Mapping Large Truck Rollovers: Identification and Mitigation Through Spatial Data Analysis

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Phase 1 Report
Identification of Large Truck Rollover Concentrations by State

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AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
AF	Accident Frequency
ATRI	American Transportation Research Institute
CR	Crash Rate
DOT	Department of Transportation
EB	Empirical Bayes
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GIS	Geographic Information System
GPS	Global Positioning System
GVW	Gross Vehicle Weight
HSID	Hot Spot Identification
MPO	Metropolitan Planning Organization
PAR	Potential for Accident Reduction
PDOE	Property Damage Only Equivalent
POC	Point of Contact
RTM	Regression to the Mean
VMT	Vehicle Miles Traveled

ABSTRACT

Crashes involving large trucks often result in numerous impediments to the transportation system, severe property damage and serious injuries or fatalities. In 2009 there were over 8,000 large truck crashes in which a rollover was categorized as the "most harmful event" for the large truck.[1] Truck rollovers also tend to be severe; over half (52%) of all large truck occupant fatalities involved a rollover in 2009.[2] To study this issue, fatal crash data from the Fatality Analysis Reporting System (FARS) and non-fatal crash data obtained from various state agencies were analyzed and mapped in a Geographic Information System (GIS) to explore the prevalence of large truck rollover events at particular sites. This report identifies dense concentrations of large truck rollovers using historical crash data from 2001 to 2009. This analysis demonstrates that a geographic database of large truck rollover events can be created to identify locations where large truck rollovers frequently occur. Future phases of the research will explore technology solutions to reduce the occurrence of rollover crashes and improve the overall safety of the transportation system.

[1] *Large Truck and Bus Crash Facts 2009*. Washington DC : Federal Motor Carrier Safety Administration, United States Department of Transportation, 2011. FMCSA-RRA-11-025.

[2] *Fatality Facts 2009: Large Trucks*. Highway Safety Research and Communications. [Online] Insurance Institute for Highway Safety. [Cited: October 31, 2011.] http://www.iihs.org/research/fatality_facts_2009/largetrucks.html.

1.0 INTRODUCTION

Mitigating the impact of large truck rollover events is vital to improving the safety and efficiency of the nation's transportation system. In 2009 there were over 8,000 large truck crashes in which a rollover was categorized as the "most harmful event" for the large truck.[3] While this accounts for only 2.8 percent of all U.S. Department of Transportation (DOT) reported large truck crashes, truck rollovers tend to be severe.[4] Over half (52%) of all large truck occupant fatalities involved a rollover in 2009.[5] In addition to the loss of life, rollovers are extremely costly. A 2009 study found the cost of a rollover that resulted only in property damage to be, on average, $196,958.[6] That average cost increased nearly six-fold to $1,143,018 when a fatality occurred.[7] Large truck rollovers are often induced by factors that are unique to the truck and its operating environment. Although not all large trucks are configured in the same manner, or have similar load weights and distributions, historical crash data indicates that large trucks are prone to rollover at particular speeds and locations. For example, while research has established that particular road geometries such as curves and interstate interchanges can increase the likelihood of a rollover, not all locations with these design features are equally problematic. Furthermore, rollover concentrations are not limited to a single stretch of road but rather may span multiple intersecting roads as the result of the interaction between the roads, all of which may have varying geometries, functional classes and exposure rates.

This research focuses on identifying the locations that have the highest frequency of large truck rollovers. Given that drivers often have little warning of an impending rollover, information concerning the location of rollover hot spots can be used to alert drivers prior to entering an area with a history of multiple rollovers. With this knowledge, drivers will have the ability to modify their driving behavior as they maneuver these sites.

Furthermore, identification of high-frequency rollover locations will allow the ATRI Research Team to determine if a common design feature is present at these sites and if this feature correlates to rollover risk. This information is valuable to transportation stakeholders tasked with improving the safety of the transportation network. Once physical road characteristics that increase the likelihood of rollovers are identified, preventative measures can be taken to decrease the risk of this crash type. Reducing the number of rollover crashes would also result in fewer negative secondary impacts, such as congestion and clean-up costs, which affect both the trucking industry and the general public.

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[3] *Large Truck and Bus Crash Facts 2009.* Washington DC : Federal Motor Carrier safety Administration, United States Department of Transportation, 2011. FMCSA-RRA-11-025.
[4] Ibid.
[5] *Fatality Facts 2009: Large Trucks.* Highway Safety Research and Communications. [Online] Insurance Institute for Highway Safety. [Cited: October 31, 2011.] http://www.iihs.org/research/fatality_facts_2009/largetrucks.html.
[6] *Analysis of Benefits and Costs of Roll Stability Control Systems for the Trucking Industry.* Washington, DC : American Transportation Research Institute, US Department of Transportation, Federal Motor Carrier Safety Administration, 2009. FMCSA-RRT-09-020.
[7] Ibid.

The scope of this research has been divided into three phases. The purpose of this report, Phase 1, is to develop a national truck rollover database to determine locations where rollovers have frequently occurred. Information regarding the location of these rollover hot spots can then be distributed through state-specific summary reports and through an on-line interactive map application.

Phase 2, which commenced in March, 2012, is to design an in-cab warning system to notify large truck operators in real-time as they near a site where truck rollovers frequently occur. This will allow drivers to adjust their driving behavior accordingly and potentially lower rollover risk. In Phase 3, the focus will be to conduct an analysis of the infrastructure design and signage features of each high-frequency rollover location to identify and categorize possible roadway design issues. This research will inform those who have the ability to address infrastructure issues of potential problems related to roadway design or signage.

This report summarizes the results of Phase 1 of the research which identifies high-frequency rollover locations. The report is presented in three sections as follows:

- Section One: Literature review related to large truck rollover crash causation and the use of Geographic Information Systems (GIS) in spatial crash analysis;
- Section Two: The methodology for identifying dense concentrations of rollover accidents;
- Section Three: The research results and the next steps.

2.0 LITERATURE REVIEW

A large body of truck research exists that addresses various safety aspects, causal factors and preventative measures of truck crashes. Past research has used numerous methodologies to predict or explain the cause of truck rollover crashes. While causal factors for large truck rollovers are generally understood, there is a shortage of literature focusing on the spatial analysis of rollover accidents based on historical crash data. GIS has been successfully used for spatial rollover analysis, however previous GIS research was limited to a restricted study area, a narrow timeframe or utilized only fatal crash data.

2.1 Causal Factors in Large Truck Rollover Crashes

Often, large truck rollover crashes cannot be attributed to a single cause. A recent study sought to identify the most prevalent causes of large truck rollover crashes by analyzing descriptions of 231 crashes of this type. The report found that failing to adjust speed to curves, loads, brake condition, road surfaces and intersections were causes of nearly 50 percent of the rollover crashes.[8]

Factors regularly influencing large truck rollovers can generally be grouped into three categories: driver error; large truck design characteristics; and the operating environment, with driver error being the most significant. Specifically, lack of attention and control errors are cited as two major driver errors contributing to truck rollover events.[9] When considering tank truck rollover accidents, research found that driver error was a contributing factor in 74 percent of crashes.[10] Another study, using data collected from police-reported crashes in North Carolina from 1996 to 1998, found speeding, reckless driving, alcohol and drug use, non-use of restraints, and traffic control violations as driving behaviors associated with higher rollover propensity. In that study, reckless driving increased the possibility of a rollover by approximately 19 percent. Likewise, speeding, passing improperly, and the use of alcohol and drugs increased the chance of rollover by 17, 21 and 11 percent, respectively.[11]

Trucks have unique features distinct from passenger cars that contribute to high rollover susceptibility, including design, functional ability, and high center of gravity. Particular types of trucks are more vulnerable to rollovers and may experience more severe rollovers. For example, tank trucks transport low viscosity liquid payloads, have high centers of gravity and experience constant shifting of their liquid cargo, all of which contribute to low rollover stability thresholds. Due to these design and payload

[8] *Analysis of Large Truck Rollover Crashes.* McKnight, James A. and Bahouth, George T. 5, s.l. : Traffic Injury Prevention, 2009, Vol. 10. 10.1080/15389580903135291
[9] Ibid.
[10] *Cargo Tank Roll Stability Study: Final Report.* Washington, D.C. : Batelle, U.S. Department of Transportation, 2007.
[11] *Risk Factors in Large Truck Rollovers and Injury Severity: Analysis of Single-Vehicle Collisions.* Khattak, Asad J, Schneider, Robert J and and Targa, Felipe. Wasington, D.C. : Transportation Research Board, 2003. TRB Paper: 03-2331.

characteristics, cargo tank trucks account for 31 percent of fatal large truck rollover crashes, yet represent a much smaller percentage of all types of fatal large truck crashes (only 15%).[12] Even among the same type of truck, load distributions, tank type (baffled vs. non-baffled) and cargo type are known to have significant impacts on a large truck's dynamic rollover threshold. One study tested three different load configurations: empty; partially loaded; and fully loaded. Under all load configurations, research found that even when trucks traveled at or below the posted speed limit, the lateral accelerations for the trailer surpassed the projected lateral accelerations expected from the roadway geometry. The partially loaded truck however, exhibited the highest rollover propensity indicating the influence of load types and distribution on the trailer rollover thresholds.[13]

Often, factors unrelated to the driver and the truck, such as operating environment, amplify the risk of a large truck accident. Design features posing increased risks to trucks include curves, interstate ramps, speed, intersections, lane merges, and work zones.[14] In particular, curves increase the rollover propensity by nine percent, as well as increase the chance of truck occupant injury by four percent.[15] When discussing truck performance relative to other vehicles, research suggests a re-evaluation of speed limits on curves as most are designed for cars and fail to consider various truck configurations, load distributions and cargo types.[16,17]

2.2 Methods for Spatial Analysis of Large Truck Rollover Crashes

With all of the possible contributing factors to large truck rollovers, identification of accident-prone locations (or "hot spots" as they are often referred to as in the literature) is vital to identifying appropriate countermeasures. The literature indicates several methods for hot spot identification (HSID) currently in practice including: accident frequencies (AF); crash rates (CR); Empirical Bayes (EB); potential for accident reduction (PAR); and property damage only equivalents (PDOE).

With the AF method, sites are identified by the total number of observed accidents at a particular location. This method is useful for identifying the locations with the highest frequency of crashes and is one of most commonly used HSID methods in practice.[18] However, AF cannot be used to make statements regarding the relative safety of an

[12] *Cargo Tank Roll Stability Study: Final Report.* Washington, D.C. : Batelle, U.S. Department of Transportation, 2007.
[13] *Heavy Truck Dynamic Rollover: Effect of Load Distribution, Cargo Type, and Road Design Characteristics.* García, L.O, Innes J.D. and Wilson. F.R. Washington DC : Transportation Research Board, 2002.
[14] *The Domain of Truck and Bus Safety Research.* Washington D.C. : Transportation Research Board, 2007. Transportation Research Circular E-C117.
[15] *Risk Factors in Large Truck Rollovers and Injury Severity: Analysis of Single-Vehicle Collisions.* Khattak, Asad J, Schneider, Robert J and and Targa, Felipe. Wasington, D.C. : Transportation Research Board, 2003. TRB Paper: 03-2331.
[16] Ibid
[17] *Heavy Truck Dynamic Rollover: Effect of Load Distribution, Cargo Type, and Road Design Characteristics.* García, L.O, Innes J.D. and Wilson. F.R. Washington DC : Transportation Research Board, 2002.
[18] *The Influence of Underreported Crashes on Hot Spot Identification.* Truong, A., et al. 1, Washington, D.C. : Journal of Transportation of the Institute of Transportation Engineers, 2011, Vol. 1.

identified site compared to other sites.[19] Furthermore, this method is susceptible to random variations in crash counts, known as regression to the mean (RTM) bias, and could result in reduced accuracy in location identification.[20]

The CR method, however, uses a volume metric, typically average annual daily traffic (AADT) or vehicle miles traveled (VMT), to establish exposure at certain locations. This method assumes a linear relationship between accidents and exposure and requires a volume metric at all sites to function properly. For this reason, preference is often given to the AF method over the CR method, as recent research has shown the relationship between crash probability and traffic volume as a nonlinear relationship (effects are not proportional to their causes) and the relationship of traffic volume to AF to be curvilinear (related, but the relationship does not follow a straight line).[21]

The EB method aims to solve both of the problems presented in AF and CR methods by accounting for both accident history (AF) and performance compared to similar reference sites (CR). The EB method produces reliable results; though large amounts of associated accident data (such as geometry, speed limits and traffic volume) are required for proper analysis.[22,23] Furthermore, underreported crash data have a greater effect on EB results compared to the AF method.[24]

Other methods (e.g. PAR) rank sites according the observed number of crashes compared to the expected number of crashes based on crash histories at similar sites.[25,26] This method assumes that the number of preventable crashes at a given location is equal to the number of crashes in excess of the expected number of crashes.[27] Some literature proposes that ranking hot spots using PAR may be more accurate and thus more cost effective (when considering site treatment) than AF or CR, while other research conversely suggests that, due to possible inaccuracies in the estimation of expected number of accidents at a site, AF produces better outcomes.[28]

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[19] *Black Spot Analysis Methods: Literature Review.* Geurts, K. and Wets, G. s.l. : Steunpunt Verkeersveiligheid bij Stijgende Mobiliteit, 2003. RA-2003-07.
[20] *The Influence of Underreported Crashes on Hot Spot Identification.* Truong, A., et al. 1, Washington, D.C. : Journal of Transportation of the Institute of Transportation Engineers, 2011, Vol. 1.
[21] *Identifying Large Truck Hot Spots Using Crash Counts and PDOEs.* Vadlamanai, C., et al. 1, s.l. : Journal of Transportation Engineering, 2011, Vol. 137. 0733-947X.
[22] Ibid.
[23] *New Criteria for Evaluating Methods of Identifying Hot Spots.* Cheng, W. and Washington, S. Washington, D.C. : Transportation Research Record: Journal of the Transportation Research Board, 2008, Vol. NO. 2083. 10.3141/2083-09.
[24] *The Influence of Underreported Crashes on Hot Spot Identification.* Truong, A., et al. 1, Washington, D.C. : Journal of Transportation of the Institute of Transportation Engineers, 2011, Vol. 1.
[25] *Black Spot Analysis Methods: Literature Review.* Geurts, K. and Wets, G. s.l. : Steunpunt Verkeersveiligheid bij Stijgende Mobiliteit, 2003. RA-2003-07.
[26] *Identifying Large Truck Hot Spots Using Crash Counts and PDOEs.* Vadlamanai, C., et al. 1, s.l. : Journal of Transportation Engineering, 2011, Vol. 137. 0733-947X.
[27] *The Influence of Underreported Crashes on Hot Spot Identification.* Truong, A., et al. 1, Washington, D.C. : Journal of Transportation of the Institute of Transportation Engineers, 2011, Vol. 1.
[28] *The Application of Empirical Bayes Approach for Identifying and Ranking Hazardous Junctions Case Study: Singapore Signalized Junctions.* Kusumawati, A. and Wong, Y.D. Singapore : Journal of the Eastern Asia Society for Transportation Studies, 2010, Vol. 8.

Since fatal crashes have a significant cost to society, PDOE considers crash severity in order to rank locations based on their societal costs.[29,30] In the PDOE methodology, locations with a high proportion of severe crashes are ranked higher than sites with large numbers of property damage-only crashes. PDOEs are less prone to analysis errors due to the impact of underreporting. However, the use of PDOE for a before-after analysis of site conditions is problematic and further exploration is needed.[31]

While there are numerous methods for conducting a spatial analysis of crash records, the appropriate methodology for a specific study is ultimately determined by the characteristics and constraints of the research. Of particular importance is the availability of data. The AF method requires the least amount of data, but is less descriptive about the relative crash risk between hot spots. Other methods attempt to overcome this shortcoming, but require more data such as volume and crash severity.

2.3 Application of GIS to Spatial Analysis of Large Truck Rollover Crashes

With several methods available for accident analysis, many researchers, planners and transportation officials are increasingly using GIS as a tool for both spatial and statistical analysis of crash locations. The Federal Highway Administration (FHWA) has created the "GIS-Based Crash Referencing and Analysis System" to assist with problem site identification and countermeasure evaluation studies. The system is comprised of five tools designed for use in a GIS environment including:

- spot/intersection analysis (identifies crashes within a defined distance from a spot/intersection);
- strip analysis (identifies crashes on a defined route within a defined segment length);
- cluster analysis (identifies crashes clustered around a particular feature);
- sliding-scale analysis (identifies segments with high numbers of crashes on a defined route); and
- corridor analysis (identifies high crash concentrations within a corridor).

By enabling spatial relationship analysis, incorporating non-traditional databases and facilitating automatic links between locations and data, FHWA found that the GIS-based system was more advantageous than traditional computerized crash analysis systems.[32]

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[29] *Property Damage Crash Equivalency Factors for Solving the Crash Frequency-Severity Dilemma: Case Study on South Korean Rural Roads.* Oh, J., Washington, S. and and Lee, D. Berkeley, CA : Safe Transportation Research & Education Center, Institute of Transportation Studies, UC Berkeley, 2010. RR-2010-9.
[30] *A Comparison of Rollovers with Non-Rollovers and Analysis of Injury Severity in Large Truck Crashes.* Khattak, A., Schnieder, R. and and Targa, F. Knoxville, TN : Southeastern Transportation Center, 2002.
[31] *Property Damage Crash Equivalency Factors for Solving the Crash Frequency-Severity Dilemma: Case Study on South Korean Rural Roads.* Oh, J., Washington, S. and and Lee, D. Berkeley, CA : Safe Transportation Research & Education Center, Institute of Transportation Studies, UC Berkeley, 2010. RR-2010-9.
[32] *Summary Report: GIS-Based Crash Referencing and Analysis System*. Washingotn D.C. : Federal Highway Administration, United States Department of Transportation, 1999. FHWA-RD-99-081.

GIS also has advantages in identifying locations where particular events are overrepresented, known as "hot spots." Identifying hot spots is important to understanding where the interaction of several roads is contributing to higher crash frequencies, as opposed to examining stretches of roadway individually. Due to congestion, urban crash hot spots often span multiple adjacent roads.[33] When examining crash locations visually, dense clusters of crashes may be difficult to determine. Use of a GIS allows researchers to analyze the spatial relationship of one crash location to those of other crashes within a determined proximity.

The Houston-Galveston Metropolitan Safety Planning Program is an example of a Metropolitan Planning Organization (MPO) that used a GIS to develop a crash information system. For this program, these were areas where data indicated crash occurrences at least once every two weeks. The crash information system also calculated crash volumes and determined high-risk hot spots from the identified sites using associated databases contained in the GIS.[34]

2.4 Summary of Literature Review

Despite ample research on the causal factors of large truck crashes, there is less literature associated with the spatial analysis of these crashes. While research has established particular road geometries such as curves and interstate interchanges as features that increase rollover likelihood, not all locations with these design features are dangerous, as some present a higher risk than others. Furthermore, rollover concentrations are not limited to a single stretch of road but rather may span multiple intersecting roads as the result of the interaction between the roads – all of which may have varying geometries, functional classes and exposure rates. Therefore, spatial analysis of rollovers is necessary to further understand how multiple causal factors can combine to induce a rollover. The literature identifies several different methods for spatially determining crash hot spots. Each method has benefits and limitations and the applicability of a method to a particular analysis depends on the research scope and the availability of data. When considering any HSID method, it is important to note that all methods identify "potential" locations, which can then be investigated further to determine if remediation is needed. GIS tools have successfully been utilized to conduct hot spot analyses using vehicle crash data, particularly in instances where the affected location is influenced by the interaction of several different roads. However, no known national spatial analysis of large truck rollover crashes has been conducted to date.

