Transit Vehicle Collision Characteristics for Connected Vehicle Applications Research

Analysis of Collisions Involving Transit Vehicles and Applicability of Connected Vehicle Solutions

www.its.dot.gov/index.htm
Final Report — November 2013
Publication Number: FHWA-JPO-13-116

U.S. Department of Transportation
Research and Innovative Technology Administration

Produced by
U.S. Department of Transportation
ITS Joint Program Office
Research and Innovative Technology Administration

Notice

Technical Report Documentation Page

1. Report No. **FHWA-JPO-13-116**	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Transit Vehicle Collision Characteristics for Connected Vehicle Applications Research Analysis of Collisions Involving Transit Vehicles and Applicability of Connected Vehicle Solutions		**5. Report Date** November 2013 **6. Performing Organization Code**
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9. Performing Organization Name And Address Noblis 600 Maryland Ave., SW, Suite 755 Washington, DC 20024		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-11-D-00018
12. Sponsoring Agency Name and Address ITS-Joint Program Office Research and Innovative Technology Administration 1200 New Jersey Avenue, S.E. Washington, DC 20590		**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code** **HOIT-1**
15. Supplementary Notes		

16. Abstract

The transit industry has always shown a great interest in the adoption of transformational safety technologies to improve the safety of its passengers and drivers, as well as all road users including pedestrians. Due to its unique characteristics and behaviors, such as vehicle size and frequent stops/starts, transit often deals with safety challenges and priorities that are often different from those for light duty and commercial vehicles. The purpose of this report was to identify candidate transit crash scenarios for near-term connected vehicle safety research using data from the 2010 National Transit Database (NTD). The study identifies motor bus collision types according to collision characteristics, including the type of object the transit vehicle collided with (e.g., pedestrian, motor vehicles, infrastructure elements, etc.), the location of the collision (e.g., mid-block or at an intersection), and the geographic relationship between vehicles when they collided. The study revealed some prominent characteristics (such as geographic relationship between vehicles) related to motor bus crashes, and how these characteristics are amenable to connected vehicle solutions. The study then ranks collision types by frequency, cost, and average cost per crash. Based on the findings, recommendations for potential application areas for connected vehicle transit safety are introduced. These areas include:

- Transit-Vehicle/Pedestrian Warning Applications: These applications may consider vehicle-to-infrastructure (V2I) or vehicle-to-pedestrian (V2P) communications to provide warnings to transit vehicles of a pedestrian's presence in the roadway – either in a crosswalk or outside of the crosswalk.
- Bus Stop Warning Applications: Using vehicle awareness messages, applications could be developed to alert nearby vehicles or pedestrians of the presence of a transit vehicle at or near a bus stop.
- Left Turn Assist Warning Applications: These applications could provide information to drivers performing unprotected left turns to judge the gaps in oncoming traffic and to inform them of hazards to completing a safe left turn. These applications may be supported using vehicle-to-vehicle (V2V) communications where vehicles share information about their location, speed, trajectories, and other vehicles at the intersection.
- Forward Collision Warning Applications: These applications could alert and then warn drivers if they fail to brake when a vehicle in their path is stopped or traveling slower.
- Blind Spot Warning/Lane Change Warning Applications: These applications could warn drivers when they try to change lanes if there is a car in the blind spot of an overtaking vehicle.
- Angle Collisions at Intersections Warning Applications: These applications could provide warnings to drivers at signalized intersections, at intersections equipped with stop signs, highway rail intersections (HRI), or light rail intersections.

17. Key Words Connected Vehicles, Transit, Collisions, Safety, Vehicle-to-Infrastructure (V2I), Vehicle-to-Vehicle (V2V), Vehicle-to-Pedestrian (V2P)	**18. Distribution Statement**		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 95	**22. Price**

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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1 Introduction

One of the main focuses of the U.S. Department of Transportation's (USDOT's) Connected Vehicle Research program is to use connected vehicle technology to improve safety. Connected vehicle safety applications are designed to increase situational awareness and reduce crashes through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) data transmissions that support driver advisories and warnings. Transit vehicles are expected to leverage these applications to improve transit safety through reduction of the occurrence of crashes that result in injuries and fatalities to passengers, motorists, pedestrians and bicyclists, as well as damage to vehicles and property. Transit crashes are responsible for hundreds of deaths, thousands of injuries and millions of dollars in property damage each year.

To determine whether and the extent to which connected vehicles can effectively reduce the number and severity of traffic crashes that involve transit vehicles, a thorough understanding of transit collision characteristics becomes necessary. This study analyzed transit collision datasets from the National Transit Database (NTD) which is the Federal Transit Administration's (FTA's) primary national database for statistics related to the transit industry. The NTD includes data on transit organization characteristics, vehicle fleet size and characteristics, revenues and subsidies, operating and maintenance costs, safety and security, vehicle fleet reliability and inventory, and services consumed and supplied. These data have been used extensively by the transit community to derive values for transit performance measures and have become the sole source of standardized and comprehensive data for use by all constituencies of the transit industry. The transit collision analysis performed for this study analyzed 2010 NTD Transit Collision Data. The report identifies collision types according to collision characteristics, including the transit mode (e.g., motor bus, light rail, etc.), type of object the transit vehicle collided with (e.g., pedestrian, motor vehicles, etc.), the location of the collision (e.g., mid-block or at an intersection), and the geographic relationship between vehicles when they collided. The report then ranks collision types by frequency, cost, and average cost per crash. These rankings were then used to identify connected vehicle transit safety application areas for future USDOT connected vehicle research.

1.1 Connected Vehicle Research

Connected vehicle research is both a concept and a program of services that can transform travel as we know it. Connected vehicle research combines leading edge technologies – advanced wireless communications, on-board computer processing, advanced vehicle-sensors, Global Positioning System (GPS) navigation, smart infrastructure, and others – to provide the capability for vehicles to identify threats, hazards, and delays on the roadway and to communicate this information over wireless networks to provide drivers with alerts, warnings, and real time road network information. At its foundation is a communications network that supports V2V two-way communications, V2I[1] one- and two-way communications, and vehicle or infrastructure-to-

[1] Although two-way communications between vehicles and infrastructure is usually called "V2I", one-way communication is generally distinguished by designating the initiator of the communications first. Thus, one-

device2 (X2D) one- and two-way communications to support cooperative system capability. Connected vehicles enable a surface transportation system in which crashes are significantly reduced and roadway operators and travelers have the information they need about travel conditions to operate more effectively. Connected vehicle research will establish an information backbone for the surface transportation system that will support applications to enhance safety and mobility and, ultimately, an information-rich surface transportation system. Connected vehicle research also supports applications to enhance livable communities, environmental stewardship, and traveler convenience and choices.

The ability to identify, collect, process, exchange, and transmit real-time data provides drivers with an opportunity for greater situational awareness of the events, potential threats, and imminent hazards within the vehicle's environment. When combined with technologies that intuitively and clearly present alerts, advice, and warnings, drivers can make better and safer driving decisions. Additionally, when further combined with automated vehicle-safety applications, connected vehicle technology enables the vehicle to respond and react in a timely fashion when the driver either cannot or does not react quickly enough. Vehicle safety systems, because of the need for frequently broadcasted real-time data, are expected to use dedicated short range communications (DSRC) technology for active safety applications. Many of the other envisioned applications could use other technologies, such as third generation (3G) cellular or other Wireless Fidelity (Wi-Fi) communications, as well as DSRC. The rapid pace of technological evolution provides tremendous opportunities for connected vehicles, and the USDOT's connected vehicle program is positioned to capitalize upon these advances as they happen.

The USDOT currently has a very active set of research programs focused on the development of crash avoidance systems based on both V2V and V2I (meaning both I2V and V2I) DSRC technology. The USDOT is also actively researching ways to improve mobility and reduce environmental impacts of transportation, using wireless communications (not necessarily based on DSRC technology). The expectation is that, in the future, in-vehicle systems will run a combination of safety, mobility, and environmental applications that communicate using the most effective wireless technologies available.

1.2 Connected Vehicle Research for Safety

Connected vehicle safety applications are designed to increase situational awareness and reduce crashes through V2V and V2I data transmission that support driver advisories and warnings. The connected vehicle safety program is divided into two areas: V2V communications for safety and V2I communications for safety.

- **V2V Communications for Safety.** V2V communications for safety is the dynamic wireless exchange of data between nearby vehicles offering the opportunity for significant safety improvements. By exchanging anonymous, vehicle-based data regarding position, speed, and location (at a minimum), V2V communications enables a vehicle to: sense threats and

way infrastructure-to-vehicle communications is called "I2V" and one-way vehicle-to infrastructure communications uses the more common "V2I" designation.

[2] In this context, the term "device" refers only to devices that are "carry-in" devices, i.e., devices that can be temporarily installed in vehicles and are not connected to in-vehicle information systems. These devices include ones (e.g., smart phones) that could also be carried by pedestrians or other users of the roadways (e.g., cyclists).

hazards with a 360 degree awareness of the position of other vehicles and the threat or hazard they present; calculate risk; and issue driver advisories or warnings to avoid and mitigate crashes. At the heart of V2V communications is a basic application known as the vehicle awareness message. This message can be derived using non-vehicle-based technologies such as GPS to identify location and speed of a vehicle, or vehicle-based sensor data wherein the location and speed data are derived from the vehicle's computer and are combined with other data such as latitude, longitude, or angle to produce a richer, more detailed situational awareness of the position of other vehicles.

- **V2I Communications for Safety.** V2I communications for safety is the wireless exchange of critical safety and operational data between vehicles and roadway infrastructure, intended primarily to avoid or mitigate motor vehicle crashes, but also to enable a wide range of other safety, mobility, and environmental benefits. V2I communications apply to all vehicle types and all roads, and transform infrastructure equipment into "smart infrastructure" through the incorporation of algorithms that use data exchanged between vehicles and infrastructure elements to perform calculations that recognize high-risk situations in advance, resulting in driver alerts and warnings through specific countermeasures. One particularly important advance is the ability for traffic signal systems to communicate the signal phase and timing (SPaT) information to the vehicle in support of delivering active safety advisories and warnings to drivers. Early implementation of the SPaT application can enable near-term benefits from V2I communications in the form of reduced crashes, which in turn demonstrates benefits that can help accelerate deployment.

The transit industry has always shown a great interest in the adoption of transformational safety technologies to improve the safety of its passengers and drivers, as well as all road users and pedestrians. Due to its unique characteristics and behaviors, such as vehicle size and frequent stops/starts, transit often deals with safety challenges and priorities that are often different from those for light and commercial vehicles.

1.3 The Transit V2I Safety Research Program

The Intelligent Transportation Systems (ITS) Joint Program Office (JPO) is charged with planning and execution the ITS Program as authorized by Congress. The ITS JPO is part of the Research and Innovative Technology Administration (RITA) of the USDOT. This program encompasses a broad range of technologies applied to the surface transportation system. Under collaborative and transparent governance structure established for ITS JPO projects, the ITS JPO coordinates with and executes the program jointly in cooperation with all of the surface transportation modal administrations within the DOT to ensure full coordination of activities and leveraging of research efforts.

The USDOT is engaged in assessing applications that realize the full potential of connected vehicles, travelers, and infrastructure to enhance current operational practices and transform future surface transportation systems management. This effort is a collaborative initiative spanning the ITS JPO, Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Traffic Safety Administration (NHTSA). These agencies of the Federal Government work closely with the American Association of State Highway and Transportation Officials (AASHTO), which represents state transportation agencies across the country, as well as the numerous private sector interests (car manufacturers, technology companies, etc.) in working together to develop a nationwide system for ITS to be deployed in the future. The Connected Vehicle program is a major RITA program, focusing on the use of V2V and V2I transmission of information to promote safety, mobility, and the environment.

One foundational element of the Connected Vehicle research efforts is the Transit V2I research area. A successful Transit V2I Program will lead to the more rapid and cost-effective deployment of interoperable technologies and applications that improve transit safety and enhance mobility for transit vehicles. The Transit V2I Program will act to promote the highest levels of collaboration and cooperation in the research and development of V2I applications for connected vehicles. The Transit V2I Program positions the federal government to take on an appropriate and influential role as a technology steward for a continually evolving integrated transportation system.

2 The National Transit Database

The NTD was established by Congress to be the nation's primary source for information and statistics on the transit systems of the United States. Recipients or beneficiaries of grants from the FTA under the Urbanized Area Formula Program (§5307) or Other than Urbanized Area (Rural) Formula Program (§5311) are required by statute to submit data to the NTD. Over 690 transit providers in urbanized areas currently report to the NTD through an Internet-based reporting system. Each year, NTD performance data are used to apportion over $5 billion of FTA funds to transit agencies. Annual NTD reports are submitted to Congress summarizing transit service and safety data. This section provides a summary of the type of data transit agencies enter into the NTD.

2.1 Reportable Incident Report Form (S&S-40)

The Reportable Incident Report form (S&S-40) was designed to capture detailed information on the most severe safety and security incidents occurring in the transit environment. Detailed data, available from sources such as accident, incident, or police reports are used to complete the Reportable Incident Report form (S&S-40). The information required on the form is intended to be of a level that can be collected at or near the time the incident occurred.

Transit agencies must complete one Reportable Incident Report form (S&S-40) for each reportable incident (safety or security incident) occurring during the reporting period. Commuter rail operators are only required to report security incidents to NTD. Commuter rail operators are currently required to report safety incidents to the Federal Railroad Administration. Reportable Incident Report forms (S&S-40) are due thirty days after the reportable incident occurred.

2.2 Reportable Incidents

According to the NTD, a reportable incident is an event that involves a transit vehicle or occurs on transit-controlled property and meets one or more of the following conditions:

- A fatality (including a suicide or deaths resulting from Other Safety Occurrences),
- Injuries requiring immediate medical attention away from the scene for one or more persons,
- Property damage equal to or exceeding $25,000, and/or
- An evacuation for life safety reasons.

The following paragraphs highlight the important aspects of each reportable incident threshold.

2.2.1 Fatality

For NTD purposes, a fatality is a transit-caused death, confirmed within thirty days of a transit incident, due to a collision, derailment, fire, hazardous material spill, Act of God, evacuation, security incident or other incident. Fatalities include transit-related suicides. There is one exception to this rule: Deaths resulting from illnesses or other natural causes, or otherwise not associated with an incident, are not reported on either incident form. For example, if a person in a rail facility suffers a fatal heart attack it would not be reported to NTD.

2.2.2 Injury

For NTD reporting purposes, an injury requires immediate medical attention away from the scene of the incident. Immediate medical attention includes transport to the hospital by ambulance. It also includes transport immediately from the incident scene to a hospital or physician's office by another type of emergency vehicle, by passenger vehicle, or through other means of transport. Immediate medical attention means that medical attention was sought without delay after the incident occurred. An individual seeking medical care several hours after an incident or in the days following an incident is not considered to have received immediate medical attention. The medical attention received must be at a location other than the location at which the incident occurred. The intent of this distinction is to exclude incidents that only require minor first aid or other assistance received at the scene. This distinction is not, however, intended to be burdensome for the transit agency. It is not a requirement that an agency follow-up on each person transported by ambulance, for example, to ensure that they actually received medical attention at the hospital. It is acceptable to count each person immediately transported by ambulance as an injury.

2.2.3 Property Damage

Incidents involving property damage equal to or exceeding $25,000 require the completion of a Reportable Incident Report form (S&S-40). Property damage includes, but is not limited to, the following:

- Transit and non-transit vehicle damage,
- Stations as well as non-transit facilities, and
- Right-of-way (ROW) and items surrounding ROW, such as utility poles.

The key points regarding estimated property damage are:

- Estimated damage does not only include transit property damage, but also damage to other vehicles and property (other than personal property) involved in the incident and not owned by the transit agency.
- The amount paid (or an estimate made for insurance purposes) is reported for property damage. In the case where replacement is necessary, the depreciated replacement cost is reported.
- The cost of clearing wreckage or damage to non-transit agency property is also included in the property damage value.
- The cost of an accident or a criminal investigation is not included in the estimated property damage.
- Damage to personal property, such as the value of laptops, cell phones, or other personal property items damaged or destroyed in an incident are not included in the estimated property damage.

2.3 Reporting Incidents

Incident types that are reported using the Reportable Incident Report form (S&S-40) include the following incident types. ***For the purposes of this analysis, only collisions are considered.***

- **Collision.** All collisions involving at least one transit vehicle, or taking place on transit property, are reported using the Reportable Incident Report form (S&S-40). Collisions are subject to the thresholds for a reportable incident.
- **Mainline Derailment.** All derailments occurring on mainline track are considered a reportable incident. The mainline track is the primary rail over which rail transit vehicles travel between stations. It does not include yard and siding track. This threshold applies only to rail incidents (other than commuter rail (CR)).
- **Fire.** Fires occurring on or in transit property must meet the thresholds for a reportable incident. The fire requires the act of suppression to occur at the time of the incident.
- **Hazardous Material Spill.** Hazardous material spills that occur on or in transit property include bunker fuel, diesel, electric battery, ethanol, hybrid diesel, grain additive, liquefied natural gas, methanol, bio-diesel, compressed natural gas, dual fuel, electric propulsion, gasoline, hybrid gasoline, kerosene and liquefied petroleum gas. The hazardous material spill must have caused imminent danger to life, health, or the environment, and had special attention given at the time of the incident.
- **Act of God.** An Act of God is a natural and unavoidable catastrophe that interrupts the expected course of events, such as earthquakes, floods, hurricanes, tornados, other high winds, lightning, snow and ice storms.
- **Bomb Threat, Bombing, Chemical, Biological, Nuclear/Radiological Releases.** Security incidents that occur on or in transit property and meet the reporting thresholds for a reportable incident are any terrorism-related events such as bomb threats, bombings, chemical, biological, nuclear/radiological releases. Security incidents also include other system security events, such as arson, sabotage, hijacking and cyber security events.
- **Aggravated Assault, Robbery, Rape, Burglary, Suicide or Larceny/Theft, Vandalism.** Robberies, burglaries, larcenies/thefts or vandalism, as well as other personal events such as aggravated assault, rape, suicide, attempted suicide and homicide.
- **Arrest or Citation for Other Assault, Trespassing, Non-Violent Civil Disturbance, or Fare Evasion.** All arrests or citations for other assault, trespassing, non-violent civil disturbance, vandalism, or fare evasion are reported on the Safety and Security Monthly Summary Incident Report form (S&S-50).
- **Other Safety Occurrences not Otherwise Classified Incidents (Slip and Fall, Electric Shock, etc.).** Other safety occurrences not otherwise classified may include slip and fall accidents and electric shock incidents. Other safety occurrence not otherwise classified resulting in one or more injuries are reported using the Safety and Security Monthly Summary Report form (S&S-50) as Other Safety Occurrences not Otherwise Classified while incidents resulting in one or more fatalities are reported using the Reportable Incident form (S&S-40).

2.3.1 Reporting Rail Collisions

The Reportable Incident Report form (S&S-40) collects information about the number of rail transit and other motor vehicles involved, the location of the collision, what the vehicles were doing when they collided with, etc. Transit agencies are required to provide data for the following fields for a rail collision:

- **Number of Rail Transit Trains Involved.** The number of rail transit trains involved in the collision.
- **Location.** The location (i.e., revenue facility, grade crossing) at which the collision occurred. If the location is not listed, transit agencies can select ‘Other’ and use a ‘Describe Box’ to provide a location description.
- **Collision With.** The vehicle, object or person (other than the transit vehicle) involved in the collision.
- **Number of Other Motor Vehicles Involved.** The number of other motor vehicles (i.e., automobiles, buses) involved in the collision.
- **Number of Cars in Rail Transit Train.** The total number of cars in the rail transit train.
- **Number of Cars Derailed.** The total number of cars in the rail transit train that derailed as a result of the collision.
- **Train Action.** The action that the train was involved in when the collision occurred (i.e., going straight, making a stop). If the action is not listed, the transit agency can select ‘Other’ and use the ‘Describe Box’ to provide a description of the action.
- **Collision Type.** The orientation of the vehicle(s) when the collision occurred (i.e., rear-ended, angle, sideswipe). Each choice is from the point of view of the transit vehicle. For example, rear-ended means that another vehicle hit the back of the rail transit train, while rear-ending means the rail transit train hit the back of another vehicle.
- **Train Speed.** The speed (in miles per hour) at which the rail transit train was traveling when the collision occurred. If the transit agency does not know the exact speed, they may estimate the speed of the vehicle.
- **Other Motor Vehicle Type.** The type of other motor vehicle (i.e., automobile, motorcycle) that was involved in the collision. If the vehicle type is not listed, the transit agency can select ‘Other’ and use the ‘Describe Box’ to describe the vehicle type.
- **Other Motor Vehicle Action.** The action that the other motor vehicle was involved in when the collision occurred (i.e., going straight, making a turn). If the action is not listed, the transit agency can select ‘Other’ and use the ‘Describe Box’ to provide a description of the action.
- **Collision Type.** The orientation of the vehicle(s) when the collision occurred (i.e., rear-ended, angle, sideswipe). Each choice is from the point of view of the motor vehicle. That is, rear-ended means that another vehicle hit the back of the motor vehicle, while rear-ending means the motor vehicle hit the back of another vehicle.

2.3.2 Reporting Non-Rail Collisions

The non-rail transit collision screens ask the reporter to provide information about the number of transit vehicles and other motor vehicles involved, with what the collision occurred, as well as other collision information. Similar data fields are included in the Reportable Incident Report form (S&S-40) for non-rail collisions. These fields include:

- **Number of Non-Rail Transit Trains Involved.** The number of non-rail transit vehicles involved in the collision.

- **Location.** The location (i.e., revenue facility, grade crossing) at which the collision occurred. If the location is not listed, the transit agency can select ‘Other’ and use the ‘Describe Box’ to provide a description of the location.
- **Collision With.** The vehicle, object or person (other than the transit vehicle) that was involved in the collision. If the list does not contain a description that fits the transit agency’s needs, they can select ‘Other’.
- **Number of Other Motor Vehicles Involved.** The number of other motor vehicles (i.e., automobiles, motorcycles) involved in the collision.
- **Transit Vehicle Type.** The type of transit vehicle involved in the collision. If the needed vehicle type is not listed, the transit agency can select ‘Other’ and use the ‘Describe Box’ to provide a description of the transit vehicle type.
- **Vehicle Action.** The action that the vehicle was involved in when the collision occurred (i.e., going straight, making a stop). If the needed action is not listed, the transit agency can select ‘Other’ and use the ‘Describe Box’ to provide a description of the action.
- **Collision Type.** The orientation of the vehicle(s) when the collision occurred (i.e., rear-ended, angle, sideswipe). Each choice is from the point of view of the transit vehicle. That is, rear-ended means that another vehicle hit the back of the transit vehicle, while rear-ending means the transit vehicle hit the back of another vehicle.
- **Vehicle Speed.** The speed (in miles per hour) at which the transit vehicle was traveling when the collision occurred.

3 Collision, Injury, and Fatality Trends (2005-2010)

This section provides an overview of collision data in the NTD summarizing collisions for different transit modes between 2005 and 2010. A transit mode is defined by the NTD as “a system for carrying transit passengers described by specific ROW, technology, and operational features”. Four transit modes are described in this report, including demand responsive, heavy rail, light rail, and motor bus.

- **Demand Responsive.** A transit mode comprised of passenger cars, vans or small buses operating in response to calls from passengers or their agents to the transit operator, who then dispatches a vehicle to pick up the passengers and transport them to their destinations.
- **Heavy Rail.** A transit mode that is an electric railway with the capacity for a heavy volume of traffic. Heavy rail is characterized by: (a) high speed and rapid acceleration passenger rail cars operating singly or in multi-car trains on fixed rails, (b) separate ROW from which all other vehicular and foot traffic are excluded, (c) sophisticated signaling, and (d) high platform loading.
- **Light Rail.** A transit mode that typically is an electric railway with a light volume traffic capacity compared to heavy rail. Light rail is characterized by: (a) passenger rail cars operating singly (or in short, usually two car, trains) on fixed rails in shared or exclusive ROW, (b) low or high platform loading, and (c) vehicle power drawn from an overhead electric line via a trolley or a pantograph.
- **Motor Bus.** A transit mode comprised of rubber-tired passenger vehicles operating on fixed routes and schedules over roadways. Vehicles are powered by diesel, gasoline, battery, or alternative fuel engines contained within the vehicle.

