Alternative Crash Severity Ranking Measures and the Implications on Crash Severity Ranking Procedures

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ABSTRACT

Most states currently use ranking procedures to identify intersections with safety concerns. One objective of a state intersection ranking procedure is to provide a reliable start to the prioritization of safety improvements. For efficiency purposes, it is crucial to have a ranking system that identifies intersections with the most severe safety concerns. Otherwise, potentially hazardous intersections could be overlooked.

Crash severity rankings are a part of many state safety management plans and are often used in combination with crash frequency and/or crash rate rankings. While the procedures for calculating crash frequency and crash rate at intersections are straightforward, there is no standard procedure for calculating crash severity. In fact, the methods used to define crash severity vary throughout the nation. Consequently, different approaches can produce different results, despite their common objective.

The research presented in this paper had multiple objectives. The first objective was to introduce and describe a variety of used-in-practice crash severity ranking methodologies utilized by state DOTs. The second objective was to examine three years (1998 to 2000) of Wisconsin intersection crash data to identify or more closely define crash severity at intersections by exploring its relationship with crash type and vehicle damage. The third objective was to develop alternative crash severity ranking methodologies based on crash type and vehicle damage. The new crash severity ranking procedures developed from this work are then presented and compared to the results of four example state DOT ranking procedures.

Key words: crash frequency—crash rate—crash severity ranking—safety management
PROBLEM STATEMENT

Crash severity rankings are a part of many state safety management plans and are often used in combination with crash frequency and/or crash rate rankings. While the procedures for calculating crash frequency and crash rate at intersections are well known, there is not a customary procedure for calculating crash severity. In fact, throughout the nation, a variety of methodologies are used to calculate crash severity. Consequently, these approaches can produce considerably different results, despite their common objective.

Another cause for concern with crash severity rankings is the weights typically applied to fatal crashes. Crash severity rankings based on the comprehensive costs of different injury levels (i.e., value loss methods) typically weigh fatal crashes much more heavily than lesser injury crashes. As a result, intersections that observed a fatality typically rank very high on the list. Fatal crashes, however, are a rare event at individual intersections and, nationwide, fatalities only occur in about 0.6% of all traffic crashes (National Highway Traffic Safety Administration 2005). Therefore, in crash severity ranking procedures that heavily weigh fatalities, potentially hazardous intersections that did not observe a fatality in the time period analyzed may be overlooked.

Also, since most crash severity ranking procedures are solely based on the injury outcomes in crashes, they are also subject to the variability associated with injuries caused by a variety of factors. These factors include seatbelt usage, number of occupants, age of occupants, mode of transportation, crash type, speed of impact, extent of vehicle damage, etc. Consequently, the results of a crash severity ranking may be skewed by factors that affect the injury outcomes in a crash, even factors that are not related to the geometry or operations of a roadway.

OBJECTIVES

This research had multiple objectives. The first objective was to introduce and describe a variety of crash severity ranking procedures used in practice by state DOTs.

The next objective was to identify or more closely define crash severity at intersections by exploring the impacts that crash type and vehicle damage have on the injuries sustained by occupants. These two factors were chosen because the United States General Accounting Office (GAO) once concluded that crash type and speed of impact, which has been shown to relate to vehicle deformation (Mackay, Hill, Parkin, and Munns 1993), were the two most important factors related to the injury risk of occupants (GAO 1995). Also, both of these factors are related to the geometry and operations of roadways.

Another objective was to develop crash severity ranking procedures based on crash type and vehicle damage. It was hypothesized that rankings based on these two factors, which are related to the injury risk of occupants and the geometry and operations of roadways, may provide more appropriate crash severity ranking results. The new ranking procedures utilized an approach based on the average injury cost per vehicle.

The last objective was to evaluate and compare the results of the developed alternative ranking procedures and the results of example used-in-practice ranking procedures using a subset of Wisconsin intersection crash data.
RESEARCH METHODOLOGY

The crash severity ranking procedures used by state DOTs were determined through a review of previous research and by contacting state DOTs via email and/or telephone. The ranking methodologies described and evaluated in this study were from states located in the Midwestern United States.