[33] *Houston, Texas, Metropolitan Traffic Safety Planning Program.* Levine, Ned. Washington, D.C. : Transportation Research Record: Journal of the Transportation Research Board, 2006, Vol. NO. 1969.
[34] Ibid.

3.0 METHODOLOGY

Currently, there is no national spatially-indexed database of high-frequency large truck rollover locations. In an effort to identify the location of rollover hot spots, this research utilizes GIS tools to analyze historical crash data using the AF method. GIS technologies are well-suited for collecting, analyzing and integrating a significant quantity of large truck rollover location data with geographic coordinates. By utilizing the AF method, the resulting analysis provides a list of rollover hot spots with the highest number of large truck rollovers.

The analysis uses both fatal and nonfatal large truck rollover data for the years 2001-2009 (where available) from FARS and from individual state vehicle crash databases. A summary report was created for each participating state and includes the number of fatal and nonfatal rollover crashes for each year as well as the top rollover locations based on highest frequency of rollover events.

3.1 Defining Data Elements and Review of Data Sources

Prior to initiating data collection, the ATRI Research Team set criteria that all crash records must meet in order to be included in the analysis. These criteria were established to eliminate erroneous crash data elements and create standardization among rollover events in the spatial database. Furthermore, due to the spatial nature of this research, precise location data was needed to distinguish specific truck rollover sites. Location data collected in this phase of the research will aid rigorous spatial analysis of high-frequency rollover locations in subsequent research phases.

Given these requirements, acceptable records were defined as rollover crash data which met the following criteria:

- Involved one or more vehicles with a gross vehicle weight (GVW) of 26,001 pounds or more (i.e. large trucks);
- Occurred between the years 2001 and 2009;
- Contained specific location data (latitude/longitude coordinates).

The challenge in conducting a national spatial analysis of large truck rollovers is the myriad databases of crash records maintained by the federal government, state governments and private motor carriers. There is no single national database that meets the aforementioned research requirements. Therefore, a combination of databases was necessary. Each crash database, however, is governed by different reporting requirements and covers various geographies. While different databases can be standardized to some degree, the integration of multiple databases creates challenges. To limit the impacts of using multiple databases, the ATRI Research Team reviewed numerous databases to select the most appropriate sources of data.

One potential source of large truck rollover data was the FARS database. FARS records motor vehicle crashes from all 50 states that result in the death of a vehicle

occupant or non-motorist within thirty days of the crash.[35] Therefore, FARS is intended as a national census of fatal accidents. Over 100 coded data elements are included in each crash record. Of particular benefit to this study, the FARS database began recording geographic coordinates (longitude/latitude) in 2001. This database is generally considered to be comprehensive with little underreporting; however, it is restricted to only those crashes resulting in a fatality.

Another potential source of rollover data was individual motor carriers. While many carriers maintain detailed records of truck crash events, the granularity of location attributes varies greatly as not all fleets are equipped with GPS capabilities.

Individual states also collect crash data; however, this data exists in a range of formats with varying collection and reporting procedures. Crash data for some states is available for download through online state record portals while other states require a more formal process for acquiring data. Although all states must meet federal mandatory minimum reporting requirements, the quality of data reported still varies greatly between states. States began using geographic coordinates to record crash location at different dates and also classify trucks using varying categorical definitions. For example, one state may classify trucks by number of axles and another by GVW. Additionally, some states do not differentiate between types of rollovers (e.g. blowovers).

Due to the availability of coordinate data and unlikelihood of significant underreporting, the FARS database was chosen as the source for fatal rollover data. The reporting standards and ability to query data based on crash event, GVW and date of crash made this database a reliable and time-efficient source of rollover crash records. For non-fatal rollover data, other databases, such as those maintained by motor carriers, did not meet the data requirements for the research. Despite the challenges that the inconsistent data reporting techniques created, it was determined that state data was the best source for data on non-fatal rollover events. Given that it was not methodologically sound to directly compare states that collect data in different manners, it was determined that conducting the analysis on a state-by-state basis was the most appropriate method.

In collaboration with the American Association of State Highway and Transportation Officials (AASHTO), the ATRI Research Team solicited state Departments of Transportation (DOT) for traffic incident data that contained location data for large truck rollover crashes. AASHTO initiated outreach to identify each state's most appropriate point of contact (POC). The ATRI Research Team continued the data collection effort by contacting each state's POC individually to pursue the data request.

3.2 Data Assimilation and Mapping

[35] *Fatality Analysis Reporting System Fatal Crash Data Overview (Brochure).* National Highway Traffic Safety Administration. [Online] [Cited: November 1, 2011.] http://www-nrd.nhtsa.dot.gov/Pubs/FARSBrochure.pdf.

Once data was received from the states that elected to participate in the study, the information was converted to a format appropriate for use in a GIS software platform. Significant data review was conducted prior to adding records from both FARS and individual state data sources to the spatial database. Various state data coding elements were reviewed with state contacts to capture truck rollover records that closely matched the defined data element criteria developed by ATRI. Rollover data was standardized in terms of geographic projection and attributes and then mapped in Environmental Systems Research Institute's ArcGIS software using the coordinates contained in the crash record. Graphical display of the rollover locations in GIS then allowed for spatial analysis of the events.

Since third party entities collected the rollover data, there are a few caveats that should be considered in order to use the data appropriately. For example, as the data was collected by the states, researchers can only verify that the data is accurate as much as the individual state standards would imply. Thus, integrity of the national rollover database may be affected by issues such as miscoding, underreporting, accuracy of coordinates (which leads to undercounting), attribute categorization and specificity of data to this study. However, the data review conducted by the ATRI Research Team increased the accuracy of the records contained in the database, in terms of meeting the desired attribute criteria. Nevertheless, issues such as underreporting or miscoding on behalf of the states cannot be corrected by the researchers' methodology. It is believed that undercounting is the most relevant issue due to the lack of geographic coordinates in most state datasets.

3.3 Cluster Identification Procedures

Spatial analysis tools were applied in the GIS environment to determine "clustering" of rollover incidents at specified locations. Since the database consisted of individual points where the only attribute is location, points had to be manually clustered. Cluster tolerance was set at a 0.25 mile integration level. Integration allows identification of those locations where rollovers occurred most frequently by combining all rollover locations that occurred within a 0.25 mile radius of another rollover incident into one representative point. This representative point is the centroid of all rollover events that constitute that cluster. For example, Cluster 1 may contain points A, B, and C. Point A may be 0.25 miles from point B but 0.5 miles from point C. Even though points A and C are more than 0.25 miles apart, they are considered part of the same cluster due to their spatial relationship to point B. Therefore, in this example, point B would be the centroid and the representative point of Cluster 1. Integration is illustrated in Figure 1. It is important to note that centroids do not always match the location of any single point within a cluster.

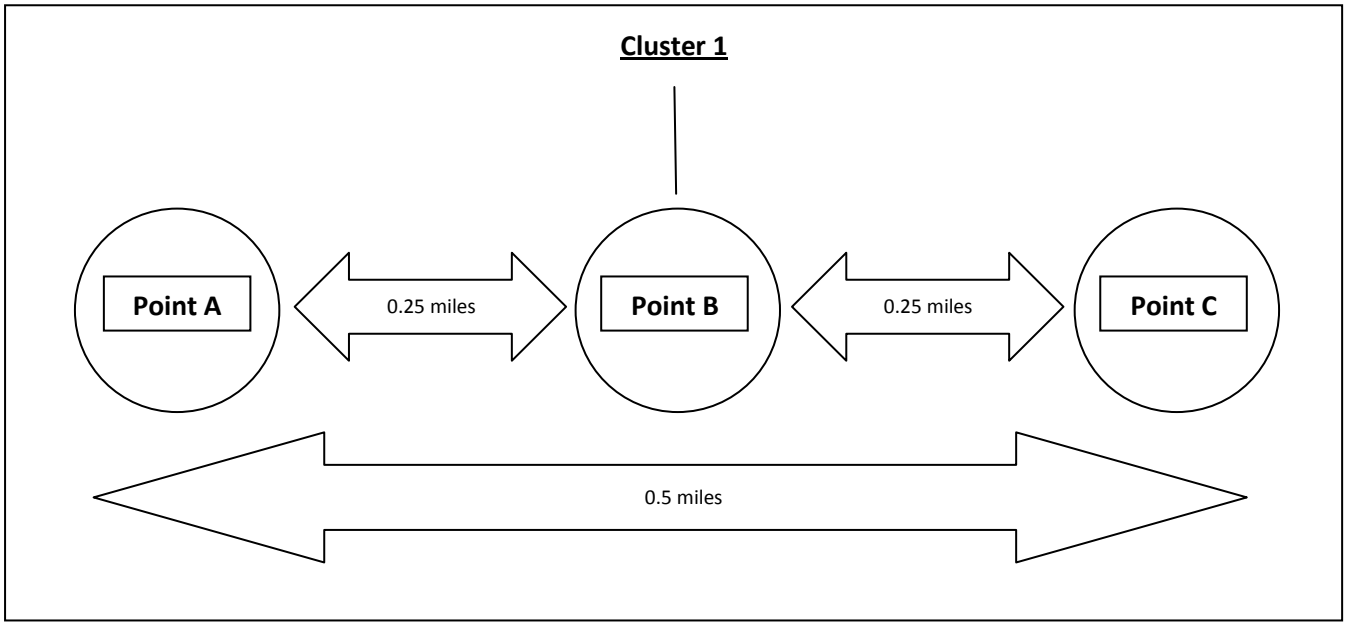


Figure 1. Cluster Tolerance

To aggregate and analyze the rollover records at each cluster, it was necessary to apply one of the spatial analysis methods discussed in the literature review. Given the disparities in reporting techniques among each state, it was necessary to pick a methodology that was applicable to all the participating states. Since the AF method requires the least amount of data to function, it was chosen as the spatial analysis methodology for the Phase 1 research. Other methods were tested but did not meet the research objectives or were not flexible enough to accommodate the data variation among states. Specifically, the ATRI Research Team investigated utilizing the CR method to establish relative rollover risk among locations. However, a valid database of volume metrics on a national or state scale with coverage for every rollover location did not exist. For example, oftentimes a rollover cluster was centered at an intersection between an Interstate highway and a local road, with rollovers occurring on both roads as well as the Interstate exit ramps. While volume data could be attributed to the Interstate, no national or state source of data existed for the local road or for the Interstate exit ramps. Regardless, establishing crash rates was not the desired outcome of this phase of research as the intent was to identify the locations with the highest frequency of rollovers for further investigation, rather than compare and rank locations based on relative rollover risk. Other ranking methods, such as PDOE, were also not applicable due to limitations in meeting the Phase 1 objectives. Therefore it was determined that the AF method, which identifies rollover clusters with the highest frequency of rollovers, was the most applicable method. As prescribed by the AF method, once the centroids of each cluster were identified, each rollover contained within the cluster was aggregated to produce a total rollover count for that cluster. These rollover clusters should be considered locations for further investigation and possible remediation.

3.4 State Reports

One challenge presented by data collection inconsistencies among the states is the comparison of rollover activity between states. These inconsistencies prohibit a direct comparison between two states since the data reporting techniques are not uniform. For example, one state may utilize GPS technology more frequently, thus producing a greater number of crash records that are suitable for this study. Therefore, results from the analysis are presented on a state-by-state basis through individual state reports and are not directly comparable (see Appendix A).

A summary report was generated for every state supplying data that met the research requirements. While a total of 39 states provided data, several factors excluded eight of those states from the database, reducing the number of analysis states to 31. Databases for each state also varied in the number of years of data each contained, with not all states having data for the same years. The report includes the total number of rollovers for each state by year and severity (fatal vs. non-fatal), a map showing the locations with the greatest number of rollovers and a table listing detailed location information and number of rollovers for each site. While the state reports are not asserting the relative rollover risk of these locations compared to other sites within or between states, they are valuable tools for identifying areas of concern for future research.

4.0 RESULTS AND CONCLUSIONS

A total of 31 states contributed more than 48,000 non-fatal large truck rollover records. While 39 states initially participated, data from eight states was not integrated into the database due to either lack of required data elements or conformity issues. One state formally declined participation in the data request citing legal concerns. The remaining ten states did not respond to requests for participation by the time of publication. Figure 2 displays participation by state. While data from 2001-2009 was requested, not every participating state was able to provide data for all nine years.

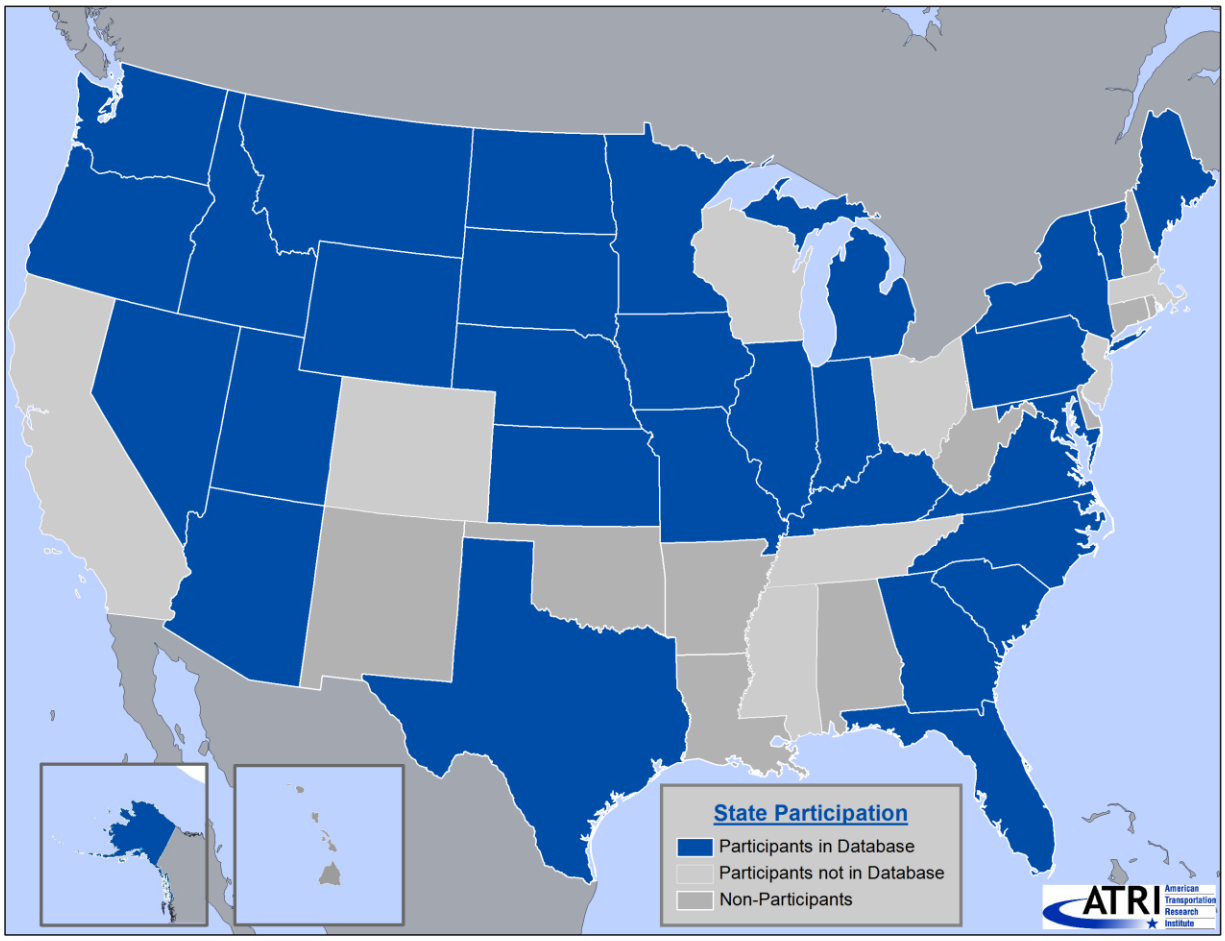


Figure 2. Participation by State

The state data was combined with 2,691 large truck rollover fatality records from the FARS database. Although a total of 51,229 rollover crash records are included in this database, it should not be considered a census of every large truck-involved rollover. As previously noted, there are a number of challenges to compiling a national rollover database, which resulted in some degree of undercounting. Most of the difficulty involved obtaining and formatting non-fatal data from the states. Issues with coding, truck classification, providing coordinates, and duplicate records meant that many

possible truck rollover sites could not be located and added to the database. The accuracy of the data also varies based upon the accuracy of data supplied to ATRI by the states.

To identify the locations where the greatest number of rollovers occurred, ATRI researchers utilized the AF method to identify groupings of rollovers that were spatially proximate. This method was effective for identifying rollover concentrations, especially those concentrations that were not limited to a single stretch of road but rather multiple intersecting roads. For each rollover concentration, the total number of rollovers within each cluster was calculated. In each state, the identified clusters were then sorted by the total number of rollovers to determine the locations with the largest number of rollovers. As discussed in the methodology, the lack of a national truck volume database prohibited the calculating of relative rollover risk among the identified clusters.

In addition to the state reports provided in Appendix A, the results of this research are also available through an online map. This web-based interactive application increases the utility and availability of this research and is intended to further promote the use of spatial technologies in large truck crash research. The online map will also link viewers to the full research report and the state report associated with each identified location. The online map is available through ATRI's website at www.atri-online.org.

As an added quality assurance measure, each state report was reviewed by the respective state's trucking association. This process revealed that in many instances the methodology successfully identified locations where truck rollovers have been an anecdotal issue as many state trucking associations were able to corroborate the research findings with an understanding of their state's truck crash involvement. Additionally, the state trucking associations were able to identify rollover hot spots that are currently (or were recently) undergoing design improvements. For example, at one identified rollover hot spot in Washington, an interchange upgrade has recently been completed that improves the turn radius of the exit. In situations where the ATRI Research Team was made aware of infrastructure improvements during the study period, a notation to that effect was added to the state report. The overlap of locations identified in the research with locations targeted for design improvements strengthens the integrity of both the research findings and the state infrastructure investments in those locations.