Other modes such as automated guideway, cable car, ferryboat, Puerto-Rico’s jitney system, trolley bus, and vanpool are grouped together and labeled as ‘Other’. Definitions used in this report are included in Appendix B.

3.1 Motor Bus/Pedestrian Collisions at Transit Stops/Stations

NTD data from 2005 to 2010 were made available to the analysis team and are summarized in Table 3-1. As shown in the table, the total number of collisions reported per year to the NTD between 2005 and 2007 were significantly higher than the total number of collisions reported per year between 2008 and 2010. While it is not known why these numbers vary, it is assumed that there were changes made in 2008 regarding how transit agencies reported data to the NTD. These changes may have included new criteria or rules for reporting data to the NTD which may account for the differences between the two timeframes. A notable change is that the “other safety occurrences not otherwise classified” threshold changed and increased (from 1 person to 2 persons) after 2008.

Table 3-1: NTD Transit Collisions Reported from 2005 to 2010 *(Source 2010 NTD)*

Mode	2005 Collisions	2006 Collisions	2007 Collisions	2008 Collisions	2009 Collisions	2010 Collisions
Demand Responsive	1,618	1,934	1,382	672	571	549
Heavy Rail	65	102	112	62	81	116
Light Rail	73	586	577	162	169	177
Motor Bus	6,327	8,341	7,932	3,161	3,132	3,224
Other	34	88	192	35	58	42
Total	**8,117**	**11,051**	**10,094**	**4,092**	**4,011**	**4,108**

Looking at the number of collisions by mode between 2008 and 2010, motor buses have the highest number of collisions per year, followed by demand responsive, light rail, heavy rail, and other. The large number of motor bus collisions can be attributed to the fact that motor buses travel more miles per year than any other mode and thus have more opportunities to be in a collision than other modes. Additionally, there are more motor buses in the United States than vehicles from other modes. Finally, other modes such as heavy rail have dedicated right-of-way while motor buses travel on roads shared with motor vehicles, motorcycles, bicyclists, and pedestrians.

Table 3-2 depicts the number of injuries per year between 2005 and 2010 according to the NTD. Similar to Table 3-1, there are differences between data collected between 2005 and 2007 and data collected between 2008 and 2010. These differences primarily appear in the number of heavy rail injuries reported, which ranged from 3,000 to 5,000 between 2005 and 2007 to over 7,000 between 2008 and 2010. Overall, motor buses resulted in the highest number of injuries. The second highest number of injuries, however, was from heavy rail. The number of injuries per collisions for heavy rail is high with over 7,000 injuries per year while averaging only 86 collisions per year between 2008 and 2010. This increase reflects changes in reporting suicides and the injury reporting threshold. Prior to 2008 and later year, the reporting threshold was changed to 1 or more injuries.

Table 3-2: NTD Transit-Related Injuries Reported from 2005 to 2010 *(Source 2010 NTD)*

Mode	2005 Injuries	2006 Injuries	2007 Injuries	2008 Injuries	2009 Injuries	2010 Injuries
Demand Responsive	1,180	1,607	1,768	1,979	1,896	1,651
Heavy Rail	3,766	4,728	4,980	7,248	7,536	7,518
Light Rail	614	656	843	1,006	1,054	914
Motor Bus	12,266	12,704	13,981	14,179	15,249	14,803
Other	173	274	303	205	525	337
Total	**17,999**	**19,969**	**21,875**	**24,617**	**26,260**	**25,223**

Table 3-3 shows fatalities, reported by the NTD, between 2005 and 2010. Over this time period, again there is a significant increase in heavy rail fatalities after 2007. A reason for the difference may be the results of changes in 2008 and forward where suicides are included in the data. Prior to 2008, suicides were not included. Looking at the table, between 2008 and 2010, heavy rail had the highest number of fatalities followed by motor buses. Between 2008 and 2010 there was an average of 86 heavy rail collisions per year with an average of 88 fatalities per year. This ratio is significantly higher than any other mode.

Table 3-3: NTD Transit-Related Fatalities Reported from 2005 to 2010 *(Source 2010 NTD)*

Mode	2005 Fatalities	2006 Fatalities	2007 Fatalities	2008 Fatalities	2009 Fatalities	2010 Fatalities
Demand Responsive	12	12	11	7	7	10
Heavy Rail	35	23	32	67	100	96
Light Rail	19	17	33	16	34	24
Motor Bus	75	107	104	80	78	84
Other	3	3	5	2	7	7
Total	**144**	**162**	**185**	**172**	**226**	**221**

Upon further inspection of the NTD data, the analysis team decided to focus its analysis on transit collisions for the year 2010. This decision was made based on the following reasons:

- NTD data between 2005 and 2007 showed significant differences when compared to data from 2008 to 2010. The reasons for these differences were unknown, but may be attributed to how the data were collected over this time period.
- After looking at the data, there were a lot of similarities between NTD data collected between 2008 and 2010. It was assumed that analyzing additional years would result in seeing trends similar to the 2010 data.
- The 2010 data included 4,108 collision records. To perform a detailed analysis, these individual collision records would need to be analyzed in detail which would require a substantial amount of resources.
- At the time the analysis was performed, 2011 NTD was not available to the analysis team.

3.2 2010 NTD Transit Collisions, Injuries, and Fatalities

Table 3-4 shows a summary of the number of transit collisions, injuries, and fatalities by transit mode in 2010. Motor buses account for 78.4% of all transit collisions, followed by demand responsive transit (13.4%), light rail (4.3%), and heavy rail (2.8%). While motor bus collisions represent the large majority of collisions (78.4%), the number of injuries associated with motor bus collisions accounted for only 58.7% of all injuries. On the other hand, while heavy rail only accounted for 2.8% of all collisions, this mode resulted in 29.8% of all injuries and 43.4% of all fatalities. The high number of heavy rail injuries and fatalities is due to the fact that although heavy rail collisions are less frequent, they are often more severe than collisions from other transit modes. Additionally, there are a higher proportion of suicide attempts involving rail (particularly heavy rail) than other modes. However more fatalities and injuries in the light rail, motor bus, and demand responsive modes involve pedestrians, cyclists, and drivers of other motor vehicles.

Table 3-4: 2010 NTD Collisions, Injuries, and Fatalities by Mode *(Source 2010 NTD)*

Mode	Number of Collisions *(%)*	Number of Injuries *(%)*	Number of Fatalities *(%)*
Demand Responsive	549 *(13.4%)*	1,651 *(6.5%)*	10 *(4.5%)*
Heavy Rail	116 *(2.8%)*	7,518 *(29.8%)*	96 *(43.4%)*
Light Rail	177 *(4.3%)*	914 *(3.6%)*	24 *(10.9%)*
Motor Bus	3,224 *(78.4%)*	14,803 *(58.7%)*	84 *(38.0%)*
Other	42 *(1.1%)*	337 *(1.3%)*	7 *(3.2%)*
Total	**4,108**	**25,223**	**221**

3.3 2010 NTD Transit Collisions Categorized by Object Hit

Table 3-5 breaks down the 2010 NTD collisions by the object hit. Objects defined by the NTD include: motor vehicles, persons, fixed objects, rail vehicles, and other. As shown in this table demand responsive transit vehicles have the most collisions with motor vehicles (86.4%). The vast majority of heavy rail collisions occurred with a person (93.1%). Light rail vehicles have the most collisions with motor vehicles (58.4%), followed by 36.7% of collisions with pedestrians. Finally, motor buses have the most collisions with motor vehicles (83.2%), followed by 13.9% with pedestrians.

Table 3-5: 2010 NTD Collision Data by Object Hit *(Source 2010 NTD)*

Object Hit	Demand Resp. (%)	Heavy Rail (%)	Light Rail (%)	Motor Bus (%)	Other (%)	Total
With Motor Vehicle	475 *(86.4%)*	1 *(0.9%)*	104 *(58.4%)*	2,684 *(83.2%)*	29 *(70.7%)*	**3,293**
With Person	44 *(8.0%)*	108 *(93.1%)*	65 *(36.7%)*	451 *(13.9%)*	8 *(19.5%)*	**676**
With Fixed Object*	29 *(5.2%)*	3 *(2.6%)*	3 *(1.7%)*	80 *(2.4%)*	2 *(4.8%)*	**117**
With Rail Vehicle	0 *(0.0%)*	2 *(1.7%)*	4 *(2.2%)*	0 *(0.0%)*	1 *(2.4%)*	**7**
With Other**	2 *(0.4%)*	2 *(1.7%)*	1 *(0.5%)*	10 *(2.4%)*	1 *(2.4%)*	**16**
Total	**549**	**116**	**177**	**3,224**	**41**	**4,108**

** Heavy and light rail collisions with fixed objects include collisions where an object falls onto the rail track or collision where an object is fixed, but protruding over the rail track*

*** 'Other' includes modes such as automated guideway, cable car, ferryboat, Puerto-Rico's jitney system, trolley bus, and vanpool*

3.4 2010 NTD Injuries and Fatalities

In 2010, the NTD reported that there were 25,223 injuries resulting from transit collisions. This includes injuries to passengers, revenue facility occupants, employees, bicyclists, pedestrians, other vehicle occupants, and suicide attempts. Table 3-6 and Figure 3-1 depict injuries by mode. The data show:

- **Demand Responsive.** Passengers account for 61.7% of all demand responsive injuries, followed by employees (15.5%), and other vehicle occupants (14.8%).

- **Heavy Rail.** Revenue facility occupants account for 62.5% of all heavy rail injuries, followed by passengers which accounted for 33.8% of the injuries.
- **Light Rail.** Passengers account for 46.8% of all light rail injuries. Nearly 25% of injuries occur with revenue facility occupants and 9.6% with other vehicle occupants.
- **Motor Bus.** The vast majority of motor bus injuries are with passengers (70.6%), followed by 11.3% of injuries associated with other vehicle occupants.

In 2010 there were 221 fatalities according to the NTD. Table 3-7 and Figure 3-2 show a summary of 2010 fatalities by mode. Demand responsive transit has the highest percentage of fatalities with other vehicle occupant followed by passengers which accounted for 30% of the demand responsive fatalities. Most heavy rail fatalities were the results of suicides (42.7%). Over thirty-seven percent of light rail fatalities were between light rail vehicles and pedestrians. Finally, motor bus fatalities were highest with pedestrians and other vehicle occupants, both accounting for 32.1% of all motor bus fatalities.

Table 3-6: 2010 NTD Persons Injured by Mode *(Source 2010 NTD)*

Person Injured	Demand Resp. *(%)*	Heavy Rail *(%)*	Light Rail *(%)*	Motor Bus *(%)*	Other *(%)*	Total
Passenger	1,018 *(61.7%)*	2,544 *(33.8%)*	428 *(46.8%)*	10,456 *(70.6%)*	211 *(62.6%)*	**14,657**
Rev Facility Occupant	62 *(3.8%)*	4,695 *(62.5%)*	227 *(24.8%)*	594 *(4.0%)*	63 *(18.7%)*	**5,641**
Employee	256 *(15.5%)*	89 *(1.2%)*	78 *(8.5%)*	1,088 *(7.3%)*	25 *(7.4%)*	**1,536**
Bicyclist	12 *(0.7%)*	1 *(0.0%)*	6 *(0.7%)*	97 *(0.7%)*	1 *(0.3%)*	**117**
Pedestrian	33 *(2.0%)*	3 *(0.0%)*	34 *(3.7%)*	283 *(1.9%)*	6 *(1.8%)*	**359**
Other Vehicle Occupant	245 *(14.8%)*	3 *(0.0%)*	88 *(9.6%)*	1,674 *(11.3%)*	15 *(4.5%)*	**2,025**
Suicide	0 *(0.0%)*	33 *(0.4%)*	5 *(0.5%)*	0 *(0.0%)*	1 *(0.3%)*	**39**
Other	25 *(1.5%)*	126 *(1.7%)*	48 *(5.3%)*	609 *(4.1%)*	15 *(4.5%)*	**823**
Total	**1,651**	**7,518**	**914**	**14,803**	**337**	**25,223**

Table 3-7: 2010 NTD Fatalities by Mode *(Source 2010 NTD)*

Person Injured	Demand Resp. *(%)*	Heavy Rail *(%)*	Light Rail *(%)*	Motor Bus *(%)*	Other *(%)*	Total
Passenger	3 *(30.0%)*	3 *(3.1%)*	0 *(0.0%)*	3 *(3.6%)*	1 *(14.3%)*	**10**
Rev Facility Occupant	0 *(0.0%)*	28 *(29.2%)*	1 *(4.2%)*	10 *(11.9%)*	0 *(0.0%)*	**39**
Employee	1 *(10.0%)*	3 *(3.1%)*	0 *(0.0%)*	1 *(1.2%)*	1 *(14.3%)*	**6**
Bicyclist	0 *(0.0%)*	0 *(0.0%)*	2 *(8.3%)*	10 *(11.9%)*	0 *(0.0%)*	**12**
Pedestrian	2 *(20.0%)*	9 *(9.4%)*	9 *(37.5%)*	27 *(32.1%)*	0 *(0.0%)*	**47**
Other Vehicle Occupant	4 *(40.0%)*	0 *(0.0%)*	4 *(16.7%)*	27 *(32.1%)*	2 *(28.6%)*	**37**
Suicide	0 *(0.0%)*	41 *(42.7%)*	6 *(25.0%)*	3 *(3.6%)*	2 *(28.6%)*	**52**
Other	0 *(0.0%)*	12 *(12.5%)*	2 *(8.3%)*	3 *(3.6%)*	1 *(14.3%)*	**18**
Total	**10**	**96**	**24**	**84**	**7**	**221**

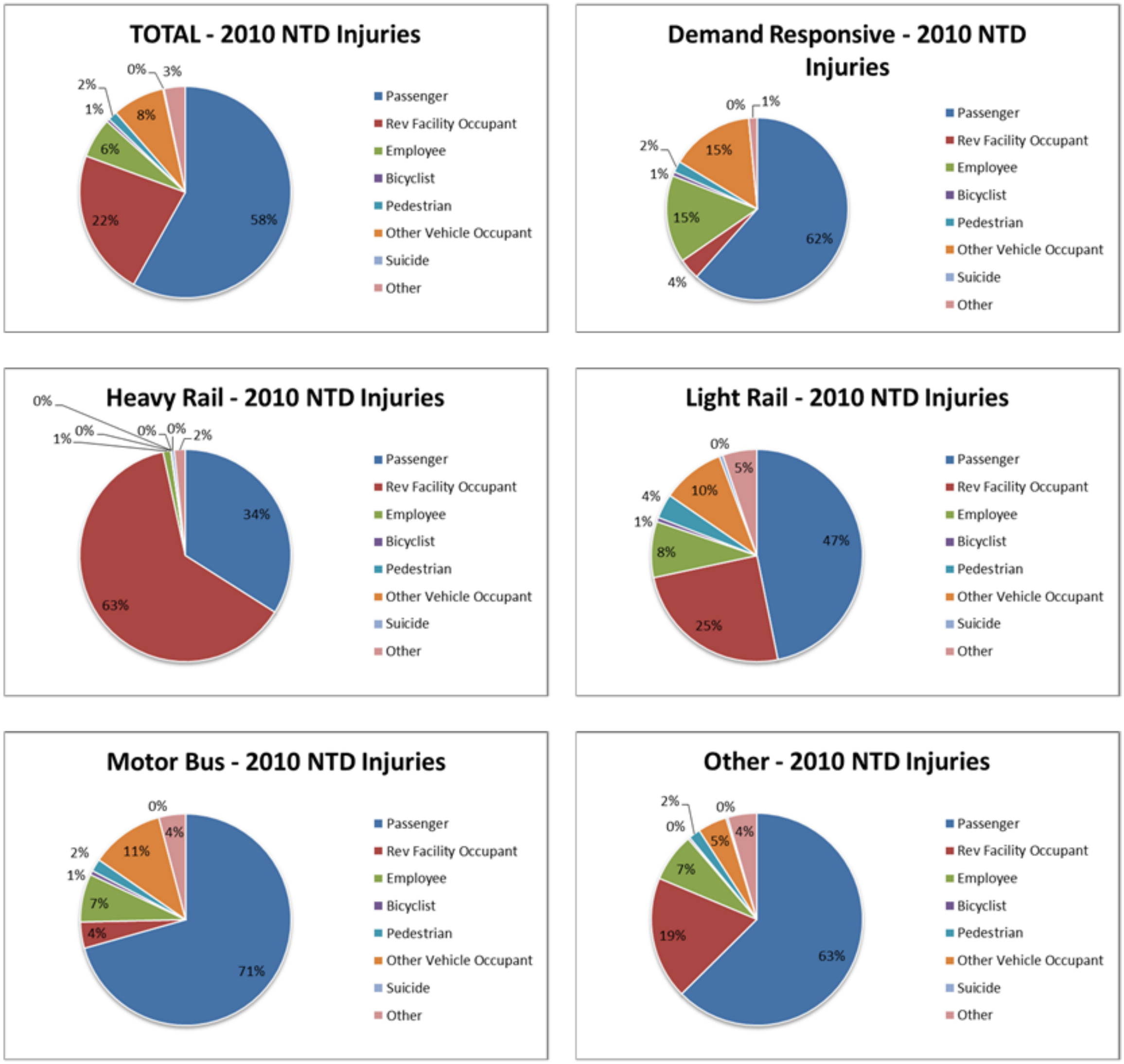

Figure 3-1: 2010 NTD Injuries by Mode *(Source 2010 NTD)*

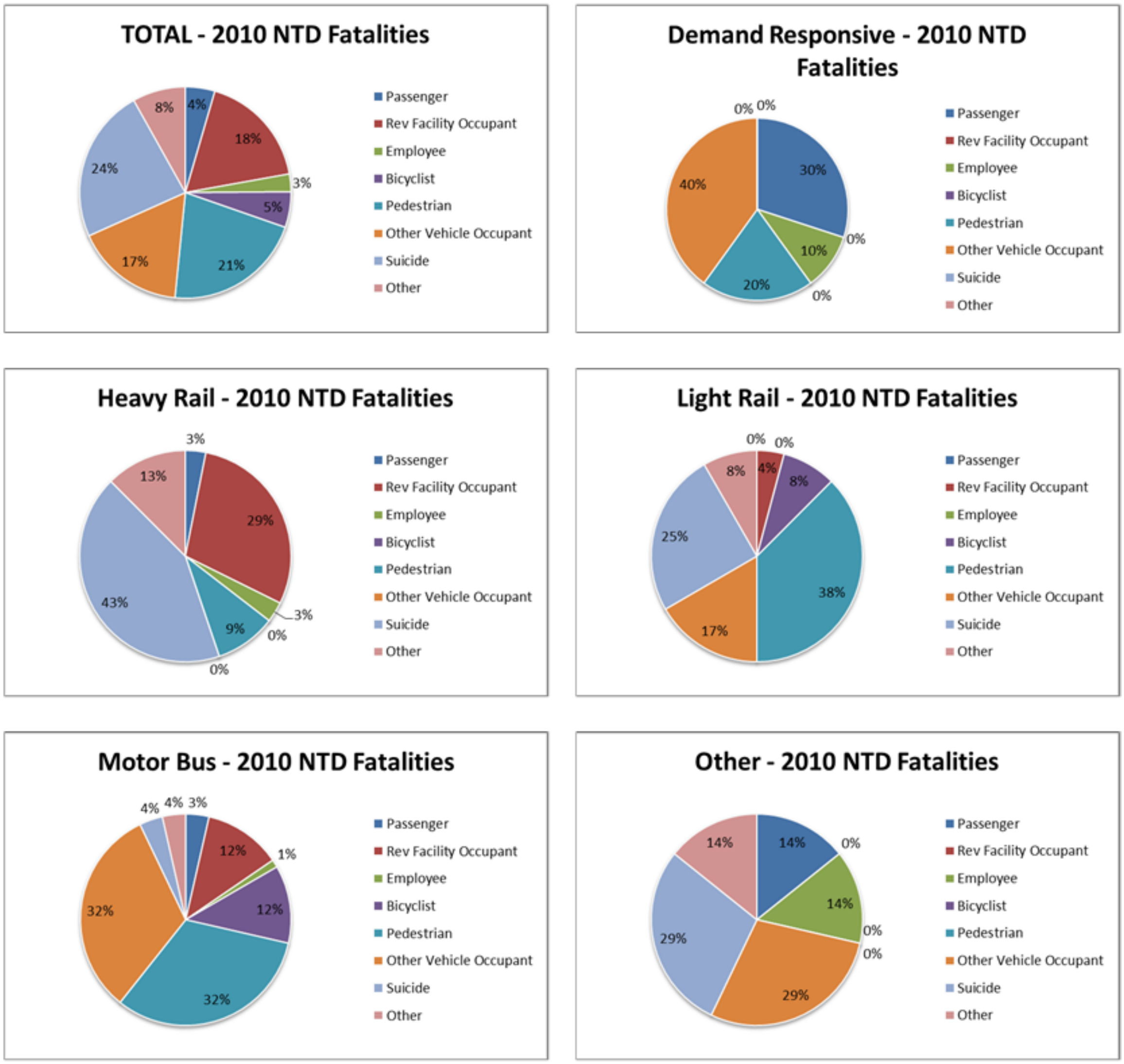

Figure 3-2: 2010 NTD Fatalities by Mode *(Source 2010 NTD)*

4 Transit Collision Analysis Approach

The information contained in Section 3 provides a high-level overview of transit collisions. To determine whether and the extent to which connected vehicles can effectively reduce the number of and severity of traffic collisions involving transit vehicles; a more thorough understanding of transit collision characteristics is necessary. This section describes the approach used by the analysis team to conduct a detailed transit collision analysis. It describes an overview of the 2010 NTD, gaps in the NTD data and how those gaps were overcome, the approach for categorizing transit collisions, and normalization or extrapolation of the NTD data to perform a more detailed analysis. Figure 4-1 depicts the approach, including six (6) steps. These steps are described in more detail in this section of the report.