Crash type, vehicle damage, and their impact on the injury severity of vehicle occupants in intersection crashes were evaluated. The database used for the exploration of these two factors consisted of data from reported intersection crashes in the state of Wisconsin from 1998 to 2000. The database contained information for 141,161 crashes, which involved 274,285 vehicles, 407,870 vehicle occupants, and 2,348 pedestrians. Crashes with incomplete descriptive data were not analyzed. The number and types of injuries observed by occupants in vehicles in nine different crash types and in vehicles sustaining five different vehicle damage levels were explored. Crash type was defined as the most harmful event of each vehicle.

Two alternative crash severity ranking methodologies were developed by calculating average injury costs per vehicle for vehicles in nine crash types and for vehicles sustaining five different levels of vehicle damage. The average injury cost per vehicle in each category was calculated as the sum of the 2003 National Safety Council comprehensive injury costs in that category divided by the number of vehicles in that category (see Equation 1) (National Safety Council 2003). The results were rounded to the nearest thousandth dollar.

\[
AC = \frac{N \times \$1,900 + C \times \$20,200 + B \times \$42,500 + A \times \$165,000 + K \times \$3,340,000}{\text{Number of Vehicles}}
\]

(1)

where

\begin{align*}
AC &= \text{Average cost of injuries per vehicle} \\
N &= \text{Number of occupants reporting no injuries} \\
C &= \text{Number of occupants reporting possible injuries} \\
B &= \text{Number of occupants reporting non-incapacitating injuries} \\
A &= \text{Number of occupants reporting incapacitating injuries} \\
K &= \text{Number of occupants killed}
\end{align*}

The two alternative crash severity ranking methodologies and four state DOT crash severity ranking methodologies were applied to a subset of Wisconsin intersection crash data containing 1,369 intersections and 25,633 crashes. This sample contained 73 fatal crashes, 10,754 injury crashes and 14,806 property damage only (PDO) crashes. The top 100 intersections resulting from each of the six ranking methodologies were evaluated and compared based on the following measures:

- Similarities between ranking results
- Annual stability
- Identification of severe events
KEY FINDINGS

Used-In-Practice Crash Severity Rankings

Table 1 shows the four used-in-practice crash severity ranking procedures evaluated in this study. These ranking procedures follow two basic methodologies: equivalent property damage only (EPDO) and value loss (i.e., an estimate of the economic loss associated with crashes).

Table 1. Used-in-practice crash severity ranking methods, with applied weights

<table>
<thead>
<tr>
<th>Ranking Method</th>
<th>No injury</th>
<th>Possible injury</th>
<th>Non-incapacitating injury</th>
<th>Incapacitating injury</th>
<th>Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Dakota DOT&lt;sup&gt;a&lt;/sup&gt;  (EPDO, simple)</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Illinois DOT&lt;sup&gt;b&lt;/sup&gt;  (EPDO, complex)</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Iowa DOT&lt;sup&gt;c&lt;/sup&gt;  (value loss)</td>
<td>$2,500</td>
<td>$2,500</td>
<td>$10,000</td>
<td>$150,000</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Minnesota DOT&lt;sup&gt;ac&lt;/sup&gt;  (value loss, reduced fatal)</td>
<td>$4,200</td>
<td>$29,000</td>
<td>$58,000</td>
<td>$270,000</td>
<td>$540,000</td>
</tr>
</tbody>
</table>

<sup>a</sup>Weights or costs applied to each crash based on the maximum injury observed
<sup>b</sup>Weights or costs applied to each occupant based on the injury observed, plus the actual cost of the property damage, or $2,500 if unknown
<sup>c</sup>If three or more fatal crashes occurred at a specific location, the cost applied to the third or any additional fatal crashes is $3,400,000

The EPDO ranking method is a common crash severity ranking approach. In this approach, injury crashes and fatal crashes are assigned weights that are intended to represent their equivalent in PDO crashes. The North Dakota DOT and the Illinois DOT both utilize EPDO ranking approaches; however, their methods are slightly different. The Illinois DOT method (i.e., EPDO, complex) requires more data than the North Dakota DOT method (i.e., EPDO, simple) because it uses five injury categories (Hallmark and Basavaraju 2002), while the North Dakota DOT method uses three (North Dakota DOT 2000).