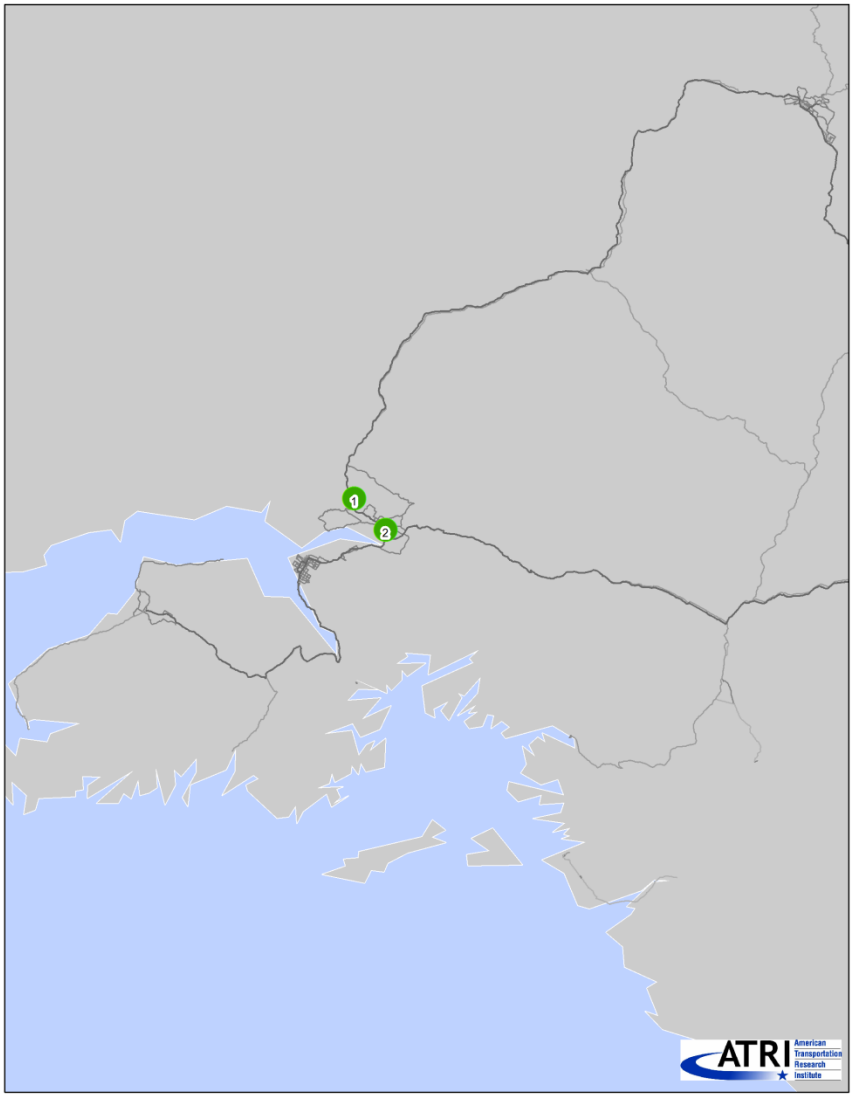
When considering investment at potentially dangerous locations, it is important to fully investigate the underlying factors influencing the rollover events. This report presents the findings of the first phase of a three-part research effort on the safety impacts of roadway design. The locations identified in Phase 1 are areas of interest for further investigation in the second and third research phases, which may be conducted concurrently. Due to the significant role of driver error in rollover events, the national rollover database will be used in Phase 2 as a beta source to test technology that enables an in-cab warning system to notify commercial drivers in real-time as they are nearing a location where truck rollovers frequently occur. In Phase 3, the focus will be to conduct an analysis of the features of each high-frequency rollover location to identify

and categorize possible roadway design issues, signage issues and other phenomenon, such as congestion, which may be contributing to rollover crashes at these sites. This research will inform those who have the ability to address infrastructure issues of potential problems related to roadway design or signage.

The findings of this research can provide valuable insight into the location of potential rollover hot spots to researchers, transportation planners and the trucking industry. Given the high cost of truck rollovers, reducing rollovers is a critical objective for the trucking industry. The Phase 1 analysis demonstrates that a national database of high-frequency rollover locations can be created. It is envisioned that this national database will grow as more states collaborate on rollover research and the expanded use of GPS technology improves the quality of the data that states collect. Furthermore, the Phase 1 research demonstrates the need for more uniform crash recording procedures among states. An enhanced national standard for reporting all crash types would significantly improve the utility of the rollover database. However, despite the need for better data collection procedures, the Phase 1 database provides the ATRI Research Team with a foundation to proceed with the second and third phases of the large truck rollover research.

APPENDIX A

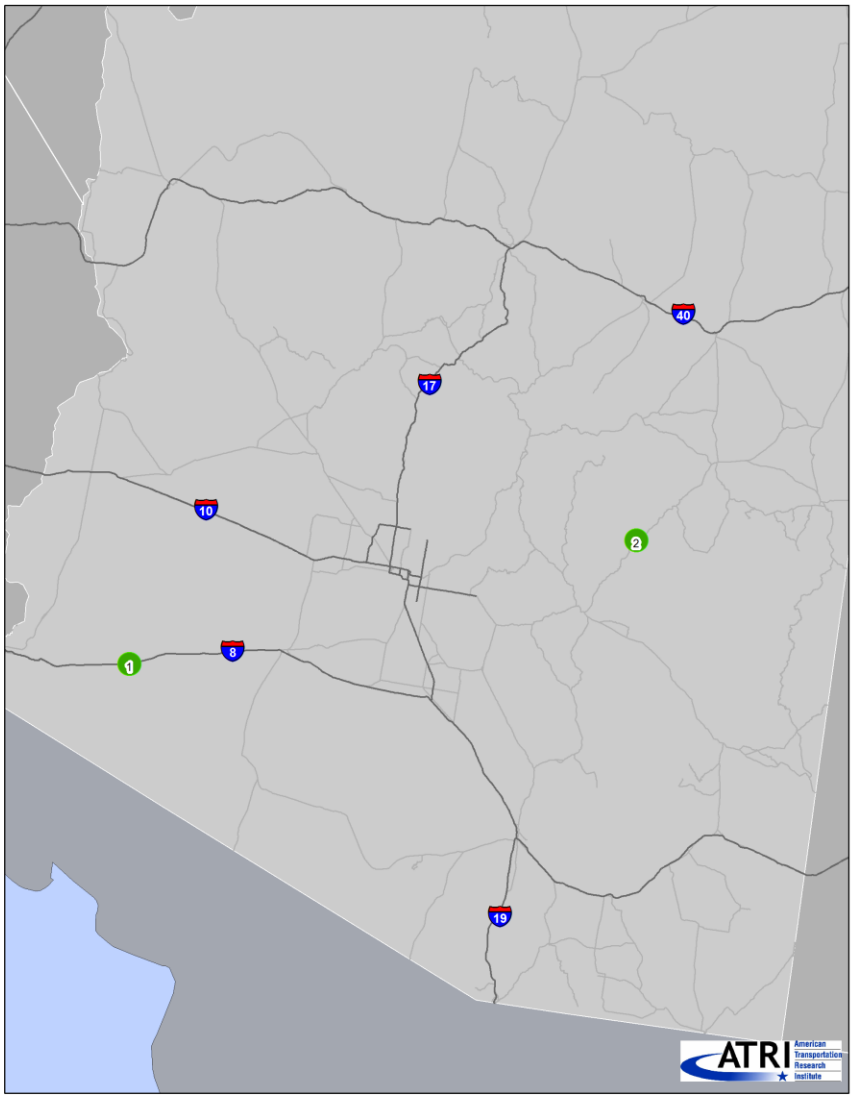
Alaska



Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	2	21	23
2002	0	11	11
2003	0	7	7
2004	3	6	9
2005	0	4	4
2006	0	2	2
2007	1	4	5
2008	1	5	6
2009	0	14	14
All Years	7	74	81

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-A3 near W King Arthur Dr	2
2	I-A3 near Hyer Rd	2

Arizona

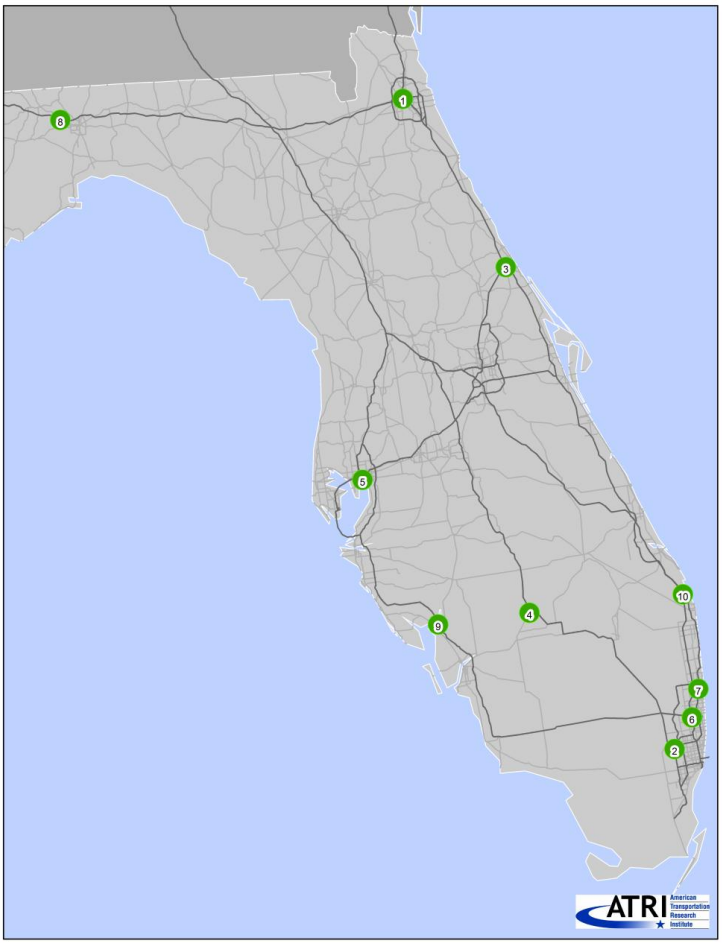


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	*	*	*
2005	*	*	*
2006	*	*	*
2007	*	*	*
2008	*	*	*
2009	6	199	205
All Years	6	199	205

*Coordinate data for this year not provided by state

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-8 near Exit 54	4
2	US 60/SR 77 near Primitive Rd	3

Florida

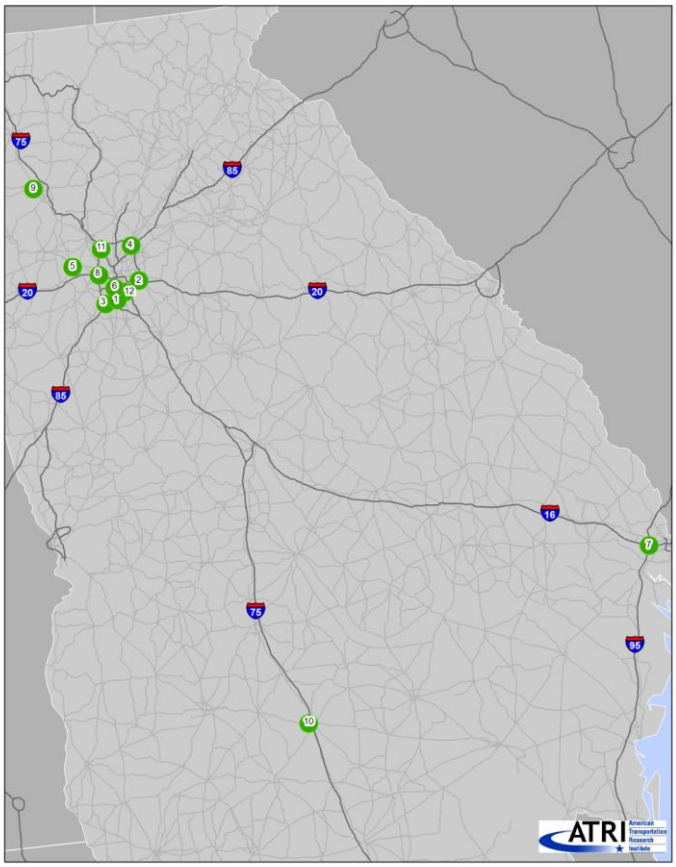


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	*	*	*
2005	41	667	708
2006	30	627	657
2007	26	425	451
2008	22	462	484
2009	16	280	296
All Years	135	2461	2596

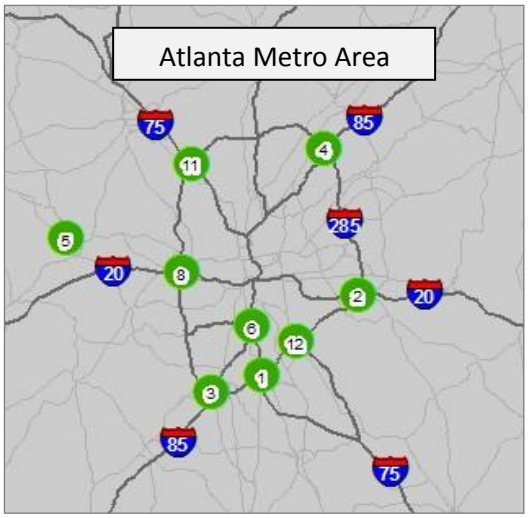
*Coordinate data for this year not provided by state

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-95 and I-10	14
2	Florida Tpke and US 27	11
3	I-95 and I-4	10
4	US 27 at SR 29	8
5	US 41 and Maritime Blvd and S Bermuda Blvd	7
6	Florida Tpke and I-595	7
7	I-95 at Exit 38 A, E Copans Rd	7
8	I-10 and US 90	6
9	US 17 and I-75	6
10	I-95 Exit 83, Donald Ross Rd	6

Georgia

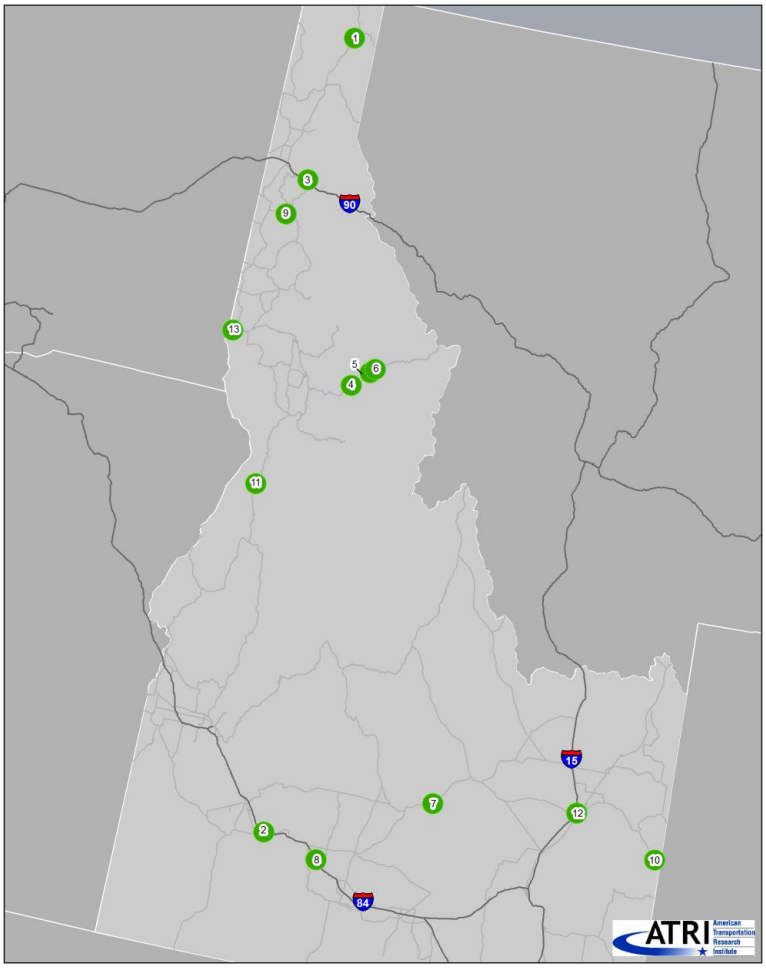


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	16	451	467
2002	18	421	439
2003	21	524	545
2004	15	563	578
2005	18	630	648
2006	26	600	626
2007	28	488	516
2008	23	471	494
2009	19	249	268
All Years	184	4397	4581



Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-285 and I-75 (South Side)	35
2	I-285 and I-20 (East Side)	32
3	I-285 and I-85 (South Side)	31
4	I-285 and I-85 (North Side)	17
5	US 278 and Spur 6	16
6	I-75 between SR 166 and I-85	16
7	I-95 and I-16	15
8	I-285 and I-20 (West Side)	14
9	US 411 and US 41/Joe Frank Harris Pkwy SE	11
10	I-75 between US 319 and Old Omega Rd	11
11	I-285 and I-75 (North Side)	11
12	I-285 and US 23/Moreland Ave	11

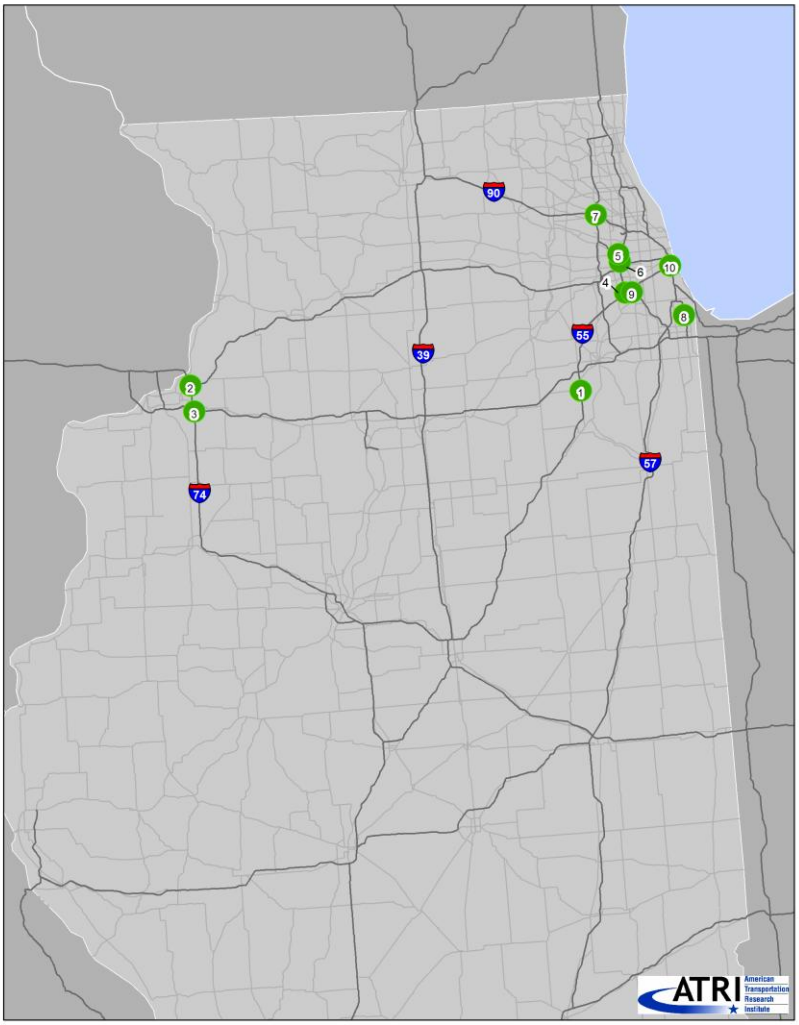
Idaho



Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	8	184	192
2002	6	175	181
2003	6	149	155
2004	9	226	235
2005	4	209	213
2006	5	199	204
2007	5	190	195
2008	4	178	182
2009	2	126	128
All Years	49	1636	1685

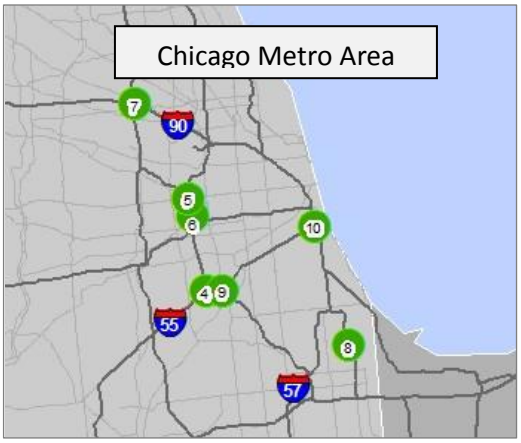
Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	S Main St (US 2/95) near Eisenhower St	14
2	I-84 between Exit 112 and Exit 114	6
3	I-90 near Exit 28	6
4	US 12 near Van Camp Trail	5
5	US 12 near Idaho Centennial Trail	5
6	US 12 near Idaho Centennial Trail	5
7	US 26/US 93 near Lava Lake Rd	5
8	I-84 near S 1400 E/E 2500 S	5
9	SR 5 near Woodbury Ln	5
10	US 26 near Forgetful Ln	5
11	US 95 near River Ln	5
12	I-15 and US 20/Grand View Dr	5
13	US 95 and US 12	5

