Secondary Crashes: 
An Important Component of 
Roadway Incident Management

Traffic safety specialists assume that “secondary crashes” result from incidents which increase traffic congestion. Yet, the literature presents few references to frequency of occurrence of these crashes, and no references to contributing factors. Without knowing the extent of the problem, recommendations for resolution are not practical. This article explores temporal and spatial analysis of incidents on urban arterial roadways to help identify those crashes, which were likely to be secondary. It found more than 15% of the crashes reported by police may have fit the definition; that is, occurred partly or entirely as the result of an earlier event. Such crashes appear to result more from external distractions to the driving task rather than commonly held beliefs that causation results mainly from internal distractions and errors in driver perceptions. Issues of defining such crashes are addressed through the use of geographic information systems along with temporal assumptions.

This article shows when secondary crashes are likely to occur and what classes of incidents were most likely to be related. In general, one third of all crashes classed as secondary occurred within 200 meters of the initial event and most within the time required to handle that event. Additionally, crashes represented approximately 60% of the primary incidents. Disabled vehicles and police citing motorists for traffic violations represented most of the remaining causes. Finally, the article identifies potential countermeasures which reduce the likelihood of external distractions affecting the driver and leading to the secondary crash.

by Richard A. Raub

In measuring the effect of incidents on delay, traffic engineers and researchers tend to treat each incident as a unique occurrence rather than as an extension of an earlier event. However, two situations come to mind which are obvious extensions. One is the overheated vehicle
resulting from extended idling in delays caused by an incident. A second situation is the crash which may result from the congestion. This secondary incident should be considered an extension of the earlier incident and the costs of clearing it should be part of the costs associated with the original event. Knowing the costs is important in examining the effectiveness of strategies designed to reduce the impact of incidents. What has not been measured is the likelihood of occurrence or its duration, especially a crash.

Not much is known about the rate at which vehicles overheat as a result of delays in traffic. Newer vehicles with better cooling systems are not as likely to do so. Moreover, an overheated vehicle usually can be pulled to the side and should not generate additional significant delay. On the other hand, a crash can result in further delay both from lane blockage and additional spacing by passing motorists. In this latter case, the literature appears particularly devoid of work identifying what percentage of crashes may have resulted from previous events affecting traffic flow. Data available from the study of urban arterial roadway incidents completed by Raub and others suggested that secondary crashes occurred more frequently than expected. Subsequent analysis of crashes showed that secondary crashes might represent as many as 15% of all crashes and occur as frequently as 1 in every 20 incidents along major urban roadways (excluding freeways). As this article shows, these crashes may add as much as 69 minutes of additional delay to each incident when a secondary crash occurs.

For this study, a "secondary crash" is identified as a crash which occurred after an earlier event but for which that earlier event was a contributing factor. The most common example is where a motorist passing an incident slows to look and is struck from behind by another inattentive driver. However, collisions can occur between motorists and personnel at the scene, merging vehicles as a result of lane reduction, unexpected turns or stops, and even opposite-direction sideswipe collisions because drivers in one direction have moved into lanes of opposing drivers. Moreover, these crashes are not necessarily limited to the immediate vicinity of an incident, but could occur in any part of the affected traffic stream.

Discussions with responders to incidents elicit stories of secondary crashes they have witnessed. However, no systematic study has quantified the extent of the problem. Only one reference emerges from the literature, the work by Owens in Great Britain in 1978. As part of filming the effect of incidents on traffic delay along a British motorway, he was able to identify crashes which happened after an earlier incident but appeared to have been related to it. Out of 75 crashes viewed on film, 13, or 17%, were placed in the category of secondary crash. Roberts, Webb, and Coe also filmed traffic on British motorways for similar purposes to Owens, but did not report their observations of secondary crashes. Lari, Christianson, and Porter referred to secondary crashes in their research related to incidents on freeways around Minneapolis. Finally, Loveday and Jarrett discussed clustering crashes in certain locations without identifying whether the clusters arose because of a series of independent or dependent events. All of this research used limited access roadways; none was along urban arterial roadways. The work by Raub, therefore, may provide the first look at what occurs on surface streets.