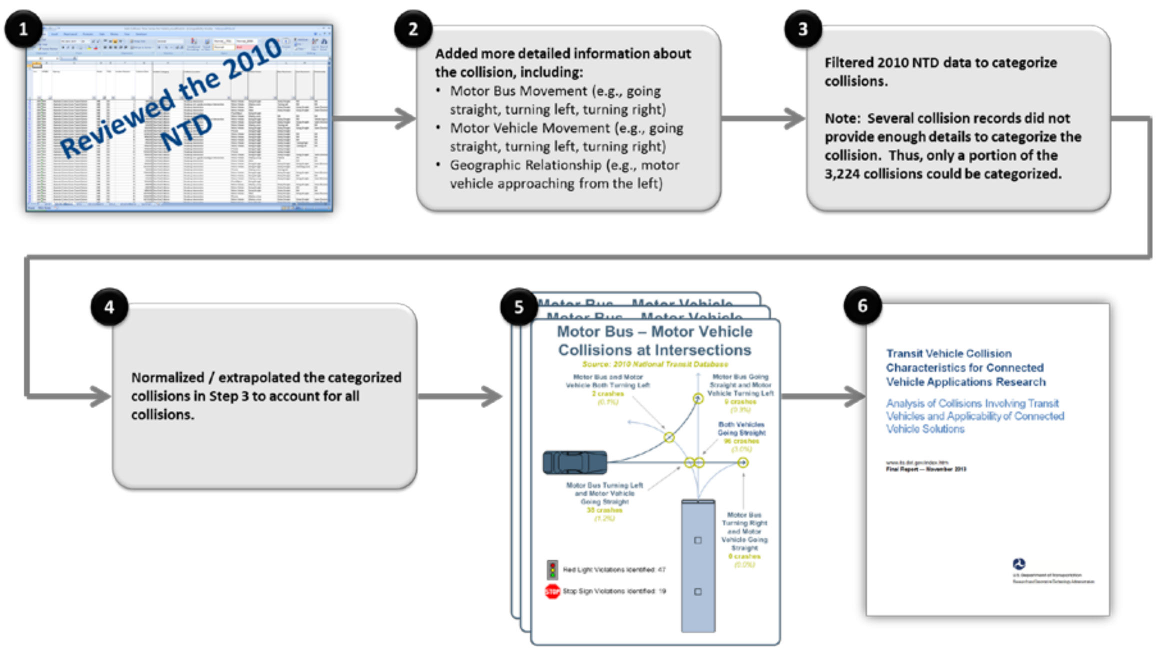

Figure 4-1: Transit Collision Analysis Approach (*Source*: *Noblis, 2013*)

4.1 Step 1: Review the NTD

The first step was to review the NTD to determine what type of data was available to the analysis team to perform a detailed collision analysis. Upon reviewing the NTD, the following data fields were identified:

- **Agency.** The name of the transit agency.
- **Mode.** Data about the mode or type of transit vehicle. The NTD contains twenty modes. These modes included everything from motor buses to the jitney system in Puerto Rico.

- **Collision Location.** Data about the location of the collision. Examples of collision locations include revenue facility, roadway – grade crossing, roadway – non-grade crossing, and roadway – intersection.
- **Collision With.** Data about the type of object the transit vehicle collided with. Examples include motor vehicle, person, animal, and fixed object.
- **Transit Vehicle Action.** Data about the action the transit vehicle was taking when it collided with the other object. Examples include going straight, making a turn, leaving a stop, and making a stop.
- **Collision Type.** Data about the type of collision including whether the collision was a head-on collision, sideswipe, rear end, or angle collision.
- **Vehicle Speed.** Data about the speed of the transit vehicle when it collided with the other object.
- **Incident Description.** Detailed descriptions of the collision. These descriptions are entered as free form text from transit agencies across the United States.

These data fields from S&S-40 were contained within a Microsoft Excel spreadsheet that allowed the data to be sorted or queried easily. By sorting the data, it was possible to determine some initial results including the number of collisions occurring at intersections or at mid-block, the number of head-on collisions versus sideswipes, or the number of collisions between motor buses and motor vehicles as compared to collisions between motor buses and pedestrians.

4.2 Step 2: Add Additional Data to the NTD

While the NTD contained several data fields that could be sorted easily, it lacked some data necessary to perform a more detailed analysis. These limitations are summarized below:

- **Transit Vehicle's Turning Movement.** The NTD included a data field for the transit vehicle's action as 'making a turn'; however it did not differentiate whether the transit vehicle was making a left turn or a right turn.
- **Motor Vehicle's Action.** The NTD did not include a data field for a motor vehicle's movement (e.g., going straight, turning left, or turning right).
- **Vehicle Geographic Relationship.** The NTD did not define a data field describing the geographic relationship between two vehicles that were involved in a collision. For example, it was not possible to determine if the motor vehicle was approaching the transit vehicle at an intersection from the left, from the right, driving in the same direction, or approaching the transit vehicle from the opposite direction.

While the existing data fields did not include data to address the limitations identified above, there was an "incident description" data field in the NTD that contained more detailed information for each collision record. Data in the "incident description" data field was entered as free form text and varied in their level of detail. For example, some collision records had very detailed information about collisions making it easy to obtain additional characteristics about the collision. These details included the transit vehicle's turning movement and geographic relationships as two vehicles approached an intersection. Other collision records lacked this detail; simply stating that "The Motor Vehicle hit the Bus".

Data from the "incident description" data was analyzed further for all 3,224 motor bus collision records. These collision records were analyses to obtain more detailed information about collisions such as the transit vehicle's turning movement, motor vehicle's action, and vehicle geographic relationship when two or more vehicles collided. New data fields were created in the NTD to account for these data and data was entered into these data fields accordingly. For collision records where it was not possible to determine the turning movement or relationship between vehicles, 'NA' was entered into the data field.

4.3 Step 3: Filter the Data to Determine Collision Types for a Sample

Once the analysis team appended the additional data fields to the NTD data, it was then possible to filter the database to determine collision types for a large sample of the data. Nine categories were identified:

1. Motor Bus Collisions with Pedestrians at Intersections
2. Motor Bus Collisions with Pedestrians at Mid-Block
3. Motor Bus Collisions with Motor Vehicles at Intersections – Motor Bus Turning Left
4. Motor Bus Collisions with Motor Vehicles at Intersections – Motor Bus Turning Right
5. Motor Bus Collisions with Motor Vehicles at Intersections – Motor Bus Going Straight
6. Motor Bus Collisions with Motor Vehicles at Intersections – Motor Bus at Bus Stop
7. Motor Bus Collisions with Motor Vehicles at Mid-Block – Motor Bus Going Straight
8. Motor Bus Collisions with Motor Vehicles at Mid-Block – Motor Bus at Bus Stop
9. Light Rail Collisions with Motor Vehicles

These categories were further broken down by the movement of the motor bus and motor vehicle. As a result there were forty-four (44) collision types identified. Collision types are provided in the table below.

Table 4-1: Collision Categories and Collision Types (*Source*: *Noblis, 2013*)

MOTOR BUS COLLISIONS WITH PEDESTRIANS

Collisions at Intersection
- Motor Bus Going Straight
- Motor Bus Turning Left
- Motor Bus Turning Right

Mid-Block Collisions
- Motor Bus Going Straight
- Motor Bus Leaving a Bus Stop
- Motor Bus Making a Bus Stop

MOTOR BUS COLLISIONS WITH MOTOR VEHICLES AT INTERSECTIONS

Motor Bus Turning Left
- Motor Vehicle Approaching from Left – Going Straight
- Motor Vehicle Approaching from Left – Turning Left
- Motor Vehicle Approaching from Left – Turning Right
- Motor Vehicle Approaching from Opposite Direction – Going Straight
- Motor Vehicle Approaching from Opposite Direction – Turning Left
- Motor Vehicle Approaching from Opposite Direction – Turning Right
- Motor Vehicle Approaching from Right - Going Straight
- Motor Vehicle Approaching from Right- Turning Left
- Motor Vehicle Approaching in Same Direction - Turning Left
- Motor Vehicle Approaching in Same Direction - Going Straight

Motor Bus Turning Right
- Motor Vehicle Approaching from Left - Going Straight
- Motor Vehicle Approaching from Opposite Direction - Turning Left
- Motor Vehicle Approaching in Same Direction - Turning Right
- Motor Vehicle Approaching in Same Direction - Going Straight

Motor Bus Going Straight
- Motor Vehicle Approaching from Left - Going Straight
- Motor Vehicle Approaching from Left - Turning Left
- Motor Vehicle Approaching from Opposite Direction - Going Straight
- Motor Vehicle Approaching from Opposite Direction - Turning Left
- Motor Vehicle Approaching from Right - Going Straight
- Motor Vehicle Approaching from Right - Turning Right
- Motor Vehicle Approaching from Right - Turning Left
- Motor Vehicle Approaching in Same Direction – Rear Ending
- Motor Vehicle Driving in Same Direction - Rear Ended
- Motor Vehicle Driving in Same Direction - Switching Lanes
- Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus
- Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus

Motor Bus at Bus Stop
- Motor Bus Leaving a Bus Stop
- Motor Bus Making a Bus Stop

MOTOR BUS COLLISIONS WITH MOTOR VEHICLES AT MID-BLOCK

Motor Bus Going Straight
- Motor Vehicle Approaching in Same Direction - Going Straight or Switching Lanes
- Motor Vehicle Parked - Same Direction
- Motor Vehicle Approaching from Opposite Direction - Going Straight
- Motor Vehicle Approaching from Opposite Direction - Turning Left
- Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus
- Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus
- Motor Vehicle Approaching from Left or Right

Motor Bus at Bus Stop
- Motor Bus Leaving a Bus Stop
- Motor Bus Making a Bus Stop

LIGHT RAIL COLLISIONS WITH MOTOR VEHICLES

- Motor Vehicle Going Straight
- Motor Vehicle Turning Left
- Motor Vehicle Turning Right

Nomenclature for motor vehicle approaches at intersections is illustrated in Figure 4-2 which shows that a motor vehicle may approach a motor bus at an intersection from: (1) the left, (2) the opposite direction, (3) the right, or(4) the same direction. This nomenclature is used throughout this report when identifying a motor vehicle's relationship to a motor bus at an intersection.

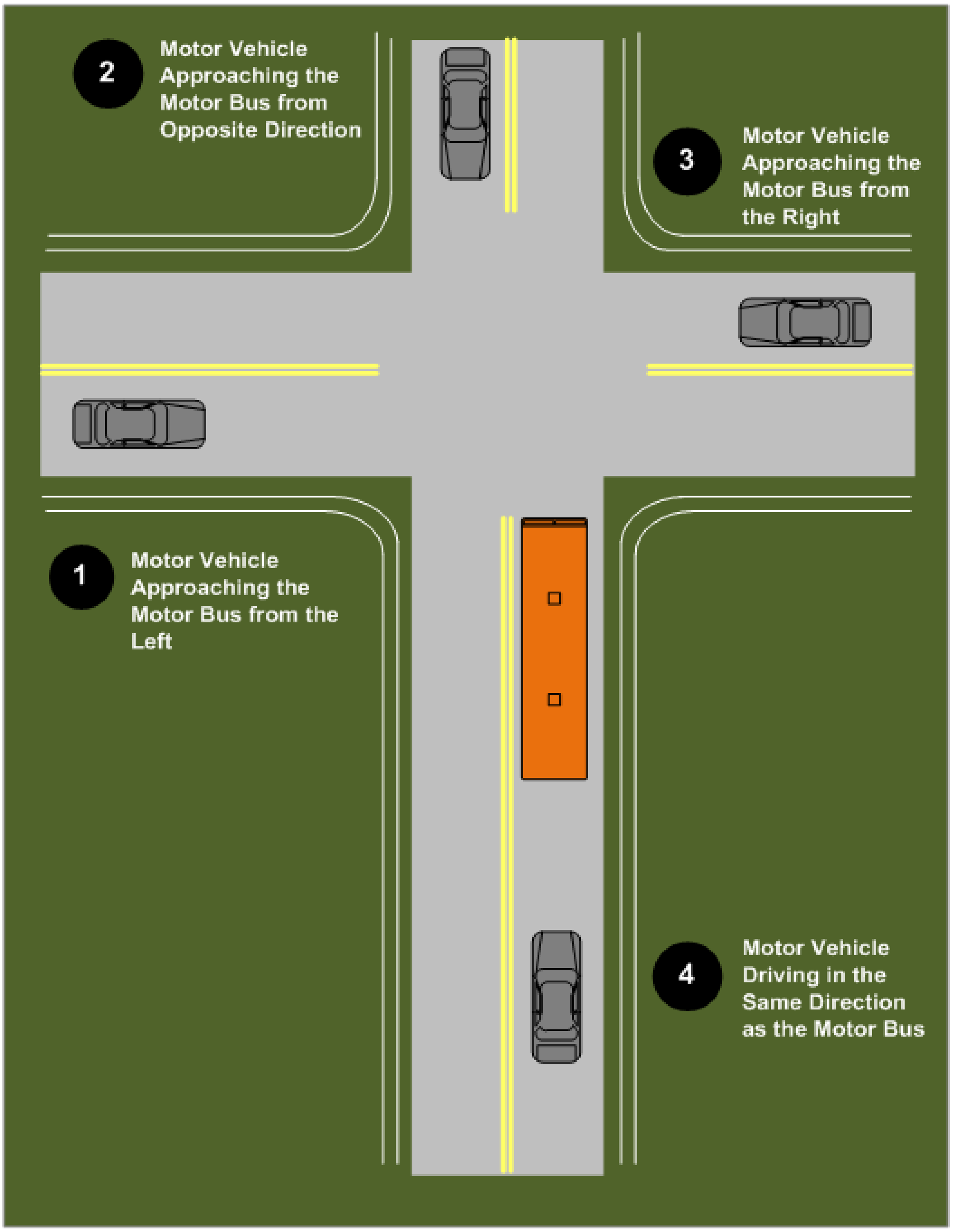

Figure 4-2: Nomenclature for Motor Vehicle Approaches at Intersections *(Source: Noblis, 2013)*

The next step was to filter the NTD to determine the number of collisions for each collision type. For example, to determine the number of motor bus collisions with pedestrians at intersections when the motor bus is turning right, the following filter was applied: (a) filter the 'mode' by 'MB', (b) filter by the 'collision location' by 'roadway: intersection', (c) filter 'collision with' by 'person', and (d) filter 'bus movement' by 'turning right'. These filters were conducted for each of the collision types listed in Table 4-1 and the results were entered into a separate spreadsheet.

4.4 Step 4: Normalize/Extrapolate the Data

Categorizing a collision record required data from several data fields. Unfortunately, there were several collision records that lacked data from one or more data field making it impossible to categorize the collision record. After conducting the filters described in the previous step, only 2,244 of the 3,224 motor bus collisions were categorized. This accounted for 69.6% of all the collision records meaning that 30.4% of collision records in the 2010 NTD could not be categorized. Of these collision records there were 307 collision records where the bus's turning movement (e.g., turning left or right) was not known. Additionally, the car movement could not be determined for 757 collision records and the geographic relationship could not be determined for 799 collision records.

After looking at the collision categories and collision types, it was determined that some categories and types have more unknowns than other categories. For example, collisions between motor buses and pedestrians had fewer unknowns than collisions between motor buses and motor vehicles. In this example, the only potential unknown for a motor bus and pedestrian collision is the motor bus' turning movement (e.g., turning left or turning right). However, motor bus collisions with motor vehicles have three potential unknowns: (1) the bus' turning movement, (2) the motor vehicle's movement, and (3) the geographic relationship. Therefore there were a higher percentage of motor vehicle collisions with pedestrians that were analyzed than motor vehicle collisions with motor vehicles. Because of these discrepancies, it was not possible to compare the frequency of collisions from the 2,244 collisions analyzed. As a result, the analysis team determined that it was necessary to normalize or extrapolate the data so that all 3,224 motor bus collisions were accounted for.

To normalize the data, for each collision category, the analysis team broke down the collisions in the 2010 NTD into the following categories:

- **Motor Bus Collisions with Pedestrians.** There were 451 collision records in the 2010 NTD of which 370 were analyzed in Step 3.
- **Motor Bus Collisions with Motor Vehicles at Intersections.** There were 1,606 collision records in the 2010 NTD of which 941 were analyzed in Step 3.
- **Motor Bus Collisions with Motor Vehicle at Mid-Block.** There were 1,029 collision records in the 2010 NTD of which 795 were analyzed in Step 3.

To account for these discrepancies, the total number of collisions for a collision category from the 2010 NTD was divided by the number of collisions analyzed in step three for that collision category. The result was then multiplied by number of collisions for a specific collision type. An example of this normalization is shown below:

$$\text{Motor Bus Collisions with Pedestrians at Intersections when the Motor Bus was Going Straight}$$
$$= \frac{(\text{Total Number of Motor Bus Pedestrian Collisions Reported in the 2010 NTD})}{(\text{Number of Motor Bus Pedestrian Collisions Analyzed in Step 3 })}$$
$$\times\ (\text{Collisions from Step 3 for Motor Bus Collisions wwhen the Motor Bus was Going Straight})$$

$$\text{Motor Bus Collisions with Pedestrians at Intersections when the Motor Bus was Going Straight} = \frac{451}{370} \times 107$$

$$\text{Motor Bus Collisions with Pedestrians at Intersections when the Motor Bus was Going Straight} = 130 \text{ collisions}$$

In summary, the normalization process resulted in the number of collisions analyzed being multiplied by a multiplier. This multiplier was specific to each collision category and varied depending on the number of unknowns for that particular collision category. Appendix C shows the multipliers used for each collision category. This resulted in an extrapolation of the data according to the collision categories. Appendix C also shows the data for each collision type calculated from step 3 and the results from the data extrapolation or normalization conducted in step 4. This approach ensured that the total number of collisions used for this analysis equaled the total number of collision records in the 2010 NTD.

4.5 Step 5: Conduct Data Analysis

Once the data were normalized, it was possible to create tables and graphics depicting the number or frequency of collisions for each collision type. These tables and graphics are included in Section 5 of this report and were used by the analysis team to draw conclusions about collisions with higher frequencies than others. This allowed the analysis team to make recommendations on the types of collisions that should be further explored by the connected vehicle Transit Program.

4.6 Step 6: Develop Transit Collision Analysis Report

The final step was to create this report, ‘Transit Vehicle Collision Characteristics for Connected Vehicle Research Applications’.

5 Motor Bus Collisions

The NTD defines a motor bus as a shared-ride transportation service operating over regular streets and roads, according to fixed routes. According to the NTD, in 2010 there were 3,224 motor bus collisions in the United States that resulted in 14,803 injuries, and 84 fatalities. The following sections of the report discuss motor bus collisions in more detail. It should be noted that the numbers used for the analysis are the normalized/extrapolated numbers.

- Section 5.1 breaks down the number of motor bus collisions by location.
- Section 5.2 provides a summary of motor bus collisions categorized by collision type.
- Section 5.3 discusses motor bus collisions with pedestrians. These collisions account for 451 of the 3,224 motor bus collisions or approximately 13.9% of all motor bus collisions.
- Section 5.4 discusses motor bus collisions with motor vehicles at intersections. This includes signalized intersections, un-signalized intersections, and intersections equipped with stop or yield signs. These collisions account for 1,606 collisions or 49.8% of all motor bus collisions.
- Section 5.5 discusses mid-block motor bus collisions with motor vehicles. In 2010, there were 1,029 mid-block collisions which accounts for 31.9% of all motor bus collisions.
- Section 5.6 discusses motor bus collisions with motor vehicles at bus stop. There were 287 collisions at bus stops reported in 2010.

5.1 Motor Bus Collisions Categorized by Location

The NTD defines six categories for location: (1) Non-Revenue Facility, (2) Revenue Facility: Terminal Center, (3) Roadway: Grade Crossing, (4) Roadway: Intersection, (5) Roadway: Not a Grade Crossing or Intersection, and (6) Other. Table 5-1 includes a breakdown of 2010 NTD data by the collision location. These data show that Roadway: Intersections had the highest number of collisions in 2010 with 1,883 or 58.4% of all motor bus collisions. The location with the second highest number of collisions was at Roadway: Not a Grade Crossing or Intersection which accounted for 1,241 or 38.5% of all motor bus collisions. The remaining locations accounted for a little more than three percent of all motor bus collisions combined.

Table 5-1: Motor Bus Collisions by Location

Location	Number of Collisions	Percentage
Non-Revenue Facility	4	0.1%
Revenue Facility: Terminal Center	45	1.4%
Roadway: Grade Crossing	18	0.6%
Roadway: Intersection	1,883	58.4%
Roadway: Not a Grade Crossing or Intersection	1,241	38.5%
Other	33	1.0%
Total	**3,224**	**100%**

Collision data can also be presented by Collision Category (see Table 4-1). When sorted by collision category, the highest percentage of motor bus collisions occurred with motor vehicles at intersections, accounting for 49.8% of all motor bus collisions. The second highest percentage of collisions occurred between motor buses and motor vehicles at mid-block (31.9%). Motor bus collisions with pedestrians accounted for a total of 14% of all motor bus collisions with 8.2% of collisions occurring at intersections and 5.8% occurring at mid-block.

Table 5-2: Motor Bus Collisions by Collision Category

Collision Category	Number of Collisions	Percentage
Motor Bus Collisions with Pedestrians at Intersections	263	8.2%
Motor Bus Collisions with Pedestrians at Mid-Block	186	5.8%
Motor Bus Collisions with Motor Vehicles at Intersections	1,606	49.8%
Motor Bus Collisions with Motor Vehicles at Mid-Block	1,029	31.9%
Motor Vehicle Collisions with Fixed Objects	80	2.5%
Motor Vehicle Collisions with Rail Vehicle	0	0.0%
Other	58	1.8%
Total	**3,224**	**100%**

5.2 Motor Bus Collisions Categorized by Collision Type

Table 5-3 shows a breakdown of motor bus collisions by NTD collision type. The NTD includes seven collision types: angle, head-on, other front impact, rear-ended, rear-ending, sideswipe, and other. Definitions for these collision types are included in Appendix B. In 2010, angle collisions accounted for 32.0% of all motor bus collisions, followed by collisions where the transit vehicle was rear-ended collisions (22.0%), and then other front impact collisions which accounted for 17.5% of all collisions. Head-on, rear-ending, and sideswipe collisions all were around 8-9% of the total each.

Table 5-3: Motor Bus Collisions by NTD Collision Type

NTD Collision Type	Number of Collisions	Percentage
Angle	1,032	32.0%
Head-On	276	8.6%
Other Front Impact	563	17.5%
Rear-Ended	708	22.0%
Rear-Ending	276	8.6%
Sideswipe	312	9.7%
Other	39	1.2%
Total	**3,224**	**100%**

5.3 Motor Bus Collisions with Pedestrians

In 2010, there were 449 motor bus collisions with pedestrians accounting for 14% of all motor bus collisions. While this percentage is relatively low, these collisions often result in a large percentage of injuries or fatalities. Data show that there were 283 pedestrian injuries and 27 fatalities in 2010. Of these motor bus collisions with pedestrians that resulted in injury, 143 (50.5%) occurred when the pedestrian was in the crosswalk. Twelve fatalities occurred when the pedestrian was in the crosswalk and 15 occurred when the pedestrian was not in the crosswalk.

Table 5-4 provides a summary of motor bus collisions with pedestrians. Of the 449 collisions, 51.6% of these collisions occurred at intersections, 25.9% at mid-block, and 22.1% when the motor bus was at a bus stop. As shown in this table, collisions at intersections where the motor bus was going straight accounted for the largest percentage of collisions (28.9%). This was followed by 25.9% of collisions where the motor bus was going straight mid-block and hit a pedestrian. Together collisions where the transit vehicle was going straight accounted for 54.8% of all collisions. Collisions with pedestrians were more likely to occur when the motor bus was turning left than turning right, with 73 and 29 collisions respectively. Finally, there were slightly more collisions when the motor bus was leaving a bus stop, 58 collisions, versus when the motor bus was making a stop, 42 collisions.

Table 5-4: Motor Bus Collisions with Pedestrians

Category	Collision Type	Number of Collisions	% Pedestrian Collisions
Collisions at Intersections	Going Straight	130	28.9%
Collisions at Intersections	Turning Left	73	16.2%
Collisions at Intersections	Turning Right	29	6.5%
Collisions at Mid-Block	Going Straight	117	25.9%
Collisions at Bus Stops	Leaving a Bus Stop	58	12.8%
Collisions at Bus Stops	Stopping at a Bus Stop	42	9.3%
Total		**449**	**100%**

Figure 5-1, Figure 5-2, and Figure 5-3 depict collisions between motor buses and pedestrians using graphic to illustrate the collision type. Figure 5-1 shows motor bus collisions with pedestrians at intersections. It should be noted that the NTD does not differentiate between intersections equipped with traffic signals, stop signs, yield signs, or intersections without signage. While this information is available from other source, the NTD did not include these data and thus were not included in the analysis. The graphic shows the number of collisions when the motor bus is turning left, going straight, or turning right. Below the number of collisions, in italic gold text, is the percentage of that collision type of all 2010 NTD motor bus collisions. Thus, according to the graphic, collisions between a motor bus and a pedestrian where the motor bus is turning left accounts for 2.3% of all motor bus collisions.