Illinois



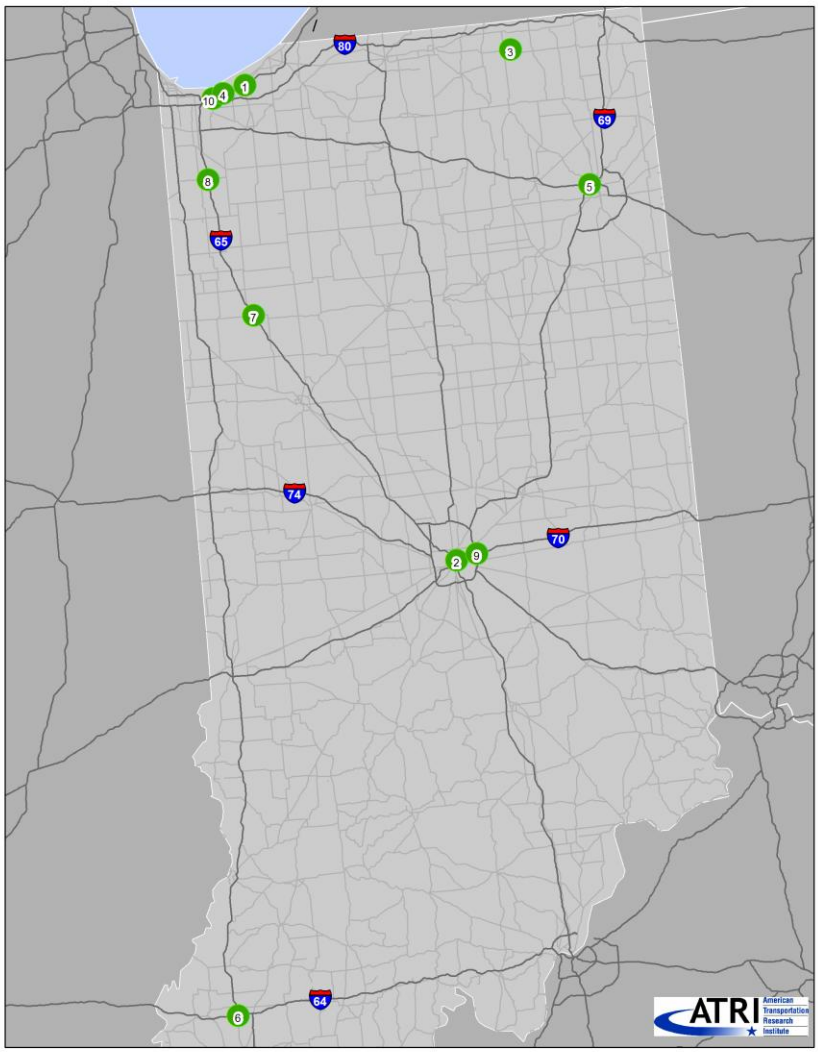
Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	*	*	*
2005	16	426	442
2006	14	419	433
2007	12	366	378
2008	14	374	388
2009	2	260	262
All Years	58	1845	1903

*Coordinate data for this year not provided by state



Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-55 and CR 17/Arsenal Rd	15
2	I-80 and I-88/SR 92	14
3	I-80 and I-74/I-280	13
4	I-294 and I-55	13
5	I-290, I-294, and SR 64/North Ave	12
6	I-294 at I-290	11
7	I-90 at SR 53	10
8	I-94 at E 130th St	10
9	I-55 and US 20/US 12	9
10	I-55 and I-94/I-90	9

Indiana

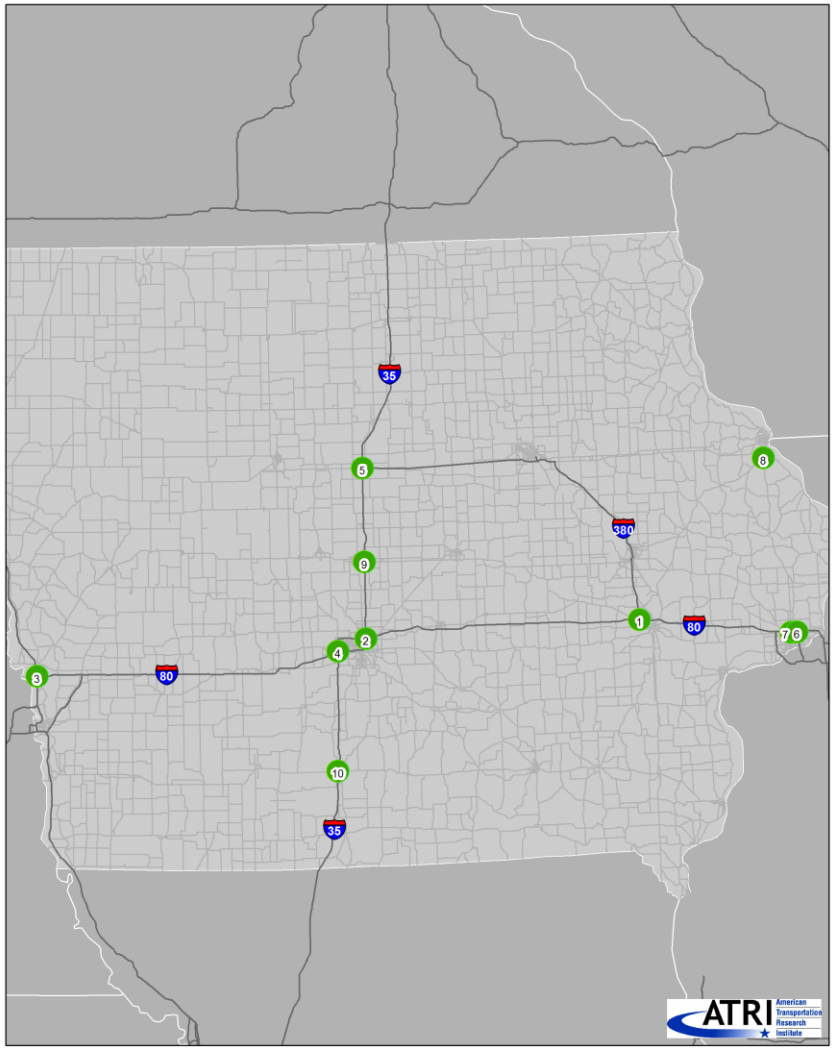


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	*	*	*
2005	*	*	*
2006	10	149	159
2007	11	108	119
2008	8	143	151
2009	7	113	120
All Years	87	513	600

*Coordinate data for this year not provided by state

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-94 and SR 49	8
2	I-65 and I-70	7
3	W CR 100 N at N CR 600 W	5
4	I-94 near SR 249/Crisman Rd	4
5	I-69, US 30/US 33, and SR 930	3
6	I-64 at US 41	3
7	I-65 and US 24/US 231	3
8	I-65 near SR 2/E 181st Ave	3
9	I-70 at I-465	3
10	I-94 near Exit 16	3

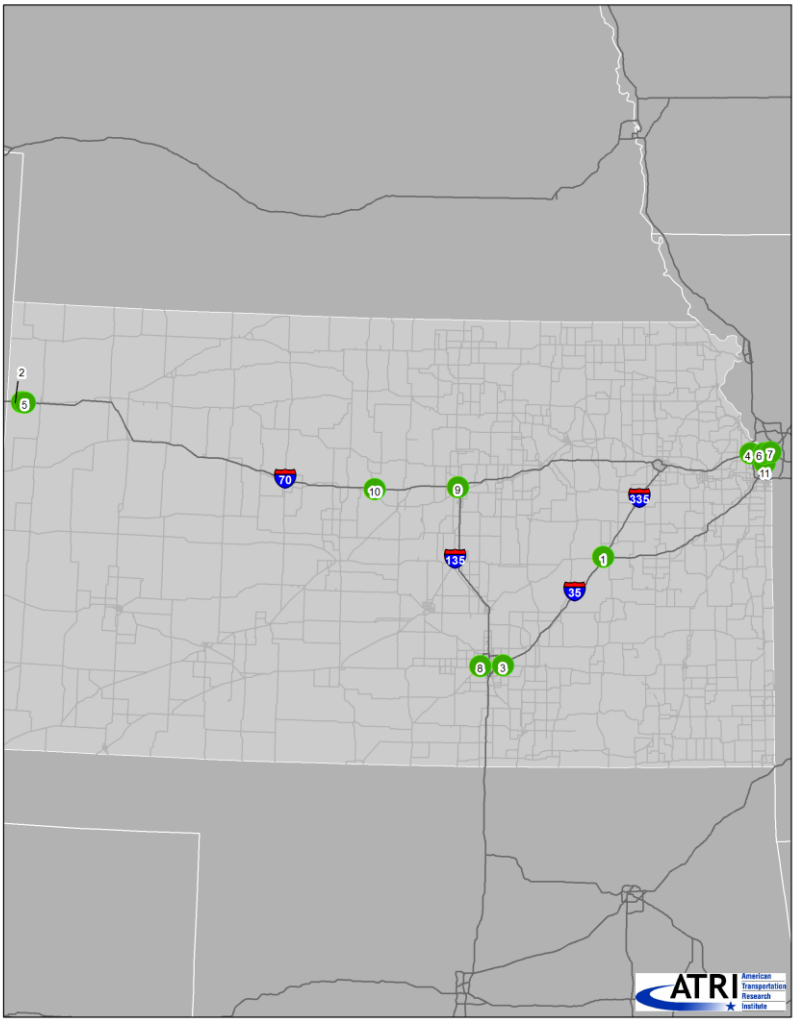
Iowa



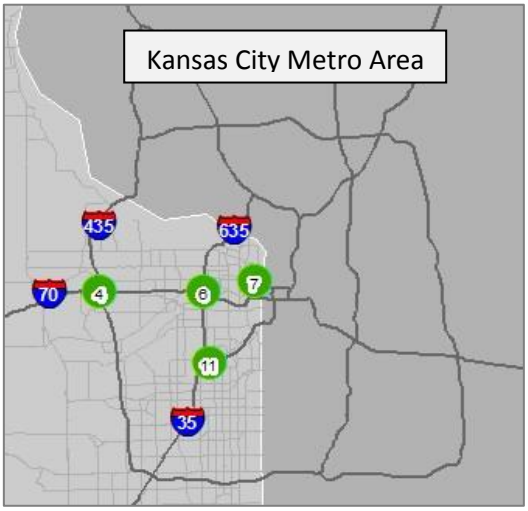
Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	6	339	345
2002	4	297	301
2003	7	300	307
2004	5	303	308
2005	5	372	377
2006	7	337	344
2007	7	380	387
2008	3	411	414
2009	4	333	337
All Years	48	3072	3120

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-80 and I-380	30
2	I-235 and I-80/I-35	22
3	I-29 and I-680	14
4	I-80/I-235 and I-35	14
5	I-35 and US 20	13
6	I-80 and I-74	12
7	I-80 and US 61	12
8	US 61 and US 151	11
9	I-35 and US 30	10
10	I-35 near US 34	9

Kansas

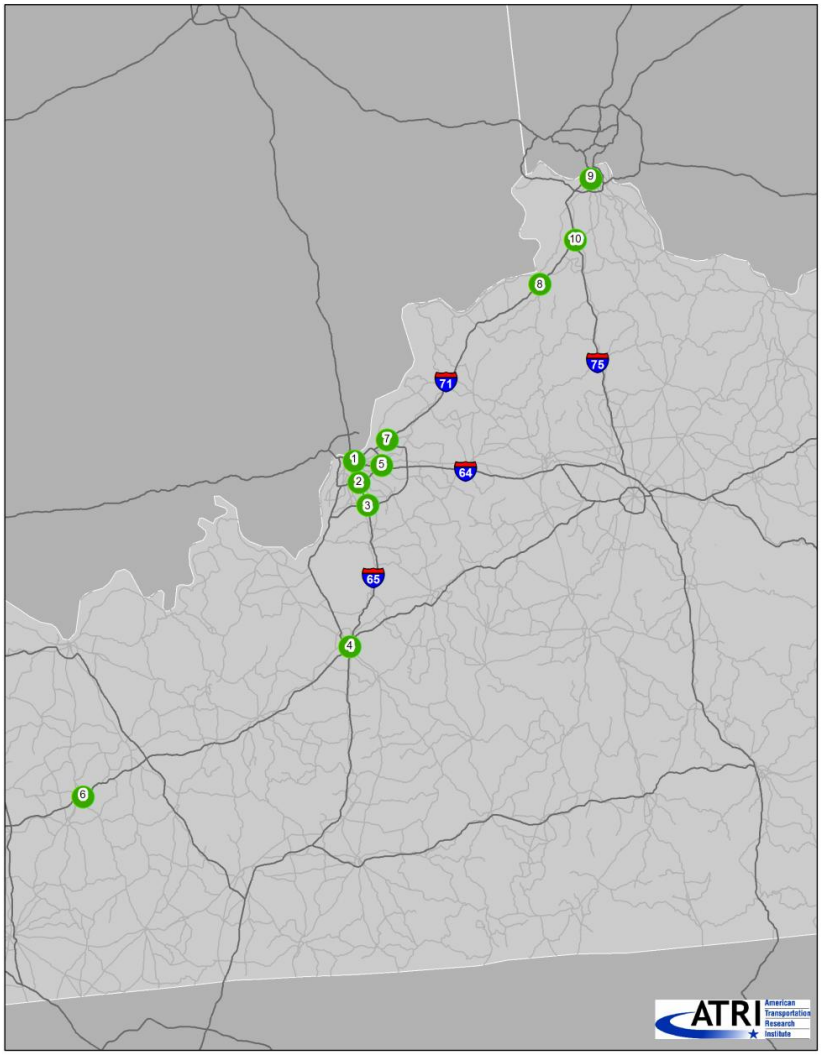


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	9	235	244
2002	12	184	196
2003	5	194	199
2004	18	270	288
2005	11	222	233
2006	13	303	316
2007	10	300	310
2008	4	261	265
2009	5	194	199
All Years	87	2163	2250

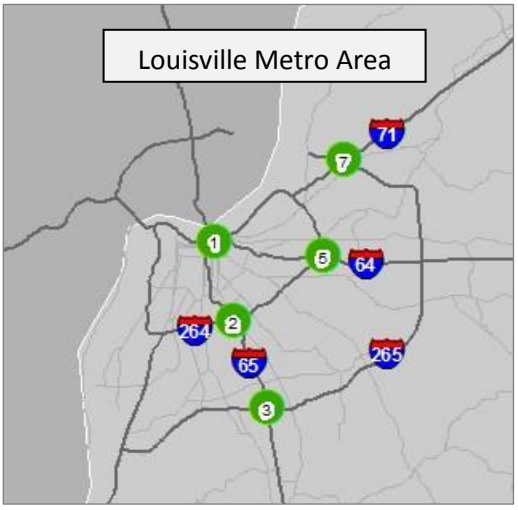


Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-335 and I-35	17
2	I-70 near Kansas Travel Information Center	16
3	US 54 and SR 96	15
4	I-435 and I-70	14
5	I-70 near Exit 9	13
6	I-635 and I-70	10
7	I-70 near Lewis and Clark Viaduct Bridge	9
8	I-235 and US 54/US 400	8
9	I-70 at I-135/US 81	8
10	I-70 near Exit 206	8
11	I-635 and I-35/US 69	8

Kentucky

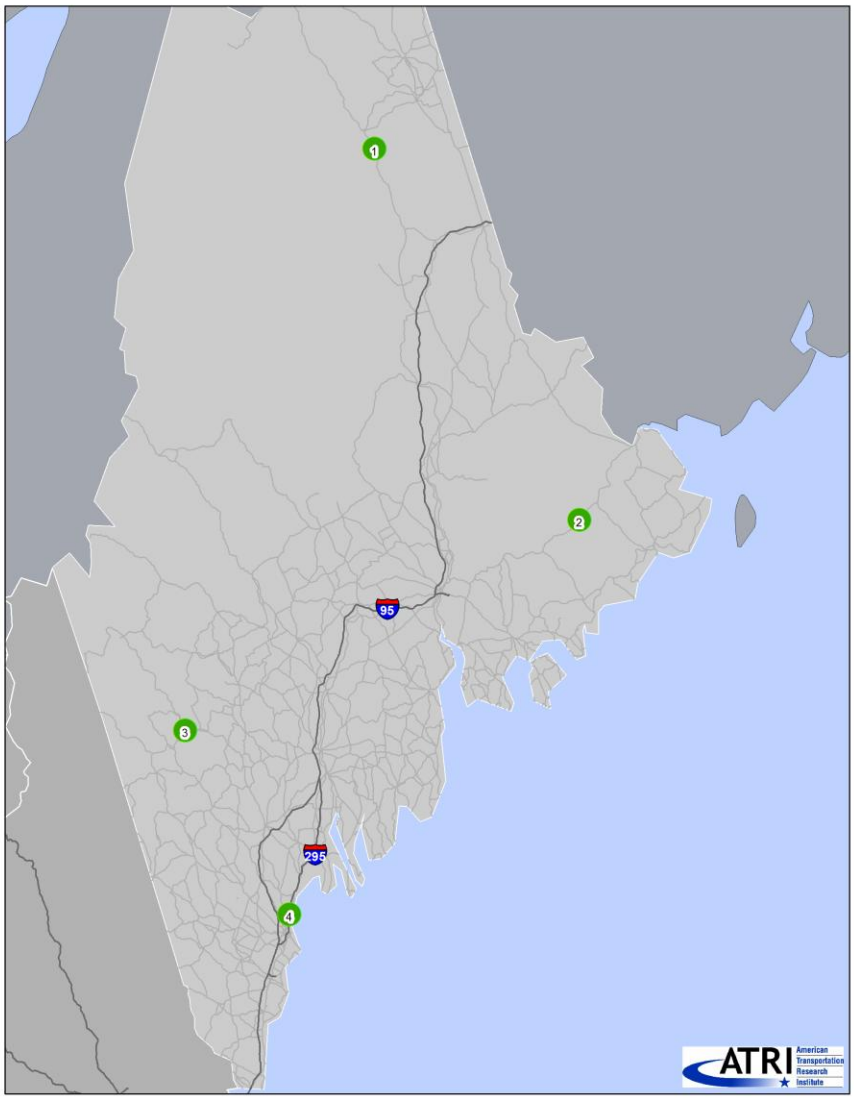


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	12	41	53
2002	13	48	61
2003	16	60	76
2004	21	73	94
2005	21	69	90
2006	15	80	95
2007	17	71	88
2008	16	66	82
2009	13	53	66
All Years	144	561	705



Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-65, I-64, and I-71	8
2	I-65 and I-264/US 60	7
3	I-65 and I-265	6
4	I-65 and Wendell H. Ford Western Kentucky Pkwy	6
5	I-64 at I-264	5
6	US 431 and Wendell H. Ford Western Kentucky Pkwy	4
7	I-71 and I-265	4
8	I-71 between SR 3002 and US 127	4
9	I-75/I-71 between Exit 189 and Exit 191	4
10	I-71 and I-75	4