Incidents for which time and motion data were available and were used in the study included crashes, disabled vehicles, fires for major traffic (e.g., driving revoked license, traffic signal malfunctions), and other events which delayed traffic flow. They were collected from urban arterial roadways in contiguous communities in the Northwest Chicago suburbs. The analysis used in this article helps identify additional delay resulting from secondary crashes.

Problems Associated with Defining and Measuring Secondary Crashes

Several difficulties are encountered when attempting to determine whether a crash was the result of an independent or simply a chance occurrence in time and space. First, police reports, which are the source of crash data, rarely include information about events which may have contributed to the crash. Second, the problem of establishing parameters which link the two events: incident and secondary crash. If even if two events fit the parameters, there is a need to confirm that first was a contributor to the subsequent crash.

Parameters which link two events (an incident and secondary crash) is a valid space-time surface, has been identified in the literature. Current studies of effects of incidents on traffic flow and its clearance are insufficient to identify how long a single incident affects traffic flow. The study...
earlier event but for which that event was a contributing factor. A common example is where a following an incident slows to a halt, a vehicle is struck from behind by an attentive driver. However, this type of crash can occur between motorists on arterial roadways, merging as a result of lane reductions, and turns or stops, and even direction sideswipe collisions. Drivers in one direction have no lanes of opposing traffic. These crashes are not necessarily the immediate vicinity, but could occur in any affected traffic stream. The rate at which these secondary crashes are likely to occur is a function of the number of cases that have been observed, and the number of cases that are likely to be missed due to the difficulty in detecting them. The literature suggests that these crashes can occur for a period ranging from 5 minutes to more than 60 minutes after incident clearance, dependent on the nature of the incident and traffic volume. For this article, the effect is assumed to last 15 minutes. While somewhat arbitrary, the assumption is based on personal observations of traffic flow on urban roadways after an incident has been cleared.

In this article, time that traffic is affected is referred to as "time of effect" and expressed as \( t_e \). The time of effect comes from the equation:

\[
 t_e = t_{1st} + 15
\]

where: \( t_{1st} \) = the time taken to clear the first event

15 = the number of additional minutes before traffic flow is assumed to return to normal

Therefore, for a crash to be considered as secondary, it has to occur within the time of effect of an earlier incident. No guidance is available for linking two events spatially. Obviously, if the two events occur at the same location within \( t_{1st} \), then they probably are related (other conditions could be suggested to argue that this time-space relationship is more complex).
More difficult however, is establishing how far from the original location the effect incident continues. The distance should be positively related to traffic volume, simply because the length of queue increases with increased arrival rates given a rate of service. On-site observations of crashes occurring during peak periods suggested that an effect covering 1,600 meters is not an unreasonable assumption. However, such an effect only would occur during periods of heavy travel or when an event lasted an extended period (e.g., 60 or more minutes). A distance of effect \( d_e \) from an event then was assumed to be less than 1,600 meters or \( d_e < 1,600 \).

Exhibit 1 displays the surface encompassed by \( t_e \) and \( d_e \) where the first event has occurred at \( t = 0 \) and \( d = 0 \) (the 0,0 point). Subsequent crashes are represented by the dots. Crashes at A and B probably were related to the initial event; they occurred at the same location. Points D and E could have been caused in part by that event. Separation by time and distance lies within the assumptions. The remaining points, C, F, and G are assumed to be independent. The figure has been simplified; the actual surface would likely be more complex depending on traffic volume and duration of the first event.

The analysis of relationships for this report showed that with few exceptions all secondary crashes occurred within 800 meters of the initial event. Where the crash lay outside that distance, either the time of effect had lasted more than 60 minutes or there was one of multiple crashes all considered related. An example of the former is where an incident occurs, a crash occurs 600 meters away while that crash is being cleared, and another occurs 600 meters farther away from the original event. The assumption made is that all crashes were related to the event; without it, neither crash could have occurred.

