
22	100		56	126		89	295
23	26		57	87		90	404
24	59		58	40		91	32
25	18		59	116		92	223
26	64		60	88		93	35
27	30		61	43		94	103
28	23		61	73		95	313
29	39		63	55		96	48
30	93		64	11		97	50
31	33		65	140		98	49
32	42		66	41		99	224
33	45		67	63		100	44
34	28						

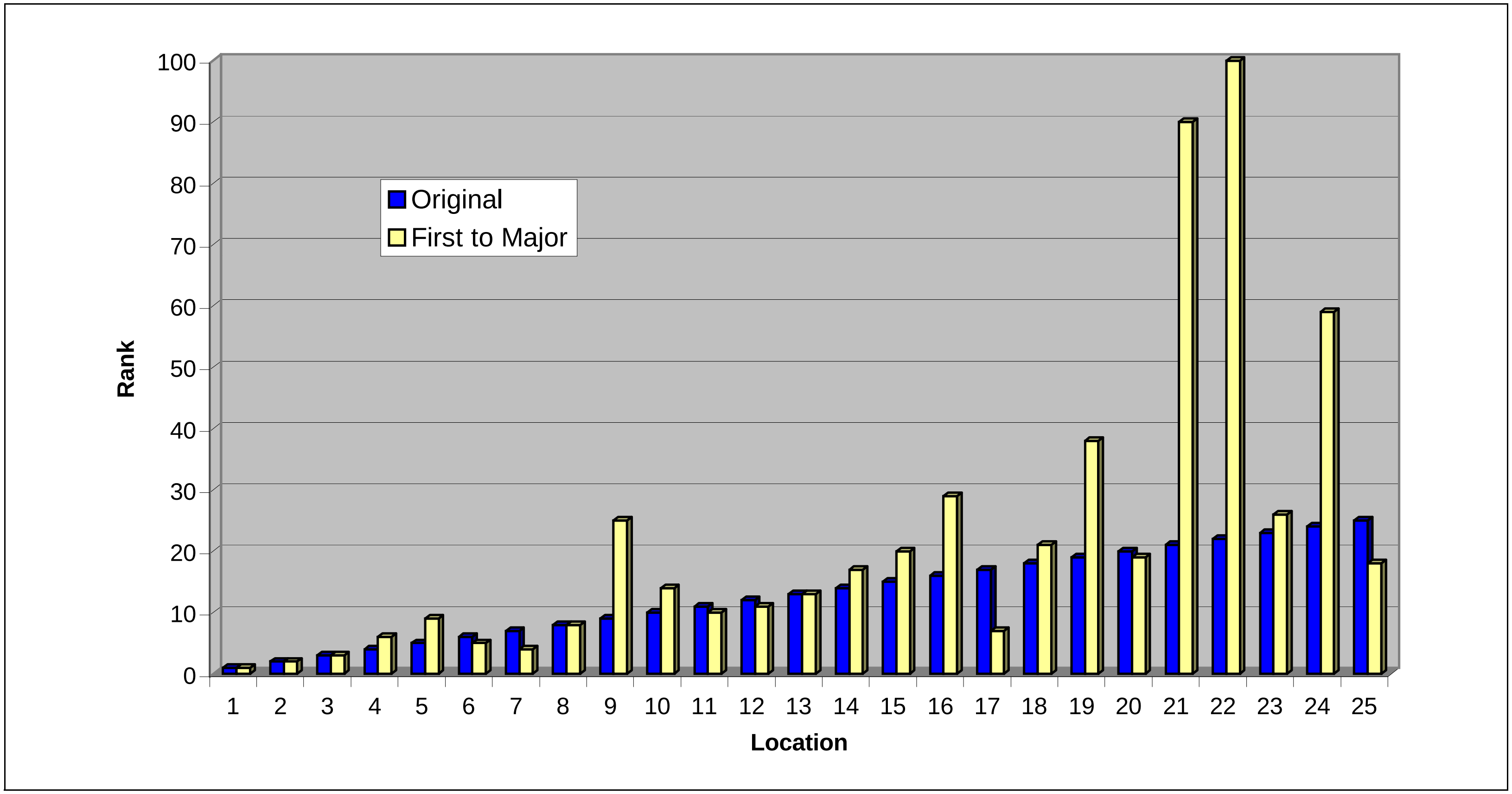

Figure 5.1. Change in Rank Between the Original Re-ranked SICL and the Scenario When the First Fatality is Reassigned the Value of a Major Injury for the Top 25 Positions

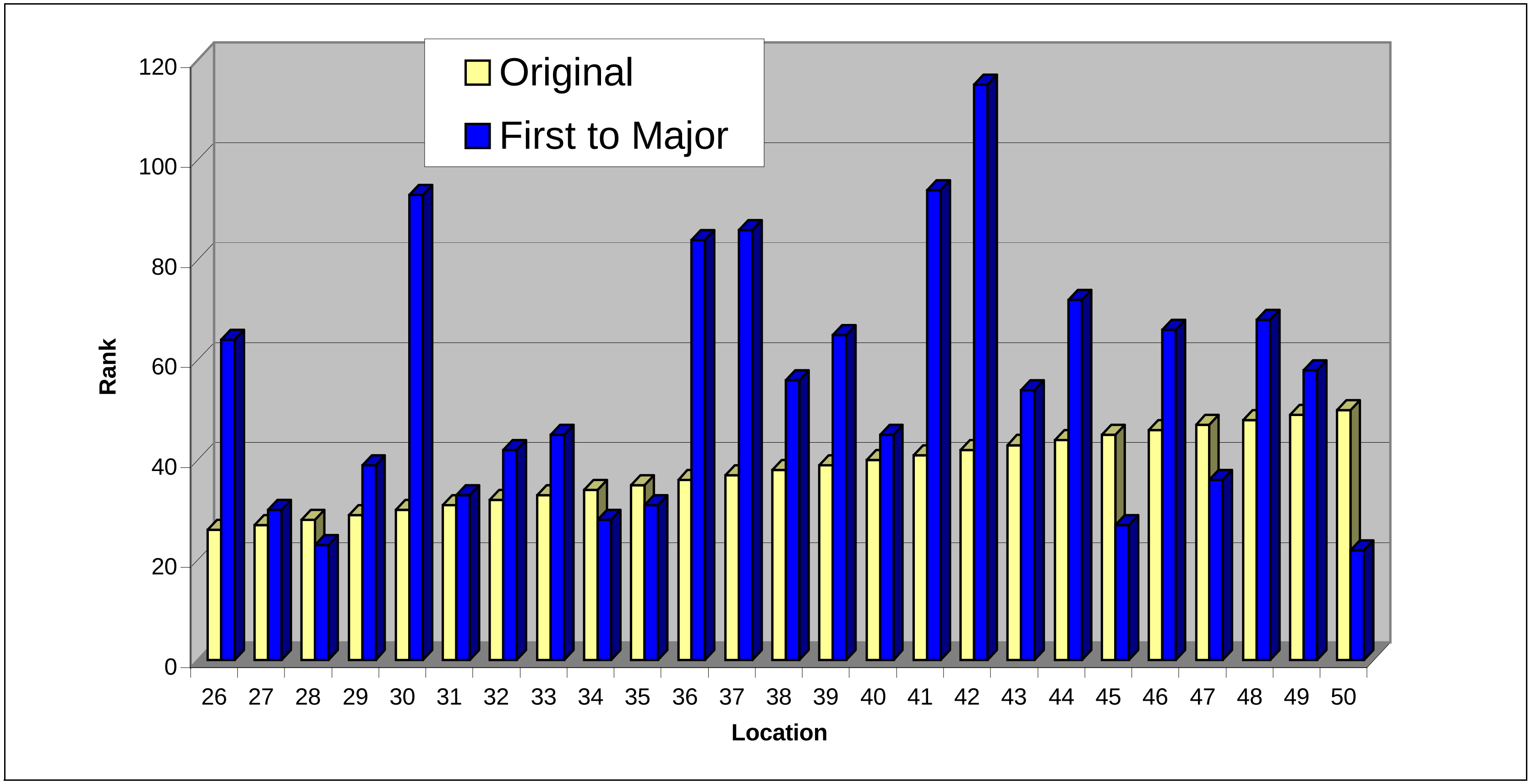

Figure 5.2. Change in Rank Between the Original Re-ranked SICL and the Scenario When the First Fatality is Reassigned the Value of a Major Injury for the Top 26 to 50 Positions

5.2.2. Only Fatality Assigned Value of Major Injury

The rationale for this scenario was that the presence of a single fatality in and of itself does not necessarily indicate that hazardous conditions are present. When a location had one and only one fatality, that fatality was reassigned the value of a major injury (60 times a possible injury) rather than 400 times a possible injury for recalculation of Value Loss. If a location had 2 or more fatalities, all fatalities were evaluated as fatalities. Value Loss was recalculated and re-ranked as for the previous scenario. A new composite value was calculated using the new Value Loss rankings.

Table 5.1 shows the change in the top 200 locations from the original rankings to the rankings that resulted when a single fatality at a location was reassigned the value of a major injury. A total of 20 (40%) of the original top 50 locations were no longer ranked in the top 50, while 23 (23%) of the locations listed in the original top 100 high crash locations would no longer have been included in the final list. This indicates that a single fatality may have a significant impact on the final ranking process.

Table 5.3 lists the original adjusted DOT rankings for the top 100 locations against their comparative rankings when a single fatality was reassigned the value of a major injury. Shown are the changes in position for individual locations. For example, the top location from the original list remained in the first position, while the location ranked 22nd fell to the 94ty position. The comparison is shown graphically in Figures 5.3 and 5.4. As shown, more significant changes occurred from positions 26 to 50 than for positions 1 to 25 as for the previous scenario.

Table 5.3. Comparison of the Original Re-ranked SICL with the Composite Ranking When the Only Fatality is Treated as Major Injury (Top 100)

Original	Only Fatal to Major	Original	Only Fatal to Major	Original	Only Fatal to Major
1	1	35	34	68	162
2	2	36	97	69	20
3	3	37	98	70	54
4	8	38	66	70	233
5	11	39	80	72	210
6	6	40	51	73	124
7	5	41	107	74	12
8	9	42	113	75	13
9	21	43	58	76	68
10	16	44	86	77	310
11	10	45	22	78	115
12	14	46	71	79	73
13	15	47	33	79	70
14	19	48	69	81	61
15	23	49	60	82	177
16	40	50	18	83	178
17	4	51	86	84	99
18	26	52	31	85	99
19	49	53	83	86	171
20	24	54	29	87	125
21	84	55	59	88	311
22	94	56	138	89	295
23	32	57	93	90	404
24	54	58	35	91	27
25	17	59	126	92	223
26	65	60	99	93	30
27	42	61	38	94	102
28	24	61	76	95	313
29	54	63	50	96	42
30	89	64	7	97	45
31	37	65	157	98	44
32	62	66	36	99	224
33	64	67	57	100	39
34	28				

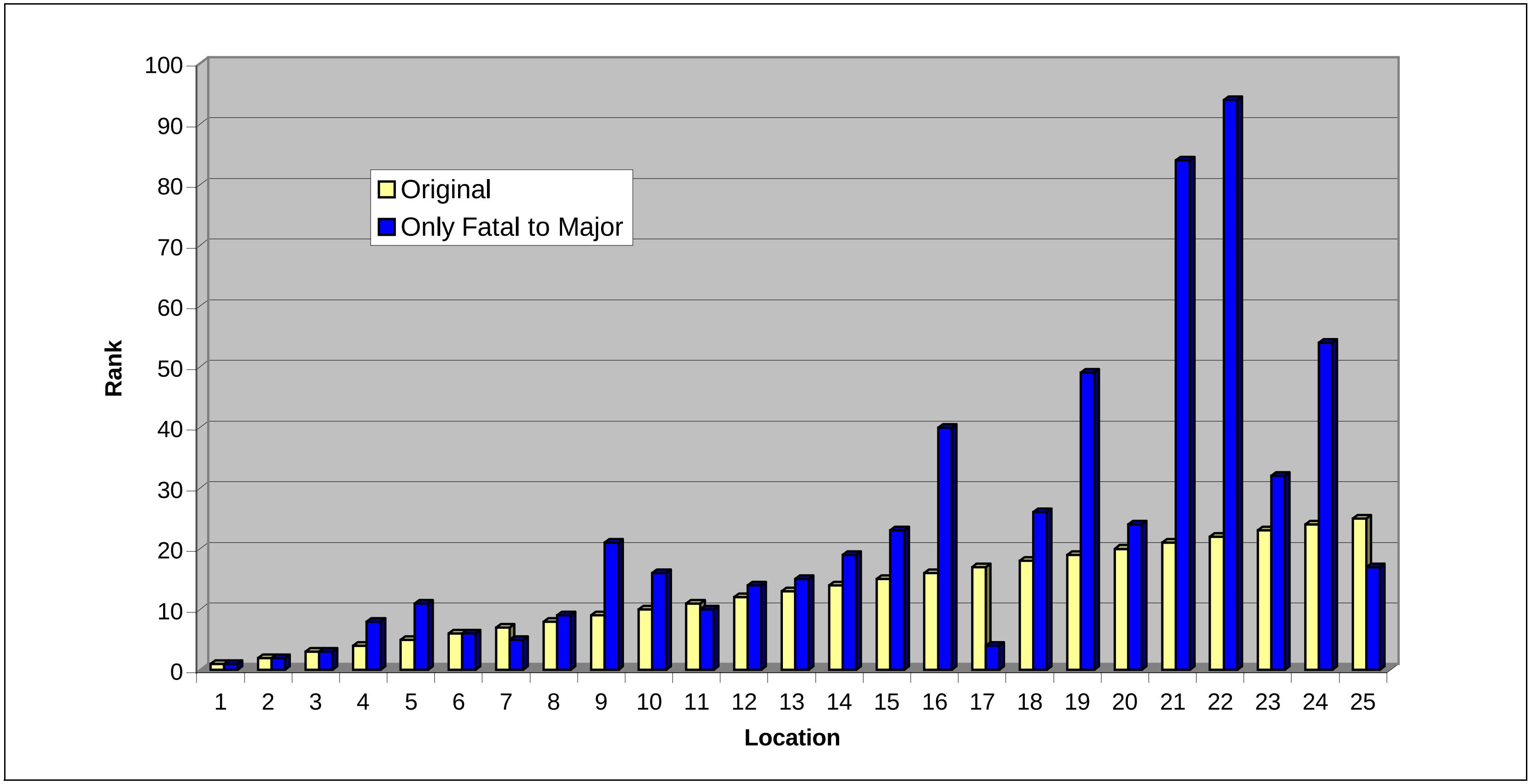

Figure 5.3. Change in Rank Between the Original Re-ranked SICL and the Scenario When the Only Fatality is Reassigned the Value of a Major Injury for the Top 25 Locations