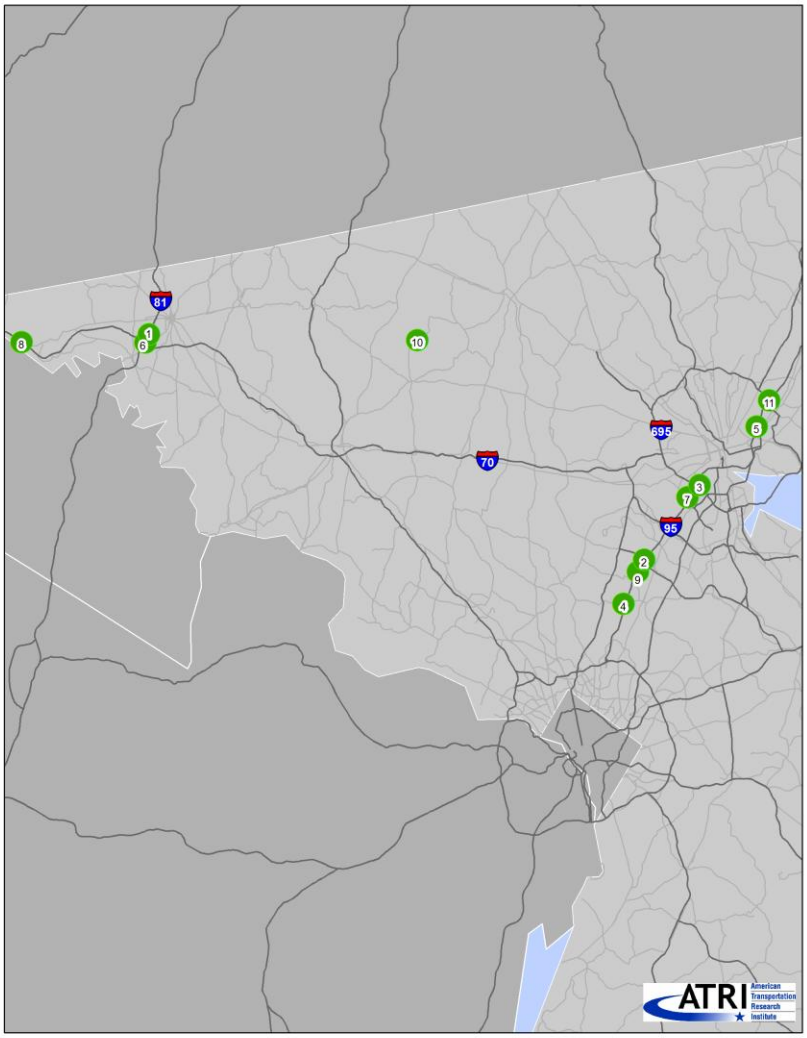
Maine



Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	3	13	16
2002	2	11	13
2003	6	12	18
2004	3	15	18
2005	4	11	15
2006	3	9	12
2007	2	11	13
2008	2	7	9
2009	2	8	10
All Years	27	97	124

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	SR 11 near Sterling Ridge Rd	2
2	SR 9 near 09-82-0 Rd	2
3	US 2 near Bridge St	2
4	Falmouth Spur at I-295	2

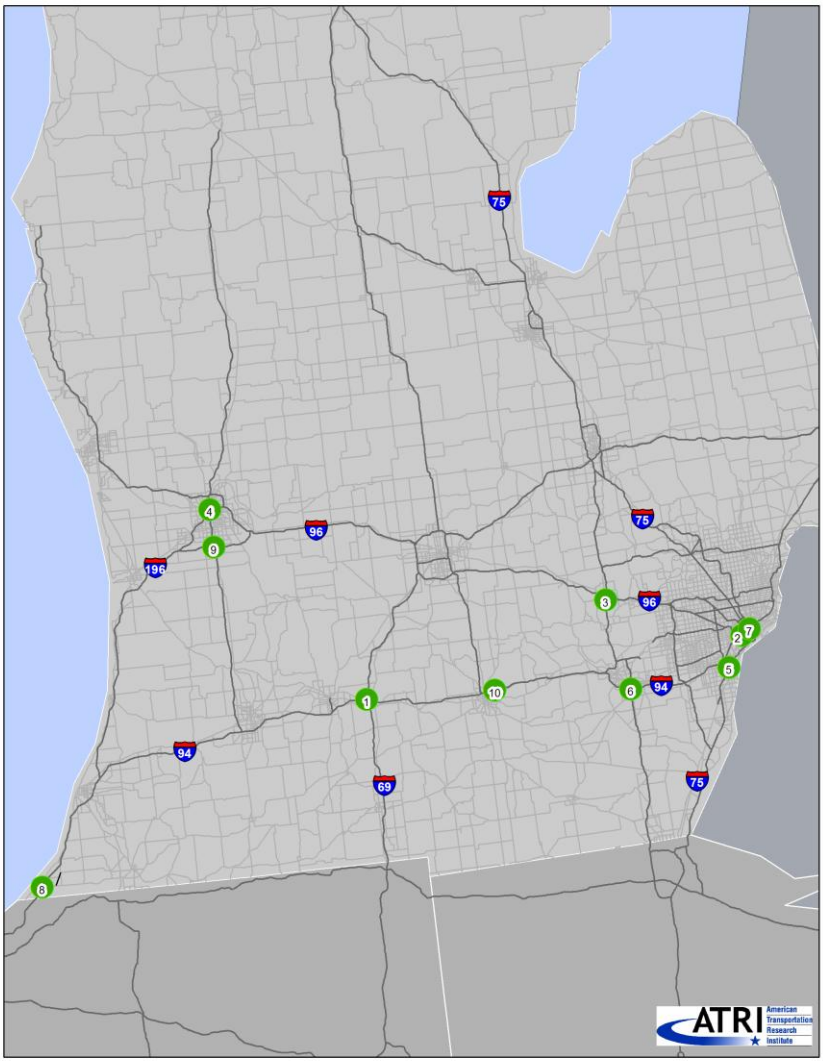
Maryland



Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	9	179	188
2002	7	136	143
2003	3	177	180
2004	5	166	171
2005	3	181	184
2006	5	153	158
2007	2	131	133
2008	5	136	141
2009	2	82	84
All Years	41	1341	1382

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-70 and I-81	15
2	I-95 and SR 32	10
3	I-95 and I-695	9
4	I-95 at SR 198	8
5	I-95 and I-895	8
6	I-81 at Halfway Blvd (Exit 5)	7
7	I-95 at I-195	7
8	I-70 near US 40	6
9	I-95 near North Welcome Center (MM 37)	6
10	SR 75/Green Valley Rd near Beaver Dam Rd	6
11	I-95 and I-695	6

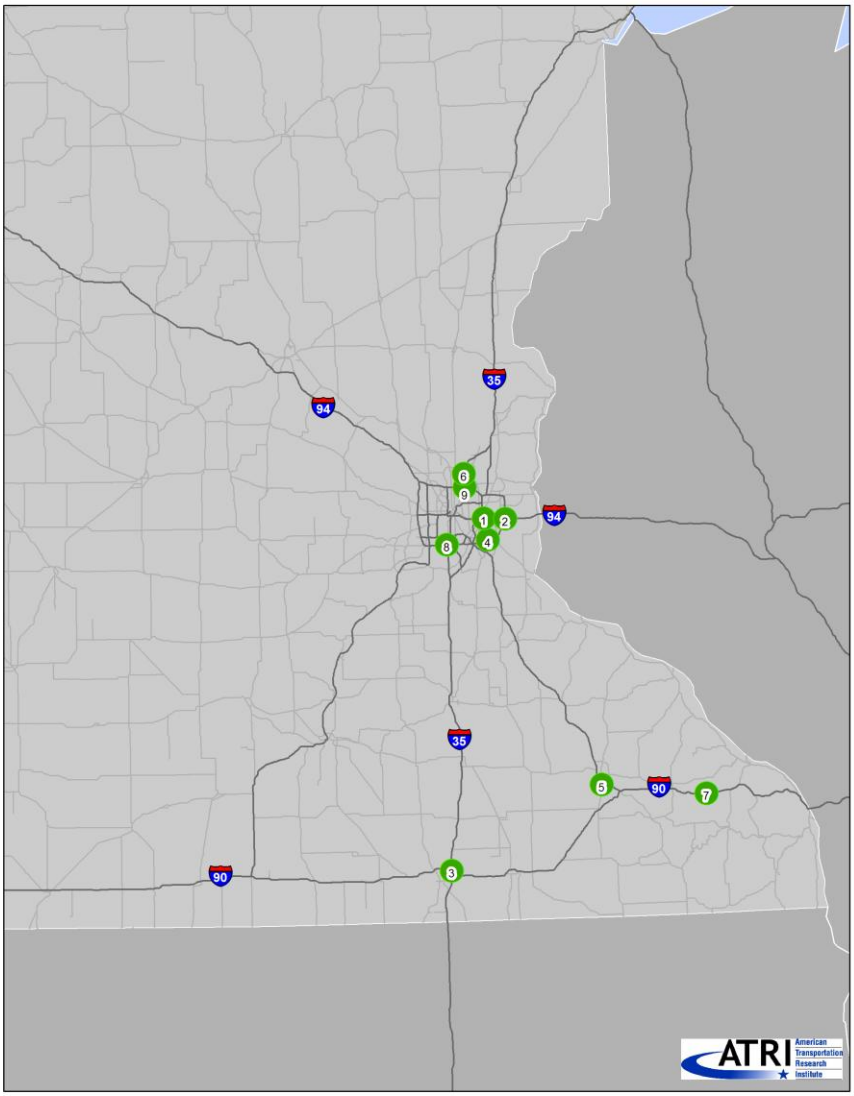
Michigan



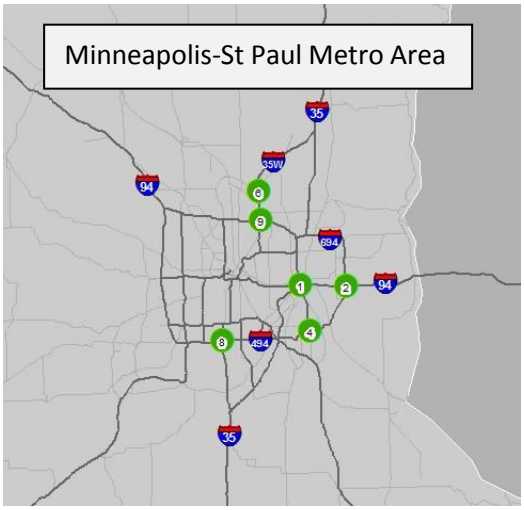
Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	9	160	169
2002	6	170	176
2003	6	191	197
2004	3	214	217
2005	5	215	220
2006	7	205	212
2007	3	186	189
2008	8	199	207
2009	4	142	146
All Years	51	1682	1733

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-69 and I-94	19
2	I-96 and I-94	13
3	I-96 and US 23	12
4	I-196 and US 131	9
5	I-75 and SR 39	9
6	I-94 and US 23	9
7	I-94 and I-75	9
8	I-94 and US 12	8
9	SR 6/Paul B Henry Hwy and US 131	7
10	I-94 and US 127	7

Minnesota

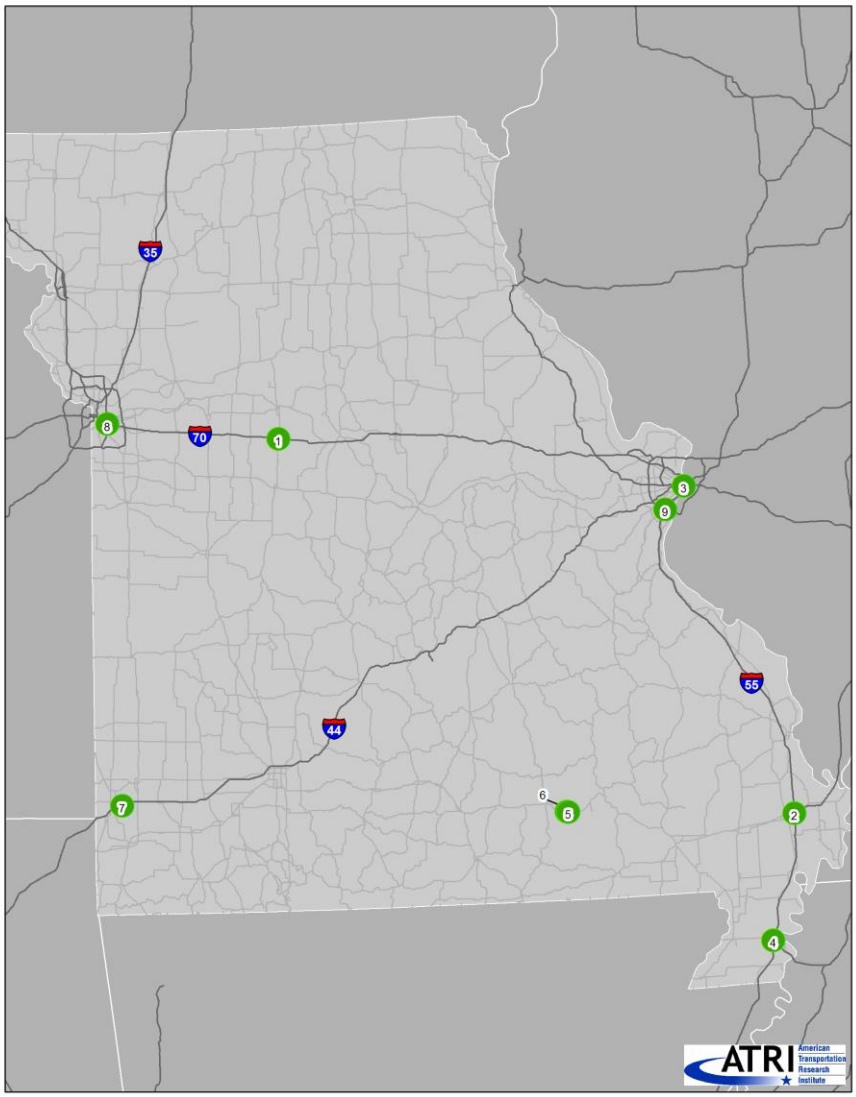


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	6	317	323
2002	12	253	265
2003	4	224	228
2004	7	270	277
2005	6	257	263
2006	10	219	229
2007	6	211	217
2008	13	224	237
2009	5	171	176
All Years	69	2146	2215



Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-94 and US 52/Lafayette Bridge	17
2	I-94, I-494 and I-694	13
3	I-90 and I-35	12
4	I-494 and US 52	12
5	US 52 and US 63	9
6	I-35W and US 10	9
7	I-90 near Exit 242/CR 29	8
8	I-35W and I-494	8
9	I-35W and I-694	7

Missouri

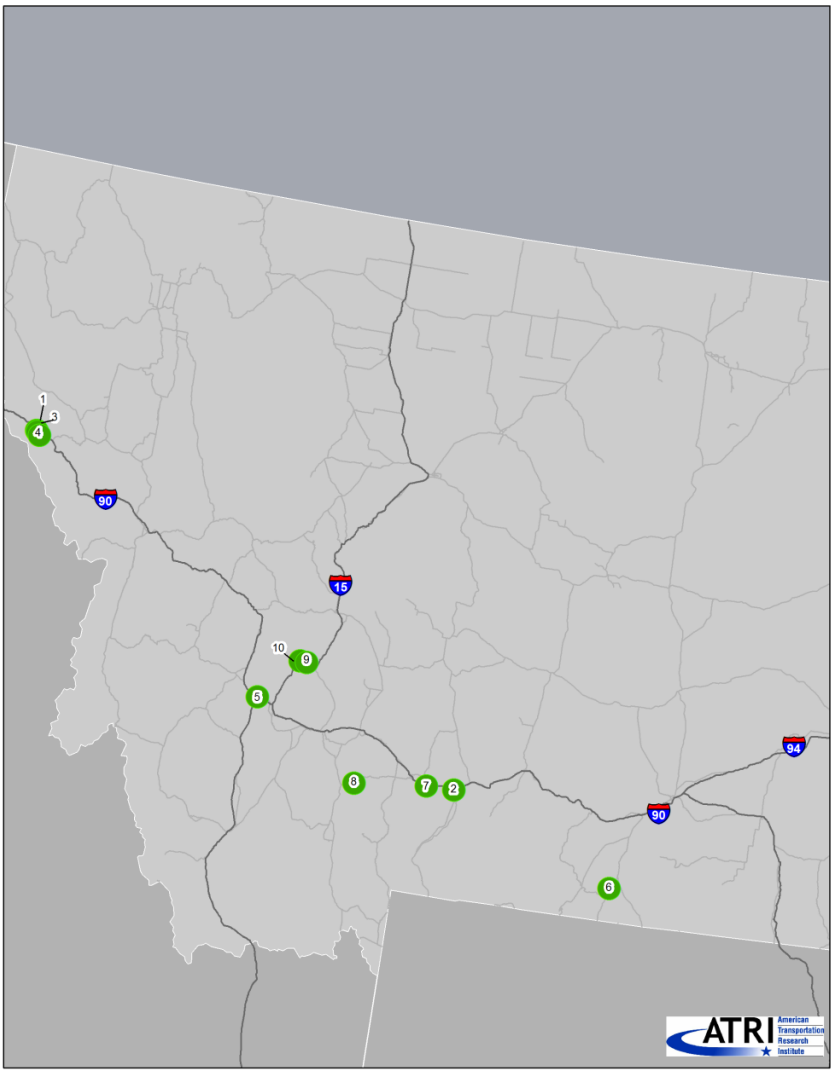


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	36	616	652
2003	29	594	623
2004	20	659	679
2005	32	609	641
2006	30	537	567
2007	31	489	520
2008	17	474	491
2009	9	407	416
All Years	204	4385	4589

*Coordinate data for this year not provided by state

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-70/ US 40 and US 65	13
2	I-57 and I-55/US 60	12
3	I-70: Poplar Street Bridge Interchange	12
4	I-55 and I-155/US 412	11
5	US 60 near CR 161	10
6	US 60 near CR 60-163	9
7	I-44 and US 71/SR 249	9
8	I-70 and I-435	9
9	I-55 and I-270/I-255	9