Another common approach for identifying and ranking intersections is to calculate the comprehensive injury costs. These methods are often referred to as value loss ranking procedures. The Iowa DOT and the Minnesota DOT both utilize value loss methods. One recognized characteristic of value loss methods is that rankings tend to be biased towards locations that have observed a fatality (Hallmark and Basavaraju 2002). This potential bias is a result of the high costs typically applied to fatal crashes. To reduce this bias, the Minnesota DOT applies a cost of $540,000 to fatal crashes (Minnesota DOT 2004). Although this cost is twice that of an incapacitating injury crash, it is far less than the $3,400,000 value the Minnesota DOT has recognized as the actual comprehensive cost of a fatal crash. The Iowa DOT crash severity ranking method does not include a fatal crash cost reduction (Pawlovich 2002). However, the Iowa DOT evaluates five years of crash data and includes an estimate of the actual property damage, both of which may help alleviate the bias towards locations that observed fatal crashes. The Minnesota DOT, North Dakota DOT, and the Illinois DOT all evaluate three years of crash data.
Crash Type

The quantity and types of injuries reported by occupants in more than 274,000 vehicles were explored. These vehicles were categorized into nine different intersection crash types.

Crash Type Frequency

Figure 1 shows the percentages of vehicles in the sampled intersection data by crash type. More than half of the vehicles were involved in angle crashes and approximately one-quarter were in rear-end collisions. Seven percent of the sampled vehicles were in sideswipe/same crashes and 6% collided with a fixed object. The remaining five crash types (i.e., head-on, overturn, non-fixed object, no collision, and sideswipe/opposite) made up the remaining 7% of the vehicle database.

![Figure 1. Crash types](image)

Crash Type Injury Outcomes

The percent of occupants by injury and crash type are shown in Figure 2. Overturns and head-on collisions appeared to be the most hazardous crash types. In overturn crashes, nearly 55% of the occupants reported some level of injury and more than 10% of occupants were incapacitated or killed. In head-on collisions, more than 5% of occupants were incapacitated or killed and about 35% of occupants reported an injury of some type. In the remaining seven crash types, more than three-quarters of the occupants did not report an injury and only a very small percentage of these occupants were incapacitated or killed.

More than 75% of vehicle occupants in the two most common intersection crash types, angles and rear-end collisions, did not report an injury. Occupants in rear-end collisions were more susceptible to possible injuries than occupants of angle crashes. However, vehicle occupants in angle crashes were about twice as likely to observe non-incapacitating and incapacitating injuries than occupants of vehicles in rear-end crashes. Occupants were nine times more likely to be killed in an angle crash than in a rear-end crash.
Figure 2. Occupant injury outcomes by crash type

**Crash Type Ranking Methodology**

The average injury cost per vehicle was determined for vehicles in each of the nine explored crash types. These costs are shown in Table 2 and are the basis for the alternative crash type ranking methodology evaluated in this paper. Vehicles in overturn collisions had the highest average cost at $101,000, which was more than double that of vehicles in any other crash type. Vehicles in the remaining eight crash types had average costs ranging from $8,000 to $41,000.

**Table 2. Crash type ranking**

<table>
<thead>
<tr>
<th>Crash type</th>
<th>Average cost per vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overturn</td>
<td>$101,000</td>
</tr>
<tr>
<td>Head-on</td>
<td>$41,000</td>
</tr>
<tr>
<td>Fixed object</td>
<td>$31,000</td>
</tr>
<tr>
<td>No collision</td>
<td>$26,000</td>
</tr>
<tr>
<td>Angle</td>
<td>$25,000</td>
</tr>
<tr>
<td>Sideswipe/opposite</td>
<td>$18,000</td>
</tr>
<tr>
<td>Rear-end</td>
<td>$13,000</td>
</tr>
<tr>
<td>Non-fixed object</td>
<td>$8,000</td>
</tr>
<tr>
<td>Sideswipe/same</td>
<td>$8,000</td>
</tr>
</tbody>
</table>
It seemed unusual that the average cost was higher for vehicles in non-collision crashes (e.g., fire/explosion, immersion, jackknife, or other) than for vehicles in crashes that involved objects or other vehicles. The individual accident records showed that the severe injuries reported in many non-collision crashes were actually the result of occupants falling out or off of a vehicle. Alcohol played a role in several of those non-collision crashes.