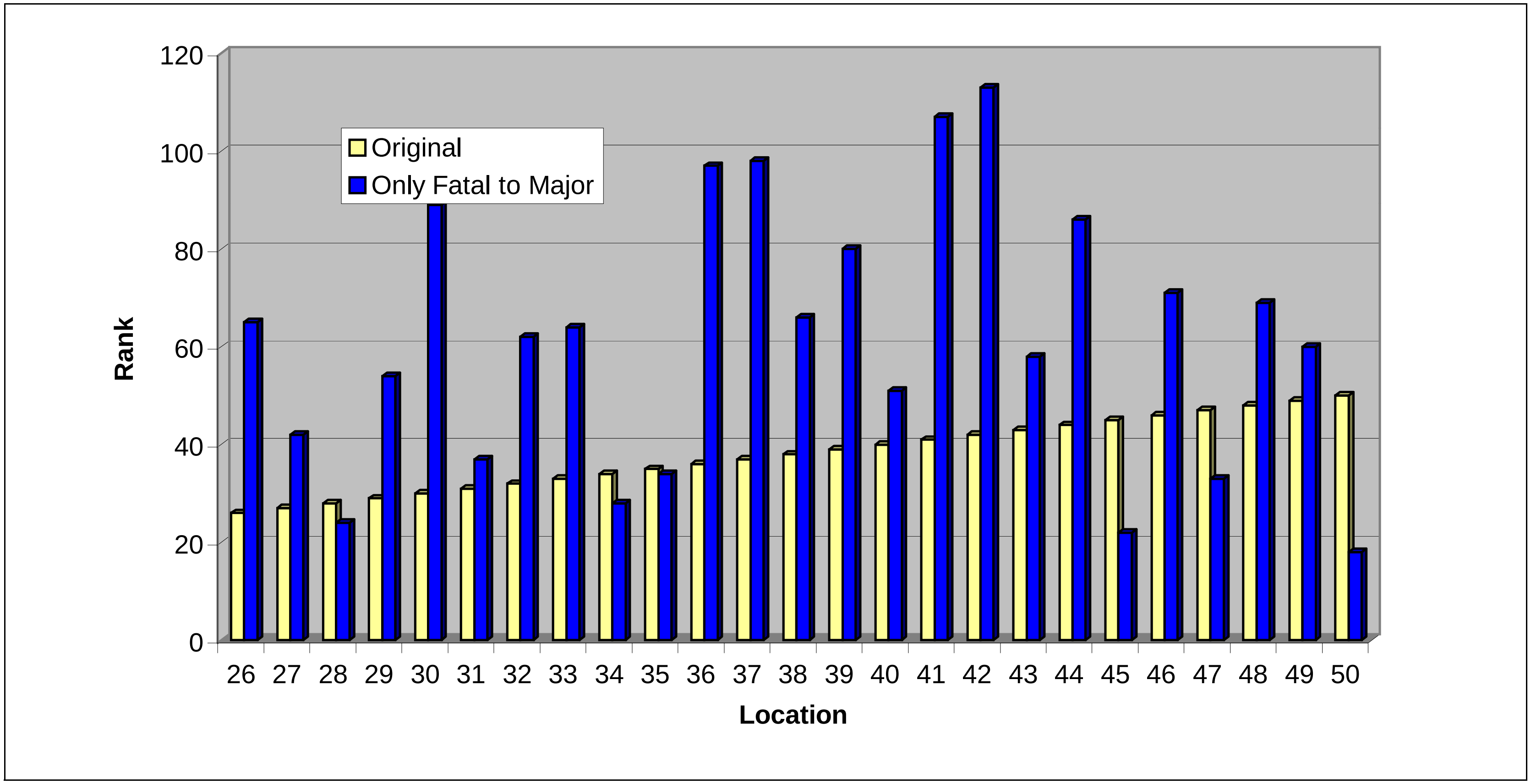

Figure 5.4. Change in Rank Between the Original Re-ranked SICL and the Scenario When the Only Fatality is Reassigned the Value of a Major Injury for Locations 26 to 50

5.2.3. All Fatalities Assigned Value of Major Injuries

For this scenario, all fatalities were reassigned the value of a major injury. This minimized the impact of fatalities altogether. Value Loss was recalculated using the adjusted value. A new composite value was computed using the new Value Loss rank and the original Crash Frequency and Crash Rate ranks from the original adjusted DOT ranking from:

Table 5.1 above shows the number of locations that dropped out of the top 50, 100, 150, and 200 positions from the re-ranked original rankings from the Iowa DOT when all fatalities were assigned 60 times the value of a possible injury rather than 400 times the value of a possible injury. A total of 18 (36%) of the re-ranked original top 50 locations were no longer ranked in the top 50, while 22 (22%) of the locations listed in the original top 100 high crash locations would no longer have been included in the final list.

Table 5.4 lists the original DOT rankings for the top 100 locations against their comparative rankings when all fatalities were reclassified as major injuries. Shown are the changes in position for individual locations. For example, the top location from the original list remained in the first position, while the location ranked 22nd fell to the 107th position. The comparison is shown graphically in Figures 5.5 and 5.6. As shown, more significant changes occurred from positions 26 to 50 than for positions 1 to 25 as for the previous two scenarios.

Table 5.4. Comparison of the Original Re-ranked SICL with the Composite Ranking When All Fatalities are Reassigned the Value Loss Value of a Major Injury (Top 100)

Original	All Fatals to Major		Original	All Fatals to Major		Original	All Fatals to Major
1	1		35	32		68	149
2	3		36	87		69	20
3	6		37	88		70	55
4	5		38	61		70	238
5	8		39	75		72	210
6	9		40	44		73	118
7	2		41	99		74	13
8	11		42	114		75	15
9	22		43	52		76	68
10	16		44	79		77	319
11	10		45	23		78	108
12	11		46	69		79	72
13	14		47	31		79	71
14	18		48	67		81	62
15	30		49	58		82	173
16	37		50	19		83	175
17	4		51	80		84	93
18	26		52	29		85	93
19	43		53	78		86	164
20	21		54	28		87	120
21	95		55	55		88	322
22	107		56	128		89	298
23	26		57	86		90	416
24	53		58	36		91	33
25	17		59	132		92	220
26	63		60	91		93	34
27	38		61	40		94	97
28	24		61	74		95	320
29	50		63	45		96	49
30	89		64	7		97	51
31	35		65	146		98	47
32	59		66	39		99	219
33	60		67	54		100	42
34	25						

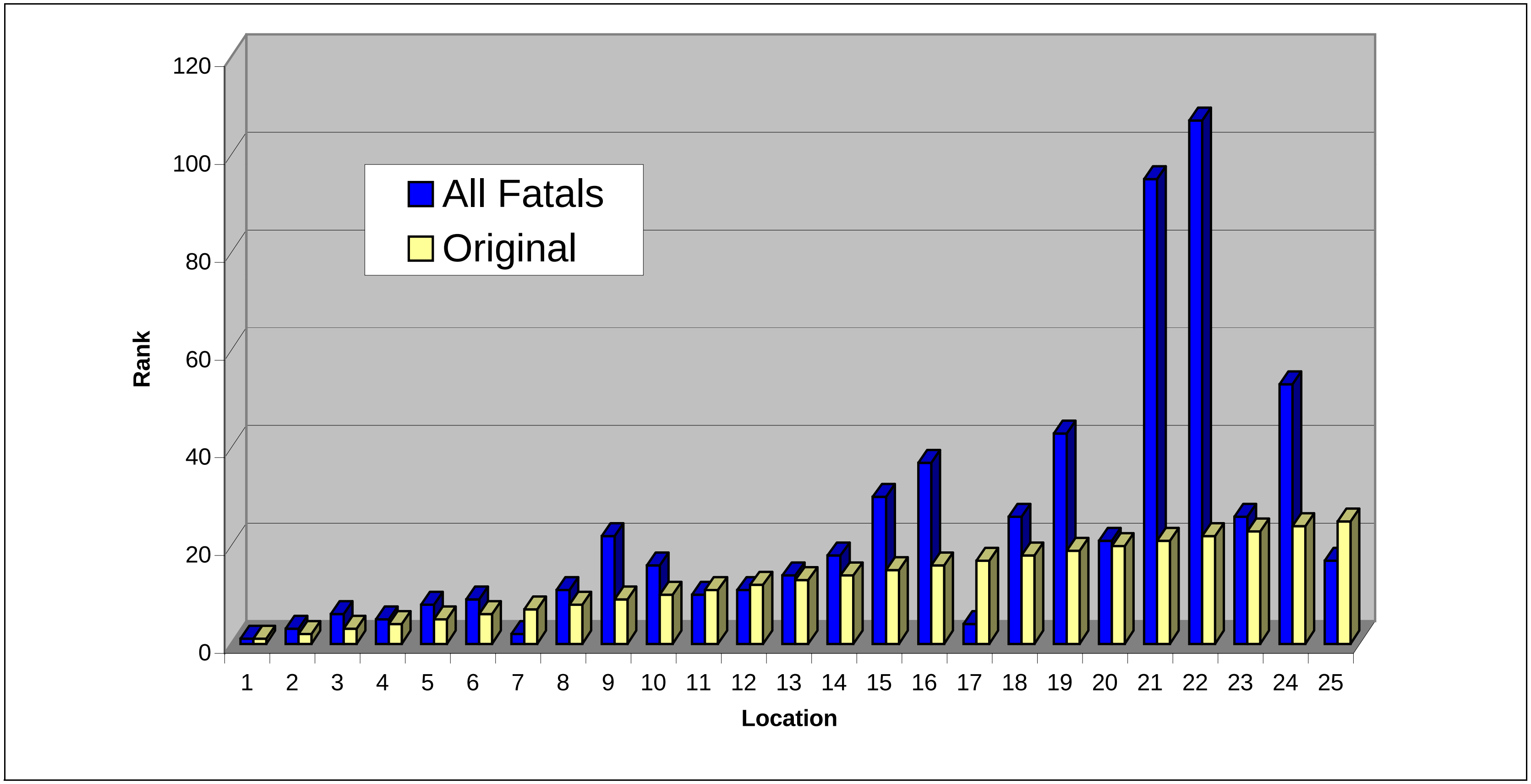

Figure 5.5. Change in Rank Between the Original Re-ranked SICL and the Scenario When All Fatalities are Reassigned the Value of a Major Injury for the Top 25 Locations