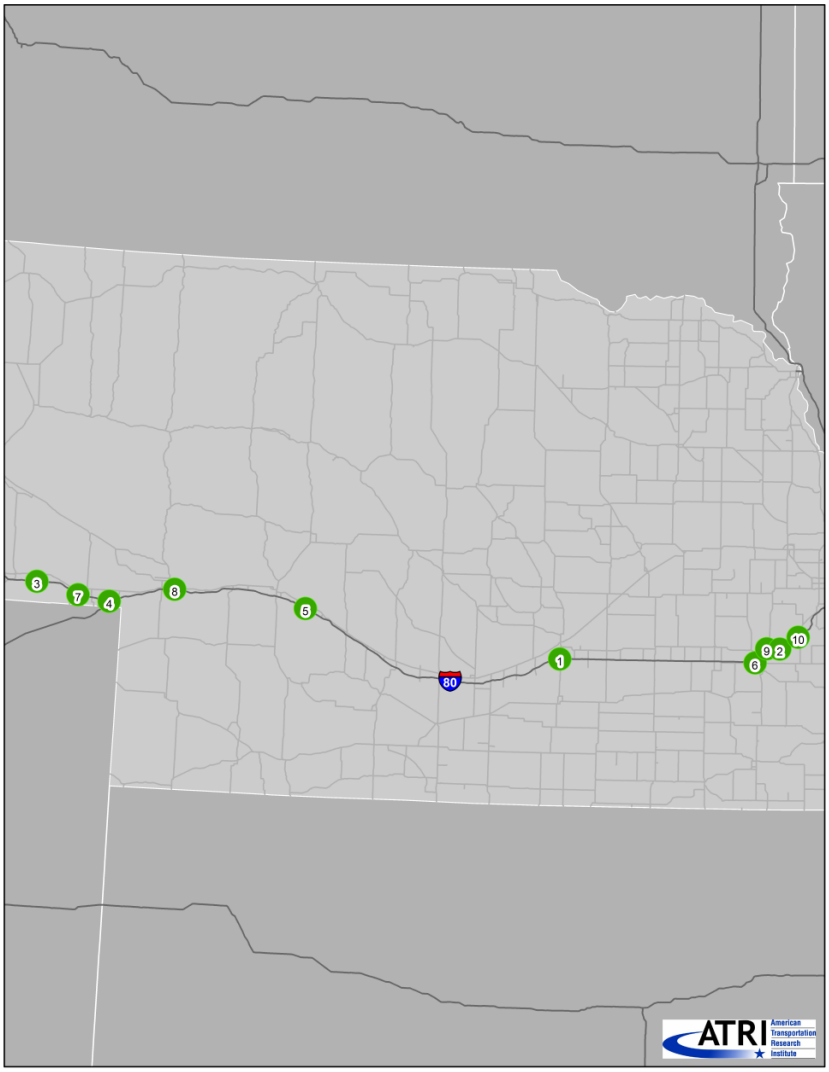
Montana



Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	10	228	238
2002	4	203	207
2003	3	214	217
2004	4	197	201
2005	2	220	222
2006	11	235	246
2007	11	212	223
2008	8	171	179
2009	5	127	132
All Years	58	1807	1865

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-90 near Exit 22	24
2	I-90 near US 10	18
3	I-90 near Exit 25	16
4	I-90 at Exit 26/Ward Creek Rd	13
5	I-90 and I-15	13
6	SR 72 near Aisenbrey Loop	9
7	I-90 near Exit 316	7
8	SR 84 near Cold Spring Rd	7
9	I-15 near Exit 160	7
10	I-15 near Exit 156	6

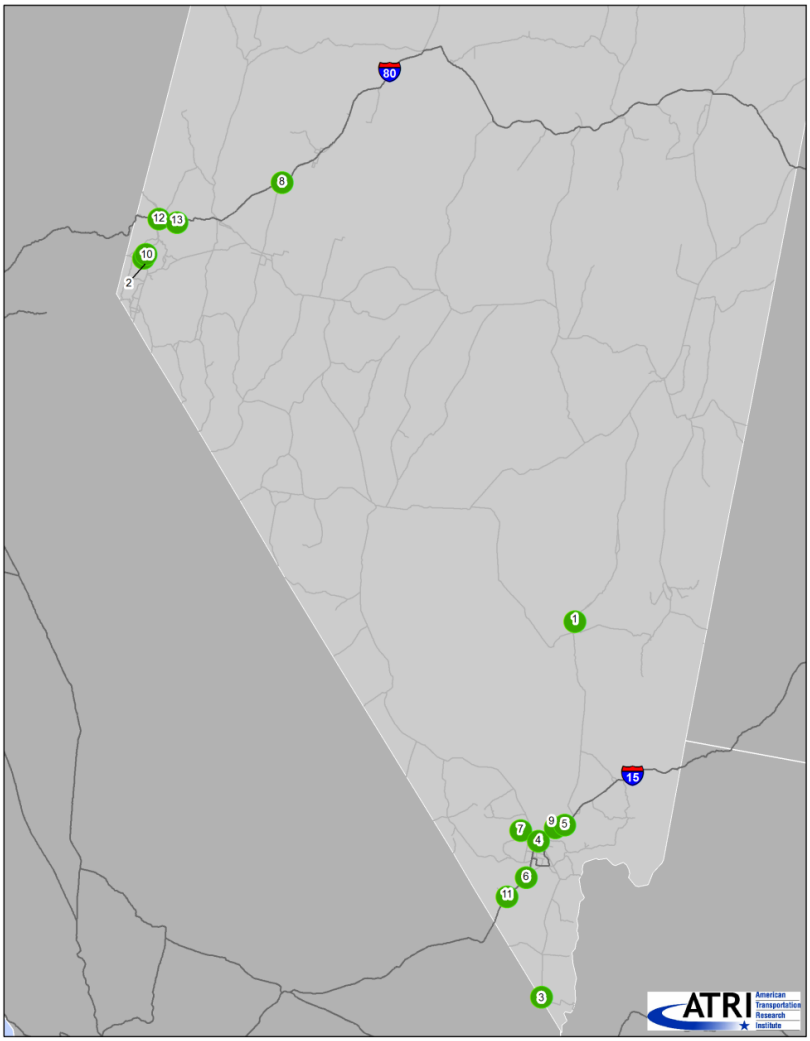
Nebraska



Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	4	171	175
2002	5	105	110
2003	6	109	115
2004	4	127	131
2005	4	118	122
2006	4	131	135
2007	3	109	112
2008	8	93	101
2009	8	93	101
All Years	46	1056	1102

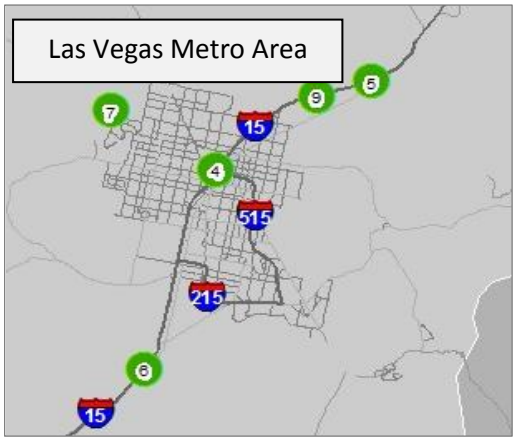
Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-80 at US 34/US 281	15
2	I-80 near US 6	13
3	I-80 at Road 135 (Link 17E)	7
4	I-80 at I-76	5
5	I-80 near Ft. McPherson Rd/Spur 56A	5
6	I-80 near US 77/Homestead Expy	5
7	I-80 near US 385	4
8	I-80 near Road East High School S (Link 51B)	4
9	I-80/US 77 near N 27th St (Exit 403)	4
10	I-80 between Church Road and Exit 420	4

Nevada



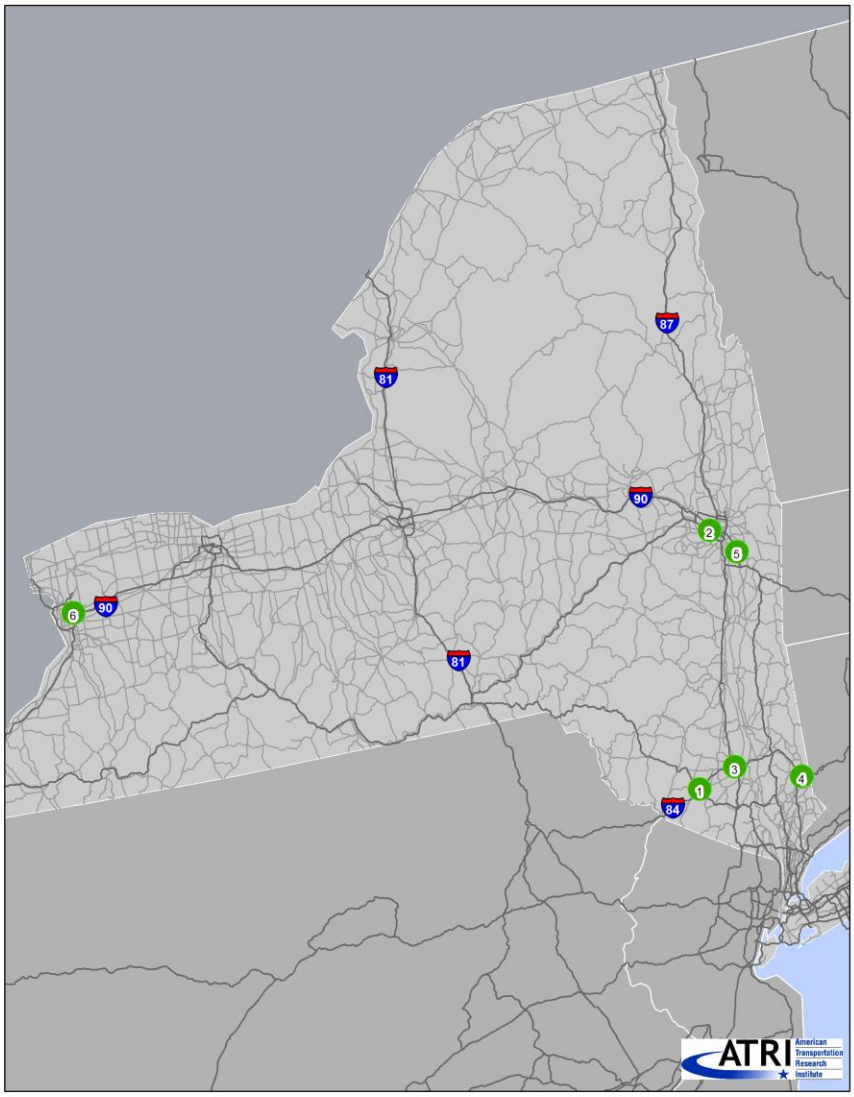
Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	2	80	82
2005	6	107	113
2006	2	108	110
2007	6	100	106
2008	1	97	98
2009	4	83	87
All Years	21	575	596

*Coordinate data for this year not provided by state



Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	SR 318 in Lincoln County near Old NV-38	7
2	Franktown Rd/Old US 395 between William Brent Rd and Lewers Creek Rd	6
3	US 95 and SR 163	6
4	I-15 and I-515/US 95	6
5	I-15 and Exit 58/SR 604	5
6	I-15 and Las Vegas Blvd S Frontage Road/Sloan Rd	5
7	SR 215 and W Cheyenne Ave	4
8	I-80 and Veterans Memorial Hwy	4
9	I-15 at Speedway Blvd	4
10	US 395 Washoe Valley between Old US 395 and Bellevue Rd	4
11	I-15 at Exit 12/ SR 161	4
12	US 395 between E 2nd St and Mill St	4
13	I-80 near Exit 23	4

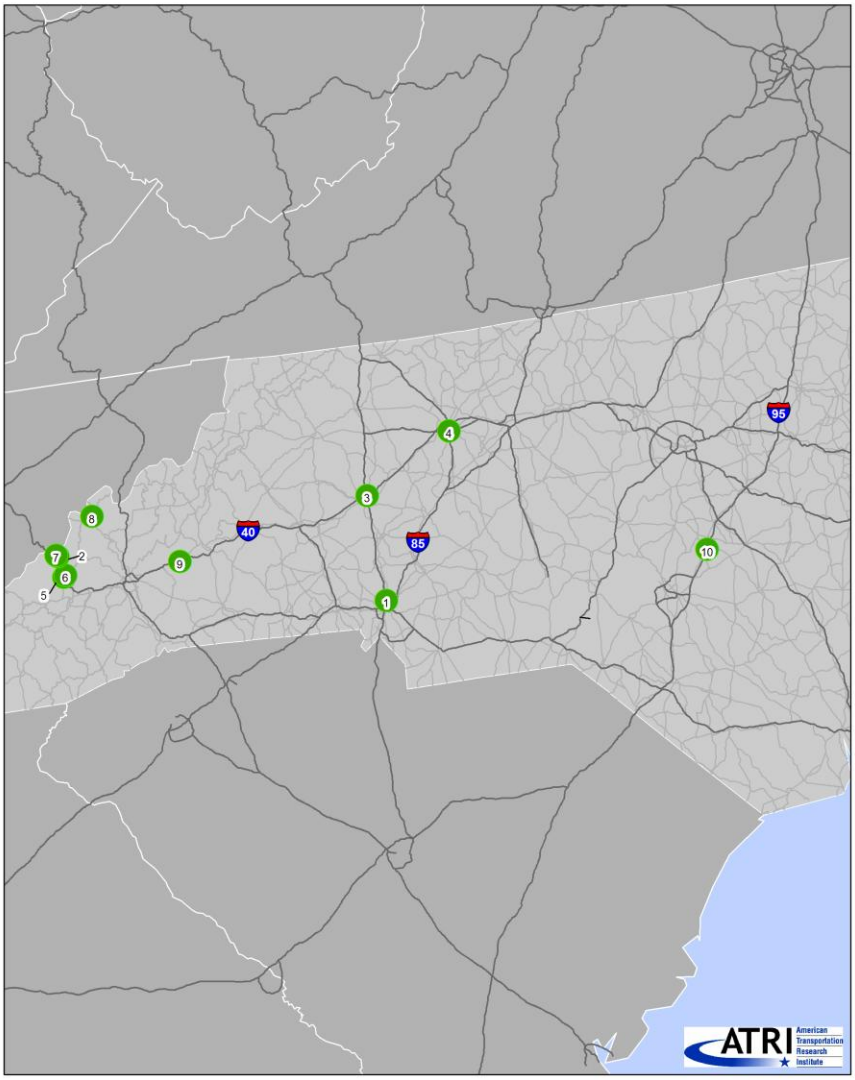
New York



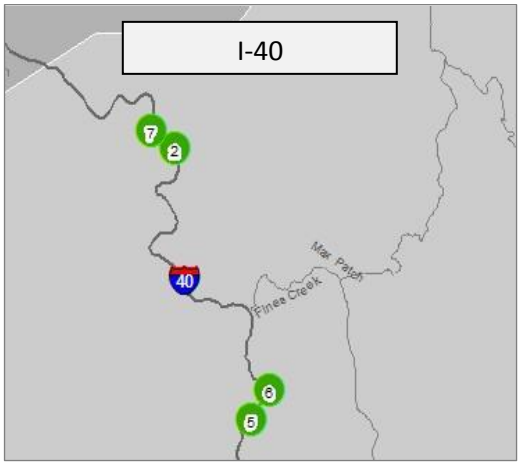
Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	9	6	15
2002	10	14	24
2003	16	78	94
2004	15	82	97
2005	11	88	99
2006	19	75	94
2007	11	63	74
2008	6	55	61
2009	6	61	67
All Years	103	522	625

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-84 and SR 17	19
2	I-90 and I-87	9
3	I-84 and I-87	9
4	I-84 at I-684	5
5	I-90 and US 20	4
6	I-90 at I-290	4

North Carolina

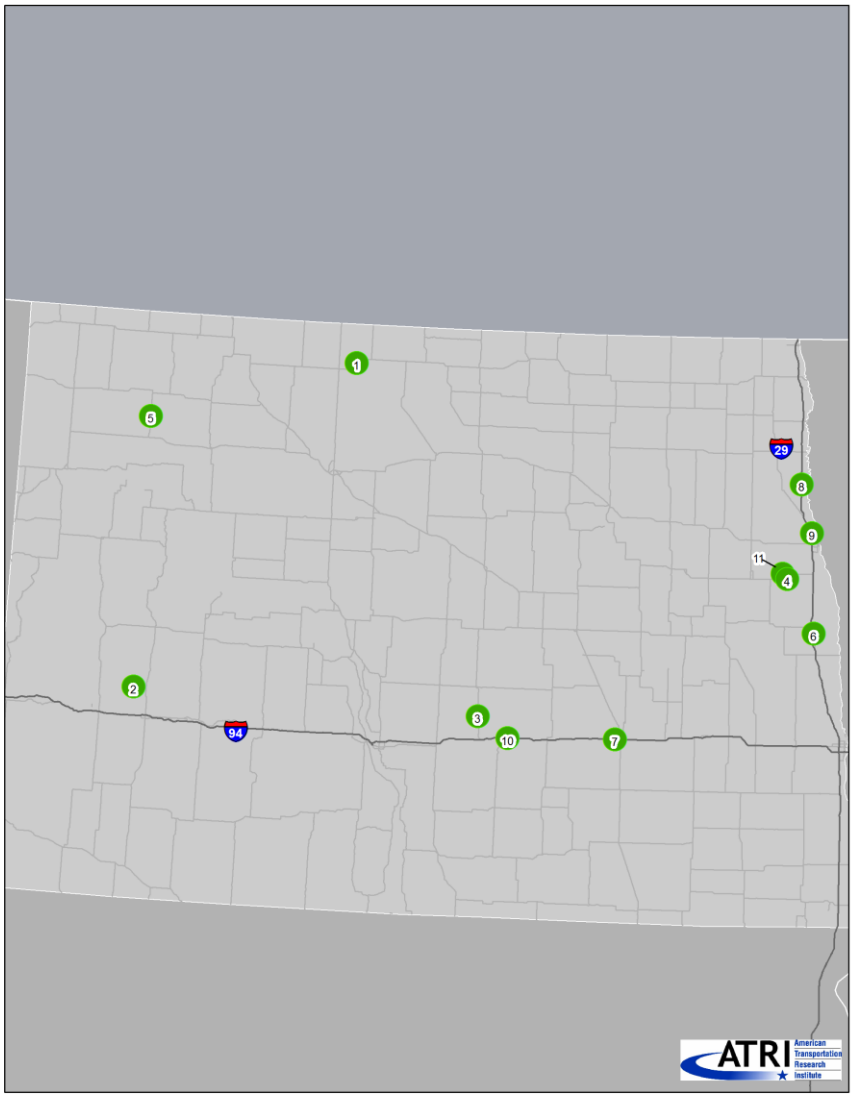


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	3	382	385
2002	16	381	397
2003	19	425	444
2004	26	436	462
2005	18	469	487
2006	15	423	438
2007	31	385	416
2008	19	332	351
2009	10	256	266
All Years	157	3489	3646



Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-85 and I-77	18
2	I-40 near Forest Service Rd 288	15
3	I-40 and I-77	11
4	I-40 and US 52	11
5	I-40 near White Oak Rd	10
6	I-40 near White Oak Rd	10
7	I-40 near Forest Service Rd 288	10
8	US 25/US 70 near SR 208	9
9	I-40 near US 70	8
10	I-95 near Bud Hawkins Rd	8