**Vehicle Damage**

The numbers and types of injuries reported by 407,870 sampled occupants in vehicles sustaining certain damage levels in intersection crashes were explored. Vehicle damage is an input on Wisconsin’s accident report form. The descriptions for each vehicle damage level are shown in Table 3 (Wisconsin Division of Motor Vehicles 1998).

**Table 3. Vehicle damage descriptions**

<table>
<thead>
<tr>
<th>Vehicle damage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>No apparent damage to vehicle.</td>
</tr>
<tr>
<td>Minor</td>
<td>Damage of cosmetic nature, or vehicle is dented but repairable. Examples: paint scratches, tire scuff marks, bumper rub marks, blown tire(s), broken windshield or window, missing trim pieces, small dents but no creased metal parts.</td>
</tr>
<tr>
<td>Moderate</td>
<td>Vehicle quarterpanels are dented or creased. Broken or missing parts can be either replaced or repaired. Vehicle frame or unibody are not damaged. Includes engine compartment fires.</td>
</tr>
<tr>
<td>Severe</td>
<td>Vehicle not drivable but may be salvaged.</td>
</tr>
<tr>
<td>Very severe</td>
<td>Vehicle is not salvageable. Examples: extensive vehicle damage due to impact of collision, vehicle fire, and vehicle rollover damaging all areas of the vehicle.</td>
</tr>
</tbody>
</table>

**Vehicle Damage Injury Outcomes**

Figure 3 shows the percent of vehicles by extent of vehicle damage. More than three-quarters of the vehicles sampled were damaged moderately or less. Approximately 17% of the vehicles were damaged severely (i.e., not drivable, but salvageable) and 5% were damaged very severely (i.e., not salvageable).

The percent of occupants by injury outcomes and damage levels are shown in Figure 4. As the level of vehicle damage increased, so did the percent of occupants that reported an injury. Very severely damaged vehicles caused the most harm to occupants. More than 65% of occupants in very severely damaged vehicles reported injuries or were killed. In particular, 2.1% of these occupants were killed and 14.6% reported incapacitating injuries.

Occupants of severely damaged vehicles were less susceptible to injury than occupants of very severely damaged vehicles, but more susceptible to injury than in vehicles damaged moderately or less. Nearly 4% of occupants in severely damaged vehicles reported incapacitating injuries and approximately 0.1% were killed.
More than 210,000 vehicles were damaged moderately or less, encompassing 78% of the vehicle database. These vehicles generally caused little or no harm to occupants. Less than 0.7% of the incapacitating injuries and less than 0.01% of the fatalities occurred in these vehicles.

Vehicle Damage Ranking Methodology

The average injury cost per vehicle was determined for vehicles sustaining each of the five damage levels. These costs are shown in Table 4 and were the basis for the vehicle damage alternative ranking methodology evaluated in this paper. Very severely damaged vehicles had the highest average cost at $170,000. This cost is more than five times that of severely damaged vehicles, and more than 15 times
that of moderately damaged vehicles. Vehicles with minor damage or vehicles not damaged had comparatively low average costs of $7,000 and $6,000, respectively.