Figure 5-2 depicts mid-block collisions between motor buses and pedestrians. This graphic only shows one movement, since the transit vehicle is always going straight mid-block and, presumably, there is not a marked mid-block crosswalk. Those collisions account for 3.6% of all motor bus collisions. Finally, Figure 5-3 depicts motor bus collisions with pedestrians at bus stops. Bus stops are typically on-street locations at the curb or in a median, sometimes with a shelter, signs, or lighting. The diagram is broken down into two collision types: (1) when the motor bus is leaving the bus stop and (2) when the motor bus is making a bus stop. Together these collisions account for 3.1% of all motor bus collisions according to 2010 NTD data.

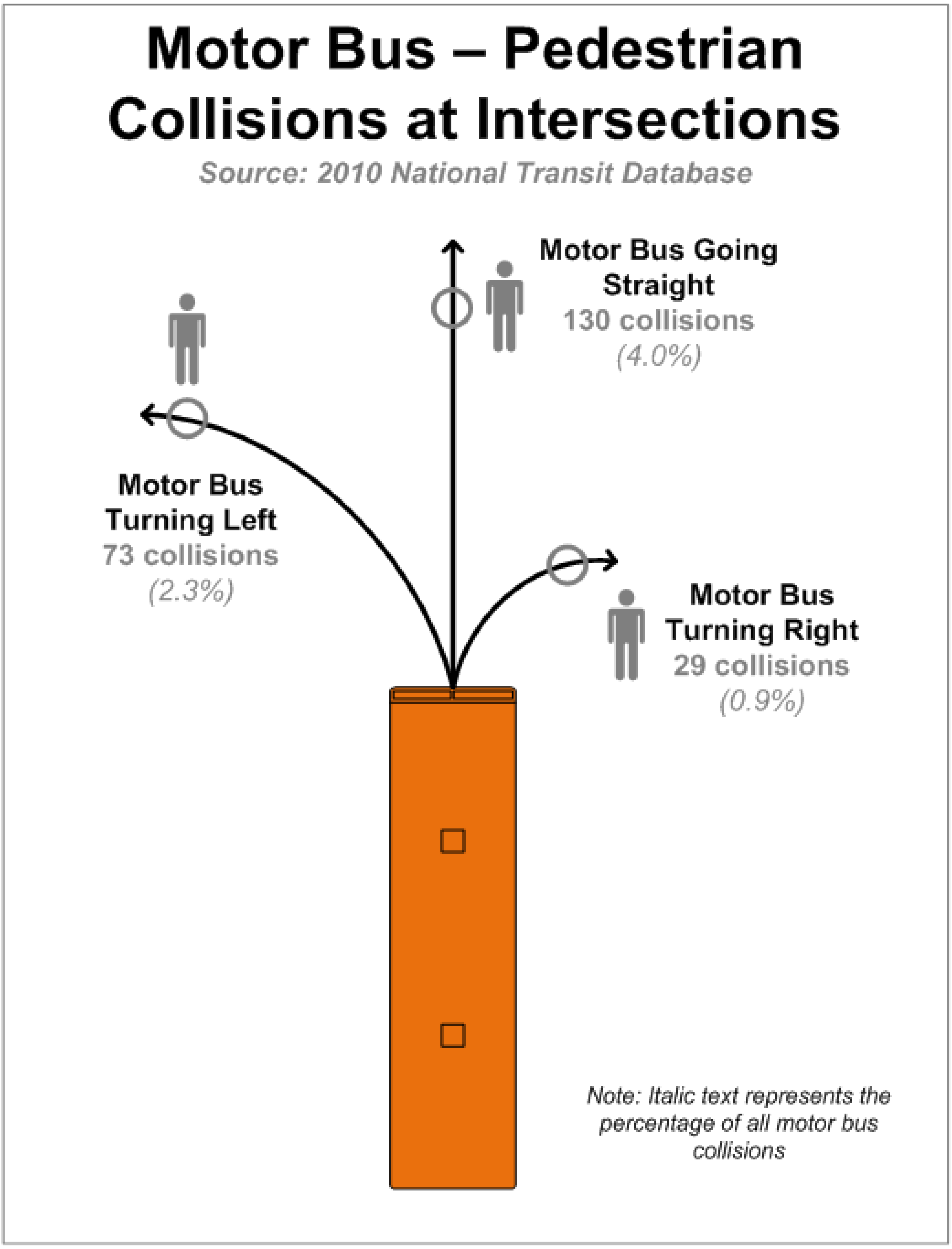

Figure 5-1: Motor Bus Collision with Pedestrians at Intersections

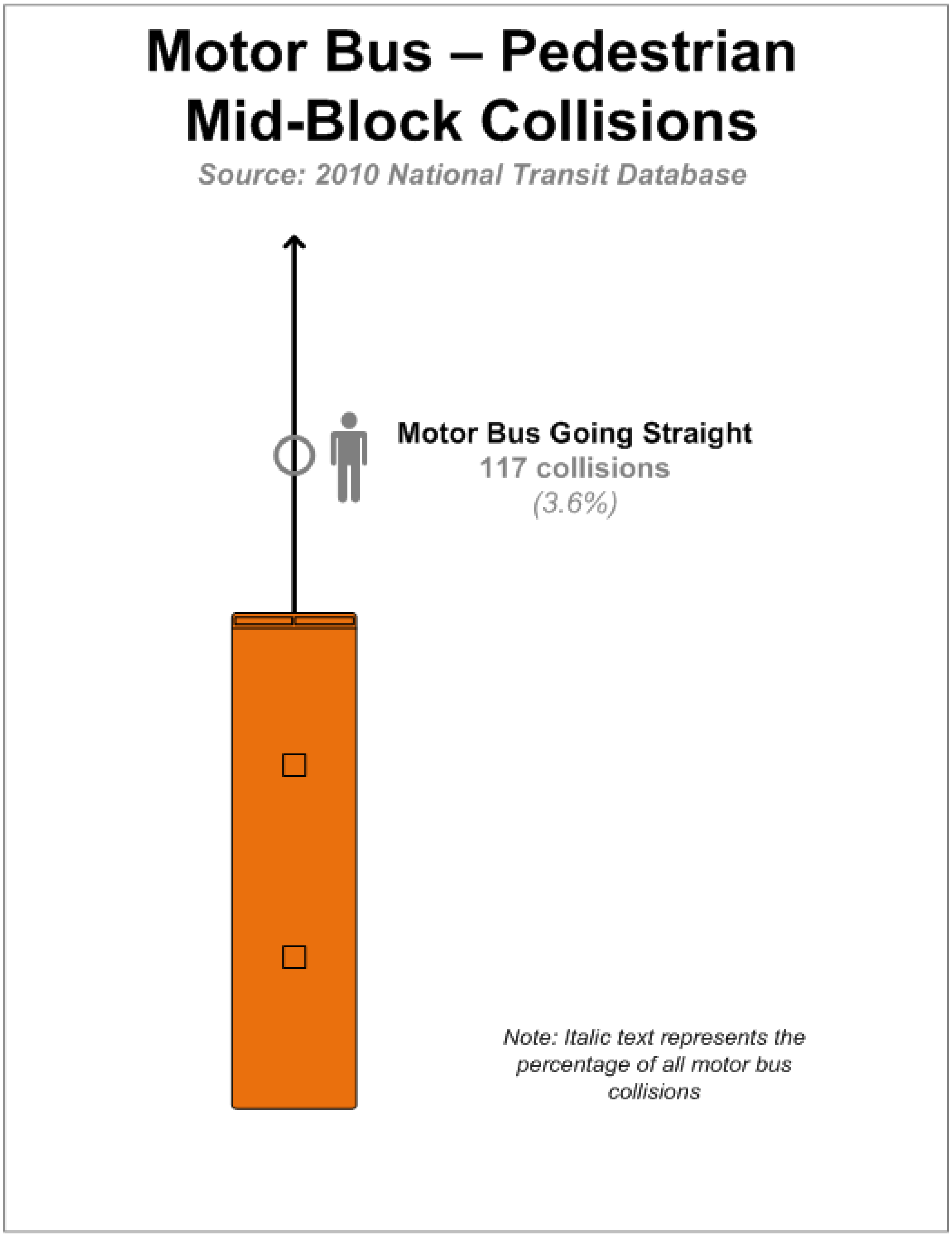

Figure 5-2: Motor Bus Collisions with Pedestrians at Mid-Block

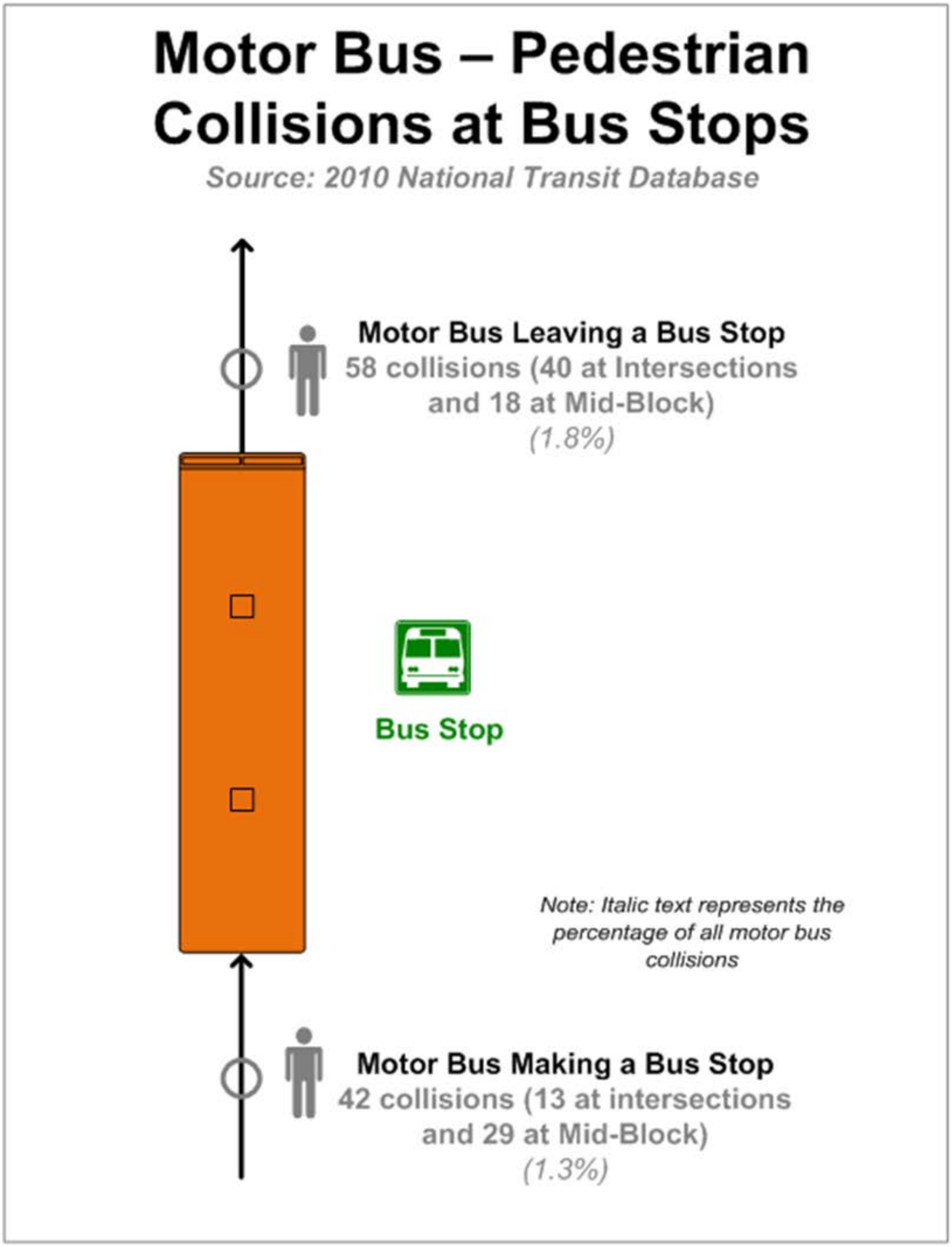

Figure 5-3: Motor Bus Collisions with Pedestrians at Bus Stops

5.4 Motor Bus Collisions with Motor Vehicles at Intersections

Motor bus collisions with motor vehicles at intersections account for 1,606 or 49.8% of all motor bus collisions. For this analysis, intersections include signalized intersections, intersections with traffic control signs (i.e., stop signs or yield signs), and intersections without traffic control devices. The NTD does not differentiate between intersection types. This section of the report investigates motor bus collisions with motor vehicles at intersections in more detail by looking at the motor bus movement, motor vehicle movement, and geographic relationship between the vehicles when they collided. An overview of Section 5.4 is provided below:

- Section 5.4.1 discusses collisions between motor buses and motor vehicles at intersections when both vehicles are traveling in the same direction.
- Section 5.4.2 discusses collisions between motor buses and motor vehicles at intersections when the motor vehicle is approaching the motor bus at the intersection from the left.
- Section 5.4.3 discusses collisions between motor buses and motor vehicles at intersections when the motor vehicle is approaching the motor bus at the intersection from the right.
- Section 5.4.4 discusses collisions between motor buses and motor vehicles at intersections when the motor vehicle is approaching the motor bus from the opposite direction at the intersection.

5.4.1 Intersection Collisions – Vehicles Traveling in Same Direction

Table 5-5 provides details of motor bus collisions with motor vehicles at intersections when both vehicles are traveling in the same direction – accounting for 913 or 56.7% of all intersection collisions. As shown in this table, the largest number of collisions occurs when the motor bus is rear-ended by a motor vehicle, accounting for 26.1% of collisions at intersections. The second highest number of collisions occurs when the motor bus is in the right lane, either stopped or going straight, and a motor vehicle to the left of the motor bus attempts to make a right turn from the left lane in front of the bus. In 2010, this occurred 130 times which accounted for 8.1% of all motor bus collisions with motor vehicles at intersections. Instances where the motor bus rear-ended a motor vehicle had the third highest frequency with 101 collisions, or 10.3% of collisions at intersections.

Figure 5-4 illustrates rear-end collisions at intersections. Rear-end collisions account for 36.4% of all intersection collisions between a motor bus and a motor vehicle and 18.1% of all collisions between motor buses and motor vehicles. As shown in the figure, instances where the motor vehicle rear-ends a motor bus occurs more frequently than a motor bus rear-ending a motor vehicle with 256 and 166 collisions identified in 2010, respectively.

Figure 5-5 depicts motor bus collisions with motor vehicles where one of the vehicles is switching lanes. Unfortunately, the NTD does not identify which vehicle is attempting the lane switch. Further analysis into the incident descriptions needs to be done to obtain this information. These collisions account for 4.7% of all intersection collisions between a motor bus and a motor vehicle and 2.3% of the total number of motor bus collisions.

Figure 5-6 depicts scenarios where the motor bus is stopped or going straight and a motor vehicle attempts to turn in front of the motor bus from an adjacent lane. As shown in the figure, these collisions are more likely to occur when a motor vehicle tries to turn right in front of the bus than turn left. One could assume that these collisions tend to occur when the motor bus is stopped at a bus stop near an intersection, a motor vehicle is behind the motor bus and moves to the left lane to pass the bus, and then turns right in front of the bus as the bus begins to accelerate.

Figure 5-7 and Figure 5-8 depict the situation where the motor bus and motor vehicle are traveling in the same direction at an intersection and the motor bus turns left or right, respectively. Both figures show that it is equally likely for collisions to occur when the motor vehicle is going straight or turning. It should be noted that the NTD does not differentiate which lane the motor vehicle is in when these collisions occur.

Table 5-5: Motor Bus Collisions with Motor Vehicles at Intersections – Both Vehicles Traveling in Same Direction

Category and Collisions Group	Number of Collisions	% of Category	% of All Intersection Collisions
Motor Vehicle Driving in Same Direction - Motor Bus Rear Ended	420	46.0%	26.1%
Motor Vehicle Driving in Same Direction - Motor Bus Rear Ending	166	18.2%	10.3%
Motor Vehicle Turning Right in Front of Motor Bus	130	14.2%	8.1%
Motor Vehicle Driving in Same Direction - Vehicle Switching Lanes	75	8.2%	4.7%
Both Vehicles Turning Left	38	4.1%	2.4%
Motor Bus Turning Left and Motor Vehicle Going Straight	34	3.7%	2.1%
Both Vehicles Turning Right	17	1.8%	1.0%
Motor Bus Turning Right and Motor Vehicle Going Straight	17	1.8%	1.0%
Motor Vehicle Turning Left in Front of Motor Bus	16	1.8%	1.0%
Total	**913**	**100%**	**56.7%**

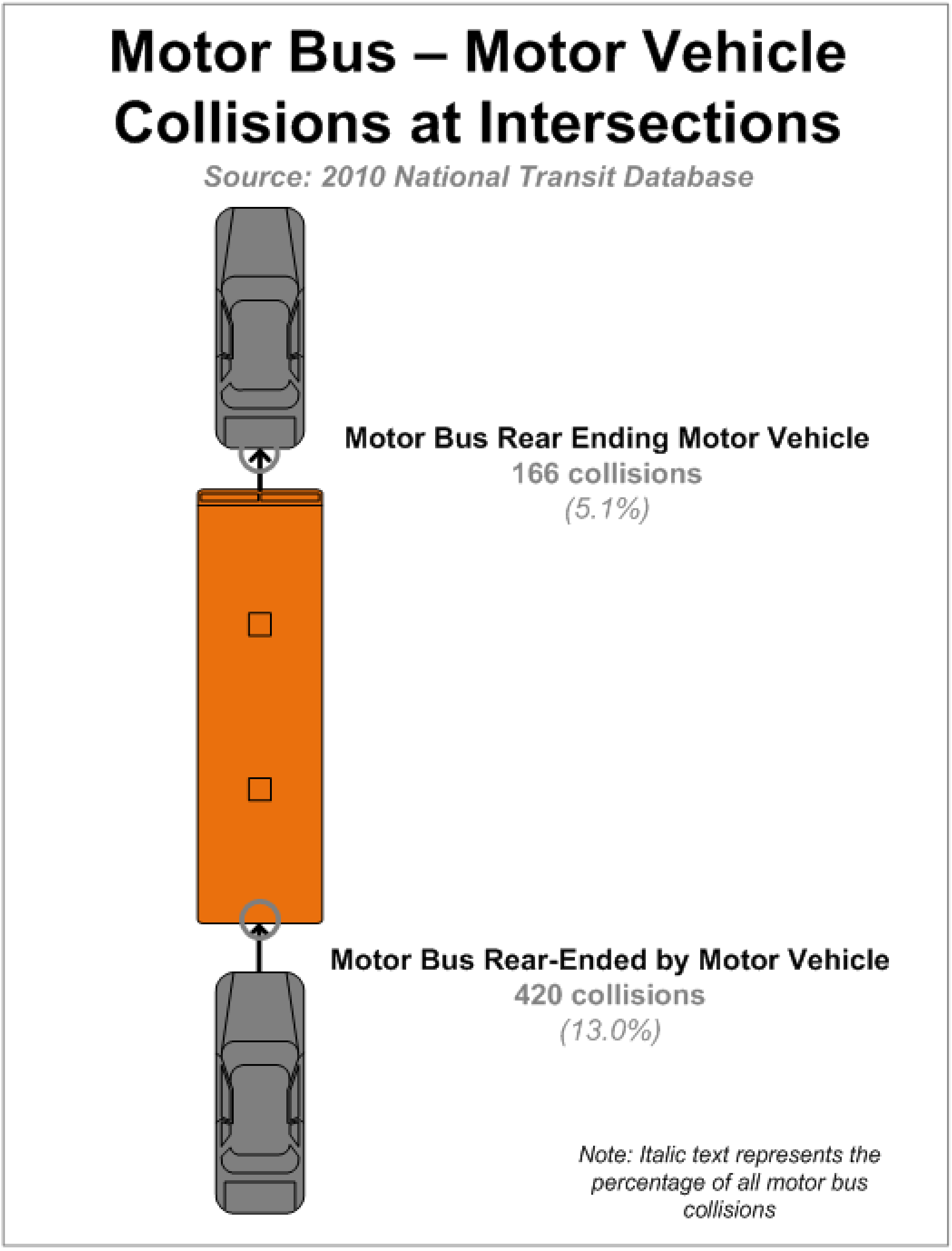

Figure 5-4: Motor Bus Going Straight and Motor Vehicle Going Straight at Intersections – Rear End Collisions

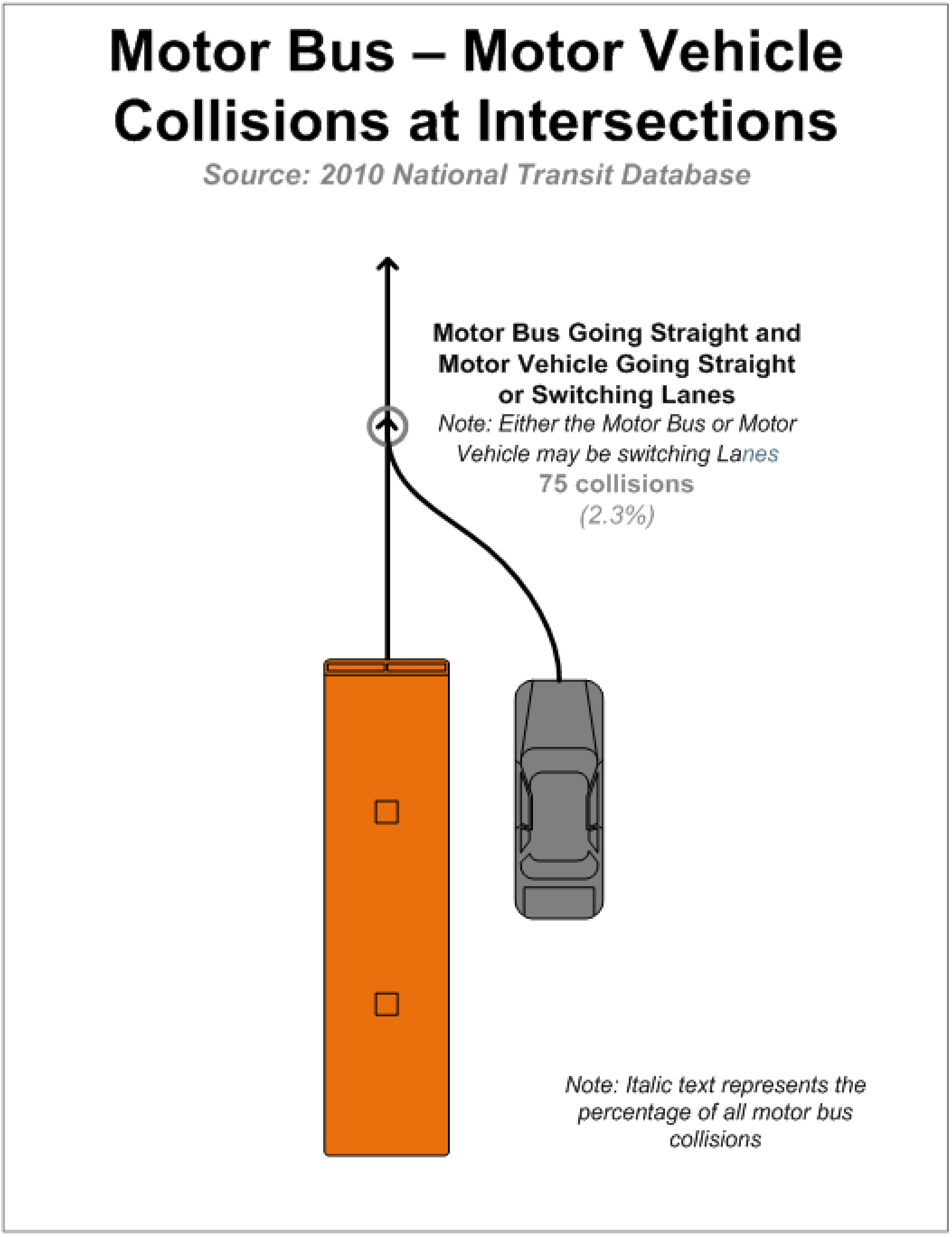

Figure 5-5: Motor Bus and Motor Vehicle Collisions at Intersections – Vehicle Switching Lanes