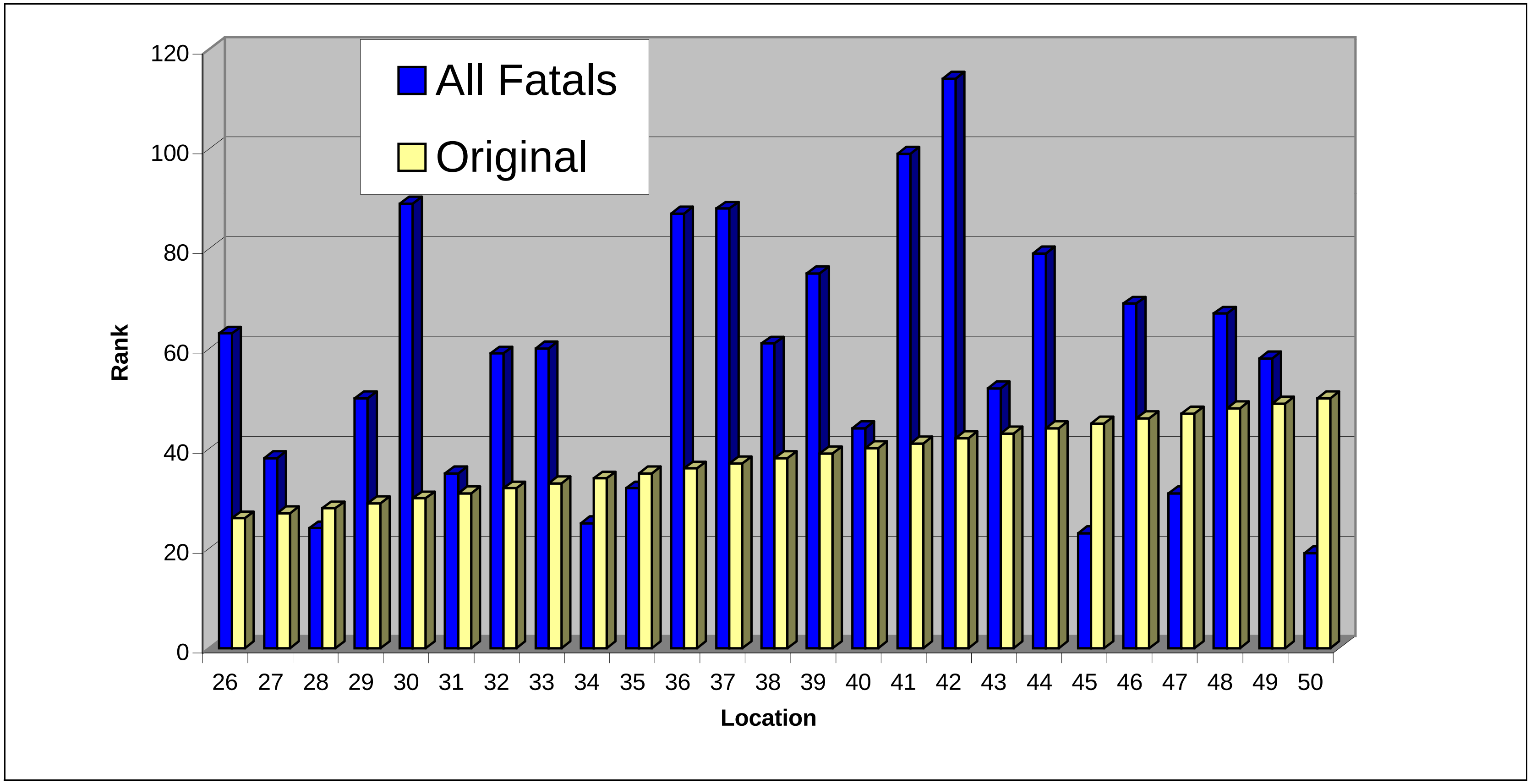

Figure 5.6. Change in Rank Between the Re-ranked Original SICL and the Scenario When All Fatalities are Reassigned the Value of a Major Injury for Locations 26 to 50

5.2.4. Count Only the First Fatality per Accident as a Fatality

A location that experiences three different crashes with a fatality each, is more likely to have a problem than location with a single crash with three fatalities. This scenario considered the impact that including multiple fatalities for a single accident had on the final ranking process. To evaluate the impact, data for each individual crash for the top 500 locations of the original Iowa DOT SICL were extracted from crash records. The number of fatalities was evaluated for each crash. If two or more fatalities resulted in a single accident, regardless of the number of vehicles involved in the crash, only one fatality was assigned the value of a fatality and the other fatalities were assigned the value of a major injury. Only the top 500 SICL locations were considered in this analysis due to the extensive data that had to be evaluated to determine whether more than one fatality occurred in a single crash.

Several of the top 500 locations also had crash rates equal to zero, indicating no volume information was available for those locations. The Iowa DOT does have a method for dealing with locations that have no volume given. However, that same method could not be applied, so locations with crash rate equal to zero were dropped from the list and Crash Frequency, Crash Rate, and Value Loss were re-ranked. The final list was also re-ranked using the adjusted ranks for Crash Frequency, Crash Rate, and Value Loss. The process was similar to that described for the previous scenarios.

Of the 500 locations, one location had a single crash with three fatalities. Twelve locations had a single crash with two fatalities. The other locations had either a single fatality or no fatalities reported. The first fatality was assigned the regular value for a fatality and the second and higher fatalities were assigned the value of a major injury. Value Loss was recalculated and re-ranked. A new composite value was also estimated as discussed for the previous scenarios and the locations re-ranked by the new composite value. Table 5.5 shows the 13 locations that had multiple fatalities per accident and compares their position in the original re-ranked SICL to their final rank in this scenario. None of the 13 multiple fatality locations were in the original re-ranked top 100 positions. Two were included in the top 150 and three were included in the top 200 positions. All 13 locations moved down in rank after the value for additional fatalities was lowered to a major injury. The top original list of the top 100 locations was not affected by treating multiple fatalities in a single crash as major injuries. However there were so few locations that had multiple fatalities that it was difficult to gauge the effect of treating those locations differently in the Value Loss calculations.

Table 5.5. Change in Rank for Locations with Multiple Fatality Crashes From Original Re-ranked SICL to Scenario SICL

Low Node	High Node	Original Adjusted Rank	Rank After Treating Multiple Fatalities as Major Injuries
340133	999999	115	156
349117	999999	138	150
348183	999999	196	198
127765	127965	210	234
236565	999999	210	250
139547	999999	237	267
239681	999999	253	275
223176	999999	268	285
211792	211793	280	329
442337	443105	285	351
233145	999999	296	295
221790	999999	314	373
211486	999999	319	359

5.3. Summary of Findings for Evaluation of Fatalities on the Final Ranking Process

Four different scenarios were used to evaluate the impact of fatalities on the Value Loss ranking and subsequently the final composite ranking that results in the safety improvement candidate list generated annually by the Iowa DOT. Since Value Loss ranking weights crashes according to severity, with significant weight given to fatal accidents, it was felt that the final ranking process may be biased towards fatalities. The impact of fatalities on the final ranking was evaluated by considering three different scenarios, which include the following:

- First Fatality Assigned Value Loss of a Major Injury
- An Only Fatality Assigned Value Loss of a Major Injury
- All Fatalities Assigned Value Loss of a Major Injury
- Count Only the First Fatality per Accident as a Fatality, Treat Others as Major Injuries

Consideration of fatalities as indicated, lowered the final Value Loss amount assigned to individual locations that were impacted by the scenario. When a fatality was reassigned the value of a major injury, the Value Loss dropped from 400 times to 60 times the value of a possible injury. The value of a fatality was reduced roughly 6.7 times its original value. This affected the Value Loss ranking of each individual location impacted by the scenario and subsequently the final composite ranking as described in the previous sections.

Significant changes occurred when the contribution of fatalities was reduced for all scenarios. At least 20% of the top 100 locations from the original re-ranked safety improvement candidate list for the 1995–1999 analysis period were not included in the individual lists of top 100 locations generated from all three test scenarios. For the top 50 locations, 30% to 40% of the original locations were not included in the final lists generated by any of the scenarios. This suggests that current weighting of fatalities significantly influences the Value Loss ranking and subsequently the final ranking process.

Even when locations remained in the top 50 or top 100, the ranking of individual locations was significantly influenced by the three different scenarios as demonstrated in Tables 5.2 to 5.4 and Figures 5.1 to 5.6. For instance, when all fatalities were reassigned the value of major injuries, the location that was ranked 9th in the original safety improvement candidate list would have dropped to the 22nd position. As a result, the priority given to individual locations changes. This may ultimately affect how resources are programmed for safety improvements.

Of particular interest is that the final safety improvement candidate list appears to be influenced by a single fatality at a location. One of the three scenarios targeted locations that had a single fatality. Under this scenario, when a location had one fatality for the five-year analysis period, that fatality was assigned a Value Loss equal to that of a major injury. When a location had two or more fatalities, all fatalities were left with the regular value of a fatality. Under this scenario, 23 of the original re-ranked 100 high crash locations were not included in the top 100 list generated when the scenario was applied. Of the top 50 locations in the original SICL, 40% were not included in the top 50 list. This suggests that the presence of even a single fatality affects which locations are selected for final rankings.

The main conclusion of this portion of the research is that the safety improvement candidate list process is influenced by fatalities, particularly a single fatality, based on the dollar value given them in the Value Loss Ranking. Given that a single fatal accident may be due to a number of variables, consideration should be given to how locations with only one fatality are treated.

5.4. Recommendations for Evaluation of Fatalities on the Final Ranking Process

As discussed, fatalities have a significant impact on the selection of safety improvement candidate locations. Whether or not this should influence the manner in which the Iowa DOT evaluates candidate locations depends on the priorities of the Iowa DOT. Prevention of fatalities may be a significant concern, particularly at the national level, and consequently a method that favors fatal locations is desirable. However, the following recommendations are offered in light of research results.

1. Consider the impact of a single fatality: Even if fatalities are a priority, the significant influence that a single fatality has on the process should be addressed. Due to the random nature of crashes, it is unlikely that the occurrence of only one fatality at a location in a five-year period indicates geometric or operation deficiencies at that location. However, the results of this research indicate that the current process is affected by a single fatality, both in terms of which locations are included in final rankings as well as the priority given to a specific location. A policy may be adopted that minimizes the impact of a single fatality by adjusting the Value Loss contribution of that fatality, similar to the methodology described in the preceding sections.

2. Analyze the temporal component of fatalities: Since fatalities influence the process significantly, it may also be advisable to consider when those fatalities occur. A location that experiences several fatalities at once may be viewed differently than a location that regularly experiences fatalities. Five fatalities at a location during a winter storm indicate a radically different problem than a location that experiences one fatality a year for five years. In the current process, both situations are treated identically. The impact of multiple fatalities per crash was evaluated but did not yield any significant conclusions since there were so few sites that actually had at least one crash with multiple fatalities. As a result, it is unlikely that enough locations have multiple fatalities per crash to significantly affect the overall ranking process. However, it is relatively easy to isolate locations that meet these criteria and treat the severity of multiple fatalities differently than single fatality crashes.

3. Minimize impact of fatalities on the ranking process: Although loss of life has tremendous societal and economic impacts, Crash Rate may be a better indication of operational or geometric deficiencies that can be corrected. If internal priorities indicate that fatalities are less of a priority than other factors, such as crash rate, consideration should be given to minimizing the contribution of Value Loss to the final composite ranking method or minimizing the contribution of fatalities.

6. SENSITIVITY ANALYSIS OF COMPOSITE RANKING COEFFICIENTS

Another objective of this research was to evaluate the coefficients used to arrive at the final SICL rankings. A sensitivity analysis was performed to evaluate the impact that each of the three methods had on the final rankings. Concern was expressed that the high values given to fatalities in the Value Loss ranking method may bias the final ranking towards locations with fatalities. Additionally, some safety researchers (Zeeger, 1986; McMillen, 1999; Laughland et al., 1975) consider Crash Rate and Severity to be better measures of safety problems than Frequency, suggesting that the three methods should not be given equal weight in the final ranking process. A sensitivity analysis would provide insight into the actual contribution that each has on the final process and provide guidance on the impact of adjustments to the model to match department priorities.

The Iowa DOT SICL process uses a combination of Crash Frequency, Crash Rate, and Value Loss to rank and identify high crash locations. Locations are ranked according to the three methods (described in more detail in Section 3.4) and then a final composite value calculated. The final composite value is determined by the following:

$$CRV_i = c_1 R_{cf(i)} + c_2 R_{cr(i)} + c_3 R_{vl(i)} \tag{6.1}$$

where

CRV_i = composite value for location i
$R_{cf(i)}$ = the rank of location i using Crash Frequency
$R_{cr(i)}$ = the rank of location i using Crash Rate
$R_{vl(i)}$ = the rank of location i using Value Loss
c_1, c_2, c_3 = weighting coefficients

After the composite value is calculated, locations are sorted in ascending order by the composite value and re-ranked. The location with the lowest composite value is assigned the rank of 1. The current Iowa DOT method gives equal weight to each of the three methods resulting in coefficients of 1/3, 1/3, and 1/3 for c_1, c_2, and c_3.

To perform a sensitivity analysis, the coefficient for each method was varied from 0 to 1. This provided a range from minimum contribution by the method to maximum contribution by the method to the final ranking. Twenty-seven different combinations of coefficients were tested to evaluate the change that would result in the final ranking. The methodology and results of the sensitivity analysis are described in the following sections.

6.1. Description of Data

The crash database used in the analysis included crashes that occurred from 1995 to 1999. A total of 10,534 crash locations in Iowa were included. This data set represented crash locations after the 1-4-8 initial screening process had been applied. Of the 10,534 locations, 2,692 were removed since no traffic volume data were available for those locations and locations without volume data could not be re-ranked using the Accident Rate Method. As a result, only 7,842 locations were used in the evaluation process. None of the removed locations were included in the top 200 positions.

6.2. Methodology

Twenty-seven combinations of coefficients were evaluated (see Tables 6.1 to 6.3). Coefficients were varied for each of the three methods; Crash Rate, Frequency, and Value Loss. For Table 6.1, the coefficient of Crash Frequency was varied from 0 to 1 in increments of 0.1. The coefficients for the other two methods were calculated so that they were equal and so that the total of the three coefficients equaled 1. In Table 6.2, the coefficients for Crash Rate were varied as for Crash Frequency and in Table 6.3, the coefficients were varied for Value Loss. A coefficient of 1 gave 100% weight to the method and a coefficient of 0 gave no weight to the method. The sensitivity of the Iowa DOT crash rankings to the new coefficient values was determined by comparing the resultant final rankings for each different set of coefficients to the Iowa DOT's original adjusted final ranking.