Table 4. Vehicle damage ranking

<table>
<thead>
<tr>
<th>Vehicle damage level</th>
<th>Average cost per vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very severe</td>
<td>$170,000</td>
</tr>
<tr>
<td>Severe</td>
<td>$33,000</td>
</tr>
<tr>
<td>Moderate</td>
<td>$11,000</td>
</tr>
<tr>
<td>Minor</td>
<td>$7,000</td>
</tr>
<tr>
<td>None</td>
<td>$6,000</td>
</tr>
</tbody>
</table>

Pedestrians

Crash type and vehicle damage are not reported for pedestrians involved in crashes. For example, the most harmful event for a vehicle that collided with a pedestrian would likely be coded as a collision with a pedestrian (i.e., non-fixed object). However, there is no crash type input for the pedestrian that was hit by the vehicle. Therefore, an average injury cost per pedestrian was calculated for the 2,348 pedestrians in this sample. The result, $109,000, was higher than the average cost for vehicles in all of the nine evaluated crash types and four of the five vehicle damage levels. The high average cost is representative of pedestrians’ elevated susceptibility to injury or fatality when impacted by a motor vehicle. This average cost per pedestrian is to be used in both the crash type and vehicle damage rankings. In the evaluated used-in-practice rankings, all injuries, including pedestrian injuries, are taken into consideration.

RANKING EVALUATIONS

Three tests were conducted to evaluate and compare the results of the two newly developed alternative crash severity rankings (see Tables 2 and 4) and the four used-in-practice crash severity rankings (see Table 1). The tests focused on the top 100 intersections identified by each ranking method using a sample set of Wisconsin intersection data containing 25,633 crashes at 1,369 intersections from 1998 to 2000.

Top 100 List Similarities

The number of intersections that appeared in two top-100 lists produced by two different ranking methodologies were counted. The purpose of this test is to gauge the amount of similarity between the results of two separate crash severity rankings, which in theory have the same objective (i.e., to identify the most hazardous intersections). The results of this test are shown in Table 5.

The two top-100 intersection lists that showed the most similarities were the lists produced by the North Dakota DOT and the Illinois DOT ranking methods. Ninety-one of the same intersections appeared in the top-100 lists produced by each of these EPDO methods. More than 80 of the same intersections appeared in the crash type ranking’s top-100 list and also appeared in the North Dakota DOT or the Illinois DOT top-100 lists. Approximately 60 of the same intersections appeared in the vehicle damage ranking’s top-100 list and in the other rankings’ top-100 lists, except for in the Iowa DOT list, in which only 36 of the same intersections appeared.
The Iowa DOT top-100 list showed the least amount of similarity to other methods’ ranking results. Only 26 to 36 intersections appeared in both the Iowa DOT’s top-100 list and in another ranking method’s top-100 list, except for the Minnesota DOT top-100 list, in which 56 of the same intersections appeared.

**Top-100 Annual Stability**

The purpose of this test was to evaluate a measure of ranking stability by ranking the intersections using only one-year periods of crash data and then determine whether a ranking method produced consistent top-100 intersection lists. The sampled intersection data was ranked by each of the six tested ranking methodologies three times, once for each year of crash data. Each ranking method’s top 100 intersections in 1998, 1999, and 2000 were determined. The intersections that appeared in the 1998, 1999, and 2000’s top-100 list were counted. The results of this annual stability test are shown in Figure 5.

The crash type ranking appeared to be the most stable ranking methodology on an annual basis. In this ranking, 53 intersections maintained a position in the 1998, 1999, and 2000 top-100 lists. The North Dakota DOT and the Illinois DOT ranking results were less stable than for the crash type ranking, but more stable than the vehicle damage and value loss ranking methods. In the Iowa DOT and the Minnesota DOT ranking results, only four and seven intersections appeared in each of the methods’ three annual top-100 lists, respectively.

### Table 5. Top-100 list similarities (intersections similar among the top-100 lists)

<table>
<thead>
<tr>
<th>Ranking method</th>
<th>Vehicle damage</th>
<th>North Dakota DOT (EPDO, simple)</th>
<th>Illinois DOT (EPDO, complex)</th>
<th>Iowa DOT (value loss)</th>
<th>Minnesota DOT (value loss, reduced fatal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash type</td>
<td>59</td>
<td>83</td>
<td>81</td>
<td>26</td>
<td>56</td>
</tr>
<tr>
<td>Vehicle damage</td>
<td>60</td>
<td>63</td>
<td>91</td>
<td>36</td>
<td>60</td>
</tr>
<tr>
<td>North Dakota DOT (EPDO, simple)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illinois DOT (EPDO, complex)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>33</td>
</tr>
<tr>
<td>Iowa DOT (value loss)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>56</td>
</tr>
</tbody>
</table>