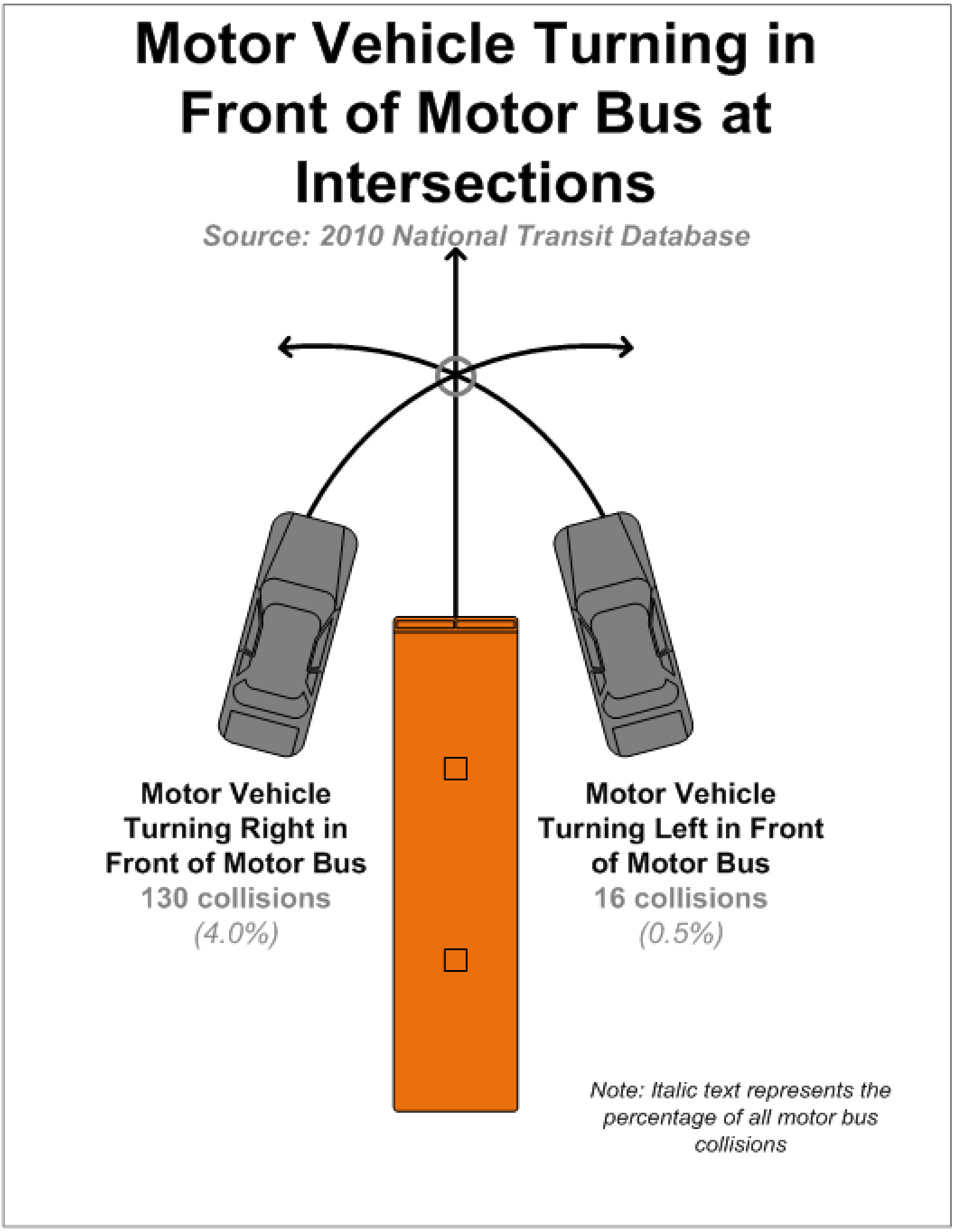

Figure 5-6: Motor Vehicle Turning in Front of Motor Bus at Intersection

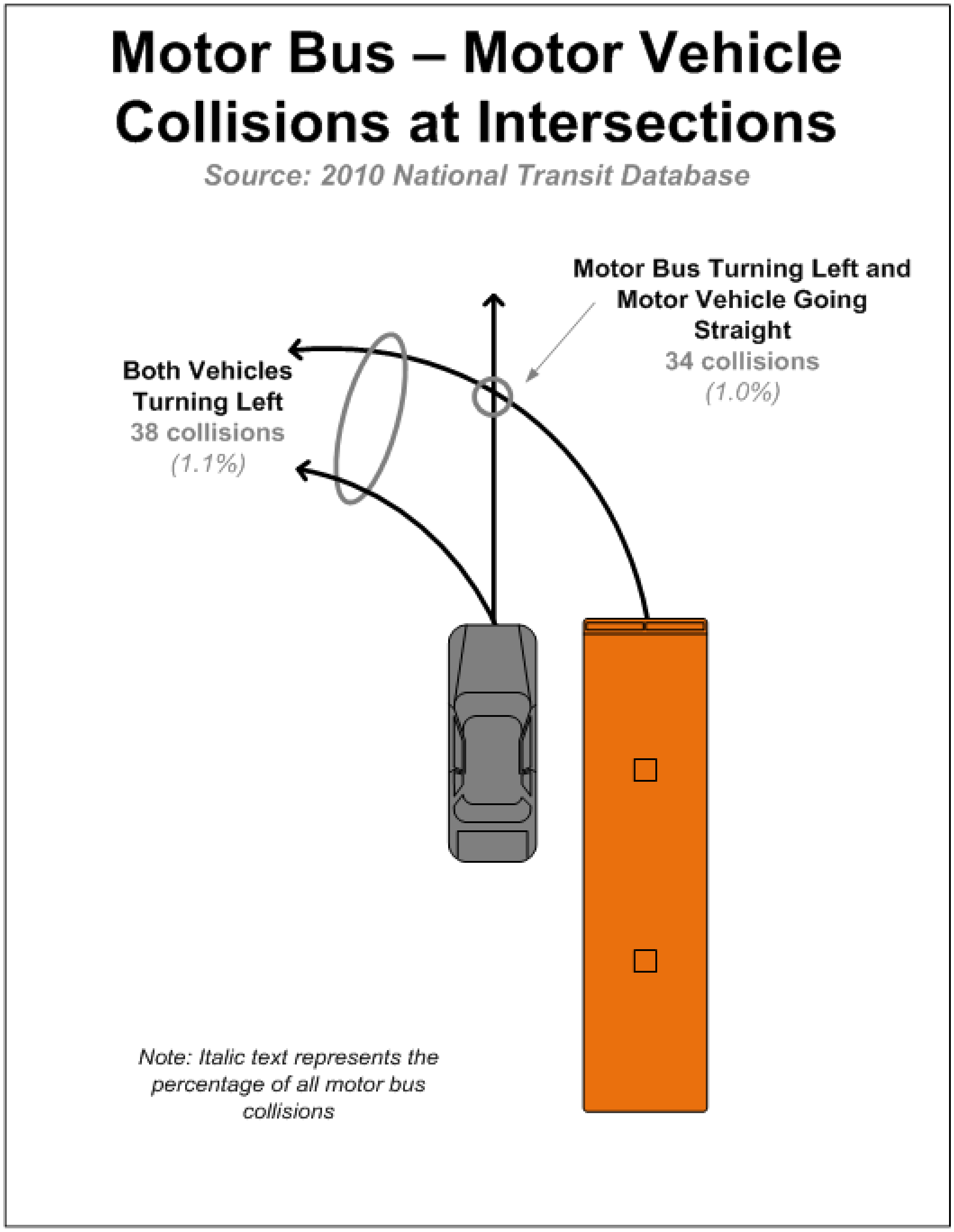

Figure 5-7: Motor Bus and Motor Vehicle Traveling in Same Direction – Motor Bus Turning Left at Intersection

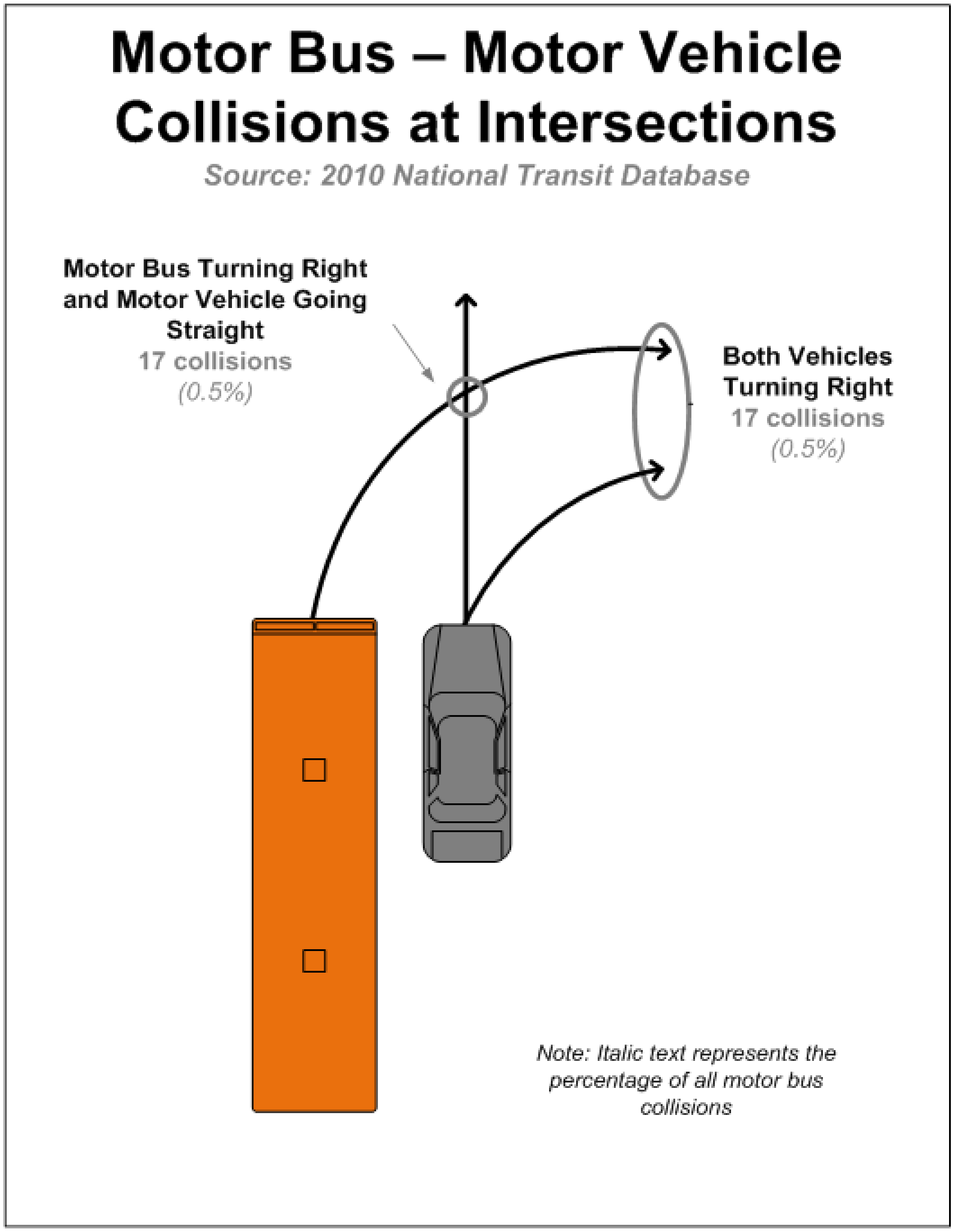

Figure 5-8: Motor Bus and Motor Vehicle Traveling in Same Direction – Motor Bus Turning Right at Intersection

5.4.2 Intersection Collisions - Motor Vehicle Approaching from Left

This section describes motor bus collisions with motor vehicles at intersections when the motor vehicle is approaching the motor bus at the intersection from the left. This accounted for 207 collisions in 2010 or 12.8% of all intersection collisions. As shown in this table, the largest percentage of collisions occurs when both vehicles are going straight through the intersection. This accounted for 134 collisions of which 66 incident descriptions stated that one of the vehicles ran a red light or a stop sign. It should be noted that the number of collisions resulting from a vehicle disobeying a traffic light or stop sign may be higher since the NTD does not require this data to be entered into the database. The second highest number of collisions occurred when the motor bus turned left and the motor vehicle was going straight through the intersection, which accounted for 55 collisions. Figure 5-9 depicts these types of collisions using an image.

Table 5-6: Motor Bus Collisions with Motor Vehicles at Intersections – Motor Vehicle Approaching from Left

Category and Collision Type	Number	% of Category	% of All Intersection Collisions
Both Vehicles Going Straight	134	64.7%	8.4%
Motor Bus Turning Left and Motor Vehicle Going Straight	55	26.5%	3.4%
Motor Bus Going Straight and Motor Vehicle Turning Left	13	6.3%	0.8%
Motor Bus and Motor Vehicle Both Turning Left	3	1.4%	0.1%
Motor Bus Turning Right and Motor Vehicle Going Straight	3	1.4%	0.1%
Total	**207**	**100%**	**12.8%**

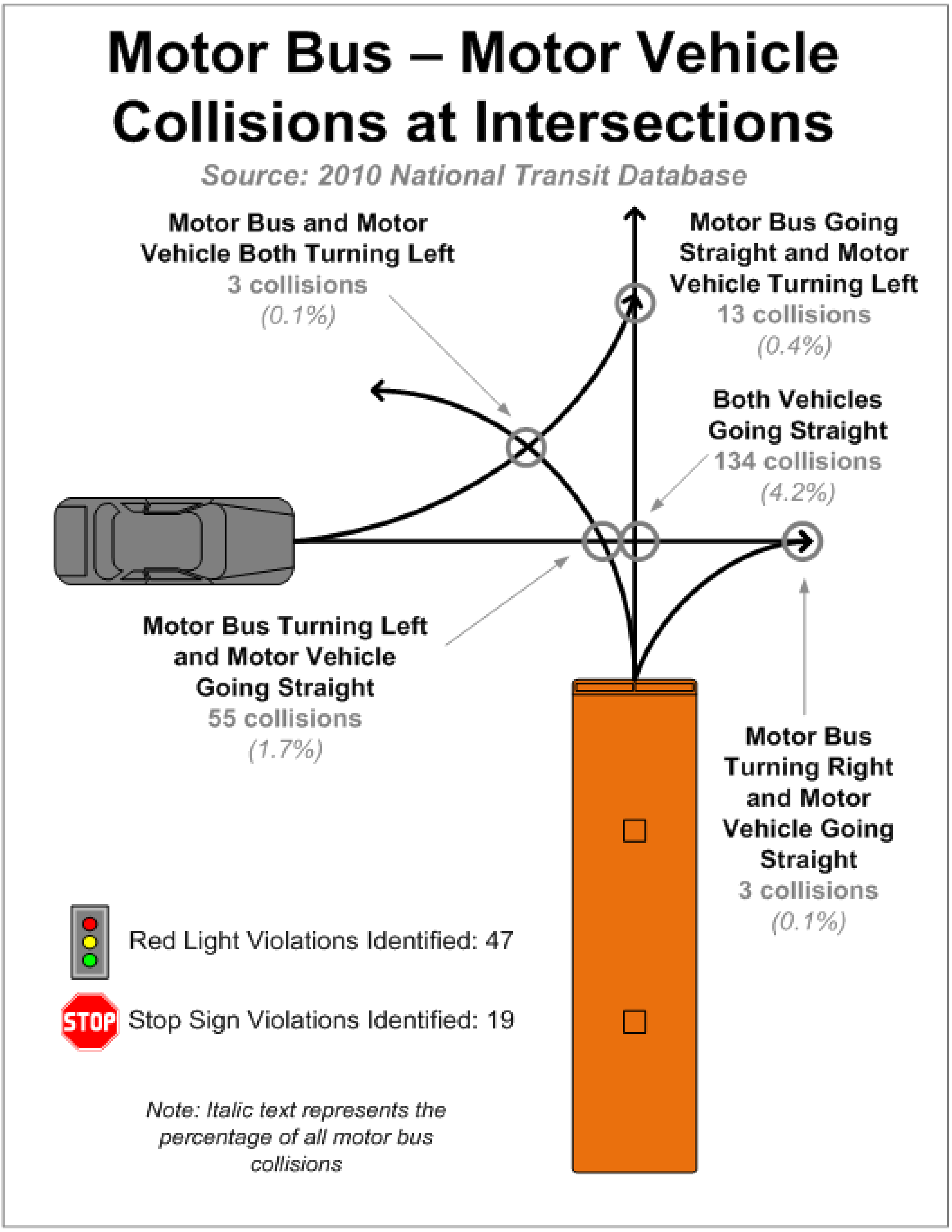

Figure 5-9: Motor Vehicle Approaching from Left at Intersection

5.4.3 Intersection Collisions - Motor Vehicle Approaching from Right

This section describes motor bus collisions with motor vehicles at intersections when the motor vehicle is approaching the motor bus at the intersection from the right. This accounted for 195 collisions in 2010 or 12.1% of all intersection collisions. As shown in this table, the largest percentage of collisions occurs when both vehicles are going straight. This accounted for 144 collisions of which 70 incident descriptions stated that one of the vehicles ran a red light or a stop sign. It should be noted that the number of collisions resulting from a vehicle disobeying a traffic light or stop sign may be higher since the NTD does not require this data to be entered into the database. The second highest number of collisions occurred when the motor vehicle turned right and the motor bus was going straight through the intersection. The total number of collisions was 31 for this scenario. Figure 5-10 depicts these types of collisions using an image.

Table 5-7: Motor Bus Collisions with Motor Vehicles at Intersections – Motor Vehicle Approaching from Right

Category and Collision Type	Number	% of Category	% of All Intersection Collisions
Both Vehicle Going Straight	144	73.9%	9.0%
Motor Bus Going Straight and Motor Vehicle Turning Right	31	15.9%	1.9%
Motor Bus Turning Left and Motor Vehicle Going Straight	14	7.2%	0.8%
Motor Bus Going Straight and Motor Vehicle Turning Left	7	3.6%	0.4%
Motor Bus and Motor Vehicle Both Turning Left	0	0.0%	0.0%
Total	**195**	**100%**	**12.1%**

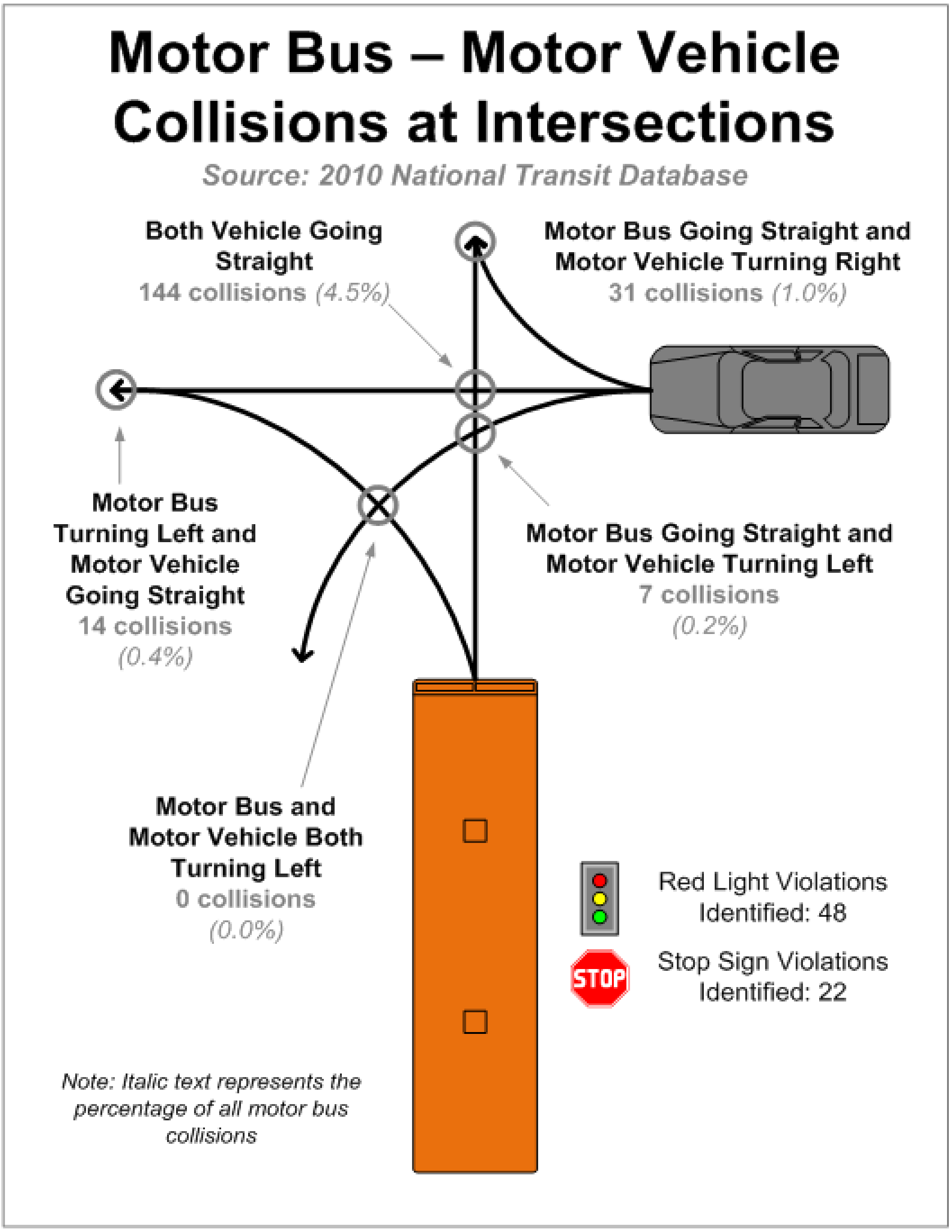

Figure 5-10: Motor Vehicle Approaching from Right at Intersection

5.4.4 Intersection – Motor Vehicle Approaching the Motor Bus at the Intersection from the Opposite Direction

The table below summarizes collisions between motor buses and motor vehicles at intersections when the motor vehicle is approaching the motor bus at the intersection from the opposite direction. This accounted for 166 collisions in 2010 or 10.3% of all intersection collisions. These collisions are most likely to occur when one of the vehicles is turning left and the other is going straight. There were 74 collisions when the motor bus was going straight and the motor vehicle was turning left. This accounted for 4.6% of all motor bus collisions at intersections. There were 65 collisions when the motor bus was turning left and motor vehicle was going straight. This accounted for 4.0% of all motor bus collisions at intersections. These two collision types represent classic left-turn-conflict collisions.

As shown in the table, there were also instances where both vehicles were going straight that resulted in head-on collisions or the vehicles collided when they were both turning left. However, these collisions represent only a small percentage of collisions at intersections. It should be noted that the analysis only showed 6 collisions resulting from a vehicle ignoring a traffic control device (e.g., traffic signal or stop sign). Figure 5-11 depicts these collisions using an image.