Identifying Secondary Crashes from the Data

In addition to time that an incident could affect the roadways, the location of the crash could be plotted on a map. The data from Exhibit 1 displays the relationship of secondary crashes to an initial event.
SECONDARY CRASHES

Ed more than 60 minutes or the crash was one of multiple crashes all considered related. An example of the latter is where an incident occurs, then a crash occurs 600 meters away, and while that crash is being cleared, another occurs 600 meters further away from the original event. The assumption made is that both crashes were related to the initial event; without it, neither crash might have occurred.

Identifying Secondary Crashes from the Data

In addition to time that an incident could affect the roadways, the location of the crash could be plotted on a map. The geocoding of each incident was done through MapInfo® software using geographically coded street files. Once the incidents were converted into a geographic information system (GIS), distances between points could be measured.

Data for the study covered the period January 9, 1995 through February 5, 1995. Although the time was not a preferred one, it represented one for which data were available and, fortunately, did not have any severe winter weather which could have confounded relationships with crash data. Additionally, the road remained free of ice and snow during this period.

Exhibit 2 shows a cross-tabulation of the data by community and by general classification of the event.

<table>
<thead>
<tr>
<th>City Name</th>
<th>Crash</th>
<th>Fire</th>
<th>Traffic Stop</th>
<th>Disabled Vehicle</th>
<th>Other</th>
<th>All Incidents</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlington Heights</td>
<td>169</td>
<td>11</td>
<td>155</td>
<td>132</td>
<td>39</td>
<td>506</td>
<td>28.2%</td>
</tr>
<tr>
<td>Buffalo Grove</td>
<td>61</td>
<td>4</td>
<td>55</td>
<td>55</td>
<td>8</td>
<td>183</td>
<td>10.2%</td>
</tr>
<tr>
<td>Elk Grove Village</td>
<td>111</td>
<td>6</td>
<td>127</td>
<td>133</td>
<td>17</td>
<td>394</td>
<td>21.9%</td>
</tr>
<tr>
<td>Mount Prospect</td>
<td>101</td>
<td>12</td>
<td>118</td>
<td>84</td>
<td>12</td>
<td>327</td>
<td>18.2%</td>
</tr>
<tr>
<td>Palatine</td>
<td>100</td>
<td>9</td>
<td>44</td>
<td>47</td>
<td>18</td>
<td>218</td>
<td>12.1%</td>
</tr>
<tr>
<td>Prospect Heights</td>
<td>37</td>
<td>2</td>
<td>18</td>
<td>40</td>
<td>6</td>
<td>103</td>
<td>5.7%</td>
</tr>
<tr>
<td>Rolling Meadows</td>
<td>48</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td>65</td>
<td>3.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>627</strong></td>
<td><strong>44</strong></td>
<td><strong>534</strong></td>
<td><strong>491</strong></td>
<td><strong>100</strong></td>
<td><strong>1,796</strong></td>
<td><strong>100.0%</strong></td>
</tr>
<tr>
<td>Percent of total</td>
<td><strong>34.9%</strong></td>
<td><strong>2.4%</strong></td>
<td><strong>29.7%</strong></td>
<td><strong>27.3%</strong></td>
<td><strong>5.6%</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
All incidents were classified either as a crash (a further distinction is made among crashes with property damage only, injuries, and other or "injuries unknown"), traffic enforcement, disabled vehicle, fire, or other. The last classification included malfunctioning traffic signals and railroad crossing gates, materials spillage, and other road blockage. Not all traffic enforcement was included, only where the police officer communicated directly with the public safety telecommunicator (generally the more serious one such as driving under the influence).

The base contained 1,796 incidents. Of these, crashes represented 35%, traffic enforcement another 30%, disabled vehicles 27%, with fire and other categories accounting for the remaining 8%. Of the crashes studied, 75% resulted in property damage only. An additional 19% had an injury, and for 6%, the injury was unknown. This last category arose because the dispatcher entry showed "injury unknown" in classifying the dispatch and the record subsequently was not changed.