Table 6.1. Coefficient Values When the Crash Frequency Coefficient Was Varied

Alternative	Crash Frequency	Crash Rate	Value Loss
1	0.0	0.50	0.50
2	0.1	0.45	0.45
3	0.2	0.40	0.40
4	0.5	0.25	0.25
5	0.6	0.20	0.20
6	0.7	0.15	0.15
7	0.8	0.10	0.10
8	0.9	0.05	0.05
9	1.0	0.00	0.00

Table 6.2. Coefficient Values When the Crash Rate Coefficient Was Varied

Alternative	Crash Frequency	Crash Rate	Value Loss
10	0.50	0.0	0.50
11	0.45	0.1	0.45
12	0.40	0.2	0.40
13	0.25	0.5	0.25
14	0.20	0.6	0.20
15	0.15	0.7	0.15
16	0.10	0.8	0.10
17	0.05	0.9	0.05
18	0.00	1.0	0.00

Table 6.3. Coefficient Values When Contribution of Value Loss is Varied

Alternative	Crash Frequency	Crash Rate	Value Loss
19	0.50	0.50	0.0
20	0.45	0.45	0.1
21	0.40	0.40	0.2
22	0.25	0.25	0.5
23	0.20	0.20	0.6
24	0.15	0.15	0.7
25	0.10	0.10	0.8
26	0.05	0.05	0.9
27	0.00	0.00	1.0

Equation 6.1 was used to determine the composite value that resulted for each set of coefficients. The final rank for each location was determined by sorting the locations in ascending order by the resulting composite value.

6.3. Results of Descriptive Statistics

The rankings produced by the different combinations of coefficients and the original rankings from the Iowa DOT are compared in the following sections. The focus is on the top 200 locations that resulted from the different analyses as compared to the original adjusted top 200 locations and the resulting changes.

6.3.1. Differences in Locations Included in Original Top 50, 100, 150, and 200 Locations from the Safety Improvement Candidate Lists

Differences in locations included in the original adjusted safety improvement candidate list and those included for any particular combination of coefficients were tested. Comparisons are provided in Tables 6.4 to 6.6 and Figures 6.1 to 6.3. The tables show locations that dropped out of the original top 50, 100, 150, and 200 positions.

Crash Frequency

Change in positions when the coefficients for Crash Frequency were varied is shown in Table 6.4. Maximum differences are noted when the coefficient for crash frequency is near 1 and 0, as expected. When the weighting combination (0, 0.5, 0.5) (Crash Frequency contribution is 0) was applied, almost 50% of the locations from the original top 50, 100, 150, and 200 positions are no longer included. Application of the combination (1, 0, 0) results in more than 40% of the locations dropping out for each category. This combination represents the ranking that would result from using Crash Frequency alone. The minimum change occurred when the combinations (0.2, 0.4, 0.4), (0.5, 0.25, 0.25), (0.6, 0.2, 0.2), and (0.7, 0.15, 0.15) were applied, with less than 20% of locations dropping out in any category. This information is also provided graphically in Figure 6.1. As shown, changes are fairly equal at both ends of the x-axis. Decreasing the contribution of Crash Frequency seems to have a similar effect on the number of locations that drop out as the contribution is increased.

Table 6.4. Locations Dropped from the Original Iowa DOT Ranking Positions When the Crash Frequency Coefficient was Varied

Combination	Top 50	Top 100	Top 150	Top 200
(0, 0.5, 0.5)*	28 (56%)	48 (48%)	75 (50%)	97 (49%)
(0.1, 0.45, 0.45)	8 (16%)	18 (18%)	33 (22%)	45 (23%)
(0.2, 0.4, 0.4)	3 (6%)	9 (9%)	15 (10%)	18 (9%)
(0.5, 0.25, 0.25)	1 (2%)	5 (5%)	14 (9%)	24 (12%)
(0.6, 0.2, 0.2)	3 (6%)	8 (8%)	23 (15%)	33 (17%)
(0.7, 0.15, 0.15)	6 (12%)	13 (13%)	27 (18%)	38 (19%)
(0.8, 0.1, 0.1)	9 (18%)	18 (18%)	36 (24%)	49 (25%)
(0.9, 0.05, 0.05)	16 (32%)	27 (27%)	47 (31%)	58 (29%)
(1, 0, 0)**	28 (56%)	48 (48%)	61 (41%)	79 (40%)

* scenario where contribution of Crash Frequency is 0
** scenario where contribution of Crash Frequency is 100%

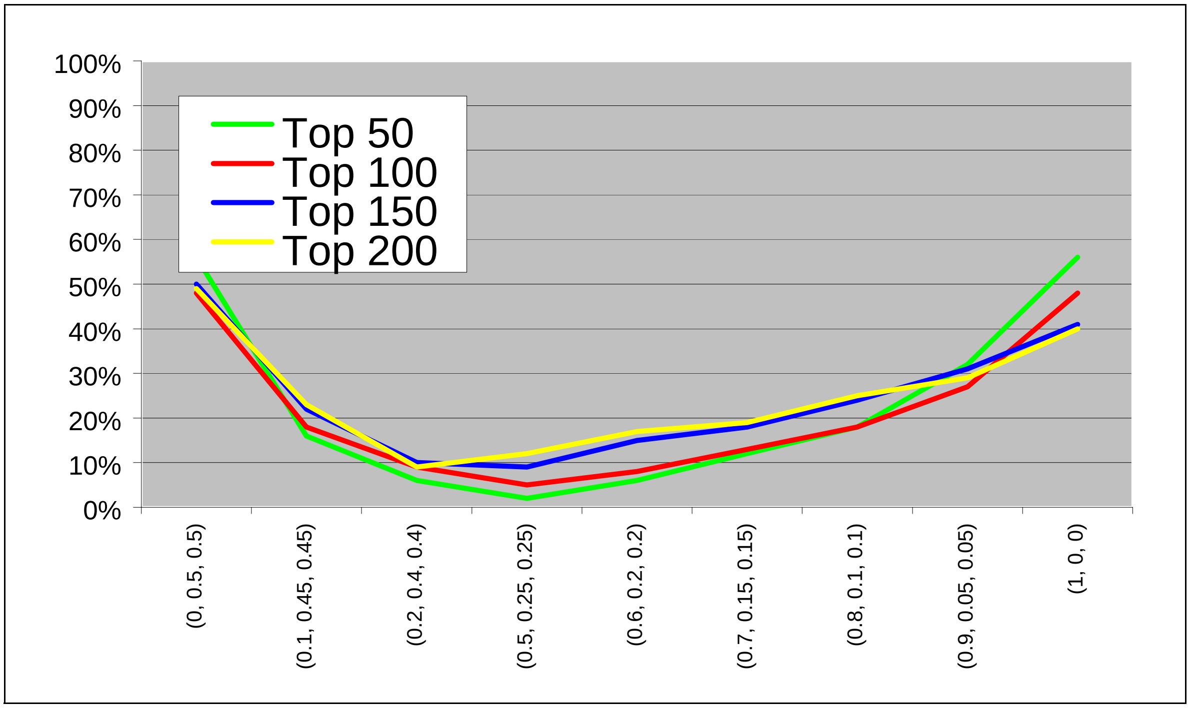

Figure 6.1. Number of Locations Dropped When Crash Frequency Varied

Crash Rate

The change in locations for the top ranking positions from the original list and those resulting when the Crash Rate coefficient was varied are shown in Table 6.5. The most significant changes occurred with the combinations (0.1, 0.8, 0.1), (0.05, 0.9, 0.05) and (0, 1, 0). These combinations represent increasing weight given to Crash Rate with (0, 1, 0) representing the ranking that would result if the Crash Rate Method were used alone. With the combination (0.1, 0.8, 0.1), more than 40% of the locations dropped out of each set of positions and for the combination (0.05, 0.9, 0.05), more than 60% of the locations dropped out. For the combination (0, 1, 0), none of the original locations remained for the Top 50 and more than 90% of the locations dropped out of the original Top 100, 150, and 200 positions. The minimum impact occurred for the combinations (0.4, 0.2, 0.4) and (0.25, 0.5, 0.25) with a change of less than 15% for each. Results are shown graphically in Figure 6.2.

The figure indicates that increasing the weight given to Crash Rate has significantly more impact on the number of locations that are dropped than minimizing the contribution of Crash Rate. If the three methods contributed equally to the final ranking process, the impact of minimizing or maximizing their individual contribution would result in similar changes. However, when the contribution of Crash Rate is increased, the resulting list of locations is less like the original list than when Crash Frequency is increased. If the SICL process is more influenced by one of the methods, increasing the contribution of that method should result in a list that is similar to the original and decreasing the contribution of that method should result in a list that is different from the original.

Table 6.5. Locations Dropped from the Original Iowa DOT Ranking When the Crash Rate Coefficient was Varied

Combination	Top 50	Top 100	Top 150	Top 200
(0.5, 0, 0.5)*	15 (30%)	29 (29%)	50 (33%)	78 (39%)
(0.45, 0.1, 0.45)	9 (18%)	14 (14%)	36 (24%)	49 (25%)
(0.4, 0.2, 0.4)	2 (4%)	7 (7%)	19 (13%)	23 (12%)
(0.25, 0.5, 0.25)	6 (12%)	13 (13%)	17 (11%)	24 (12%)
(0.2, 0.6, 0.2)	11 (22%)	23 (23%)	31 (21%)	41 (21%)
(0.15, 0.7, 0.15)	16 (32%)	34 (34%)	47 (32%)	60 (30%)
(0.1, 0.8, 0.1)	24 (48%)	52 (52%)	68 (45%)	86 (43%)
(0.05, 0.9, 0.05)	36 (72%)	72 (72%)	97 (65%)	125 (63%)
(0, 1, 0)**	50 (100%)	94 (94%)	142 (95%)	186 (93%)

* scenario where contribution of Crash Rate is 0
** scenario where contribution of Crash Rate is 100%

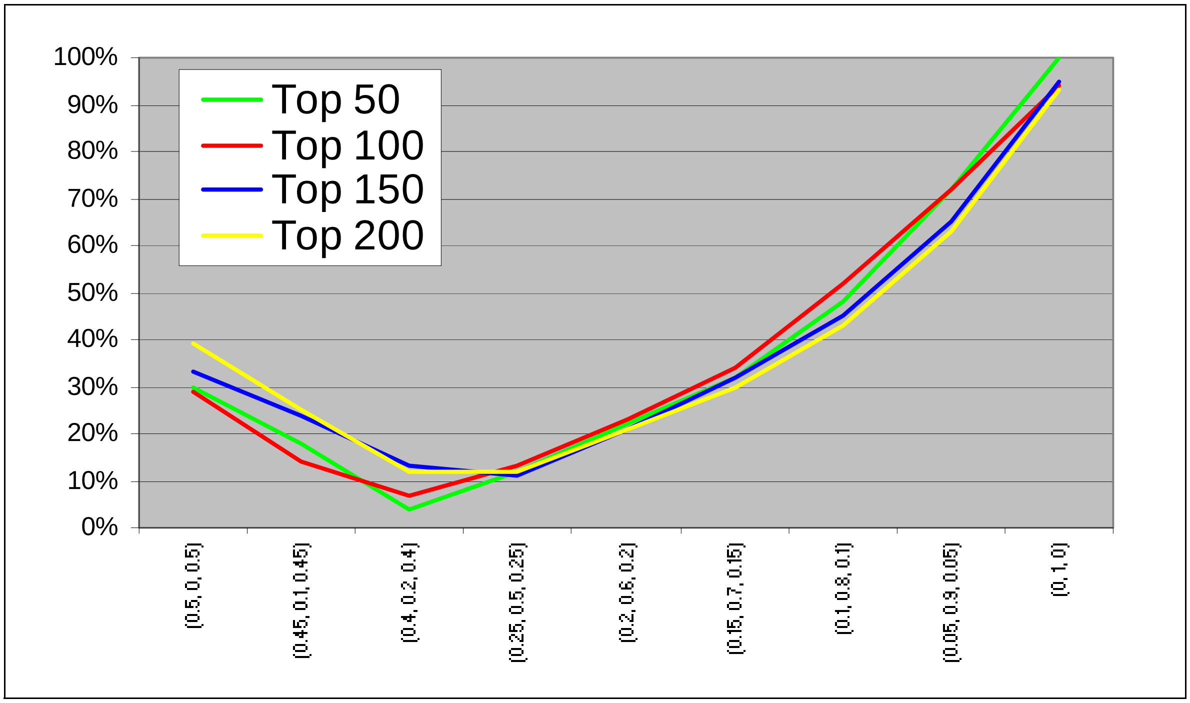

Figure 6.2. Number of Locations Dropped When Crash Rate Varied

Value Loss

The results of varying the Value Loss coefficient are shown in Table 6.6. The most significant change occurred when the coefficients (0, 0, 1) were used. This represents the ranking list that would result solely from Value Loss. Most of the top 50 locations changed and more than 80% of the original locations dropped from the Top 100, 150, and 200 positions. The combinations: (0.5, 0.5, 0), (0.05, 0.05, 0.9), and (0.1, 0.1, 0.8), also resulted in significant changes. For the combination (0.5, 0.5, 0), more than 38% of the locations dropped out of each category. This combination represents zero contribution by Value Loss. The combination (0.05, 0.05, 0.9) resulted in more than 48% of the locations dropping out of each category. Minor changes resulted for the combinations (0.4, 0.4, 0.2) and (0.25, 0.25, 0.5) for which less than 20% of the original locations dropped out of any category. The results are also shown in Figure 6.3. The impact of increasing the weight given to Value Loss appears to influence the number of crashes more significantly than decreasing the weight given to Value Loss as shown.