Table 5-8: Motor Bus Collisions with Motor Vehicles at Intersections – Motor Vehicle Approaching the Motor Bus at the Intersection from the Opposite Direction

Category and Collision Type	Number	% of Category	% of All Intersection Collisions
Motor Bus Going Straight and Motor Vehicle Turning Left	74	44.6%	4.6%
Motor Bus Turning Left and Motor Vehicle Going Straight	65	39.2%	4.0%
Both Vehicles Turning Left	13	7.8%	0.8%
Motor Bus and Motor Vehicle Both Going Straight – Head on Collision	12	7.2%	0.8%
Motor Bus Turning Right and Motor Vehicle Turning Left	3	1.8%	0.2%
Total	**166**	**100%**	**10.3%**

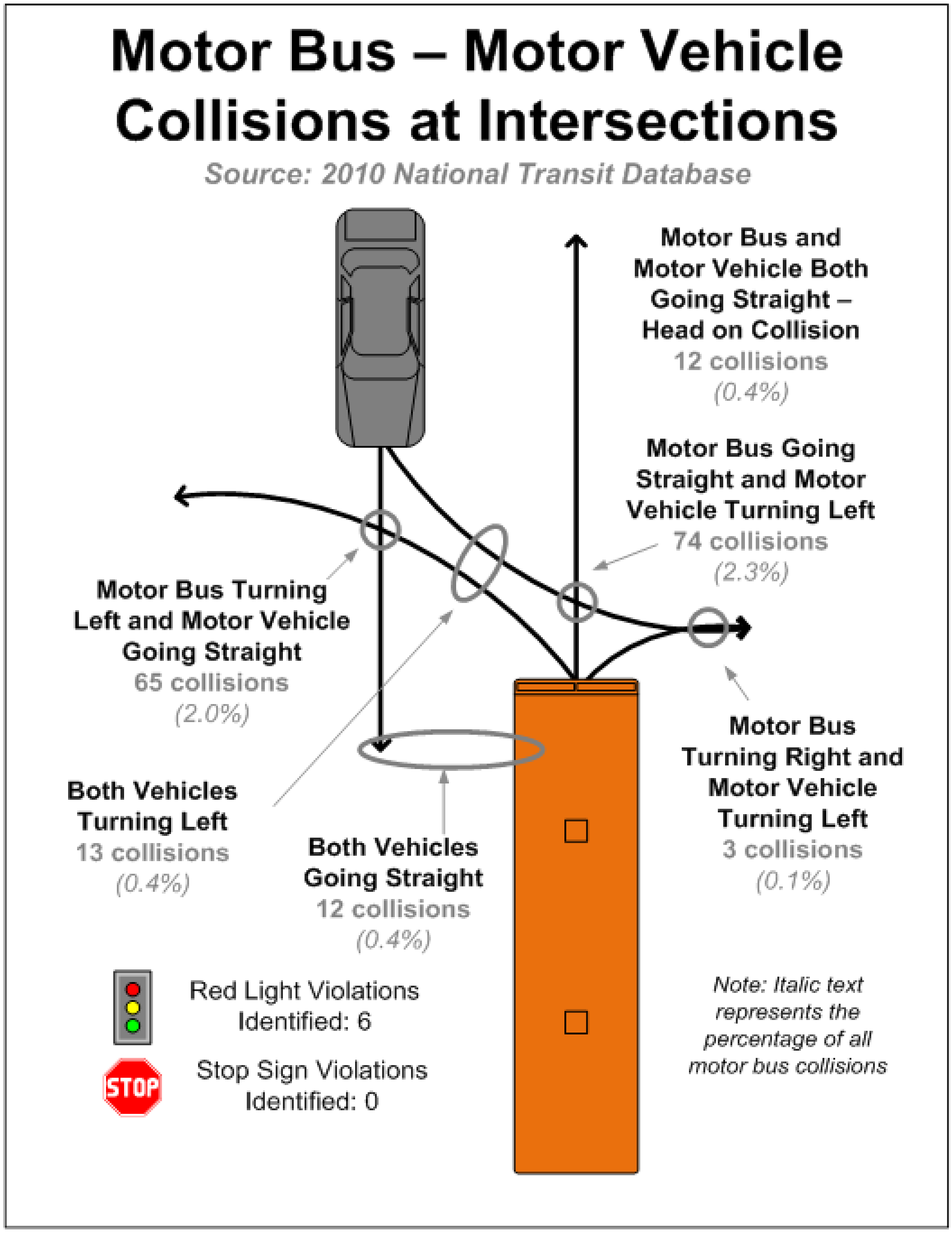

Figure 5-11: Motor Vehicle Approaching the Motor Bus at the Intersection from the Opposite Direction

5.5 Motor Bus Collisions with Motor Vehicles at Mid-Block

Table 5-9 shows that according to the NTD there were 870 mid-block collisions between motor buses and motor vehicles when the motor bus was going straight. The majority of these collisions occur when there is a rear-end collision between a motor bus and a motor vehicle. As shown in Figure 5-12, rear-end collisions account for 63.8% of all collisions at the mid-block. Instances where the motor vehicle rear-ends the motor bus occur significantly more frequently than a motor bus rear-ending a motor vehicle, with 393 and 163 collisions, respectively.

Table 5-9: Motor Bus Collisions with Motor Vehicle at Mid-Block

Category and Collision Type	Number	% of Mid-Block Collisions
Motor Vehicle Driving in Same Direction - Motor Bus Rear Ended	393	45.1%
Motor Vehicle Driving in Same Direction - Motor Bus Rear Ending	163	18.7%
Motor Vehicle Driving in Same Direction - Vehicle Switching Lanes	146	15.9%
Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Going Straight	49	6.9%
Motor Vehicle Approaching from Left or Right	36	5.1%
Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus	26	3.7%
Motor Vehicle Parked - Same Direction	23	3.2%
Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Left	22	3.1%
Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus	12	1.7%
Total	**870**	**100%**

Figure 5-13 depicts collisions where a motor bus and motor vehicle collide while one of the vehicles is switching lanes. This accounted for 146 collisions in 2012 or 15.9% of all mid-block collisions. Figure 5-14 shows mid-block collisions when the motor vehicle is approaching the motor bus from the opposite direction. As depicted in this figure, there were 49 head-on collisions when both vehicles were going straight. There were 22 collisions reported when the motor vehicle turned left in front of the bus. This may occur when a motor vehicle is turning left into a minor street such as a driveway or shopping center.

Figure 5-15 depicts movements where the motor bus and motor vehicle are traveling in the same directions and the motor vehicle attempts to: (a) turn right in front of the motor bus from the left lane, or (b) turn left in front of the motor bus from the right lane. This action is identical to the actions described at intersections and most likely occurs when the motor bus stops and the motor vehicle behind the motor bus attempts to pass the bus. Similar to intersections, there were more collisions that occurred when the motor vehicle attempted to turn right in front of the bus (26) than attempting to turn left (12).

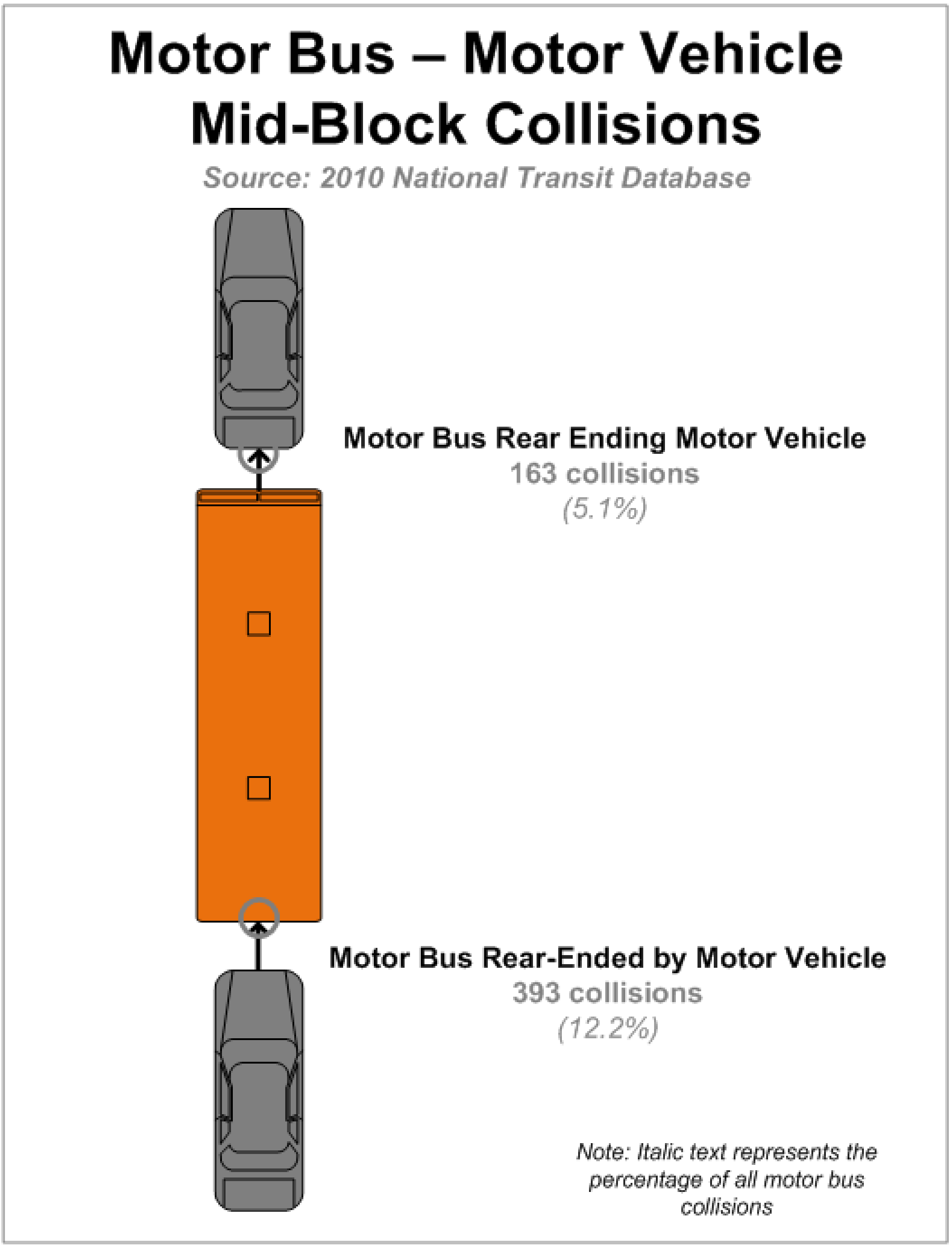

Figure 5-12: Motor Bus Going Straight and Motor Vehicle Going Straight at Mid-Block – Rear End Collisions

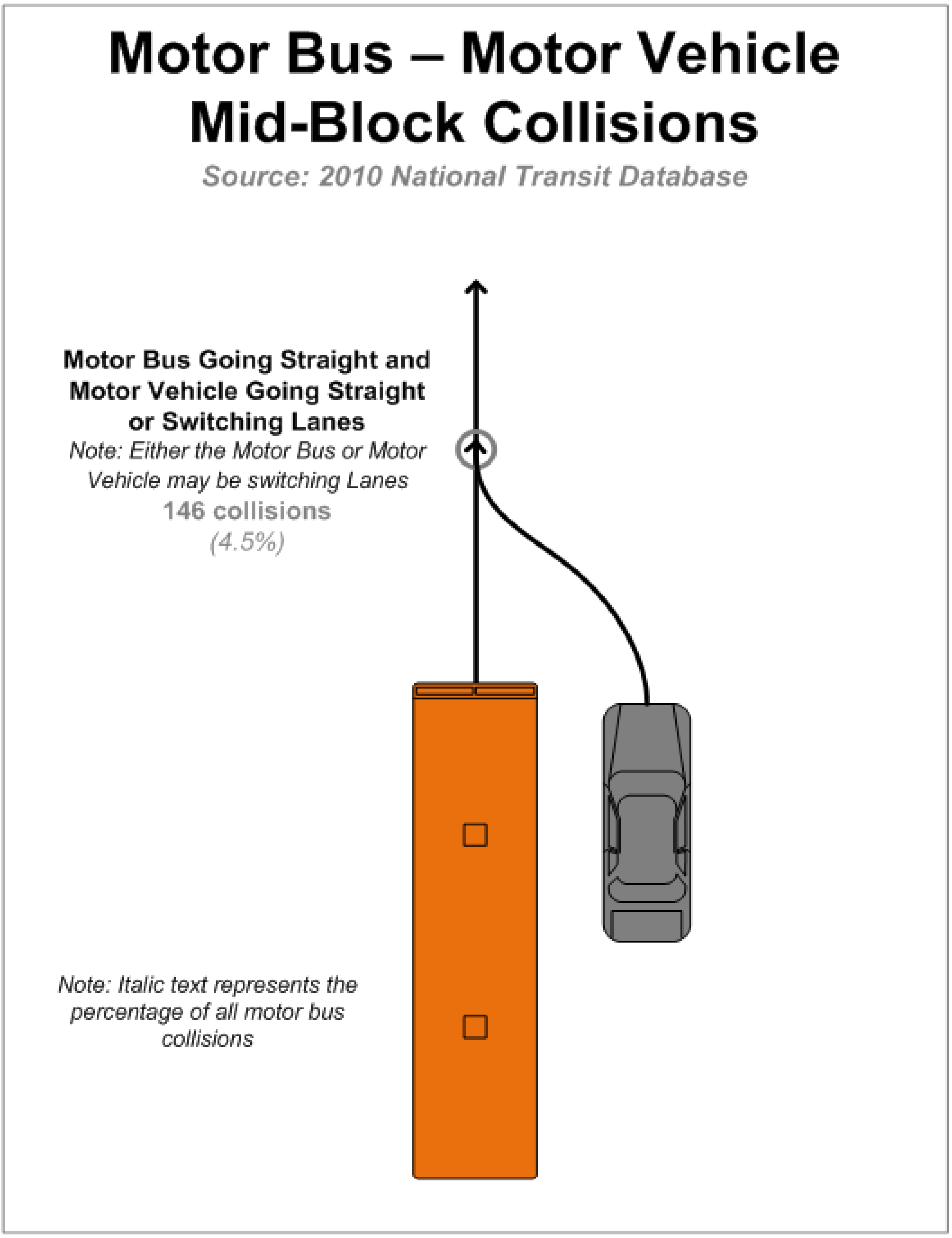

Figure 5-13: Motor Bus and Motor Vehicle Collisions at Mid-Block – Vehicle Switching Lanes

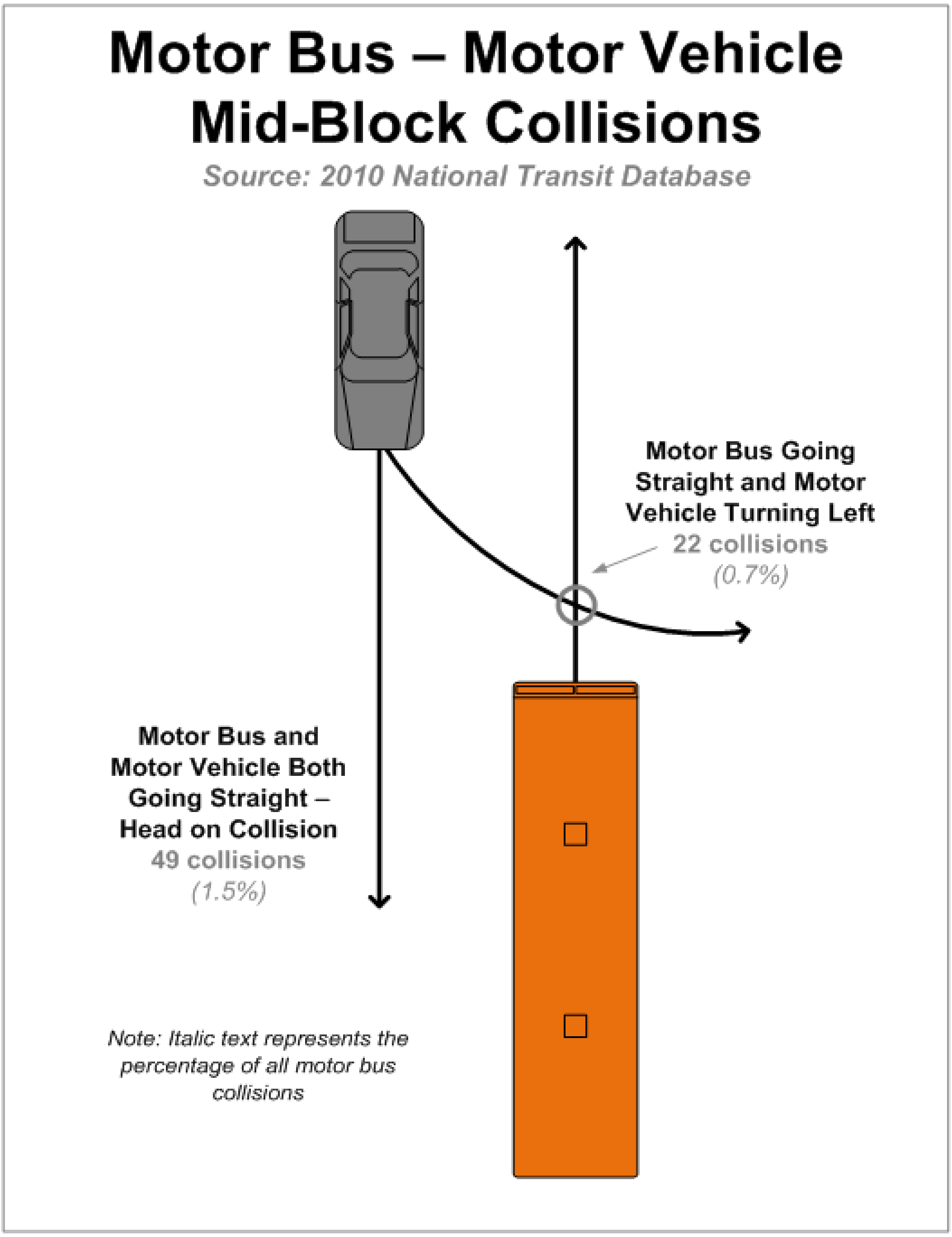

Figure 5-14: Motor Vehicle Approaching the Motor Bus from the Opposite Direction at Mid-Block

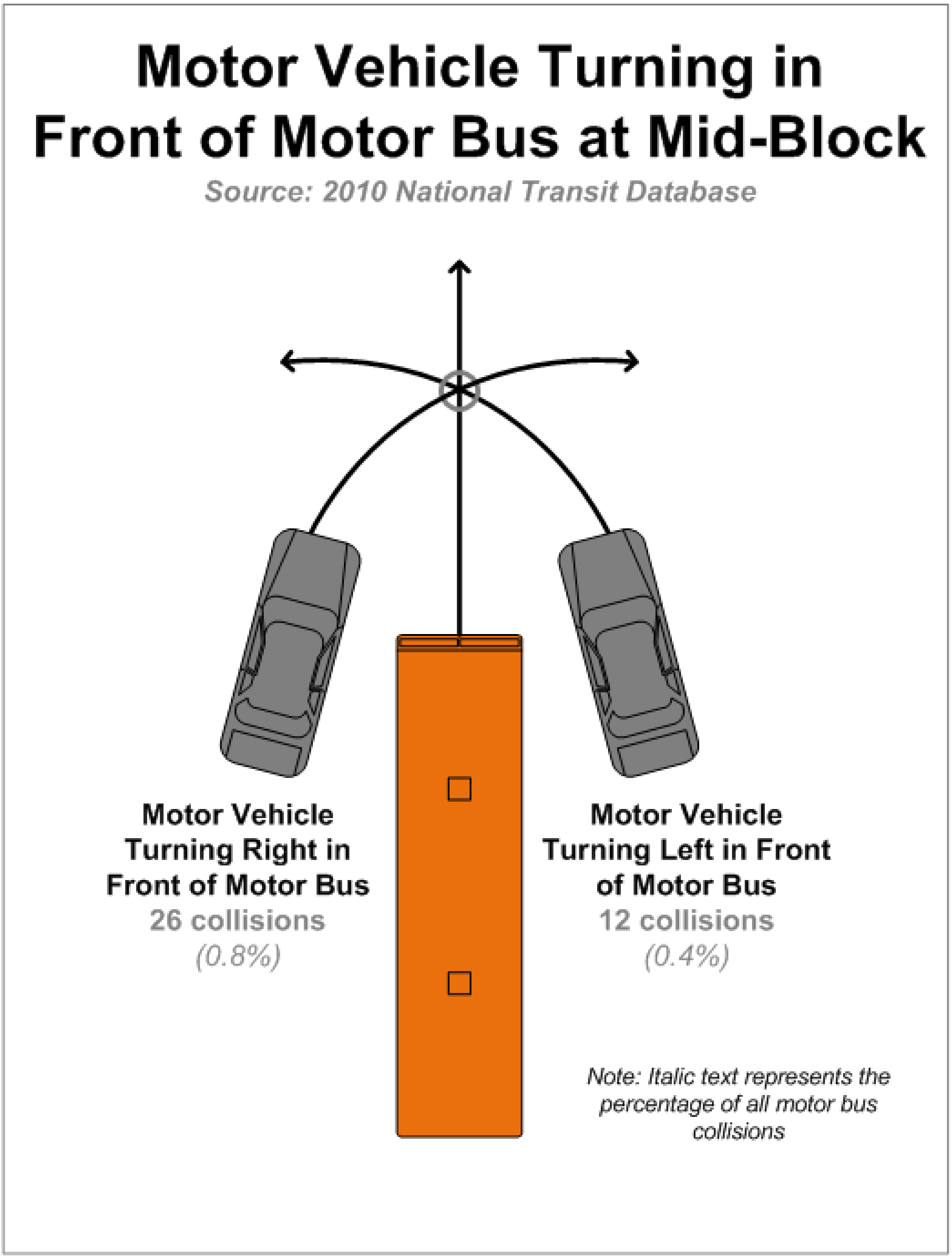

Figure 5-15: Motor Vehicle Turning in Front of Motor Bus at Mid-Block

5.6 Motor Bus Collisions with Motor Vehicles at Bus Stops

Table 5-10 shows motor bus collisions with motor vehicles at bus stops. Over fifty-seven percent of collisions at bus stops occur when the bus is stopping at the bus stop, while 42.8% occur when the bus is leaving the bus stop. There were a more collisions mid-block than collisions at intersections, 158, and 120 respectively. According to the NTD, when the motor bus was making a stop there were more midblock collisions (101) than at intersection collisions (64). The opposite can be said for collisions when a motor bus was leaving a stop where intersections had a slightly higher number of collisions (66) than mid-block (57).

While it would be helpful to know if the “intersection” bus stops were at the far side or the near side of the intersection, this information is not readily available in the NTD. As a result, this type of analysis could not be performed. The table below considers both far side and near side bus stops at intersection. It should be noted that these conflicts are different.