### Relationship Between Incidents and Subsequent Crashes

In order to determine how frequently crashes were expected to fall within both \( t_c \) and \( d_c \), a 10% sample of incidents was taken from the database, and both time and distance to the next crash following the event were measured. Because of the distribution of the 627 crashes in the database, more than one set of 10 events could be counted before a crash was found. Further, only those events between 6 A.M. and 10 P.M. were used (because these represent the extent of heavier traffic). As a result, the final sample contained 116 events from a base of 1,796 incidents for which a subsequent crash was associated. As shown in Exhibit 3, 50 of the first events were crashes and the remaining 66 were other classifications such as traffic stops. The average separation between the incident and the first subsequent crash was 8.6 kilometers and 95 minutes in time. The average distance between the initial event and subsequent crash far exceeded the maximum assumed separation of 1.6 km.

A second step was to reduce the sample of principal events to eliminate any crash which occurred beyond the elapsed time plus 15 minutes (\( t_c + 15 \) minutes) from the first event. This step was taken to yield only those events which fit within the temporal criteria (i.e., effect of the first event, so as to determine what percentage of crashes fell by chance within the 1.6 km separation). The average distance remained 8.6 km, and less than 4% of the first subsequent crashes occurred within the 1.6 km. As shown in Exhibit 4, the percent of first-occurring crashes by distance separation remained below what would have been expected by chance until 9.6 km separation.

### Exhibit 3

**Sample of Incidents and Subsequent Crashes**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Primary Event</th>
<th>Frequency</th>
<th>Separation in Distance</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash</td>
<td>50</td>
<td>10.1</td>
<td></td>
<td>11.2</td>
</tr>
<tr>
<td>Other</td>
<td>66</td>
<td>7.4</td>
<td></td>
<td>81.8</td>
</tr>
<tr>
<td>Total</td>
<td>116</td>
<td>8.6</td>
<td></td>
<td>94.5</td>
</tr>
</tbody>
</table>

a. All primary incidents occurring between 6 A.M. and 10 P.M.

### Occurrence of Secondary Crashes

Given the assumptions regarding time and distance separation (with the separation for multiple crashes of the GIS analysis showing 627 crashes recorded for the communities. This percent is substantially higher than the 3.6% of crashes which were found when incidents were selected randomly. The findings suggest that more than a chance relationship existed between initial and secondary crashes, and the earlier incident probably contributed to the later crash. Of the 97 cases, 16, or 16.5%, were injury-prod.
Occurrence of Secondary Crashes

Given the assumptions regarding time and distance separation (with added separation for multiple crashes), the results of the GIS analysis showed 97 crashes for 81 primary incidents. These crashes represent 15.5% of the 627 crashes recorded for the seven communities. This percent is substantially higher than the 3.6% of crashes which were found when incidents were selected randomly. The findings suggest that more than a chance relationship existed between incidents and secondary crashes, and that the earlier incident probably contributed to the later crash. Of the 97 crashes, 16, or 16.5%, were injury-producing.

This percentage is not significantly different from the relationship for crashes as a whole.

Average distance separating the primary event from the secondary crash was 500 meters. More than 33% of all crashes (as shown in Exhibit 5) occurred within the first 200 meters, and approximately two-thirds of the crashes had occurred at a distance of 800 meters or less from the original incident.

A final analysis of the secondary crashes showed that in 11 primary incidents, or 13.6% of the cases, more than 1 crash could be linked to the incident. In 4 cases, there were 2 secondary crashes and in 1 case 3 secondary crashes. If 1 of these primary
events was a crash, a possible outcome could be that police would face handling 4 crashes instead of the 1 to which they initially responded. During the research, one task involved debriefing responders to learn what had been done at the scene. One of the debriefings involved handling an injury crash, but 3 additional crashes followed at nearby locations. Even the responders had not originally realized that 4 had occurred and that they all appeared related.

**Primary Event**

Of these 81 primary events, 60.5% were crashes (but representing only 34.9% of all events) and another 24.7% disabled vehicles (27.3% of all events). Crashes as primary events occurred significantly more frequently than their proportion of all incidents in general. The chi square was 27.7, significant at the 0.01 level. Exhibit 6 shows the distribution by classification of the primary event. The initial effect on traffic from these primary events is also shown in Exhibit 6. This distribution of time is similar to that which was found for all 1,796 incidents within the database. Crashes lasted an average of 54.1 minutes (even though the secondary crash lasted an average of 58 minutes, the difference was not statistically significant). Although the time for fires appears short, most of the incidents were car fires or gasoline spills. The time spent on-scene usually is very short. Overall, a primary incident would be expected to cause at least 45 minutes of delay.