Table 6.6. Locations Dropped from the Original Iowa DOT Ranking When the Value Loss Coefficient was Varied

Combination	Top 50	Top 100	Top 150	Top 200
(0.5, 0.5, 0)*	27 (54%)	47 (47%)	62 (41%)	75 (38%)
(0.45, 0.45, 0.1)	15 (30%)	35 (35%)	38 (25%)	46 (23%)
(0.4, 0.4, 0.2)	5 (10%)	15 (15%)	25 (17%)	32 (16%)
(0.25, 0.25, 0.5)	3 (6%)	12 (12%)	31 (20%)	38 (19%)
(0.2, 0.2, 0.6)	9 (18%)	19 (19%)	34 (23%)	64 (19%)
(0.15, 0.15, 0.7)	11 (22%)	24 (24%)	42 (28%)	68 (34%)
(0.1, 0.1, 0.8)	15 (30%)	33 (33%)	55 (51%)	82 (42%)
(0.05, 0.05, 0.9)	28 (56%)	48 (48%)	76 (51%)	108 (54%)
(0, 0, 1)**	48 (96%)	87 (87%)	130 (87%)	168 (84%)

* scenario where contribution of Value Loss is 0

** scenario where contribution of Value Loss is 100%

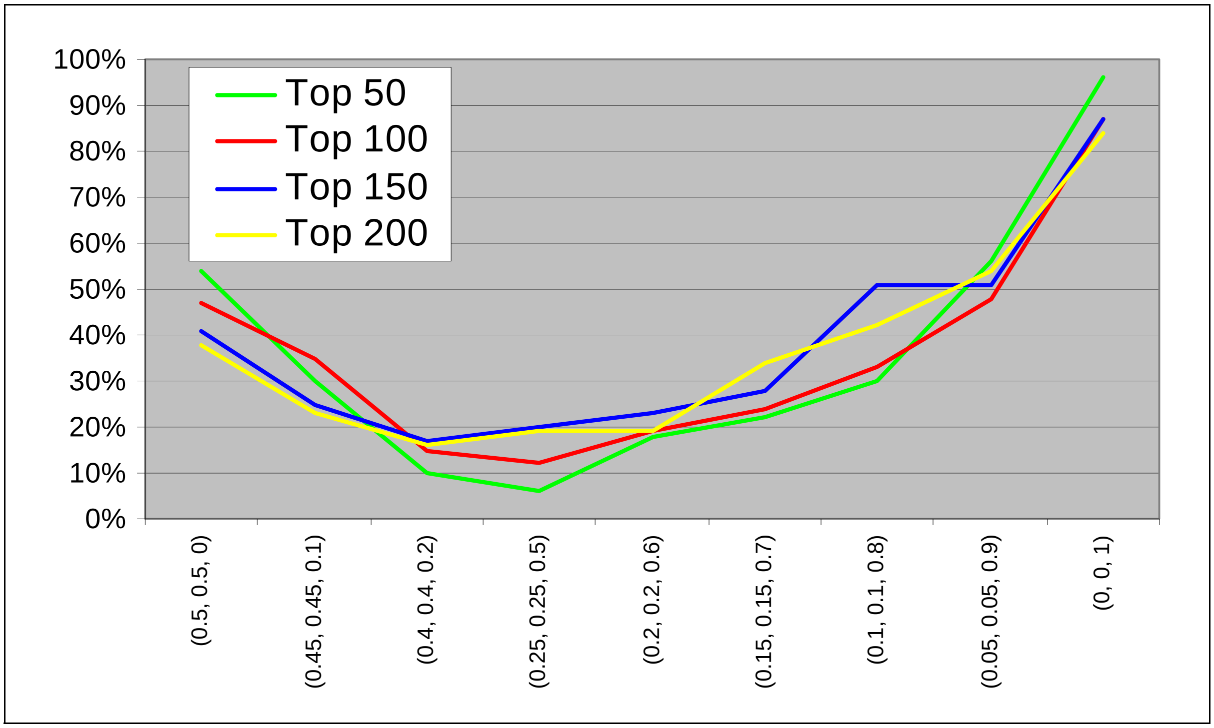

Figure 6.3. Number of Locations Dropped When Value Loss Varied

6.3.2. Change in Position for Individual Locations

The change in ranking of individual locations was also considered. Even if a location remains as one of the top 100 Safety improvement candidate locations after different weights are given to the three methods, the priority given to that location may change. This may ultimately affect how resources are programmed for safety improvements. To demonstrate changes in ranking for individual locations between the original Iowa DOT ranking and the rankings produced by the alternative combinations of coefficients, histograms were created for the most extreme cases. The extreme cases were those when the coefficient was either minimized (coefficient = 0) or maximized (coefficient = 1).

Figure 6.4 illustrates the change in rankings for locations when Crash Frequency was minimized (0, 0.5, 0.5) for the top 50 locations. The graph shows the impact on individual locations. For instance, the 5th ranked location from the original safety improvement candidate list is now ranked 100th, which would change the priority it received for further analysis significantly. As shown, the majority of locations that were originally in the top 50 positions moved down by 100 to 400 positions. Figure 6.5 shows the change in position for locations when Crash Frequency was maximized (1, 0, 0). The magnitude of change for individual locations is not as severe, although various locations change rank by 100 positions or more. It should be noted that the y-axis for Figures 6.4 to Figure 6.9 are not consistent in case comparison between the figures is made.

The change in rank for locations when Crash Rate was minimized (0.5, 0, 0.5) is provided in Figure 6.6. Most of the locations change position by less than 100. Figure 6.7 illustrates the change that resulted from maximizing Crash Rate (0, 1, 0). Most of the original top 50 locations drop to positions lower than 3000. For example, the rank of the location that was second in the original SICL drops to the rank of 3000. As shown, less change occurs when Crash Rate is minimized than when Crash Rate is maximized, indicating that Crash Rate does not influence the final ranking as much as Crash Frequency.

Figure 6.8 provides the histogram for the combination (0.5, 0.5, 0), which reflects the result when Value Loss is minimized. Figure 6.9 shows the results for the combination (0, 0, 1). This is the resulting ranking when Value Loss is maximized. The resulting change in rankings when Value Loss is minimized appear similar to the magnitude that results when Value Loss is maximized. A number of locations that were originally ranked from 1 to 50 drop to positions in the range from 200 to 800. When Value Loss is minimized the changes are more dramatic than when either Crash Rate or Crash Frequency are minimized. When Value Loss is maximized, the impact is greater than the impact of maximizing Crash Frequency and less than the impact of maximizing Crash Rate. This suggests that Value Loss may influence the final ranking more than Crash Rate but less than Crash Frequency.

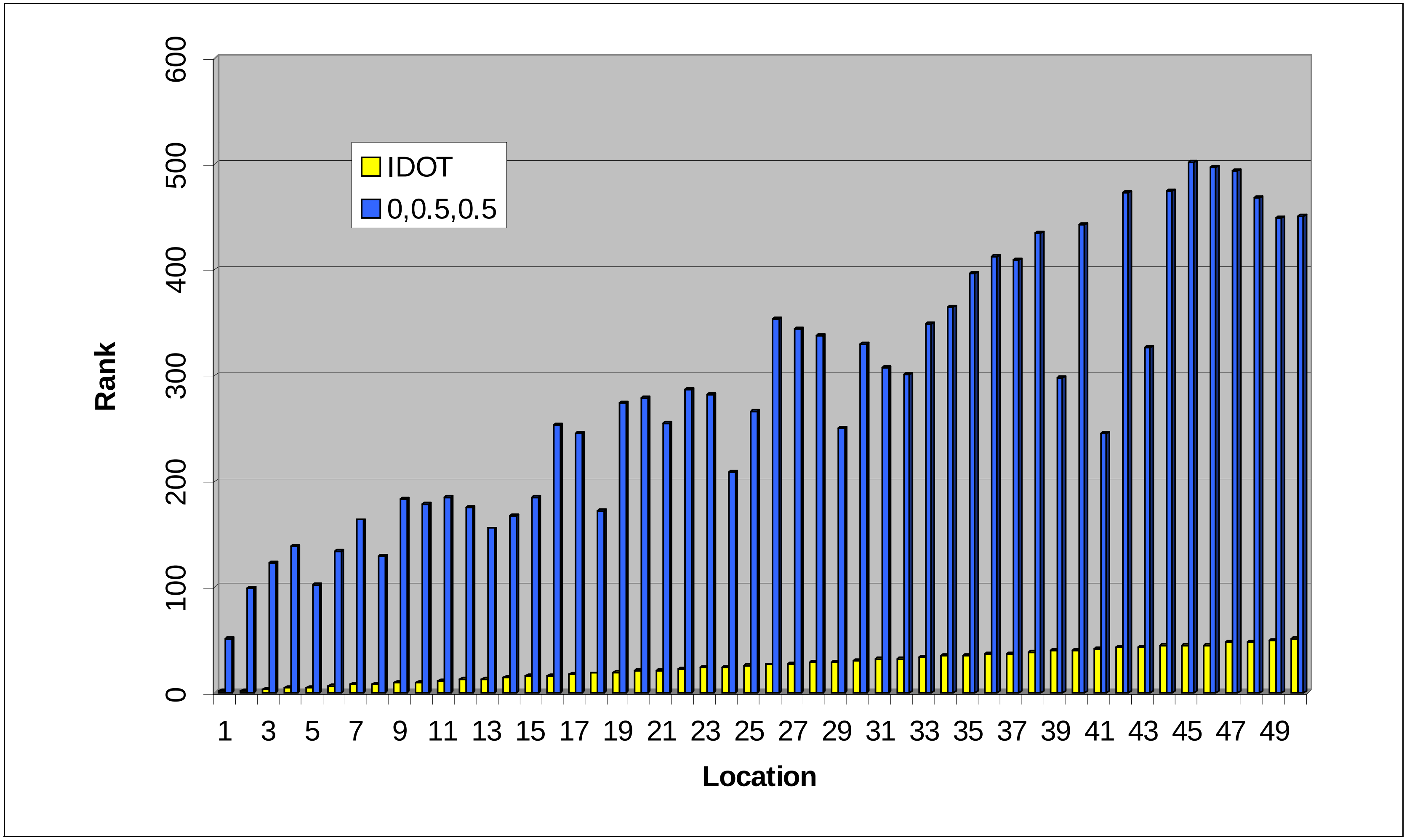

Figure 6.4. Change in Rankings for the Original Top 50 Locations When Crash Frequency is Minimized (0, 0.5, 0.5)

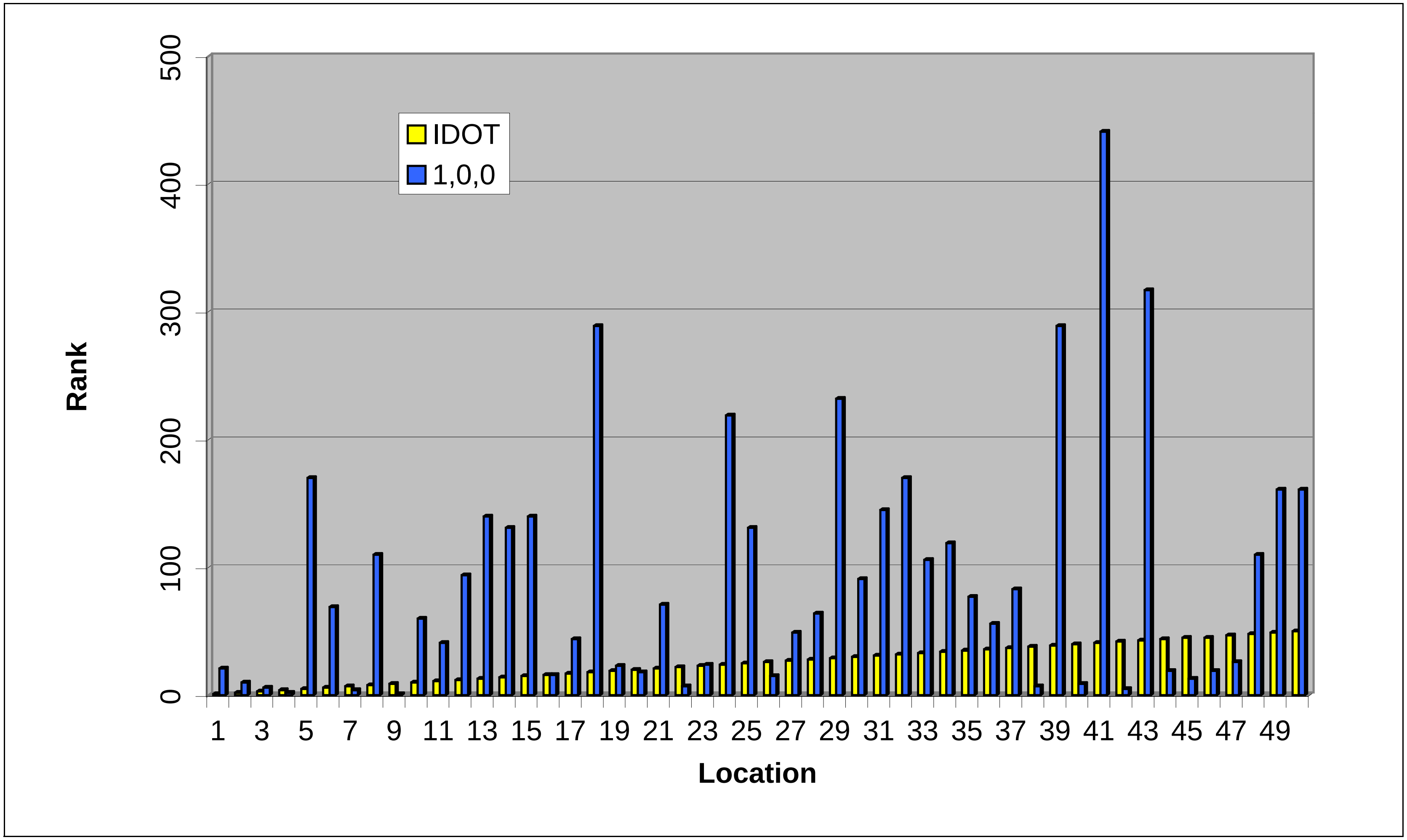

Figure 6.5. Change in Rankings for the Original Top 50 Locations When Crash Frequency is Maximized (1, 0, 0)