Table 5-10: Motor Bus and Motor Vehicle Collisions at Bus Stops

Category and Collision Type	Number	% of Mid-Block Collisions
Motor Bus Making a Stop – Mid-Block	101	35.0%
Motor Bus Making a Stop – Intersection	64	22.2%
Motor Bus Leaving a Stop – Mid-Block	57	19.7%
Motor Bus Leaving a Stop – Intersection	66	22.9%
Total	**288**	**100%**

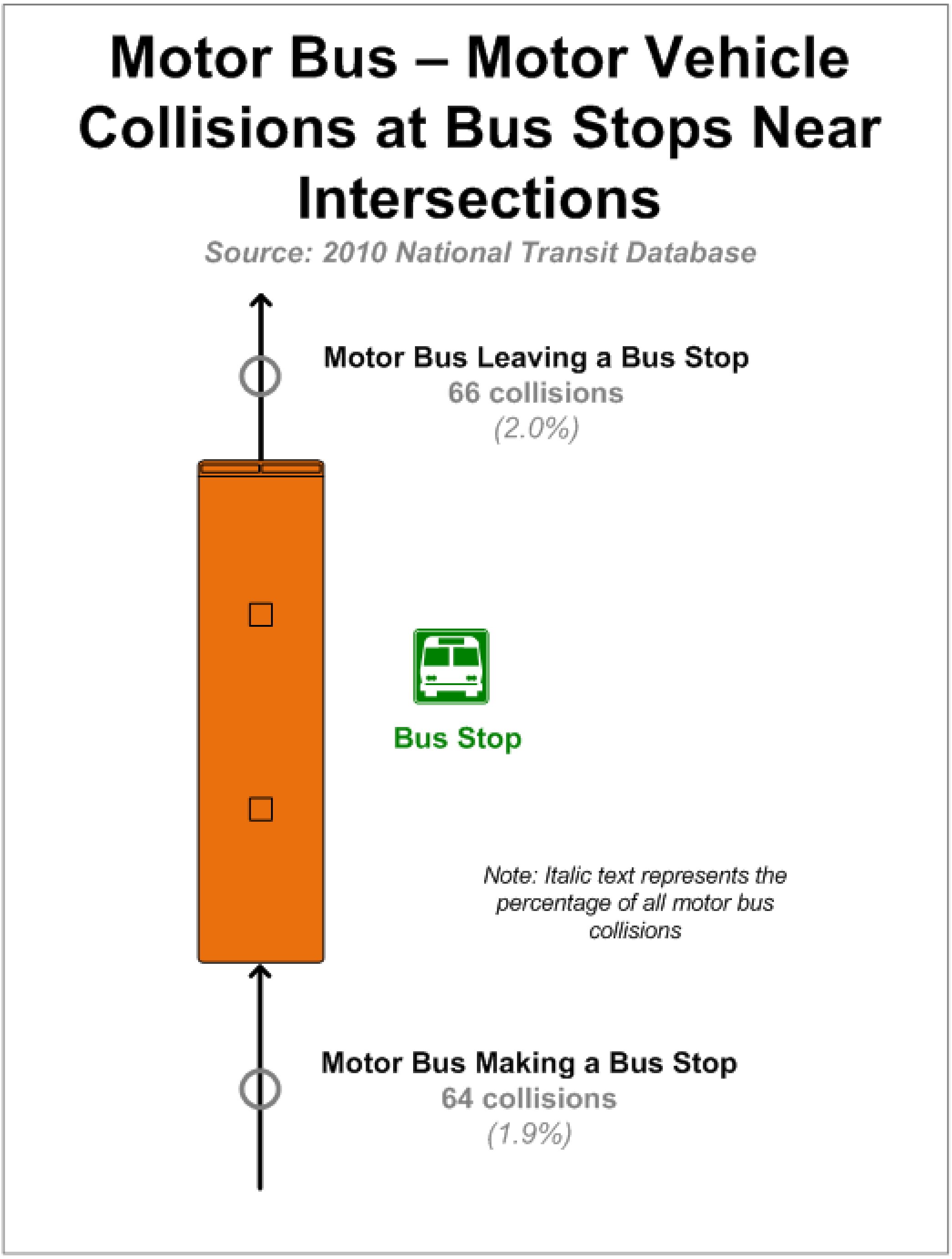

Figure 5-16: Motor Bus Collisions with Motor Vehicles at Bus Stops near Intersections

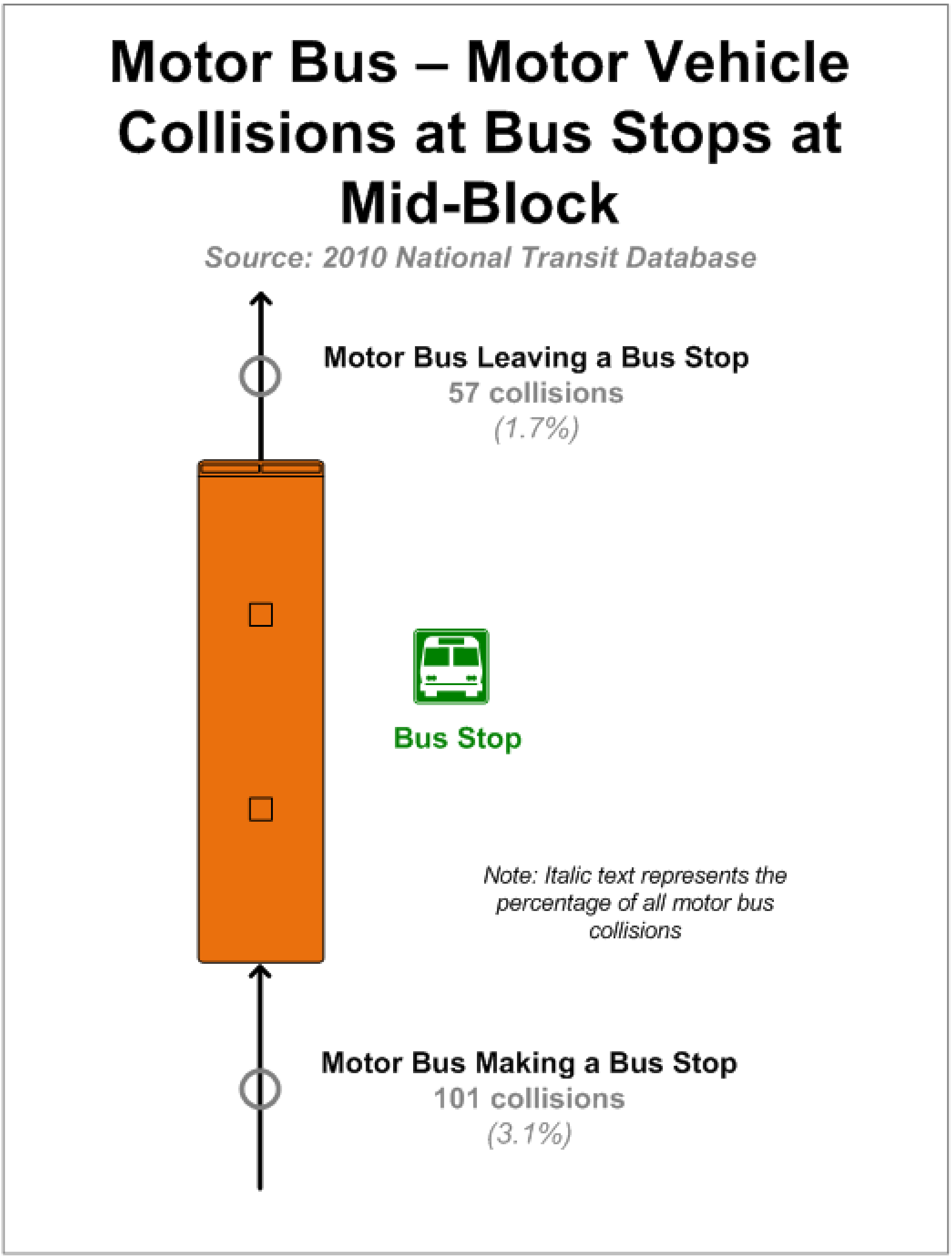

Figure 5-17: Motor Bus Collisions with Motor Vehicles at Bus Stops at Mid-Block

5.7 Motor Bus Collision Analysis

5.7.1 Analysis of Collision Types by Frequency

Table 5-11 depicts the collision types sorted by the frequency of collisions. As depicted in the table, the type of collisions occurring the most were situations where a motor bus was rear-ended or rear-ending another vehicle. This occurred more frequently at intersections than at mid-block.

The second most frequent type of collision occurred when the motor vehicle was going straight through an intersection, approaching the motor bus from either the right (No. 6) or the left (No. 7), and the motor bus was also going straight. Collisions between motor buses and pedestrians at intersections where the motor bus was going straight, was the next highest total of collisions.

Table 5-11: Collision Types Sorted by Frequency

No.	Category	Collision Type	Collision With	Figure #	Number of Collisions
1	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear Ended	Motor Vehicle	Figure 5-4	420
2	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear Ended	Motor Vehicle	Figure 5-12	393
3	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear Ending	Motor Vehicle	Figure 5-4	166
4	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear Ending	Motor Vehicle	Figure 5-12	163
5	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Switching Lanes	Motor Vehicle	Figure 5-13	146
6	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Going Straight	Motor Vehicle	Figure 5-10	144
7	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Left - Going Straight	Motor Vehicle	Figure 5-9	134
8	Collisions at Intersections	Motor Bus Going Straight	Pedestrian	Figure 5-1	130
9	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus	Motor Vehicle	Figure 5-6	130
10	Mid-Block Collisions	Motor Bus Going Straight	Pedestrian	Figure 5-2	117
11	Mid-Block - Bus Stop	Motor Bus Making a Bus Stop	Motor Vehicle	Figure 5-17	101
12	Collisions with Fixed Objects	Collisions with Fixed Objects	Collisions with Fixed Objects	N/A	80

No.	Category	Collision Type	Collision With	Figure #	Number of Collisions
13	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Switching Lanes	Motor Vehicle	Figure 5-5	75
14	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-11	74
15	Collisions at Intersections	Motor Bus Turning Left	Pedestrian	Figure 5-1	73
16	Intersection - Bus Stop	Motor Bus Leaving a Bus Stop	Motor Vehicle	Figure 5-16	66
17	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Going Straight	Motor Vehicle	Figure 5-11	65
18	Intersection - Bus Stop	Motor Bus Making a Bus Stop	Motor Vehicle	Figure 5-16	64
19	Mid-Block - Bus Stop	Motor Bus Leaving a Bus Stop	Motor Vehicle	Figure 5-17	57
20	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left - Going Straight	Motor Vehicle	Figure 5-9	55
21	Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Going Straight	Motor Vehicle	Figure 5-14	49
22	Miscellaneous Motor Vehicle Collisions	Miscellaneous Motor Vehicle Collisions	Miscellaneous Motor Vehicle	N/A	48
23	Mid-Block Collisions	Motor Bus Leaving a Bus Stop	Pedestrian	Figure 5-3	40
24	Intersection - Motor Bus Turning Left	Motor Vehicle Driving in Same Direction - Turning Left	Motor Vehicle	Figure 5-7	38
25	Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching from Left or Right	Motor Vehicle	N/A	36
26	Intersection - Motor Bus Turning Left	Motor Vehicle Driving in Same Direction - Going Straight	Motor Vehicle	Figure 5-7	34
27	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Turning Right	Motor Vehicle	Figure 5-10	31
28	Collisions at Intersections	Motor Bus Turning Right	Pedestrian	Figure 5-1	29
29	Mid-Block Collisions	Motor Bus Making a Bus Stop	Pedestrian	Figure 5-3	29
30	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus	Motor Vehicle	Figure 5-15	26

No.	Category	Collision Type	Collision With	Figure #	Number of Collisions
31	Mid-Block - Motor Bus Going Straight	Motor Vehicle Parked - Same Direction	Motor Vehicle	N/A	23
32	Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-14	22
33	Collisions at Intersections	Motor Bus Leaving a Bus Stop	Pedestrian	Figure 5-3	18
34	Intersection - Motor Bus Turning Right	Motor Vehicle Driving in Same Direction - Turning Right	Motor Vehicle	Figure 5-8	17
35	Intersection - Motor Bus Turning Right	Motor Vehicle Driving in Same Direction - Going Straight	Motor Vehicle	Figure 5-8	17
36	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus	Motor Vehicle	Figure 5-6	16
37	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Right - Going Straight	Motor Vehicle	Figure 5-10	14
38	Collisions at Intersections	Motor Bus Making a Bus Stop	Pedestrian	Figure 5-3	13
39	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Left - Turning Left	Motor Vehicle	Figure 5-9	13
40	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-11	13
41	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Going Straight	Motor Vehicle	Figure 5-11	12
42	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus	Motor Vehicle	Figure 5-15	12
43	Collisions with Other	Collisions with Other	Other	N/A	10
44	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Turning Left	Motor Vehicle	Figure 5-10	7
45	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left- Turning Left	Motor Vehicle	Figure 5-9	3
46	Intersection - Motor Bus Turning Right	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-11	3
47	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left- Turning Right	Motor Vehicle	Figure 5-9	0

No.	Category	Collision Type	Collision With	Figure #	Number of Collisions
48	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Right	Motor Vehicle	Figure 5-11	0
49	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Right- Turning Left	Motor Vehicle	Figure 5-10	0
50	Collisions with Rail Vehicle	Collisions with Rail Vehicle	Rail Vehicle	N/A	0

5.7.2 Analysis of Collision Type by Cost

Another way of looking at the data is to associate costs to the collisions. Cost estimates for fatalities, injuries, and property damage in this report were derived by referencing previous cost estimates for these metrics and then adjusting them in year 2010 dollars. The previous cost estimates referenced were found in The Costs of Highway Crashes conducted by the Urban Institute and published by the Federal Highway Administration (FHWA-RD-91-055) in 1991. It should be noted that most computerized benefit-cost models rely on accident values estimated by this 1991 Urban Institute/FHWA study. Despite its age, the FHWA study remains one of the most comprehensive and often cited studies of highway collision costs.[3]

Table 5-12 is from the 1991 Urban Institute/FHWA study and identifies the comprehensive costs per person and costs per collision by severity. In the report fatal injuries cost an average of $2,392,742 each and fatal collisions $2,722,548.

Table 5-12: Collision Cost Estimates (in 1988 Dollars)

Severity	Cost per Person	Cost per Collision
K – Fatality	$2,392,742	$2,722,548
A – Incapacitating Injury	$169,506	$228,568
B – Evident Injury	$33,227	$48,333
C – Possible Injury	$17,029	$25,228
A-B-C – Reported Nonfatal Injury	$46,355	$69,592
O – Property Damage	$1,734	$4,489

Source: The Urban Institute. "The Costs of Highway Crashes," Federal Highway Administration Research Report Number FHWA-RD-91-055, Washington, D.C., October 1991, (Table 11, page 39).

The Urban Institute/FHWA study used motor vehicle collision statistics from year 1988 to estimate costs in the report. This Transit Collision Analysis Report uses transit collision statistics from year 2010. In order to convert nominal dollars from year 1988 to year 2010 the Consumer Price Index

[3] While costs from *"The Costs of Highway Crashes"* report were used for this analysis, other reports could be used to derive costs. An example is the recent NHTSA report, titled "CICAS-V Research On Comprehensive Costs of Intersection Crashes". For more information about this report, visit: http://www-nrd.nhtsa.dot.gov/pdf/esv/esv20/07-0016-O.pdf

for all items (CPI-All Items) for the year of interest (2010) was divided by the CPI-All Items for the year 1988. This method was recommended in Appendix D of the Urban Institute/FHWA 1991 study. The CPI-All Items for 1988, as reported in Appendix D of the Urban Institute/FHWA study, is 118.3 and the CPI-All Items for 2010 is 218.1. The 2010 CPI-All Items can be found in the Consumer Price Index Detailed Report, Tables Annual Averages 2010.

To convert Year Y dollars into Year Z dollars, the following calculation is used:

$$\text{Year Z \$} = (\text{Year Y \$}) \times \frac{\text{Year Z CPI: All Items}}{\text{Year Y CPI: All Items}}$$

The calculations for the adjusted 2010 dollar values for fatality, reported nonfatal injury, and property damage are shown in Table 5-13.

Table 5-13: Adjusted Costs (in 2010 Dollars) for Collisions, Fatalities, and Property Damage

Accident Type	Estimated $2010 Calculations Using CPI-All Items	Estimated $2010
Fatalities	$2,392,742 x (218.1/118.3) =	$4,411,302
Injuries	$46,355 x (218.1/118.3) =	$85,461
Property Damage	$1,734 x (218.1/118.3) =	$3,197

To determine costs for the various different collision types, the costs from Table 5-13 were used. The 2010 NTD included information for each collision record indicating the number of fatalities, number of injuries, or property damage. It was then possible to determine the cost for each collision record using these assumptions. Table 5-14 depicts a summary of collision costs by category. As shown in the table, motor bus collisions with pedestrians have the highest cost associated to them although this category has the least amount of collisions. This is because collisions with pedestrians are more likely to result in fatalities or injury. At the same time, there are large percentages of motor bus collisions with motor vehicles that only result in property damage. As shown below, cost estimates related to motor bus collisions is estimated to be $424,402,716 in 2010.

Table 5-14: Summary of Collision Costs by Category

Category	Number of Collisions	Cost
Motor Bus Collisions with Pedestrians	451	$229,812,390
Motor Bus Collisions with Motor Vehicles at Intersections	1,606	$107,089,662
Motor Bus Collisions with Motor Vehicles at Mid-Block	1,029	$87,500,662
Other	138	NA
Total	**3,224**	**$866,183,601**

Table 5-15 is sorted according to collision types by cost. Sorting in this manner yields different results than sorting that data by frequency. The two highest costs were for motor bus rear-ended by motor vehicles either at intersection (No. 1) or mid-block (No. 2) locations. The next three highest costs were for motor bus collisions with pedestrians with the following collision types: (1) mid-block collisions where the motor bus was going straight (No. 3), (2) collisions at intersections where the motor bus was turning left (No. 4), and (3) collisions at intersections where the motor bus was going straight (No. 5). While the number of collisions for these collision types was not the highest, they were the most severe, resulting in high numbers of injuries and fatalities.

Table 5-15: Collision Types Sorted by Cost

No.	Category	Collision Types	Collision With	Figure #	Number of Collisions	Cost
1	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear-Ended	Motor Vehicle	Figure 5-4	420	$107,154,249
2	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear-Ended	Motor Vehicle	Figure 5-12	393	$94,227,109
3	Mid-Block Collisions	Motor Bus Going Straight	Pedestrian	Figure 5-2	117	$74,171,310
4	Collisions at Intersections	Motor Bus Going Straight	Pedestrian	Figure 5-1	130	$60,012,737
5	Collisions at Intersections	Motor Bus Turning Left	Pedestrian	Figure 5-1	73	$59,689,218
6	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Going Straight	Motor Vehicle	Figure 5-10	144	$42,018,946
7	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Left - Going Straight	Motor Vehicle	Figure 5-9	134	$39,745,814
8	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear-Ending	Motor Vehicle	Figure 5-12	163	$32,599,900
9	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Going Straight	Motor Vehicle	Figure 5-11	65	$31,074,306
10	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear-Ending	Motor Vehicle	Figure 5-4	166	$30,231,688
11	Mid-Block Collisions	Motor Bus Leaving a Bus Stop	Pedestrian	Figure 5-3	40	$29,598,621
12	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Switching Lanes	Motor Vehicle	Figure 5-13	146	$28,853,507
13	Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Going Straight	Motor Vehicle	Figure 5-14	49	$27,753,321
14	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus	Motor Vehicle	Figure 5-6	130	$21,648,849

No.	Category	Collision Types	Collision With	Figure #	Number of Collisions	Cost
15	Mid-Block - Bus Stop	Motor Bus Making a Bus Stop	Motor Vehicle	Figure 5-17	101	$18,680,809
16	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-11	74	$18,589,651
17	Intersection - Bus Stop	Motor Bus Making a Bus Stop	Motor Vehicle	Figure 5-16	64	$15,409,294
18	Collisions at Intersections	Motor Bus Turning Right	Pedestrian	Figure 5-1	29	$13,405,697
19	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Switching Lanes	Motor Vehicle	Figure 5-5	75	$12,009,942
20	Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-14	22	$10,204,691
21	Intersection - Motor Bus Turning Left	Motor Vehicle Driving in Same Direction - Going Straight	Motor Vehicle	Figure 5-7	34	$9,169,020
22	Mid-Block - Bus Stop	Motor Bus Leaving a Bus Stop	Motor Vehicle	Figure 5-17	57	$8,789,396
23	Mid-Block - Motor Bus Going Straight	Motor Vehicle Parked - Same Direction	Motor Vehicle	N/A	23	$8,328,365
24	Mid-Block Collisions	Motor Bus Making a Bus Stop	Pedestrian	Figure 5-3	29	$7,882,259
25	Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching from Left or Right	Motor Vehicle	N/A	36	$7,637,722
26	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left - Going Straight	Motor Vehicle	Figure 5-9	55	$7,481,127
27	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus	Motor Vehicle	Figure 5-15	26	$6,830,309
28	Intersection - Bus Stop	Motor Bus Leaving a Bus Stop	Motor Vehicle	Figure 5-16	66	$6,651,785
29	Intersection - Motor Bus Turning Left	Motor Vehicle Driving in Same Direction - Turning Left	Motor Vehicle	Figure 5-7	38	$6,257,471

No.	Category	Collision Types	Collision With	Figure #	Number of Collisions	Cost
30	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus	Motor Vehicle	Figure 5-6	16	$4,578,644
31	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Turning Right	Motor Vehicle	Figure 5-10	31	$4,442,848
32	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-11	13	$2,703,931
33	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus	Motor Vehicle	Figure 5-15	12	$2,692,015
34	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Left - Turning Left	Motor Vehicle	Figure 5-9	13	$2,563,825
35	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Right - Going Straight	Motor Vehicle	Figure 5-10	14	$2,381,716
36	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Going Straight	Motor Vehicle	Figure 5-11	12	$2,067,603
37	Intersection - Motor Bus Turning Right	Motor Vehicle Driving in Same Direction - Going Straight	Motor Vehicle	Figure 5-8	17	$2,065,683
38	Intersection - Motor Bus Turning Right	Motor Vehicle Driving in Same Direction - Turning Right	Motor Vehicle	Figure 5-8	17	$1,778,266
39	Collisions at Intersections	Motor Bus Leaving a Bus Stop	Pedestrian	Figure 5-3	18	$1,603,032
40	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Turning Left	Motor Vehicle	Figure 5-10	7	$1,422,018
41	Collisions at Intersections	Motor Bus Making a Bus Stop	Pedestrian	Figure 5-3	13	$1,175,557
42	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left- Turning Left	Motor Vehicle	Figure 5-9	3	$303,181
43	Intersection - Motor Bus Turning Right	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-11	3	$298,170

No.	Category	Collision Types	Collision With	Figure #	Number of Collisions	Cost
44	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left- Turning Right	Motor Vehicle	Figure 5-9	0	$0
45	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Right	Motor Vehicle	Figure 5-11	0	$0
46	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Right- Turning Left	Motor Vehicle	Figure 5-10	0	$0
47	Collisions with Rail Vehicle	Collisions with Rail Vehicle	Rail Vehicle	N/A	0	$0
48	Collisions with Fixed Objects	Collisions with Fixed Objects	Fixed Object	N/A	80	N/A
49	Miscellaneous Motor Vehicle Collisions	Miscellaneous Motor Vehicle Collisions	Miscellaneous Motor Vehicle	N/A	48	N/A
50	Collisions with Other	Collisions with Other	Other	N/A	10	N/A

5.7.3 Analysis of Collision Types by Average Cost per Collision

A third way of looking at collision types is to sort the data by the average cost per collision, shown in Table 5-16. Sorting the data this way allows the collision types to be analyzed by average severity (i.e., average cost per collision) so that collisions that result in more fatalities, injuries, or property damage are ranked higher than collisions that may occur more frequently but results in minor fender benders with minimal property damage, no injuries, or fatalities. The top three collision types are collision with pedestrians. These collisions may not occur as frequently as other collision types, but often result in more fatalities and injuries. Head-on collisions, mid-block, where the motor bus and motor vehicle are both going straight resulted in the highest average cost per collision for motor bus collisions between motor vehicles. The fifth highest average cost occurs when a motor vehicle approaches the motor bus at an intersection and the motor bus turns left while the motor vehicle goes straight. This results in a ‘head-on left turn’ collision which often has many fatalities and injuries.