**Methodology for Computing Additional Delay**

Given that a crash could be associated with an earlier event, the need was to determine the extent of additional delay as a result. The time spent responding to and handling the call was available from the dispatch records. Duration of the incident was measured as the difference between the time the responder (generally an officer) finished the call and the time it was received. However, the call can be cleared before an officer arrives at the scene. Data from North Central Dispatch, which represents most of the incidents in the database, provided sufficient data from which the time the roadway was cleared could be estimated.

The time the call was received by the police was not the time of the crash. However, because of the prevalence of telephones and cellular ph
Classes of Primary Incidents

<table>
<thead>
<tr>
<th>Classification</th>
<th>Average Duration (minutes)</th>
<th>Frequency</th>
<th>% of Primary Incidents</th>
<th>% of All Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash</td>
<td>54.1</td>
<td>49</td>
<td>60.5%</td>
<td>34.9%</td>
</tr>
<tr>
<td>Fire</td>
<td>12.7</td>
<td>3</td>
<td>3.7%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Traffic stop</td>
<td>29.7</td>
<td>6</td>
<td>7.4%</td>
<td>29.7</td>
</tr>
<tr>
<td>Disabled vehicle</td>
<td>34.8</td>
<td>20</td>
<td>24.7%</td>
<td>27.3%</td>
</tr>
<tr>
<td>Other</td>
<td>26.0</td>
<td>3</td>
<td>3.7%</td>
<td>5.6%</td>
</tr>
<tr>
<td><strong>All classes</strong></td>
<td><strong>44.9</strong></td>
<td><strong>81</strong></td>
<td><strong>100.0%</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

a. Chi square = 27.7 (df=4, sig. <0.01)

Methodology for Computing Additional Delay

Given that a crash could be associated with an earlier event, the next step was to determine the extent of additional delay as a result. Time for responding to and handling a call was available from the dispatch records. Duration of the incident was measured as the difference between when the responder (generally a police officer) finished the call and the time it was received. However, the scene can be cleared before an officer finishes the call. Data from Northwest Central Dispatch, which represented most of the incidents in the database, provided sufficient data from which the time the roadway was cleared could be estimated.

The time the call was received by the police was not the time of the crash. However, because of the proximity of telephones and cellular phones in the urban communities, especially along arterial roadways, an assumption has been made that the time police received a call was close enough to the occurrence of the incident that this time could be used as the start of the incident. For Dutch freeways, Willmink and Immer suggested a delay of two minutes.10

Knowing when the primary incident and secondary crash occurred and the duration of both, several measures were available. These included minutes of delay prior to the second crash ($T_a$), and minutes of additional delay ($T_d$). The latter was derived from the difference between when the primary event finished and the secondary crash was cleared. Where the difference was less than zero, there was no additional delay. Where more than one crash was associated with the primary incident, $T_a$ was the difference from the end of the primary event until the last crash was cleared.
Importance of the Analysis

This analysis of delay resulting from secondary crashes is a first attempt to address the extent to which crashes may occur on urban arterial roadways and how they can exacerbate delays already accruing from incidents. Identifying secondary crashes based on the premise that if a crash occurred within a given duration of an earlier event and within 100 meters or less, that first event may have been a contributory factor. Because information about crashes gathered by police agencies does not provide sufficient narrative that can be used to help link an incident and secondary crashes, the assumptions used in this article could not be tested.