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Intersection Crash Severity Ranking Method

Figure 5. Results of the top-100 annual stability test

Top-100 Severity Statistics

The total number of severe events that occurred in the top-100 intersections for each ranking methodology over the three-year period was determined. The purpose of this test was to evaluate the ability of a ranking to identify intersections that observed crash events that caused considerable harm to occupants. The three severe events evaluated in this test were injury crashes, fatal crashes, and very severely damaged vehicles. Table 6 shows the number of these events that occurred in the top-100 ranking intersections identified by each ranking methodology.

In five of the six ranking methods, more than 2,000 injury crashes were identified. However, the Iowa DOT ranking method, which heavily weighs fatalities, identified only 1,250 injury crashes.

Although the Iowa DOT ranking method was the least effective method for identifying intersections with high numbers of injury crashes, it identified 70 of the 73 fatal crashes that occurred in the subset of intersection data. This was considerably more fatal crashes than was identified by any other ranking method. The Minnesota DOT ranking method identified 31 fatal crashes, and the remaining methods only identified 8 to 13 fatal crashes.

Very severely damaged vehicles, which were shown earlier to correlate with considerable harm to occupants, were also evaluated in this test. As expected, the vehicle damage ranking method was the most effective method for identifying very severely damaged vehicles. More than 1,200 vehicles were very severely damaged at the top-100 intersections determined by this alternative ranking methodology. The Minnesota DOT ranking method identified 968 very severely damaged vehicles and the Iowa DOT’s method identified 871. The crash type ranking’s top-100 intersections observed the fewest number of very severely damaged vehicles, with 775 vehicles sustaining this damage level.
Table 6. Top-100 list severity statistics

<table>
<thead>
<tr>
<th>Ranking method</th>
<th>Injury crashes</th>
<th>Fatal crashes</th>
<th>Very severely damaged vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash type</td>
<td>2,268</td>
<td>8</td>
<td>775</td>
</tr>
<tr>
<td>Vehicle damage</td>
<td>2,063</td>
<td>13</td>
<td>1,232</td>
</tr>
<tr>
<td>North Dakota DOT (EPDO, simple)</td>
<td>2,394</td>
<td>9</td>
<td>787</td>
</tr>
<tr>
<td>Illinois DOT (EPDO, complex)</td>
<td>2,381</td>
<td>10</td>
<td>840</td>
</tr>
<tr>
<td>Iowa DOT (value loss)</td>
<td>1,250</td>
<td>70</td>
<td>871</td>
</tr>
<tr>
<td>Minnesota DOT (value loss, reduced fatal)</td>
<td>2,004</td>
<td>31</td>
<td>968</td>
</tr>
</tbody>
</table>

CONCLUSIONS

Nationwide, significant variability exists between the types of crash severity ranking methods used as components of safety management systems. Consequently, these approaches can produce considerably different results, despite their common objective.

In this paper, four different used-in-practice crash severity ranking methodologies were discussed. It was discovered that the North Dakota DOT and the Illinois DOT both utilize EPDO ranking approaches that apply relatively low weights to injury and fatal crashes. The major difference between these two methods is that the North Dakota DOT uses data for three basic severity levels (PDO, injury, and fatal) while the Illinois DOT uses data for five severity levels (PDO, possibly injury, non-incapacitating injury, incapacitating injury, and fatal). The Minnesota DOT and the Iowa DOT use value loss rankings based on the comprehensive injury costs of crashes. These methods apply proportionally higher weights to injury and fatal crashes than the EPDO methods. The major difference between these two value loss ranking methods is that the Minnesota DOT uses a reduced fatal crash cost. The reduced cost is equivalent to twice the cost of an incapacitating injury instead of using their actual comprehensive fatal crash cost estimate of $3,400,000.