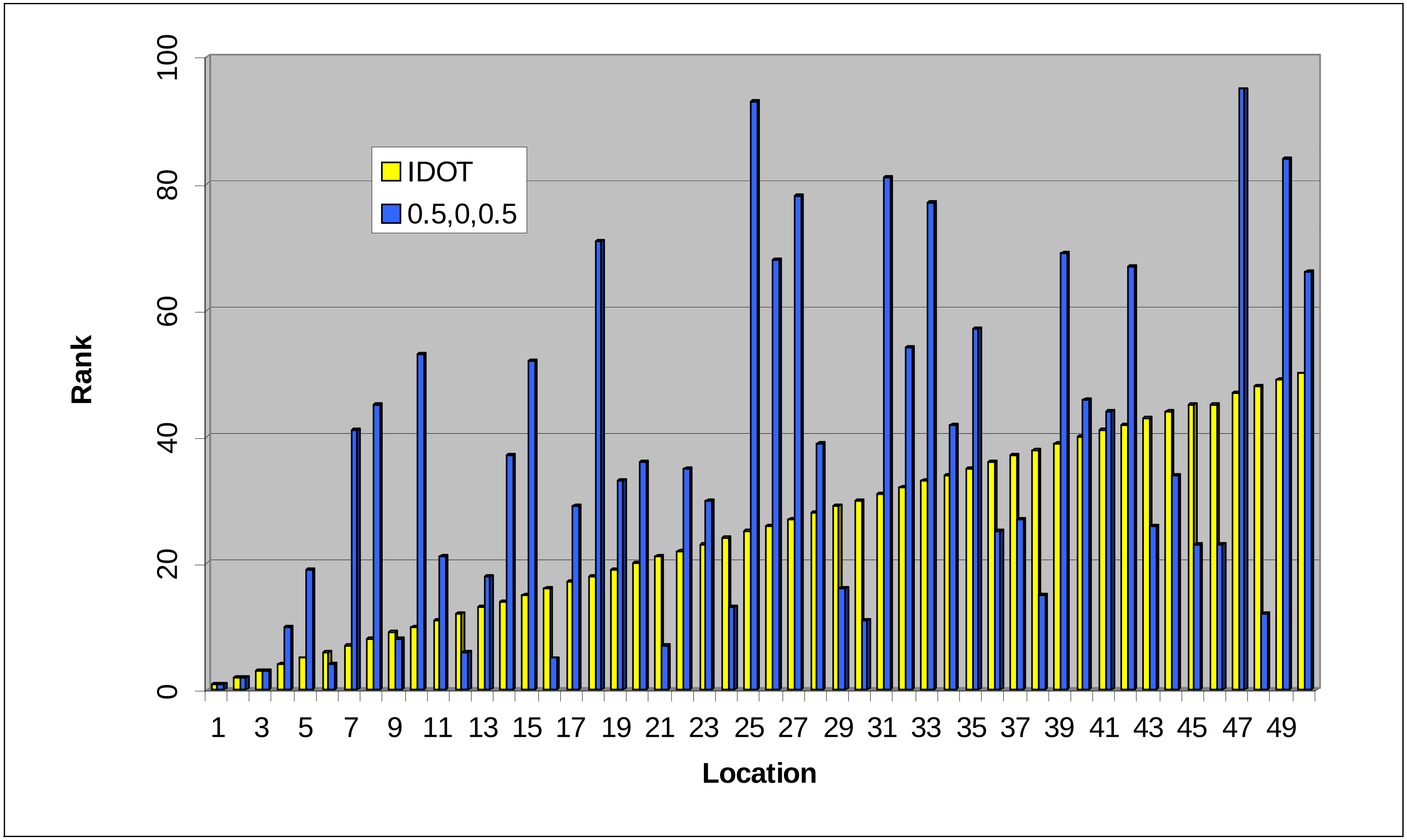

Figure 6.6. Change in Rankings for the Original Top 50 Locations When Crash Rate is Minimized (0.5, 0, 0.5)

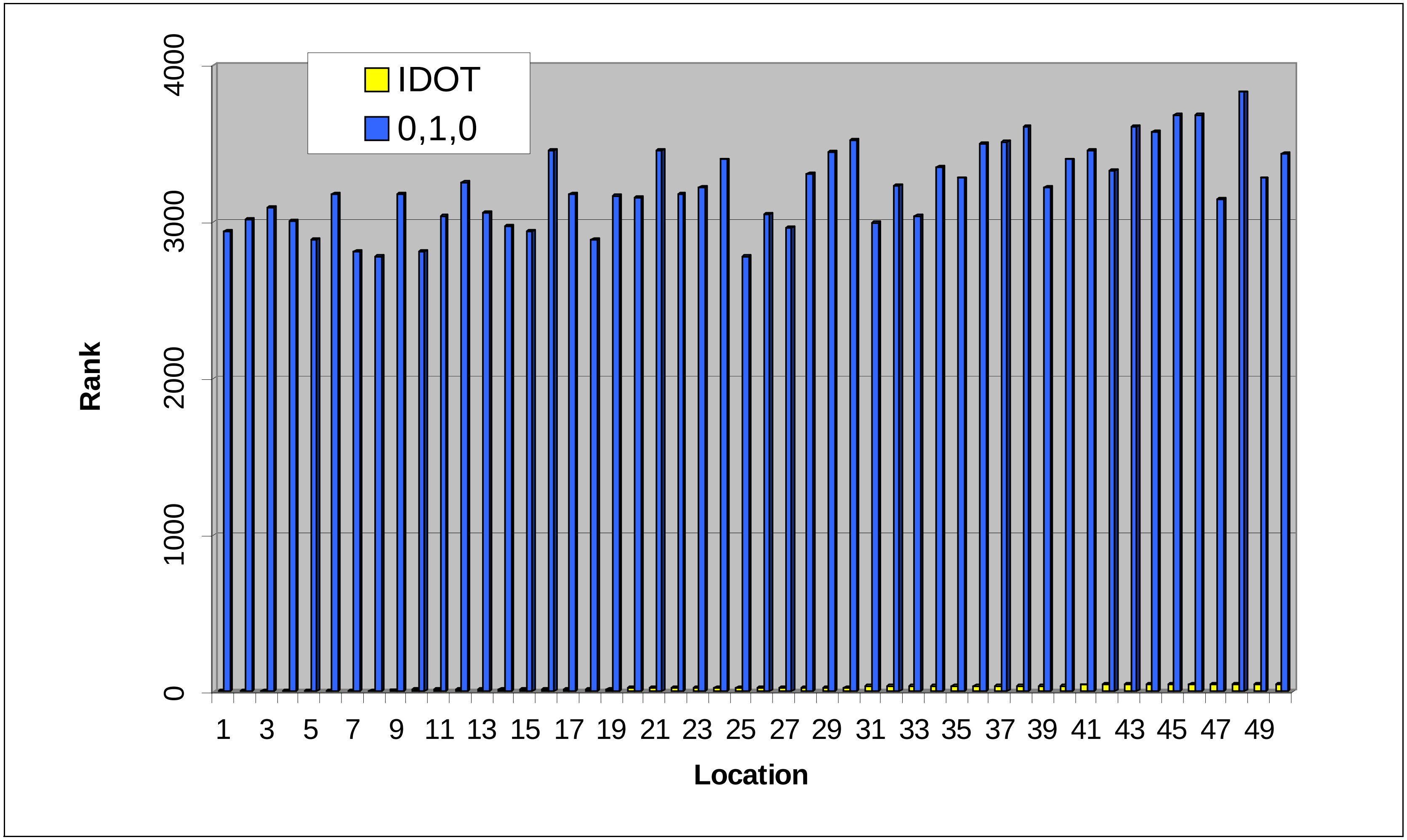

Figure 6.7. Change in Rankings for the Original Top 50 Locations When Crash Rate is Maximized (0, 1, 0)

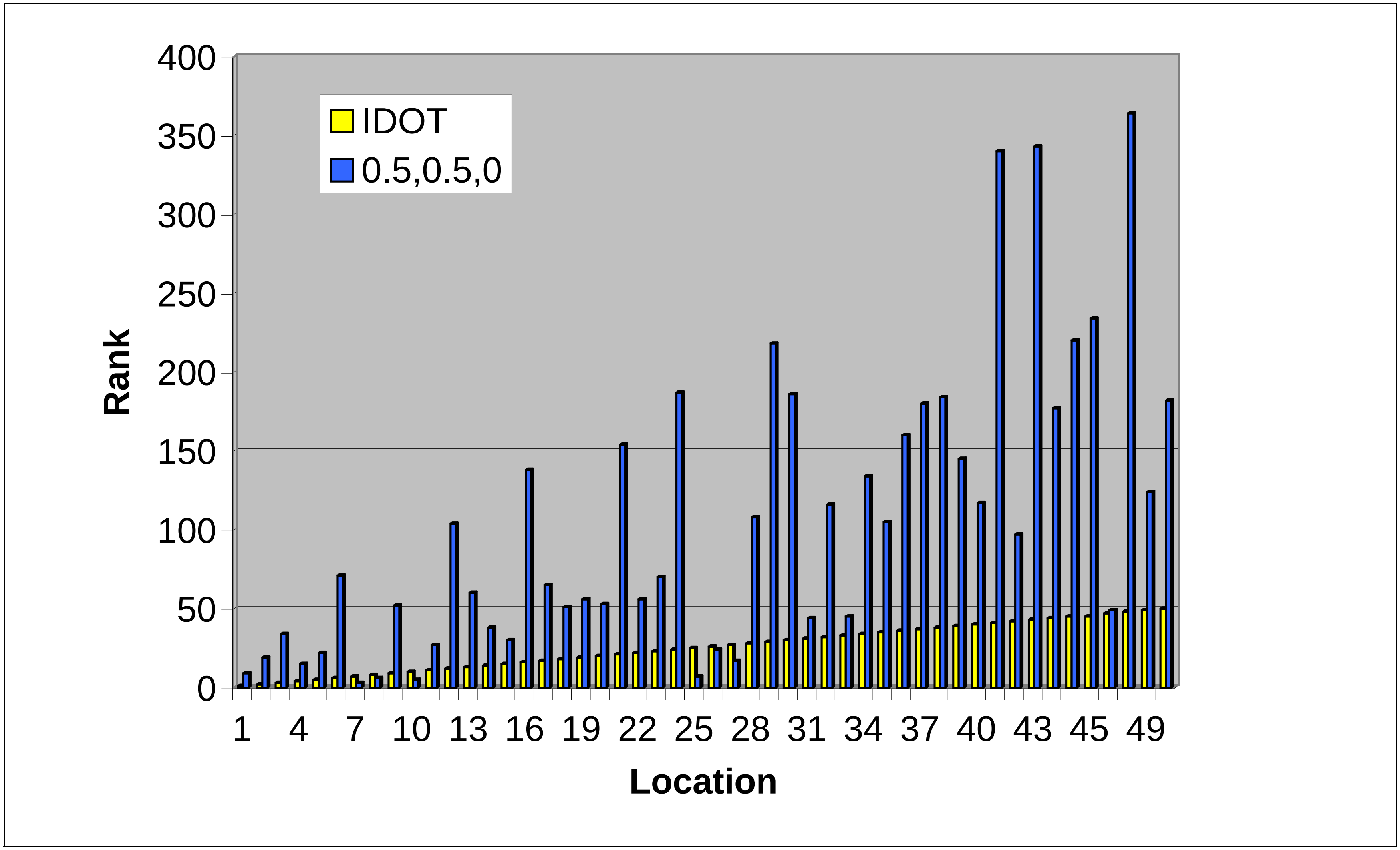

Figure 6.8. Change in Rankings for the Original Top 50 Locations When Value Loss is Minimized (0.5, 0.5, 0)