North Dakota

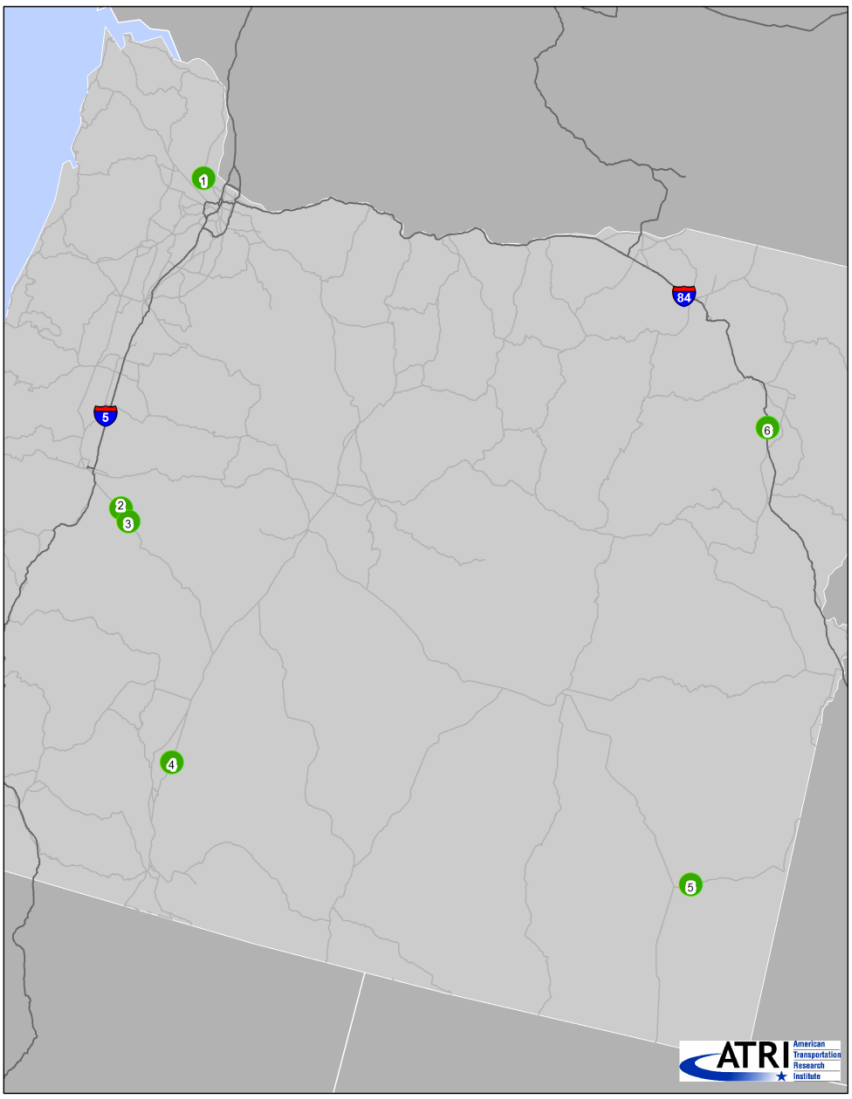


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	*	*	*
2005	2	64	66
2006	6	47	53
2007	1	54	55
2008	2	84	86
2009	3	75	78
All Years	14	324	338

*Coordinate data for this year not provided by state

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	US 83/20th Ave NW near 95th St SW	2
2	26th St SW near Dickenson Ave	2
3	26th Ave SE/SR 3 near 30th St SE	2
4	22nd St/ CR 13 and 5th Ave NE/SR 15	2
5	104th Ave NW between 72nd St NW and 71st St NW	2
6	SR 200 between CR 13/3rd St NE and 4th St NE	2
7	I-94 at Exit 256	2
8	I-29 at Exit 164	2
9	I-29 at Exit 145	2
10	I-94 near Exit 214	2
11	7th Ave NE and 24th St NE	2

Oregon

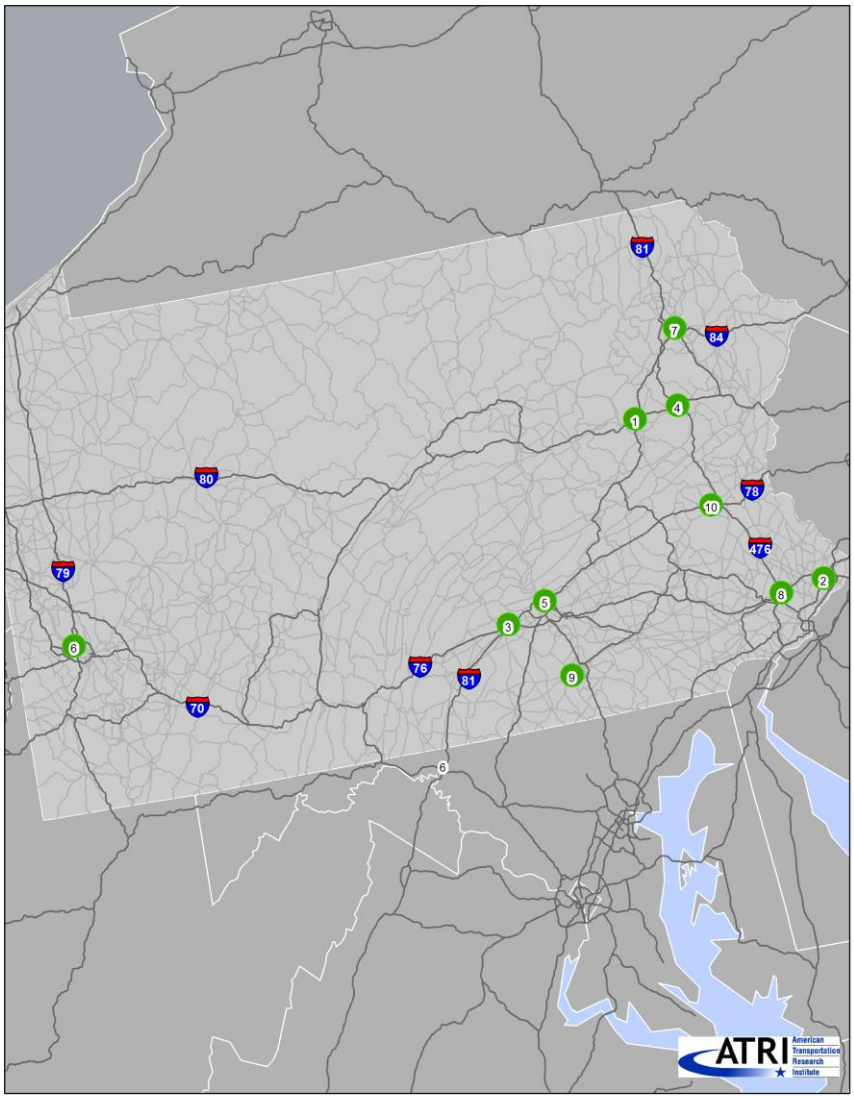


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	*	*	*
2005	*	*	*
2006	*	*	*
2007	2	154	156
2008	1	126	127
2009	4	109	113
All Years	7	389	396

*Coordinate data for this year not provided by state

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	NW Cornelius Pass Rd near NW Skyline Blvd	3
2	SR 58/Willamette Hwy near Jasper Lowell Rd	3
3	SR 58/Willamette Hwy near Goodman Creek Rd	3
4	US 97/The Dalles-California Hwy and Egan Springs Rd	3
5	US 95 near Crooked Creek State Park	3
6	I-84 near Exit 278	3

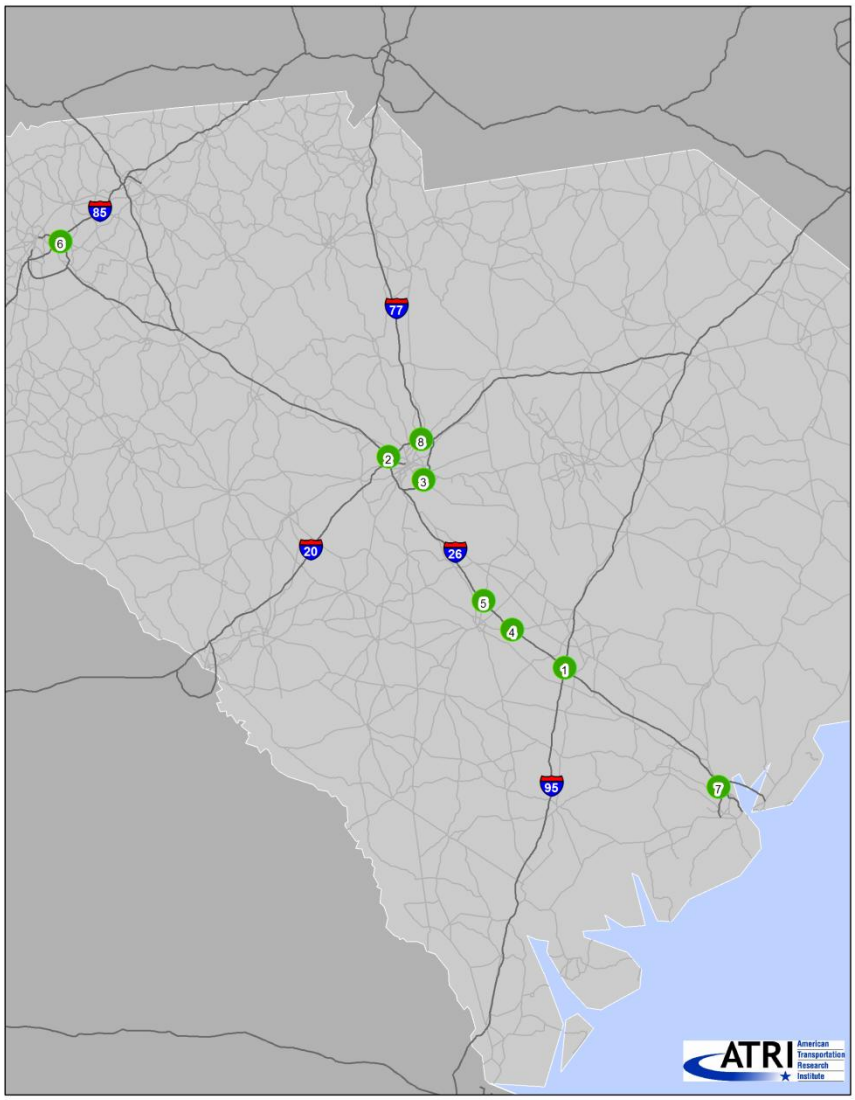
Pennsylvania



Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	14	552	566
2002	16	537	553
2003	25	587	612
2004	19	624	643
2005	15	646	661
2006	23	645	668
2007	35	632	667
2008	17	530	547
2009	16	429	445
All Years	180	5182	5362

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-81 and I-80	23
2	I-276 near Lincoln Hwy/US 1	22
3	I-76 and US 11	21
4	I-80 near I-476	20
5	I-81 and US 22/US 322	20
6	I-79 near SR 51/Exit 64	19
7	I-81, I-84/I-380, and US 6	18
8	I-476 and I-276	18
9	Lincoln Hwy/US 30 and SR 462	17
10	I-78 and SR 100	17

South Carolina

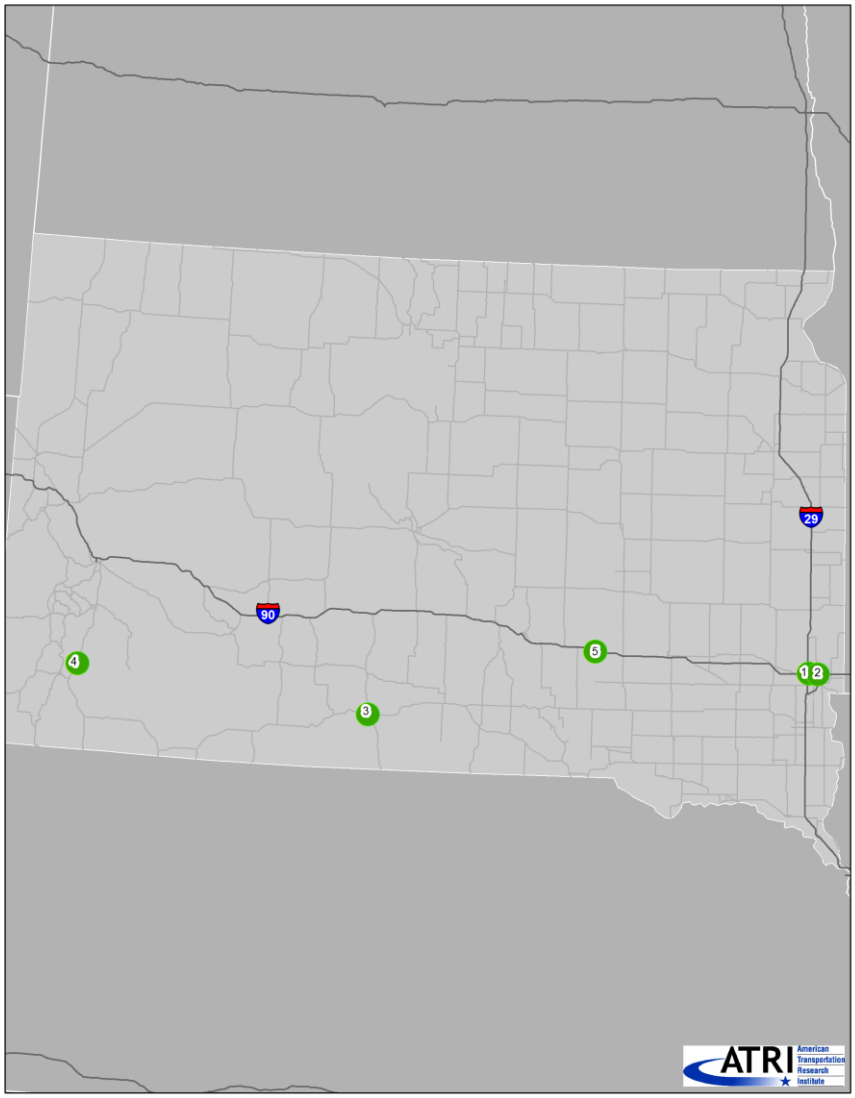


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	8	207	215
2005	7	224	231
2006	8	204	212
2007	7	211	218
2008	8	142	150
2009	7	113	120
All Years	45	1101	1149

*Coordinate data for this year not provided by state

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-95 and I-26	20
2	I-20 and I-26/I-126	11
3	I-77 and SR 48/SR 768/Bluff Rd	10
4	I-26 and US 301/Five Chop Rd	10
5	I-26 and US 601/ Saint Matthews Rd	9
6	I-385 and I-85	9
7	I-526 and I-26	8
8	I-20 and SR 277	7

South Dakota

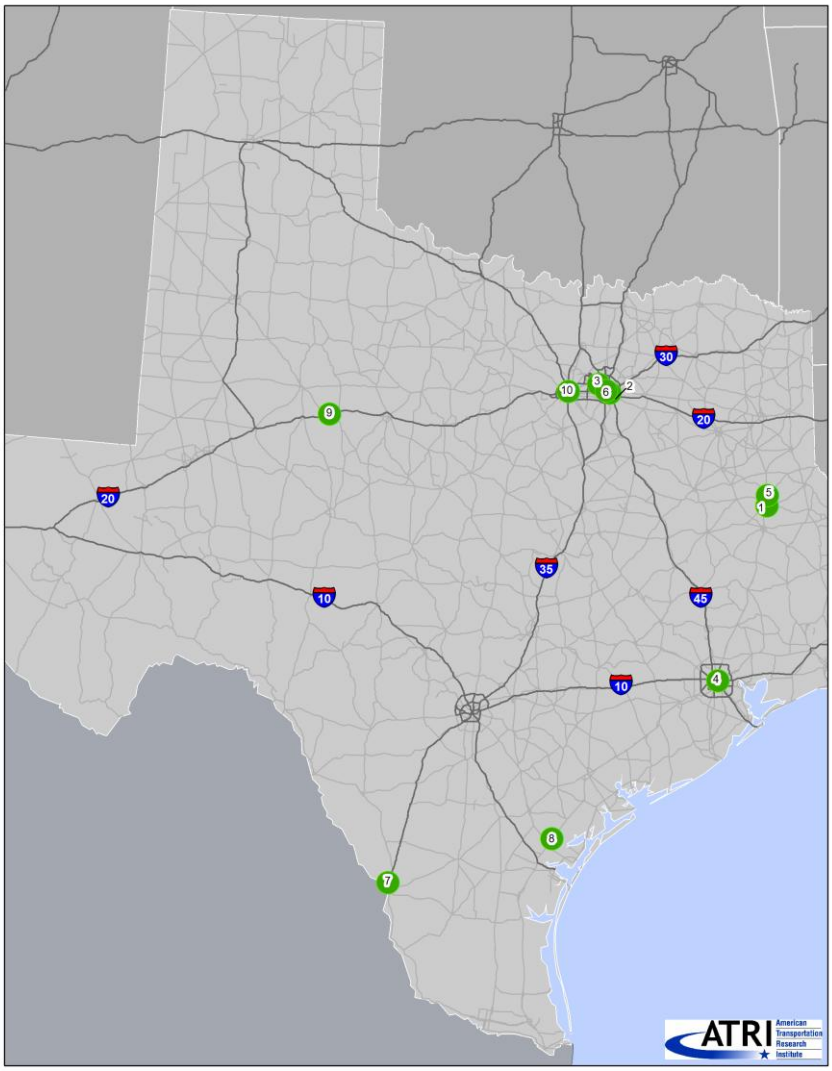


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	3	68	71
2005	4	84	88
2006	4	83	87
2007	2	70	72
2008	3	65	68
2009	2	58	60
All Years	18	428	446

*Coordinate data for this year not provided by state

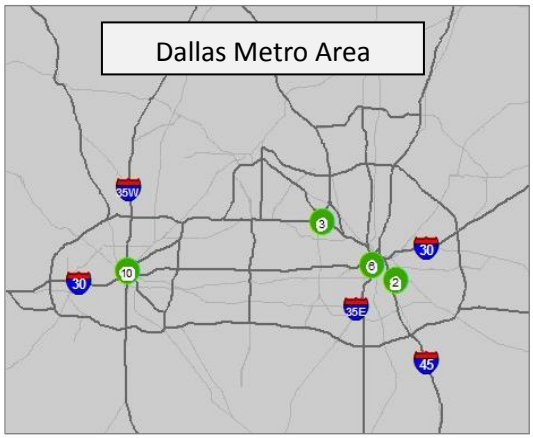
Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-90 and I-29	5
2	I-90 and I-229	4
3	US 83 and US 18	3
4	SR 79 near Buffalo Gap Jct	3
5	I-90 near Exit 296	3

Texas



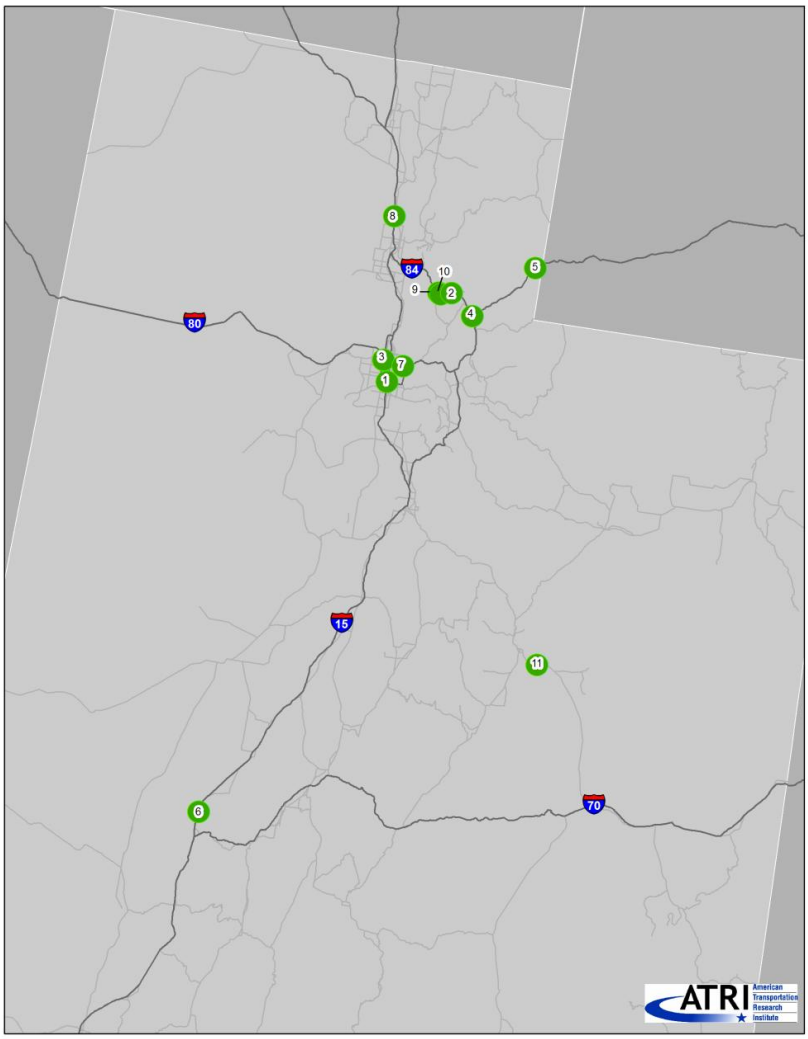
Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	*	*	*
2005	62	571	633
2006	74	648	722
2007	54	702	756
2008	64	814	878
2009	37	569	606
All Years	291	3304	3595