However, the finding that as much as 1 out of every 11 crashes may result in another crash occurring along an affected roadway is important in recognizing that the delays caused by an initial event can not be treated in isolation. All subsequent events must also be considered. The initial incident can have effects which spread further than the initial time spent by responders. The resulting combined delay often exceeds the delay associated with the first incident. Given that 1 incident can contribute to 1 or more crashes, significantly increases the costs associated with the original incident. These include those for respondents and those resulting from delay, in

<table>
<thead>
<tr>
<th>Primary Incident Classification</th>
<th>Number</th>
<th>Primary Duration</th>
<th>Time to Secondary Crash $T_c$</th>
<th>Added Delay $T_d$</th>
<th>Total Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash</td>
<td>49</td>
<td>54.1</td>
<td>35.1$^a$</td>
<td>68.7</td>
<td>103.8</td>
</tr>
<tr>
<td>Disabled Vehicle</td>
<td>20</td>
<td>34.8</td>
<td>20.5</td>
<td>67.3</td>
<td>87.8</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>24.5</td>
<td>23.3</td>
<td>71.9</td>
<td>95.2</td>
</tr>
<tr>
<td>All incidents</td>
<td>81</td>
<td>44.9</td>
<td>29.8</td>
<td>68.8</td>
<td>98.6</td>
</tr>
</tbody>
</table>

$^a$ Time to secondary crash, 35.1 minutes for primary incidents as crashes is significantly different at the 0.05 level.

Additional Delay Resulting from Secondary Crash

Exhibit 7

affected increased delays already accruing from incidents.

Identifying secondary crashes was based on the premise that if a crash occurred within a given duration (t) of an earlier event and within 1,600 meters or less, that first event may have been a contributory factor. Because information about crashes gathered by police agencies does not provide sufficient narrative that can be used to help link an incident and later crashes, the assumptions used for this article could not be tested.

However, the finding that as many as 1 out of every 11 crashes may result in another crash occurring along the affected roadway is important in showing that the delays caused by an event can not be treated in isolation. All subsequent events must also be considered. The initial incident can and does have effects which spread beyond the initial time spent by responders. The resulting combined delay far exceeds the delay associated with the incident. Given that 1 incident can contribute to 1 or more crashes significantly increases the costs associated with the original incident. These costs include those for responders, and those resulting from delay, including increased fuel usage and pollution.

Actions to reduce the initial costs may have "multiplier" effects on overall cost reduction. In some cases, eliminating the incident from the traffic stream (e.g., vehicle stops), can be done with relative ease. Even where the incident can not be eliminated, an assumption that as time increases so does the likelihood of a secondary crash can not be discarded. Therefore, responders need to consider managing the incidents to reduce the effect of that incident on other motorists who may be affected and subsequently involved in a collision. If for no other reason, a reduction in secondary crashes will reduce the police staff required to handle crash investigation.

What is needed is a better database which provides information about all actions taken by police and fire responders, and which has sufficient information to allow computing the amount of time an incident affects traffic. Further study also could benefit by better police reporting of crashes which calls attention to earlier events where applicable and to be more specific about traffic conditions and possible contributing factors.

**Endnotes**


Four factors have historically contributed to productivity improvements in the freight industry. These factors were technological improvements, maintenance-of-way (MOW) expenses, density economies, and productivity gains. This study demonstrates that the freight industry is saving $1.2 billion annually due to advancements in track performance in the 1990s. MOW expenses overall increased 31%, but costs per revenue ton-mile declined 28%. Additionally, demands on the track structure increased 73%, and freight volume increased 73%. By using project costs from historical studies and adding from the four factors were due to density economies, technological improvements, and equipment productivity gains. A historical overview of the railroad industry helps in understanding the current state of the industry.

Richard A. Raub is a research scientist with the Northwestern University Traffic Institute. He holds degrees in both economics and transportation management and has been involved in traffic safety evaluation and research along with police administration. Prior to coming to the institute, Raub worked for the Illinois Department of Transportation and State Police. He has contributed numerous articles related to a wide variety of issues in traffic safety, traffic crash research, and police administration. Currently he is performing research on improving traffic control within highway construction zones to help reduce traffic crashes.

During the late 1960s and early 1970s much attention was focused on improving the financial position of U.S. Class 1 railroad freight industry. At that time many railway companies were bankrupt, average return on net investment was near 0%, and the railroad industry was facing extensive downsizing. By the mid-1990s the railroad industry had achieved investment near 10% following decades of productivity gains through restructuring and revitalization.