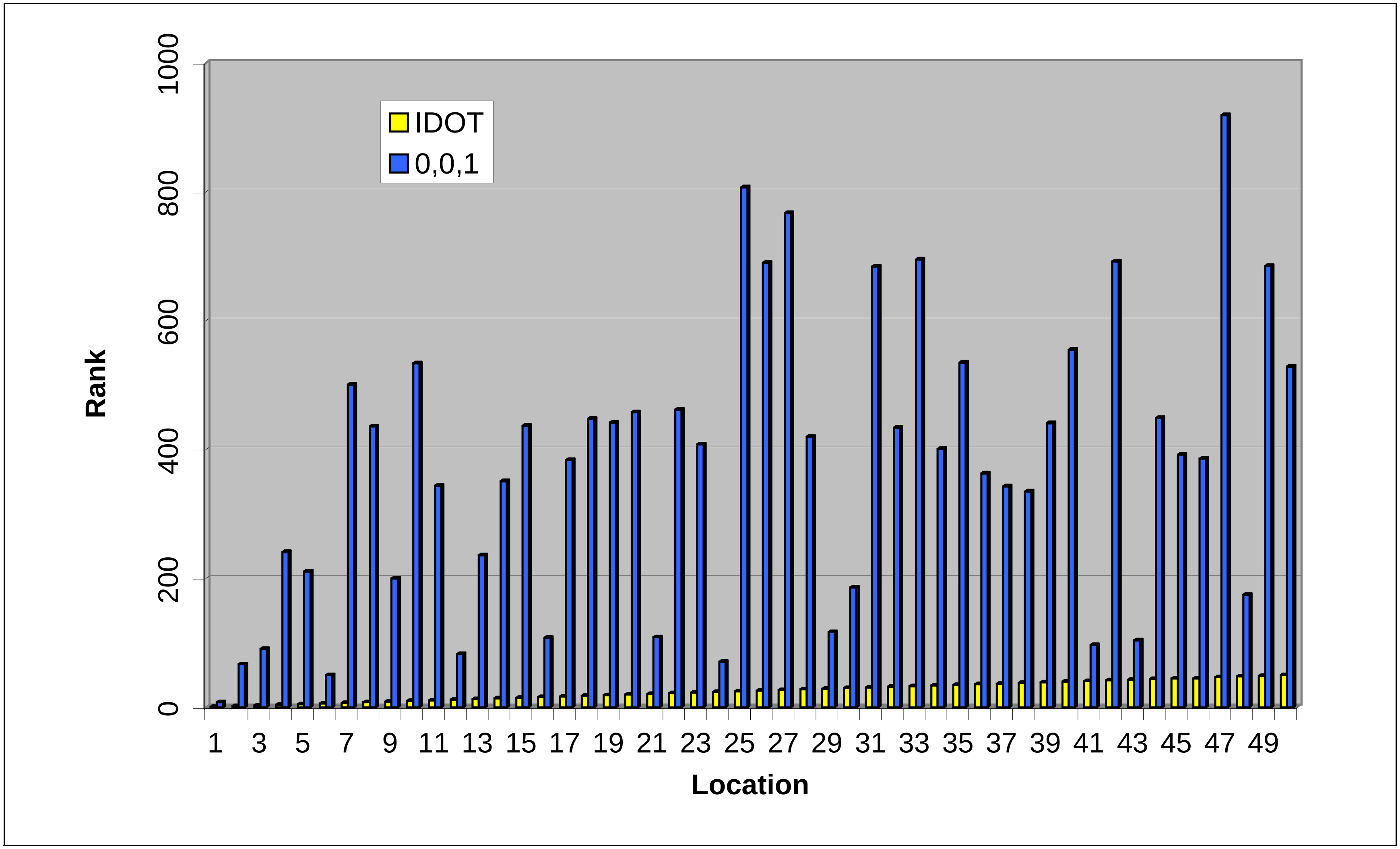

Figure 6.9. Change in Rankings for the Original Top 50 Locations When Value Loss is Maximized (0, 0, 1)

6.4. Wilcoxon Matched-Pair Signed-Rank Test

The previous section provided descriptive statistics to evaluate whether the rankings resulting from applying different coefficients would result in significantly different rankings than the original safety improvement candidate rankings. the Wilcoxon Matched-Pair Signed-Rank Test was performed to determine whether differences in the rankings were statistically significant. The Wilcoxon matched-pair signed rank test is a non-parameteric statistical test used to evaluate whether the median of the differences in the paired rankings were significantly different than zero. Non-parametrical statistical analysis is useful when the ranking data being analyzed are ordinal and cannot be assumed to have a normal distribution.

Wilcoxon's test statistic (T) values were calculated to compare the original ranking of the top 50, 100, 150, and 200 locations to the rankings resulting from different combinations of coefficients. The methodology and results are provided in the following sections.

6.4.1. Methodology

The null hypothesis (H_o) is that the median of the differences between the two rankings is zero. In other words, if the null hypothesis is not rejected, the two rankings are similar. The alternative hypothesis (H_a) is that the median of the differences between the rankings is some value other than zero. Acceptance of the alternative hypothesis leads to the conclusion that the two rankings are significantly different (Sheskin, 2000).

The Wilcoxon test used was non-directional and evaluated as a two-tailed test at the 95% level of confidence. The alternative hypothesis was supported when the computed test statistic was less than or equal to the critical two-tailed value at the 95% level of significance. Critical values for the Wilcoxon are only available for samples size up to 50. For larger sample sizes, a normal distribution approximates the sampling distribution of the Wilcoxon test statistic. The alternative hypothesis is supported when the absolute value of the Wilcoxon test statistic, whose sampling distribution is normally approximated, is greater than or equal to the critical two-tailed value for the normal distribution (Sheskin, 2000). At the 95% level of significance the critical value for the normal distribution is 1.96.

6.4.2. Results

Results of the Wilcoxon test are shown in Tables 6.7 to 6.10. A comparison of the rankings that resulted from applying different coefficients to calculate a final ranking of the top 50 locations compared to the original top 50 location ranking produced by the Iowa DOT is in Table 6.7. For samples size less than or equal to 50, the Wilcoxon T statistic was calculated and used to evaluate the null and alternative hypothesis. A comparison of the ranking for the top 100, top 150 and top 200 locations are provided in Tables 6.8, 6.9, and 6.10. The normal approximation was used to compare the top 100, 150, and 200 locations. The computed and corresponding test statistic values are shown as well as sample size. If the rank of a location did not change (i.e. the location in the fourth position stayed in the fourth position), the differences in rankings equaled zero and that location was not included in the calculation. Sample size reflects the number of locations whose rank changed and were included in calculation of the test statistic.

Table 6.7 provides the results for the original top 50 locations. As expected combinations where the ranking method that was being varied was minimized or maximized were statistically different from the original list of the top 50 safety improvement candidate locations. Fewer combinations of coefficients tested for the top 50 locations were statistically different than for the top 100, 150, and 200. Additionally, results were similar when Crash Frequency, Crash Rate, and Value Loss were varied.

Results of the Wilcoxon T comparing variations of combinations for the top 100 original locations are shown in Table 6.8. When Crash Frequency was varied, the results were similar to results described above. Combinations at the extremes when Crash Frequency was minimized or maximized were significantly different at the 95% level of confidence. All combinations of coefficients when Crash Rate was varied except the combination (0.4, 0.2, 0.4) were different from the original top 100 list. The combination (0.4, 0.2, 0.4) is fairly close to the original combination of coefficients (0.33, 0.33, 0.33), so it is expected that this coefficient values in this ranges would be similar. All of the combinations when Value Loss varied were statistically different from the original list.

Tables 6.9 and 6.10 provide results for the top 150 and 200 locations. Results are fairly similar to those reported for the top 100 locations. Fewer combinations were significantly different from the original ranking lists at the 95% level of significance when Crash Frequency was varied. When Crash Rate and Value Loss varied, almost all of the combinations were statistically different from the original lists. This indicates that the rankings produced by Crash Frequency are more like the original rankings than the other two methods. This confirms the results discussed previously.

The Wilcoxon tests indicate that the varying the coefficient values does produce SICLs that are statistically different. For the most part, the non-parametric test confirms the results of the descriptive statistics section (Section 6.3). However, beyond that they do not provide much additional information.

Table 6.7. Wilcoxon Test Results for the Original Top 50 Locations

Alternative	Sample Size	Calculated Wilcoxon T	Wilcoxon Test Statistic Value based on Sample Size	Significantly Different at 95%
Crash Frequency Varied				
(0, 0.5, 0.5)	50	0	434	**Yes**
(0.1, 0.45, 0.45	45	238.0	343	**Yes**
(0.2, 0.4, 0.4)	43	383.5	310	No
(0.5, 0.25, 0.25)	40	352.5	264	No
(0.6, 0.2, 0.2)	44	462.5	327	No
(0.7, 0.15, 0.15)	46	501	No	No
(0.8, 0.1, 0.1)	46	442.5	361	No
(0.9, 0.05, 0.05)	48	348	396	**Yes**
(1, 0, 0)	49	163	415	**Yes**
Crash Rate Varied				
(0.5, 0, 0.5)	47	281.5	378	**Yes**
(0.45, 0.1, 0.45)	44	401	327	No
(0.4, 0.2, 0.4)	44	491.5	327	No
(0.25, 0.5, 0.25)	45	381	343	No
(0.2, 0.6, 0.2)	48	321	396	**Yes**
0.15, 0.7, 0.15)	48	224.5	396	**Yes**
(0.1, 0.8, 0.1)	48	102.5	396	**Yes**
(0.05,0.9, 0.05)	50	38.5	434	**Yes**
(0, 1, 0)	50	0	434	**Yes**
Value Loss Varied				
(0.5, 0.5, 0)	50	51	434	**Yes**
(0.45, 0.45, 0.1)	49	281	415	**Yes**
(0.4, 0.4, 0.2)	44	414	327	No
(0.25, 0.25, 0.5)	45	488.5	343	No
(0.2, 0.2, 0.6)	47	433	378	No
(0.15, 01.5, 0.7)	47	340.5	378	**Yes**
(0.1, 0.1, 0.8)	48	246.5	396	**Yes**
(0.05, 0.05, 0.9)	49	132.5	415	**Yes**
(0, 0, 1)	50	0	434	**Yes**

Table 6.8. Wilcoxon Test Results for the Original Top 100 Locations

Alternative	Sample Size	Calculated Wilcoxon T	Calculated Absolute z	Significant at 95%
Crash Frequency Varied				
(0, 0.5, 0.5)	100	126.5	8.25	**Yes**
(0.1, 0.45, 0.45)	95	873.5	5.22	**Yes**
(0.2, 0.4, 0.4)	91	1181.5	3.61	**Yes**
(0.5, 0.25, 0.25)	89	1666	1.38	No
(0.6, 0.2, 0.2)	94	2037	0.74	No
(0.7, 0.15, 0.15)	96	2296.5	0.12	No
(0.8, 0.1, 0.1)	96	1981.5	1.27	No
(0.9, 0.05, 0.05)	97	1544	3.00	**Yes**
(1, 0, 0)	98	775.5	5.85	**Yes**
Crash Rate Varied				
(0.5, 0, 0.5)	97	473.5	6.85	**Yes**
(0.45, 0.1, 0.45)	94	1516.5	2.70	**Yes**
(0.4, 0.2, 0.4)	93	1749.5	1.67	No
(0.25, 0.5, 0.25)	94	1655	2.18	**Yes**
(0.2, 0.6, 0.2)	98	1411.5	3.59	**Yes**
0.15, 0.7, 0.15)	98	985	5.10	**Yes**
(0.1, 0.8, 0.1)	98	555.5	6.63	**Yes**
(0.05,0.9, 0.05)	100	232.5	7.88	**Yes**
(0, 1, 0)	100	10	8.65	**Yes**
Value Loss Varied				
(0.5, 0.5, 0)	100	329.5	7.55	**Yes**
(0.45, 0.45, 0.1)	99	944.5	5.34	**Yes**
(0.4, 0.4, 0.2)	93	1476.5	2.72	**Yes**
(0.25, 0.25, 0.5)	95	1697	2.16	**Yes**
(0.2, 0.2, 0.6)	97	1488.5	3.20	**Yes**
(0.15, 01.5, 0.7)	96	1162	4.26	**Yes**
(0.1, 0.1, 0.8)	98	886.5	5.45	**Yes**
(0.05, 0.05, 0.9)	98	479.5	6.90	**Yes**
(0, 0, 1)	100	17	8.62	**Yes**

Table 6.9. Wilcoxon Test Results for the Original Top 150 Locations

Alternative	Sample Size	Calculated Wilcoxon T	Calculated Absolute z	Significant at 95%
Crash Frequency Varied				
(0, 0.5, 0.5)	149	413	9.81	**Yes**
(0.1, 0.45, 0.45	144	1833.0	6.75	**Yes**
(0.2, 0.4, 0.4)	141	2728.5	4.69	**Yes**
(0.5, 0.25, 0.25)	139	4488.5	0.79	No
(0.6, 0.2, 0.2)	143	5097.5	0.10	No
(0.7, 0.15, 0.15)	144	4693	1.05	No
(0.8, 0.1, 0.1)	146	4153.5	2.37	**Yes**
(0.9, 0.05, 0.05)	147	3355.5	4.03	**Yes**
(1, 0, 0)	148	2142	6.45	**Yes**
Crash Rate Varied				
(0.5, 0, 0.5)	146	781	8.96	**Yes**
(0.45, 0.1, 0.45)	143	2736.5	4.86	**Yes**
(0.4, 0.2, 0.4)	142	3349	3.52	**Yes**
(0.25, 0.5, 0.25)	144	4589.5	1.26	No
(0.2, 0.6, 0.2)	148	4087.5	2.73	**Yes**
0.15, 0.7, 0.15)	148	3127.5	4.57	**Yes**
(0.1, 0.8, 0.1)	148	2017	6.69	**Yes**
(0.05,0.9, 0.05)	150	798	9.13	**Yes**
(0, 1, 0)	150	10	10.61	**Yes**
Value Loss Varied				
(0.5, 0.5, 0)	150	2062	6.76	**Yes**
(0.45, 0.45, 0.1)	149	3329	4.28	**Yes**
(0.4, 0.4, 0.2)	143	4163	1.98	**Yes**
(0.25, 0.25, 0.5)	145	3558	3.42	**Yes**
(0.2, 0.2, 0.6)	147	3155.5	4.42	**Yes**
(0.15, 01.5, 0.7)	146	2598	5.41	**Yes**
(0.1, 0.1, 0.8)	147	2029	6.59	**Yes**
(0.05, 0.05, 0.9)	147	1118	8.36	**Yes**
(0, 0, 1)	150	74.5	10.48	**Yes**