*Coordinate data for this year not provided by state



Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	US 59/South St and US 59/SR 224	9
2	Central Expy and CF Hawn Fwy/US 175	9
3	SR 183, SR 114, SR 12 and SR 482	8
4	I-10/US 90 and US 59	8
5	US 259 and US 59	7
6	I-30/US 67 and I-35E/US 77	7
7	I-35 near Bob Bullock Loop/SR 20	6
8	US 77 near Welder Wildlife	6
9	I-20/US 80 and US 84	6
10	I-35W and Martin L King Jr Fwy/US 287	6

Utah

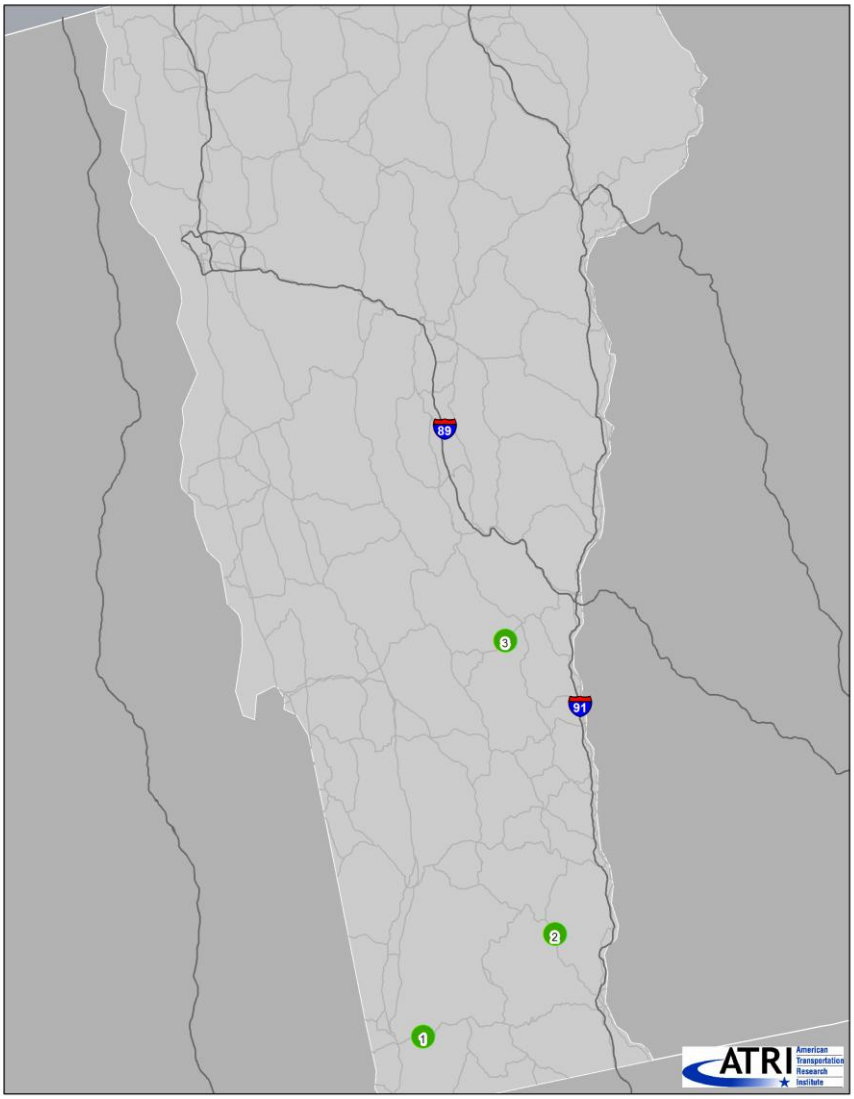


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	*	*	*
2005	*	*	*
2006	7	208	215
2007	7	228	235
2008	7	207	214
2009	10	174	184
All Years	31	817	848

*Coordinate data for this year not provided by state

Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-15 and I-215	11
2	I-84 near Exit 108	7
3	I-215 and W 2100 S	5
4	I-84 and I-80	5
5	I-80 near Exit 191	5
6	I-15 near Exit 138	4
7	I-80 and I-215	4
8	I-85/I-15 at Exit 351	4
9	I-84 at Exit 103	4
10	I-84 near Exit 103	4
11	US 6/US 191 between S East Coal Creek Rd, S Ridge Rd and Soldier Creek Rd	4

Vermont

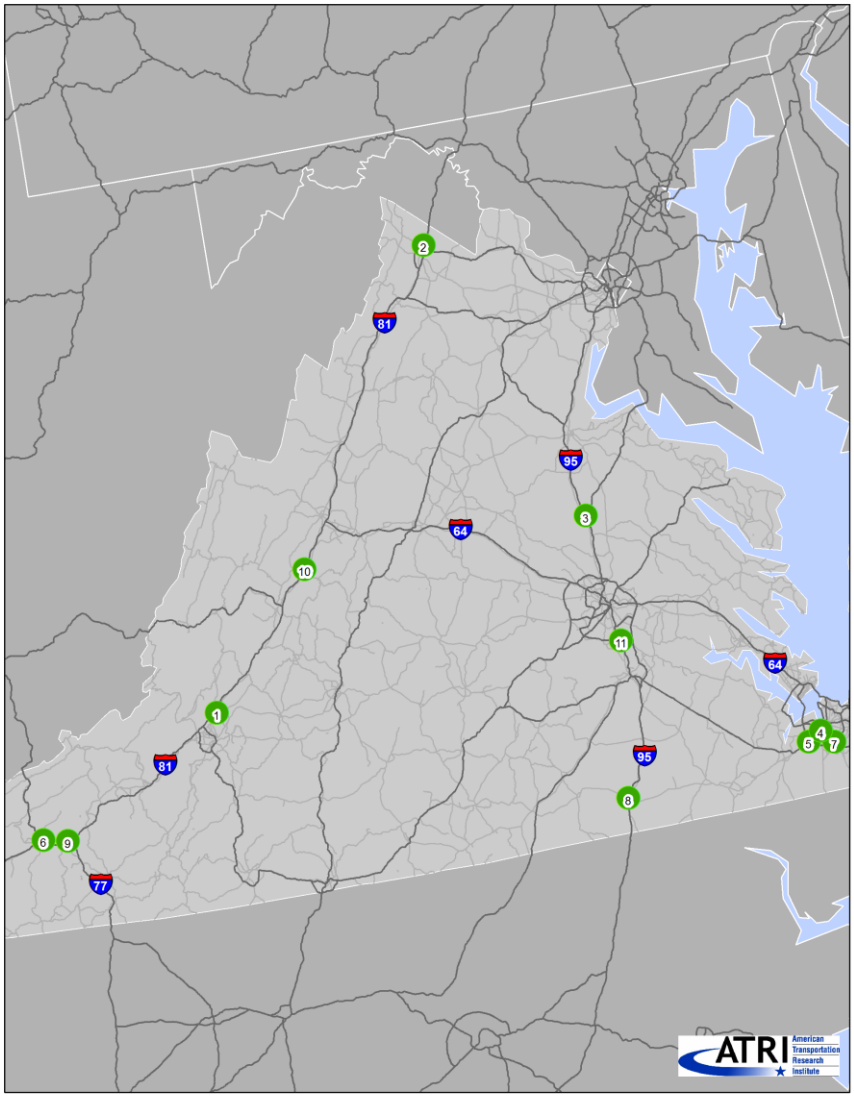


Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	*	*	*
2003	*	*	*
2004	1	1	2
2005	0	2	2
2006	1	18	19
2007	2	19	21
2008	8	4	12
2009	2	3	5
All Years	14	47	61

*Coordinate data for this year not provided by state

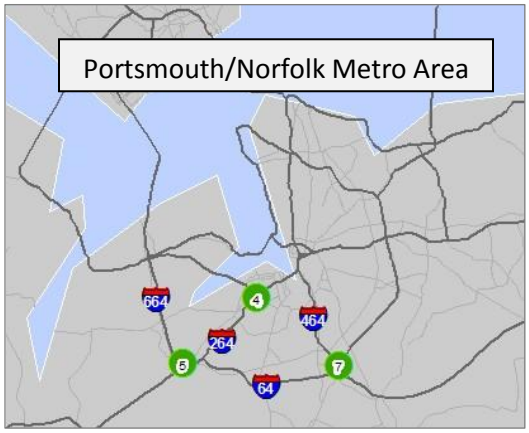
Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	SR 9 near Notch Rd	5
2	SR 30 near State Forest Rd	2
3	US 4 between Westerdale Cutoff and Doe Hill Way	2

Virginia



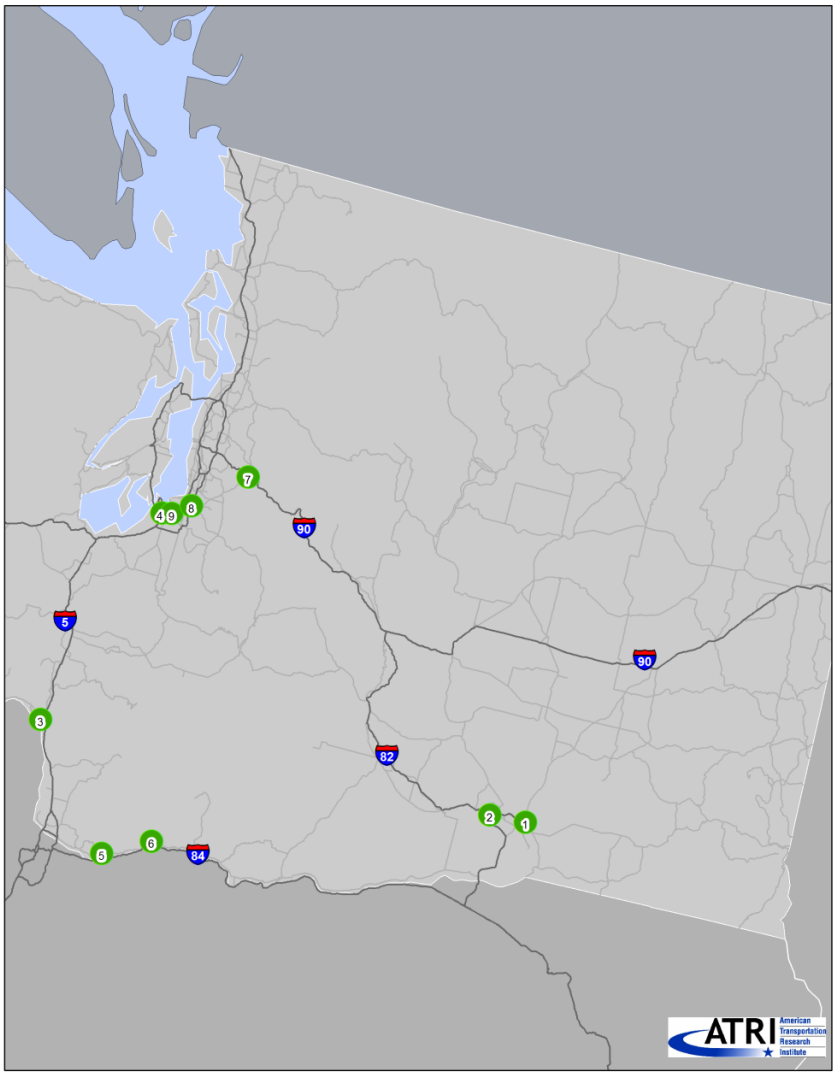
Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	6	214	220
2002	3	154	157
2003	7	178	185
2004	9	182	191
2005	9	166	175
2006	11	128	139
2007	12	118	130
2008	8	100	108
2009	*	*	*
All Years	65	1240	1305

*Coordinate data for this year not provided by state



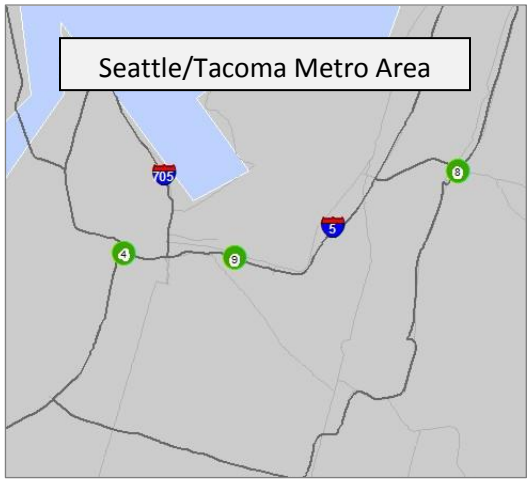
Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-81 and US 220/Cloverdale Rd	7
2	I-81 and US 11	6
3	I-95 and SR 207	5
4	I-264/US 460 and US 17	5
5	I-664 and W Military Hwy/US 13/US 58/US 460	5
6	I-77 and I-81/US 52	5
7	I-64/US 17 and I-464	5
8	I-95 at US 58	5
9	I-81/US 11 and I-77	5
10	I-81/I-64 at Exit 205/Raphine Rd	5
11	I-95 and SR 288/World War 2 Veterans Memorial Hwy	5

Washington



Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	*	*	*
2002	9	135	144
2003	4	120	124
2004	3	128	131
2005	6	165	171
2006	14	154	168
2007	8	133	141
2008	7	154	161
2009	5	118	123
All Years	56	1107	1163

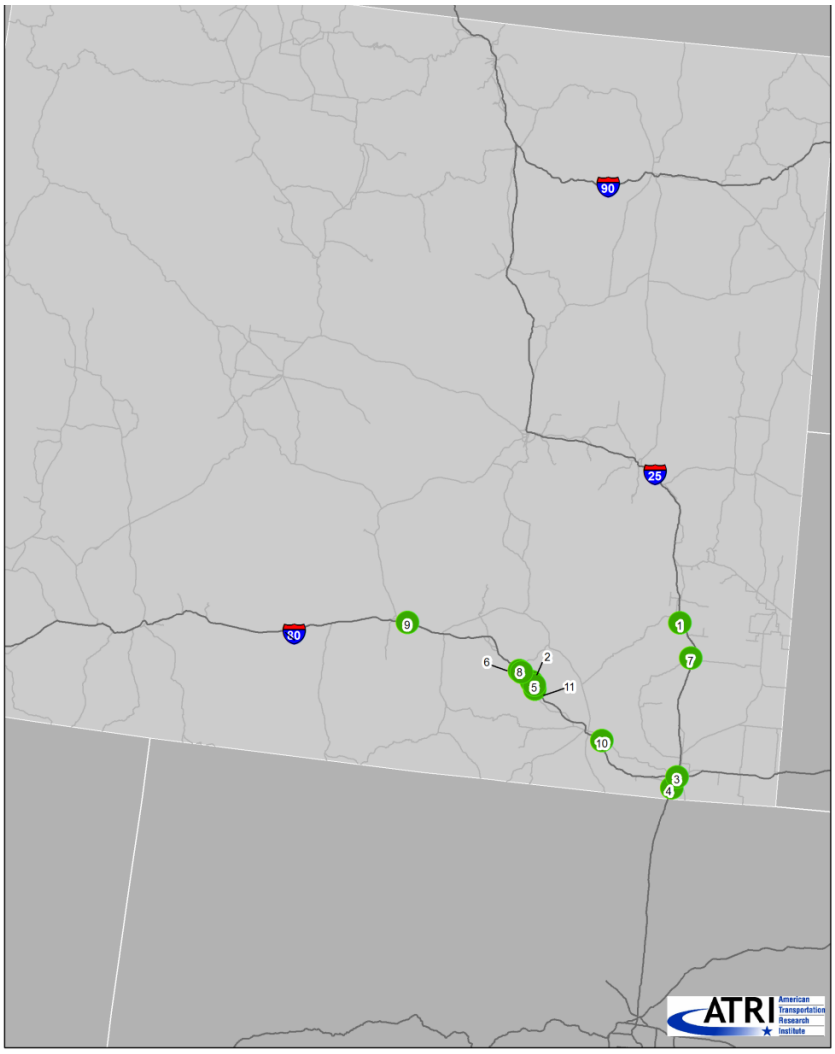
*Coordinate data for this year not provided by state



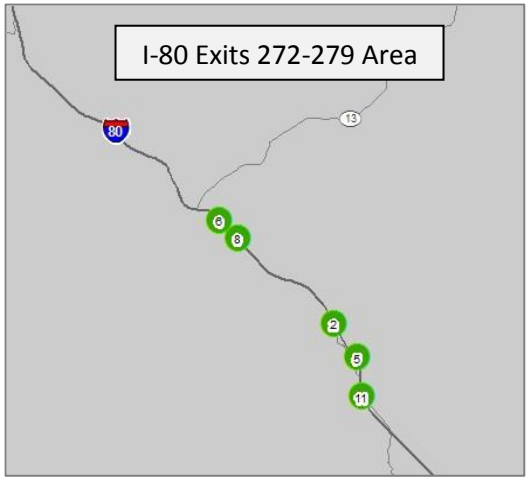
Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-182, US 395 and SR 397	14
2	I-82 and I-182	12
**3	SR 432/Tenant Way and SR 411/3rd Ave	8
**4	I-5 and SR 16	8
5	SR 14/Evergreen Hwy near Salmon Falls Rd	7
6	SR 14/Lewis and Clark Hwy near Sweeney Rd	7
7	I-90, SR 18, and SE Snoqualmie Pkwy	7
8	SR 167/Valley Fwy and SR 18	7
**9	I-5 at Exit 136A	7

**Sites are currently (or were recently) undergoing design improvements

Wyoming



Rollovers by Year and Severity			
Year	Fatal	Non-Fatal	Total Rollovers
2001	6	158	164
2002	4	197	201
2003	10	171	181
2004	8	157	165
2005	7	154	161
2006	7	230	237
2007	6	217	223
2008	5	249	254
2009	4	138	142
All Years	57	1671	1728



Top Rollover Locations		
ID	*Location*	*Number of Rollovers*
1	I-25 near Exit 70/Bordeaux Rd	59
2	I-80 near Exit 279/Dutton Creek Rd	35
3	I-80 and I-25	29
4	I-25 between Exit 2 and Exit 4	23
5	I-80 near Exit 279/Dutton Creek Rd	19
6	I-80 near Exit 272/SR 13	16
7	I-25 near Exit 54	15
8	I-80 near Exit 272/SR 13	14
9	I-80 near Exit 219/SR 76	12
10	I-80 between Buck Sullivan Spring Road and Exit 323	10
11	I-80 near Exit 279/Dutton Creek Rd	10

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