Also in this paper, crash severity was more closely defined by evaluating crash factors related to the injury risk of occupants. This was accomplished by evaluating the impacts crash type and vehicle damage had on occupant injury severity using a three-year (1998 to 2000) sample of Wisconsin intersection crash data containing information for more than 400,000 occupants. While the quantity and types of injuries observed varied between crash types, more significant differences in occupant injury risk were observed between vehicles with different vehicle damage levels. For example, in vehicles damaged very severely (i.e., not salvageable), approximately one out of every 50 occupants was killed, whereas in vehicles damaged moderately only one out of approximately 10,000 occupants was killed.

The crash type and vehicle damage relationships to injury severity were then used to develop two alternative crash severity ranking methodologies. The crash type and the vehicle damage alternative ranking methodologies were determined using an average injury cost per vehicle methodology. Average costs were calculated for nine crash types and five vehicle damage levels. It was hypothesized that one or both of the newly developed rankings may be more appropriate than the used-in-practice rankings for identifying potentially hazardous intersections.

The two newly developed alternative crash severity ranking methods and four used-in-practice crash severity ranking methods were applied to subset of Wisconsin intersection data containing 25,633 crashes occurring at 1,369 intersections from 1998 to 2000. Three tests were conducted to evaluate and compare
The results of the rankings. The tests focused on the top 100 intersections identified by each ranking method. The similarities between the results of two methods were discussed, as well as each method’s annual ranking stability, and the number of severe events (i.e., injury crashes, fatal crashes, and very severely damaged vehicles) that were observed in the top 100 intersections identified by each method. The results of the ranking evaluations are summarized below:

- The crash type ranking produced results similar to the North Dakota DOT and the Illinois DOT ranking methods. The results of this ranking showed more annual stability than all of the other evaluated rankings. The crash type ranking was also effective at identifying injury crashes, but not as effective at identifying fatal crashes or very severely damaged vehicles.
- The vehicle damage ranking produced results most similar to the Illinois DOT ranking method. The results showed more annual stability than the value loss ranking results. Compared to the other rankings, the vehicle damage ranking was effective at identifying injury crashes and even more effective at identifying very severely damaged vehicles. This method was not as effective at identifying fatal crashes.
- The two EPDO rankings (i.e., North Dakota DOT and Illinois DOT) defined crash severity slightly differently but still produced relatively similar ranking results. The North Dakota DOT method was more stable than the Illinois DOT method and both methods were more stable than the vehicle damage ranking and the two value loss rankings. Both EPDO methods were effective at identifying intersections that observed high numbers of injury crashes, but were less effective at identifying fatal crashes and very severely damaged vehicles.
- The results of the two value loss rankings (e.g., Iowa DOT and Minnesota DOT) showed some similarities and some differences between the results of the two rankings. These methods showed the least annual stability of any of the rankings evaluated. The Minnesota DOT method was effective at identifying all three severe events evaluated. The Iowa DOT ranking method, however, was the most effective method for identifying fatal crashes, but identified far less injury crashes than the other evaluated rankings. The Iowa DOT method was effective at identifying very severely damaged vehicles.

In conclusion, crash severity is a subjective measure that is inconsistently defined throughout the nation. As a result, there was not a test and/or comparison that could have decisively determined the best ranking method for finding the most hazardous intersections. The evaluation and comparisons presented in this paper identified some of the similarities and differences between the six ranking methodologies tested.

It is recommended that decision makers use the information presented in this paper to help them identify a crash severity ranking methodology that meets the needs of their jurisdiction. The two alternative ranking methods developed in this research both have characteristics that may be advantageous over current used-in-practice methods. The crash type ranking produced more consistent results than any other evaluated ranking and successfully identified intersections that observed a high number of injury crashes. The vehicle damage ranking procedure was the most effective methodology for identifying very severely damaged vehicles and provided more consistent results than the two evaluated value loss rankings. Neither of the two alternative ranking methods biased results toward fatal crash sites, and both focused on factors related to the geometry and operations of roadways. The vehicle damage ranking appeared to be very effective at identifying severe crash events that were likely to cause severe injuries and fatalities.
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Transportation.

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