Table 6.10. Wilcoxon Test Results for the Original Top 200 Locations

Alternative	Sample Size	Calculated Wilcoxon T	Absolute z	Significant at 95%
Crash Frequency Varied				
(0, 0.5, 0.5)	199	1012.5	10.99	**Yes**
(0.1, 0.45, 0.45)	194	3415.0	7.72	**Yes**
(0.2, 0.4, 0.4)	191	4994	5.46	**Yes**
(0.5, 0.25, 0.25)	188	8004	1.18	No
(0.6, 0.2, 0.2)	193	9305.5	0.07	No
(0.7, 0.15, 0.15)	193	8317	1.34	No
(0.8, 0.1, 0.1)	196	7375	2.86	**Yes**
(0.9, 0.05, 0.05)	197	6049.5	4.62	**Yes**
(1, 0, 0)	198	4183	7.02	**Yes**
Crash Rate Varied				
(0.5, 0, 0.5)	196	1400.5	10.38	**Yes**
(0.45, 0.1, 0.45)	193	4288	6.53	**Yes**
(0.4, 0.2, 0.4)	191	5504.5	4.79	**Yes**
(0.25, 0.5, 0.25)	194	8619	1.07	No
(0.2, 0.6, 0.2)	198	7476	2.94	**Yes**
0.15, 0.7, 0.15)	198	5650.5	5.20	**Yes**
(0.1, 0.8, 0.1)	198	3644.5	7.69	**Yes**
(0.05,0.9, 0.05)	200	1525	10.40	**Yes**
(0, 1, 0)	200	32	12.22	**Yes**
Value Loss Varied				
(0.5, 0.5, 0)	200	4726	6.50	**Yes**
(0.45, 0.45, 0.1)	199	6953.5	3.68	**Yes**
(0.4, 0.4, 0.2)	193	8380	1.26	No
(0.25, 0.25, 0.5)	195	5884	4.65	**Yes**
(0.2, 0.2, 0.6)	197	4994.5	5.94	**Yes**
(0.15, 01.5, 0.7)	196	4240.5	6.81	**Yes**
(0.1, 0.1, 0.8)	197	3280	8.08	**Yes**
(0.05, 0.05, 0.9)	197	1733.5	10.01	**Yes**
(0, 0, 1)	200	121.5	12.11	**Yes**

6.5. Summary and Conclusions

The Iowa DOT safety improvement candidate location prioritization process uses a combination of Crash Frequency, Crash Rate, and Value Loss, to rank and identify high crash locations. Locations are ranked according to the three methods (described in more detail in Section 3.4) and then a final composite value is calculated and a final rank assigned. In the current methodology, all three methods are given equal weight in determining the final ranking (1/3 Crash Frequency, 1/3 Crash Rate, 1/3 Value Loss).

Once the impact of fatalities on Value Loss was evaluated as described in Section 5, the next research objective was to evaluate the impact that each of the methods had on the final ranking process. Concern had been expressed that the high values given to fatalities in the Value Loss ranking method may bias the final ranking towards locations with fatalities. Additionally, some safety researchers suggest that crash rate and severity are better measures of safety than frequency, which may indicate that the three methods should not be given equal weight in the final ranking process.

A sensitivity analysis was performed to test the impact of each of the three methods on the final SICL rankings. The coefficients for each method were varied to calculate new composite values and new rankings produced that were compared to the original SICL for the 1995–1999 analysis period. The coefficient for each method was varied from 0 to 1 resulting in twenty-seven different combinations of coefficients, which gave different weights to the three individual ranking methods. A description of the data and the methodology and results of the sensitivity analysis were described in the preceding sections.

Different combinations of coefficients (see Tables 6.1, 6.2, and 6.3 for a description of the alternatives) were first evaluated using descriptive statistics and then the non-parametric Wilcoxon Matched-Pair Signed-Rank Test was applied. The descriptive statistics compared the magnitude of change that would occur in terms of how many locations that were located in the original top 50, 100, 150, and 200 positions would no longer be included when different sets of coefficients were applied. The change in ranking of individual locations was also considered. Even if a location remains as one of the top 100 SICLs after different weights are given to the three methods, the priority given to that location may change. This may ultimately affect how resources are programmed for safety improvements.

The Wilcoxon tests indicated that varying the coefficient values does produce SICLs that are statistically different than the original SICL. For the most part, the non-parametric test confirmed the results of the descriptive statistics. However, beyond that they do not provide much additional information.

Based on the results of the descriptive statistics, the following conclusions are presented:

- When Crash Frequency was maximized the least amount of change occurred between the new rankings and the original SICL.
- Similar changes in the number of original locations dropping out of the original lists occurred when Crash Frequency was minimized as when Crash Frequency was maximized (as Crash Frequency was minimized the contribution was reduced to 0; as Crash Frequency was maximized, the contribution was increased to 100%).
- Changes in the position of individual locations when Crash Frequency was minimized (average changes around 200 to 300 positions were observed) was more pronounced than when Crash Frequency was maximized (average changes around 10 to 150 positions were observed).
- Changes in the position of individual locations when Crash Frequency was maximized were less significant than for either Crash Rate or Value Loss.
- When Crash Rate was minimized, the number of original locations dropping out of the top 50, 100, 150, and 200 original locations was similar to both Crash Frequency and Value Loss.
- When Crash Rate was maximized significant changes occurred. For some combinations of coefficients over 90% of the locations were dropped from the original lists.
- When Crash Rate was maximized, the most significant change in individual locations was observed of the three methods. All locations changed position by more than 2,000 places.
- When Value Loss was minimized, the number of locations dropping out of any category (top 50, 100, 150, and 200) were comparable to both Crash Frequency and Crash Rate.
- When Value Loss was maximized, the number of locations dropping out of any category was significant and was comparable to the results obtained when Crash Rate was maximized.
- Changes in position from 10 to 950 places resulted when Value Loss was both minimized and maximized.

If the three methods contributed equally to the final ranking process, the impact of minimizing or maximizing their individual contribution would result in similar changes. However, when the contribution of Crash Rate or Value Loss is increased, the resulting list of locations is less like the original list than when Crash Frequency is increased. If the SICL process is more influenced by one of the methods, increasing the contribution of that method should result in a list that is similar to the original and decreasing the contribution of that method should result in a list that is different from the original. Consequently, the current SICL process appears to be more influenced by the Crash Frequency method than the other two methods.

6.6. Recommendations

Results indicate that the contributions of Value Loss and Crash Rate to the final Iowa DOT SICL ranking are similar. Significantly different lists than the original ranking lists result when the contribution of either is maximized. This suggests that Value Loss and Crash Rate may be correlated. This was examined but could not be proven conclusively.

When the contribution of Crash Frequency is maximized, significantly less pronounced changes occur. Little change between the original rankings and the rankings resulting from testing a particular set of coefficients when that coefficient is increased, indicates that the two rankings are similar. This suggests that the SICL ranking process is more correlated to Crash Frequency than the other two methods. Given the results of the analysis, the following recommendations are provided:

- Crash Rate and Value Loss appear to be correlated. Consideration may be given to further testing this relationship and dropping or minimizing one of the methods as appropriate.
- The sensitivity analysis indicated that Crash Frequency is more influential on the SICL process than the other two methods. If Crash Frequency is not as important to agency goals as exposure and severity, the coefficient for Crash Frequency should be minimized.
- Although not evaluated in the analysis, consideration may be given to the 5-year analysis period used for the SICL process. All of the states surveyed in Section 3 had analysis periods from 1 to 3 years. A five-year period may help avoid random fluctuations in accidents but it also masks the effects of improvements at a location. An improvement to a location made in year 5 of the analysis period that resulted in a significantly lower number of either accidents or severity would not significantly decrease that location's overall ranking for several years in the future.

7. RESULTS OF SAFETY WORKSHOP

The final stage of this research was a workshop held June 7, 2002, at the Center for Transportation Research and Education. Workshop participants discussed alternatives ways to rank high crash locations. The focus was on prevention of serious accidents. Since Value Loss is the only mechanism in the current Iowa DOT ranking method that takes severity into account, the focus was on developing a new method to allocate severity among accident types in the Value Loss Ranking.

The following recommendations were arrived at by the participants and affect the way Value Loss is calculated and subsequently locations ranked based on severity:

- Treat the first fatality as a major injury.
- Treat all fatalities as major injuries.
- Assign values for major injures that are closer to fatalities.
- Use a range of values for the various injury types rather than a dollar value. A dollar value will still be used in benefit/cost analyses. The range of values will use "possible injury" as the baseline and assigns the following values:
    - Fatality = 200 * Possible Injury
    - Major Injury = 100 * Possible Injury
    - Minor Injury = 10 * Possible Injury
    - Property Damage Only = Possible Injury

For example, value loss for a location that has one fatality, two major injuries, and five possible injuries would be calculated as follows:

$$2(200) + 2(100) + 5(1) = 605$$

- In the final ranking process, calculate the composite value using coefficients of 0.2 for Crash Frequency and Crash Rate and a coefficient of 0.6 for Value Loss (0.2, 0.2, 0.6) as indicated in Equation 7.1:

$$\text{Value}_{\text{composite}} = 0.2(\text{Crash Frequency Rank}) + 0.2(\text{Crash Rate Rank}) + 0.6(\text{Value Loss Rank}) \qquad (7.1)$$

Combinations of the above recommendations were applied to determine the effect that each would have on the original re-ranked SICL. A discussion of how the original SICL was re-ranked without location where volume was equal to zero and how composite ranking was calculated for different scenarios was presented in Section 5.2. The same procedure was followed to evaluate the different recommendations. The number of locations that were dropped from the top 50, 100, 150, and 200 positions of the original re-ranked SICL are presented in Table 7.1 for each combination. When the new injury values are applied, the 24% and 17% of the top 50 and 100 locations in the original re-ranked SICL are no longer in those positions. When the new injury values are used and the first fatality is treated as a major injury for value loss calculation, 30% and 21% of the locations are no longer in the original top 50 and 100 positions. Using the new injury values and the new coefficients (0.2, 0.2, 0.6) results in the least change in the top positions of any of the combinations listed in Table 7.1. Finally, when the suggested combination of new injury values, coefficients (0.2, 0.2, 0.6) and the first fatality is treated like a major injury a total of 18% of the locations in both the top 50 and top 100 are dropped from those lists. As shown, the combination of using new injury values and treating the first fatality as a major injury while using the original coefficients (1/3, 1/3, and 1/3) yielded the most significant changes in the top positions. It was expected that the combination of using the new values, treating the first fatality as a major injury, and new coefficients (0.2, 0.2, 0.6), which was the final recommendation of the workshop participants, would yield the greatest change. It unknown why this was not the case, however it may be a function of characteristics of the locations in the top positions rather than an indication that increasing the coefficient of Value Loss is not effective.

Table 7.1. Locations Dropped from the Original Iowa DOT Safety Improvement Candidate List When Suggested Values are Applied

Scenario	Top 50	Top 100	Top 150	Top 200
New Injury Values and Original Coefficients	12 (24%)	17 (17%)	22 (15%)	22 (11%)
New Injury Values and Treating the First Fatality as a Major Injury with Original Coefficients	15 (30%)	21 (21%)	23 (15%)	25 (13%)
New Injury Values and Coefficients (0.2, 0.2, 0.6)	8 (16%)	17 (17%)	27 (18%)	38 (19%)
New Injury Values, Coefficients (0.2, 0.2, 0.6) and Treating the First Fatality as a Major Injury	9 (18%)	18 (18%)	28 (19%)	35 (18%)

The scenario of treating all fatalities as major injuries with the new severity values was also considered. Results are shown in Table 7.2. As indicated, when all fatalities were treated as major injuries and the original coefficients of (1/3, 1/3, 1/3) were applied, 34% of the locations in the Top 50 were no longer in the Top 50 while 22% are no longer in the top 100 positions. When all fatalities were treated as major injuries and the suggested coefficients (0.2, 0.2, 0.6) were applied, only 20% of the locations dropped out of the Top 50 and 19% dropped out of the top 100 positions. Overall, treating fatalities as major injuries resulted in more significant changes for the top locations than for similar scenarios when only the first fatality was evaluated as a major injury.

Table 7.2. Locations Dropped from the Original Iowa DOT Safety Improvement Candidate List When All Fatalities are Treated as Major Injuries

Scenario	Top 50	Top 100	Top 150	Top 200
New Injury Values and Treating All Fatalities as Major Injuries with Original Coefficients	17 (34%)	22 (22%)	23 (15%)	26 (13%)
New Injury Values, Coefficients (0.2, 0.2, 0.6) and Treating All Fatalities as Major Injuries	10 (20%)	19 (19%)	27 (18%)	32 (16%)

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