Table 5-16: Collision Types Sorted by Average Cost per Collision

No.	Category	Collision Type	Collision With	Figure #	Number of Collisions	Average Cost per Collision
1	Collisions at Intersections	Motor Bus Turning Left	Pedestrian	Figure 5-1	73	$817,660.52
2	Mid-Block Collisions	Motor Bus Leaving a Bus Stop	Pedestrian	Figure 5-3	40	$739,965.53
3	Mid-Block Collisions	Motor Bus Going Straight	Pedestrian	Figure 5-2	117	$633,942.82

No.	Category	Collision Type	Collision With	Figure #	Number of Collisions	Average Cost per Collision
4	Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Going Straight	Motor Vehicle	Figure 5-14	49	$566,394.31
5	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Going Straight	Motor Vehicle	Figure 5-11	65	$478,066.25
6	Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-14	22	$463,849.59
7	Collisions at Intersections	Motor Bus Turning Right	Pedestrian	Figure 5-1	29	$462,265.41
8	Collisions at Intersections	Motor Bus Going Straight	Pedestrian	Figure 5-1	130	$461,636.44
9	Mid-Block - Motor Bus Going Straight	Motor Vehicle Parked - Same Direction	Motor Vehicle	N/A	23	$362,102.83
10	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Left - Going Straight	Motor Vehicle	Figure 5-9	134	$296,610.55
11	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Going Straight	Motor Vehicle	Figure 5-10	144	$291,798.24
12	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus	Motor Vehicle	Figure 5-6	16	$286,165.25
13	Mid-Block Collisions	Motor Bus Making a Bus Stop	Pedestrian	Figure 5-3	29	$271,802.03
14	Intersection - Motor Bus Turning Left	Motor Vehicle Driving in Same Direction - Going Straight	Motor Vehicle	Figure 5-7	34	$269,677.06
15	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus	Motor Vehicle	Figure 5-15	26	$262,704.19
16	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear-Ended	Motor Vehicle	Figure 5-4	420	$255,129.16

No.	Category	Collision Type	Collision With	Figure #	Number of Collisions	Average Cost per Collision
17	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-11	74	$251,211.50
18	Intersection - Bus Stop	Motor Bus Making a Bus Stop	Motor Vehicle	Figure 5-16	64	$240,770.22
19	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear-Ended	Motor Vehicle	Figure 5-12	393	$239,763.64
20	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus	Motor Vehicle	Figure 5-15	12	$224,334.58
21	Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching from Left or Right	Motor Vehicle	N/A	36	$212,158.94
22	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-11	13	$207,994.69
23	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Turning Left	Motor Vehicle	Figure 5-10	7	$203,145.43
24	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear-Ending	Motor Vehicle	Figure 5-12	163	$199,999.39
25	Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Switching Lanes	Motor Vehicle	Figure 5-13	146	$197,626.76
26	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Left - Turning Left	Motor Vehicle	Figure 5-9	13	$197,217.31
27	Mid-Block - Bus Stop	Motor Bus Making a Bus Stop	Motor Vehicle	Figure 5-17	101	$184,958.50
28	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear-Ending	Motor Vehicle	Figure 5-4	166	$182,118.60
29	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Going Straight	Motor Vehicle	Figure 5-11	12	$172,300.25

No.	Category	Collision Type	Collision With	Figure #	Number of Collisions	Average Cost per Collision
30	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Right - Going Straight	Motor Vehicle	Figure 5-10	14	$170,122.57
31	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus	Motor Vehicle	Figure 5-6	130	$166,529.61
32	Intersection - Motor Bus Turning Left	Motor Vehicle Driving in Same Direction - Turning Left	Motor Vehicle	Figure 5-7	38	$164,670.29
33	Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Switching Lanes	Motor Vehicle	Figure 5-5	75	$160,132.56
34	Mid-Block - Bus Stop	Motor Bus Leaving a Bus Stop	Motor Vehicle	Figure 5-17	57	$154,199.93
35	Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Turning Right	Motor Vehicle	Figure 5-10	31	$143,317.68
36	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left - Going Straight	Motor Vehicle	Figure 5-9	55	$136,020.49
37	Intersection - Motor Bus Turning Right	Motor Vehicle Driving in Same Direction - Going Straight	Motor Vehicle	Figure 5-8	17	$121,510.76
38	Intersection - Motor Bus Turning Right	Motor Vehicle Driving in Same Direction - Turning Right	Motor Vehicle	Figure 5-8	17	$104,603.88
39	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left- Turning Left	Motor Vehicle	Figure 5-9	3	$101,060.33
40	Intersection - Bus Stop	Motor Bus Leaving a Bus Stop	Motor Vehicle	Figure 5-16	66	$100,784.62
41	Intersection - Motor Bus Turning Right	Motor Vehicle Approaching the Motor Bus in the Opposite Direction - Turning Left	Motor Vehicle	Figure 5-11	3	$99,390.00
42	Collisions at Intersections	Motor Bus Making a Bus Stop	Pedestrian	Figure 5-3	13	$90,427.46
43	Collisions at Intersections	Motor Bus Leaving a Bus Stop	Pedestrian	Figure 5-3	18	$89,057.33
44	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left- Turning Right	Motor Vehicle	Figure 5-9	0	$0.00

No.	Category	Collision Type	Collision With	Figure #	Number of Collisions	Average Cost per Collision
45	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Right	Motor Vehicle	Figure 5-11	0	$0.00
46	Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Right- Turning Left	Motor Vehicle	Figure 5-10	0	$0.00
47	Collisions with Rail Vehicle	Collisions with Rail Vehicle	Rail Vehicle	N/A	0	$0.00
48	Collisions with Fixed Objects	Collisions with Fixed Objects	Fixed Object	N/A	80	N/A
49	Miscellaneous Motor Vehicle Collisions	Miscellaneous Motor Vehicle Collisions	Miscellaneous Motor Vehicle	N/A	48	N/A
50	Collisions with Other	Collisions with Other	Other	N/A	10	N/A

6 Light Rail Collisions with Motor Vehicles

Light rail collisions make up only a small fraction of all transit collisions (4.3%), account for 3.6% of all transit injuries and 10.9% of all fatalities. Most of these injuries and fatalities are due to pedestrian collisions. Analysis of light rail collisions with motor vehicles showed that traffic violations were by far the most common cause of motor vehicle collisions. These violations include motor vehicles running red lights, stop signs, ignoring traffic signs, or going around gates. Table 6-1 shows light rail collisions with motor vehicles at grade crossings. As shown in the table, 57 (55.1%) of these collisions occurred when the motor vehicle is going straight, 45 (43.5%) occurred when the motor vehicle is turning left, and only 2 (2.6%) occurred when the motor vehicle is turning right.

Table 6-1: Light Rail Collisions with Motor Vehicles at Grade Crossings

Category and Collision Type	Number	% of Mid-Block Collisions
Motor Vehicle Going Straight	57	55.1%
Motor Vehicle Turning Left	45	43.5%
Motor Vehicle Turning Right	2	2.6%
Total	**104**	**100%**

Figure 6-1 uses an image to depict light rail collisions with motor vehicles. It should be noted that the diagram groups motor vehicle movements into a single category independent of the approach. Thus, when a motor vehicle is shown turning left or right, it may represent a vehicle making that movement from each approach (i.e., approaching from the left, right, driving in the same direction as the light rail vehicle, or driving in the opposite direct approaching the light rail vehicle).

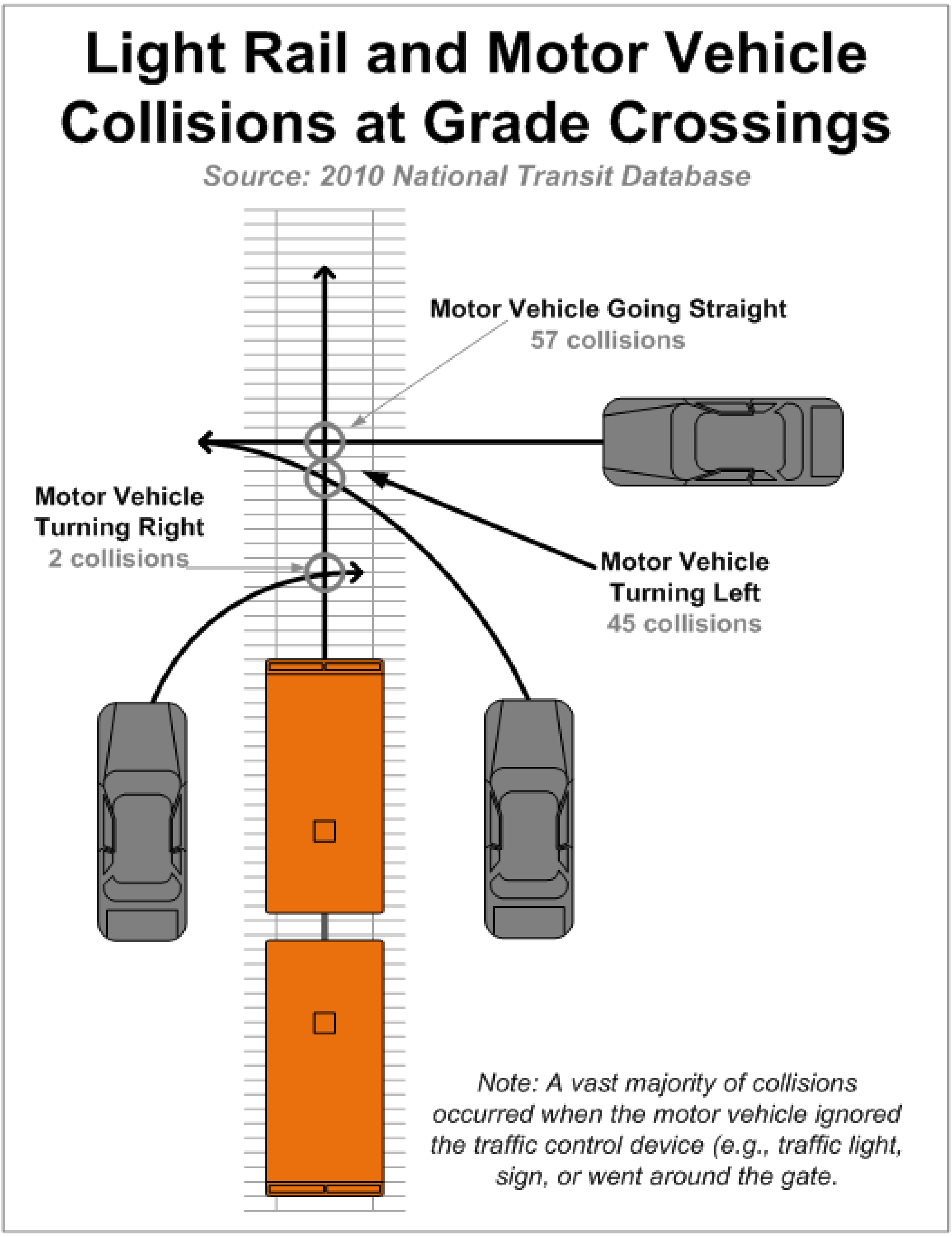

Figure 6-1: Light Rail Collisions with Motor Vehicles at Grade Crossings

7 Potential Connected Vehicle Transit Safety Application Areas

Due to its unique characteristics and behaviors, such as vehicle size and frequent stops/starts, transit often deals with safety challenges and priorities that are different from those for light vehicles. In collaboration with transit industry stakeholders, the USDOT has identified several priority Transit Connected Vehicle safety applications. Among these safety applications, two were selected for near-term development and testing:

- **Pedestrian Warning Application for Transit Vehicles.** A bus driver receives an alert of the presence of a pedestrian near or in a crosswalk as the driver makes a right or left turn at a signalized intersection. SPaT information, including pedestrian detection data, is transmitted to the bus from Roadside Equipment (RSE) via V2I communications.

The second application addresses collisions involving vehicles making illegal right turns in front of motor buses at intersections with near side bus stops.

- **Vehicle Turning Right in Front of a Transit Vehicle.** A bus driver receives an alert of a vehicle making a right turn in front of the bus as the bus driver pulls away from a bus stop. SAE J2735 DSRC messages are transmitted to the motor bus via V2V communications and are used to alert bus drivers of this situation.

The next step for the Transit Connected Vehicle Research Program is to further explore applications that can enhance transit safety using connected vehicle technologies. These application areas could significantly reduce the number of transit collisions as well as collisions caused indirectly by the presence of a transit vehicle. Using the collision statistics and characteristics identified in this report, recommendations for potential application areas for transit safety were identified. An overview of the application areas are presented below. Again, it should be noted that the numbers used for the analysis are the normalized/extrapolated numbers as described in Section 4 of this report.

7.1 Transit-Vehicle/Pedestrian Warning Applications

Transit-Vehicle/Pedestrian Warning Applications may consider V2I or vehicle-to-pedestrian (V2P)4 communications to provide warnings to transit vehicles of a pedestrian's presence in the roadway – either in a crosswalk or outside of the crosswalk. V2I applications can leverage microwave sensors at intersections that detect the presence of a pedestrian in the roadway. If a pedestrian is detected, a RSE unit may send a message to nearby vehicles using V2I communications that a pedestrian is in the roadway. Alternatively, pedestrians carrying handheld devices with connected vehicle technologies may broadcast messages about the pedestrian's location that could be received by in-vehicle transit systems.

A Pedestrian in Signalized Crosswalk Warning Application is being tested during the USDOT'S Connected Vehicle Safety Pilot. The application, part of the transit retrofit package (TRP), allows a bus driver to receive an alert of the presence of a pedestrian near or in a crosswalk as the driver makes a right or left turn at a signalized intersection. A pedestrian's presence in the crosswalk is detected using a

[4] Messages would be transmitted from the pedestrian to the vehicle, rather than from the vehicle to the pedestrian.

microwave sensor. When a pedestrian is in the crosswalk a RSE unit located at the intersection broadcasts a SPaT message containing a data object that indicates a pedestrian is in the crosswalk. This message is received by the TRP application located in the bus and the bus driver is alerted of the situation.

Looking at the Top 20 rankings by frequency, cost, and average cost per collision, Transit-Vehicle/Pedestrian Warning Applications have the potential to address several collision types, as depicted in Table 7-1. These collision types accounted for 389 collisions with an estimated cost of $236,877,583 based on 2010 NTD data. The proposed application safety area accounts for the following Top 20 Ranked Collision Types:

- **Frequency Rankings.** #8, 10, and 15
- **Total Cost Rankings.** #3, 4, 5, 11, and 18
- **Average Cost per Collision Rankings.** #1, 2, 3, 7, and 8

Table 7-1: Collision Types Addressed by Transit-Vehicle/Pedestrian Warning Applications

Category	Collision Type	Collision With	Figure #	Frequency Ranking	Cost Ranking	Average Cost per Collision Ranking
Collisions at Intersections	Motor Bus Going Straight	Pedestrian	Figure 5-1	8	4	8
Mid-Block Collisions	Motor Bus Going Straight	Pedestrian	Figure 5-2	10	3	3
Collisions at Intersections	Motor Bus Turning Left	Pedestrian	Figure 5-1	15	5	1
Mid-Block Collisions	Motor Bus Leaving a Bus Stop	Pedestrian	Figure 5-3	23	11	2
Collisions at Intersections	Motor Bus Turning Right	Pedestrian	Figure 5-1	28	18	7

7.2 Bus Stop Warning Applications

Using vehicle awareness messages, applications could be developed to alert nearby vehicles or pedestrians of the presence of a transit vehicle at or near a bus stop. These applications would provide a warning to other vehicles and pedestrians indicating the transit vehicle’s intention of pulling into or out of a bus station/stop. Bus Stop Warning Applications would leverage V2V and V2P communications allowing messages to be broadcast to nearby vehicles from buses or to buses from pedestrians carrying handheld devices. Alternatively, V2I applications may be developed allowing messages to be sent from vehicles to instrumented bus stops that would provide audible or visual alerts to pedestrians close to the vicinity of a bus stop. Alternatively, bus stops could be instrumented with sensors/detectors to warn bus drivers of pedestrians in the vicinity of the bus stop.

Looking at the Top 20 rankings by frequency, cost, and average cost per collision, Bus Stop Warning Applications have the potential to address several collision types, as depicted in Table 7-2. These collision types account for 357 collisions with an estimated cost of $87,012,164 based on 2010 NTD data. The proposed application safety area accounts for the following Top 20 Ranked Collision Types:

- **Frequency Rankings.** #11, 16, 18, and 19
- **Total Cost Rankings.** #11, 15, and 17

- **Average Cost per Collision Rankings.** #2, 13, and 18

Table 7-2: Collision Types Addressed by Bus Stop Warning Applications

Category	Collision Type	Collision With	Figure #	Frequency Ranking	Cost Ranking	Average Cost per Collision Ranking
Mid-Block Bus Stop	Motor Bus Making a Bus Stop[5]	Motor Vehicle	Figure 5-17	11	15	27
Intersection Bus Stop	Motor Bus Leaving a Bus Stop	Motor Vehicle	Figure 5-16	16	28	40
Intersection Bus Stop	Motor Bus Making a Bus Stop[6]	Motor Vehicle	Figure 5-16	18	17	18
Mid-Block Bus Stop	Motor Bus Leaving a Bus Stop	Motor Vehicle	Figure 5-17	19	22	34
Mid-Block Collisions	Motor Bus Leaving a Bus Stop	Pedestrian	Figure 5-3	23	11	2

7.3 Left Turn Assist Warning Applications

Left Turn Assist Warning Applications could provide information to drivers performing unprotected left turns to judge the gaps in oncoming traffic and to inform them of hazards to completing a safe left turn. These applications may be supported using V2V communications where vehicles share information about their location, speed, trajectories, and other vehicles at the intersection. Alternatively, these applications may also leverage V2I communications. V2I applications would combine roadside sensors, infrastructure-based messaging signs, communications technologies, positioning technologies, dynamic maps, and traffic signal interfaces.

Looking at the Top 20 rankings by frequency, cost, and average cost per collision, Left Turn Assist Warning Applications have the potential to address several collision types, as depicted in Table 7-3. These collision types listed accounted for 289 collisions with an estimated cost of $127,038,993 based on 2010 NTD data. The proposed application safety area accounts for the following Top 20 Ranked Collision Types:

- **Frequency Rankings.** #14, 17, and 20
- **Total Cost Rankings.** #9, 16, and 20
- **Average Cost per Collision Rankings.** #5, 6, 14, and 17

[5] The alert for this crash type would be provided to the motor vehicle driver and not the bus driver. The BSM could be modified to for this special case to enhance the current FCW and EEBL warning applications to alert drivers that a bus ahead of the vehicle is intending to stop at an approaching bus stop.

[6] The alert for this crash type would be provided to the motor vehicle driver and not the bus driver. The BSM could be modified to for this special case to enhance the current FCW and EEBL warning applications to alert drivers that a bus ahead of the vehicle is intending to stop at an approaching bus stop.

Table 7-3: Collision Types Addressed by Left Turn Assist Warning Applications

Category	Collision Type	Collision With	Figure #	Frequency Ranking	Cost Ranking	Average Cost per Collision Ranking
Intersection – Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction – Turning Left[7]	Motor Vehicle	Figure 5-11	14	16	17
Intersection – Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus in the Opposite Direction – Going Straight	Motor Vehicle	Figure 5-11	17	9	5
Mid-Block – Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus in the Opposite Direction – Turning Left[8]	Motor Vehicle	Figure 5-14	32	20	6

7.4 Forward Collision Warning Applications

Forward Collision Warning Applications could alert and then warn drivers if they fail to brake when a vehicle in their path is stopped or traveling slower. These applications would leverage V2V communications by sending messages about a vehicle's presence to surrounding vehicles about its current location and its intended movements. This includes transit vehicles receiving messages from nearby vehicles as well as surrounding vehicles receiving information about the transit vehicle's presence and its intended movements. An example of the types of messages that may be transmitted between vehicles includes emergency electronic brake light (EEBL) messages. EEBL applications allow drivers of vehicles to be alerted if there is a sudden braking from a lead vehicle – or several vehicles ahead. The TRP developed for the USDOT'S Safety Pilot includes basic versions of a forward collision warning application and EEBL application.

Forward collision warning applications may be applicable at bus stops to mitigate vehicles colliding into the rear of buses make stops at bus stops (see Section 7.2). The Transit Program plans to coordinate with the other connected vehicle programs investigating similar applications to ensure that transit vehicle characteristics are considered as part of the V2V research efforts. Consideration should be given to the fact that transit vehicles are longer, heavier, and take longer to stop than private motor vehicles.

Looking at the Top 20 rankings by frequency, cost, and average cost per collision, Forward Collision Warning Applications have the potential to address several collision types, as depicted in Table 7-4. These collision types accounted for 1,142 collisions with an estimated cost of $264,421,946 based on 2010 NTD data. The proposed application safety area accounts for the following Top 20 Ranked Collision Types:

- **Frequency Rankings.** #1, 2, 3, and 4
- **Total Cost Rankings.** #1, 2, 8, and 10
- **Average Cost per Collision Rankings.** #16, and 19

[7] The alert for this crash type would be provided to the motor vehicle driver and not the bus driver.
[8] The alert for this crash type would be provided to the motor vehicle driver and not the bus driver.

Table 7-4: Collision Types Addressed by Forward Collision Warning Applications

Category	Collision Type	Collision With	Figure #	Frequency Ranking	Cost Ranking	Average Cost per Collision Ranking
Intersection – Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear Ended[9]	Motor Vehicle	Figure 5-4	1	1	16
Mid-Block – Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear Ended[10]	Motor Vehicle	Figure 5-12	2	2	19
Intersection – Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Motor Bus Rear Ending	Motor Vehicle	Figure 5-4	3	10	28

7.5 Angle Collisions at Intersections Warning Applications

Angle Collision at Intersections Warning Applications could include applications that provide warnings to drivers at signalized intersections, at intersections equipped with stop signs, highway rail intersections (HRI), or light rail intersections.

Intersection Movement Assist (IMA) applications would warn the driver when it is not safe to enter an intersection—for example, when something is blocking a driver's view of opposing traffic. This scenario may occur at a signalized intersection, an intersection equipped with a stop sign, or an uncontrolled intersection. These applications would consider a vehicle's current speed and location, as well as its future trajectory to determine the likelihood of a potential collision. Using these data, the applications leverage V2V communications between vehicles to provide warnings to drivers of potential collisions at intersections.

The V2I Safety Program is researching several applications to reduce crashes at intersections including red light violation warning, stop sign violation warning, and stop sign gap assist. It is envisioned that the Transit Program will leverage the research of the V2I Safety Program. However, consideration should be given to the fact that transit vehicles are longer, heavier, and take longer to stop than private motor vehicles. Applications that have the potential to reduce angle crashes at intersections are described below:

- **Red Light Violation Warning (RLVW).** Red light violation warning applications include a cooperative vehicle and infrastructure system that assists drivers in avoiding crashes at intersections by warning the vehicle driver that a signal violation is predicted to occur. An equipped vehicle approaching an equipped intersection receives messages about the intersection geometry, SPaT information, and if necessary, position correction information. The driver is issued a warning if the vehicle processing platform determines that, given current operating conditions, the driver is predicted to violate the signal such that the vehicle enters the intersection during the red phase.
- **Stop Sign Violation Warning (SSVW).** Stop sign violation warning applications include a cooperative vehicle and infrastructure system that assists drivers in avoiding crashes at intersections by warning the vehicle driver that a stop sign violation is predicted to occur. An equipped vehicle approaching an

[9] The alert for this crash type would be provided to the motor vehicle driver and not the bus driver.
[10] The alert for this crash type would be provided to the motor vehicle driver and not the bus driver.

equipped intersection receives messages about the intersection geometry and if necessary, position correction information. The driver is issued a warning if the vehicle processing platform determines that, given current operating conditions, the driver is predicted to violate the stop sign.

- **Stop Sign Gap Assist (SSGA).** Stop sign gap assist applications provide a driver timely, relevant information regarding unsafe conditions at a stop-controlled intersection, with the premise that the driver is already aware of the stop sign intersection (stop sign violation warning would be performed by a separate application). The purpose of the application is to provide information to enable a driver to make a more informed decision regarding when it is unsafe to proceed through the intersection (i.e., gap rejection), but not make the decision for the driver.

Looking at the Top 20 rankings by frequency, cost, and average cost per collision, Angle Collisions at Intersections Warning Applications have the potential to address several collision types, as depicted in Table 7-5. These collision types accounted for 278 collisions with an estimated cost of $72,345,714 based on 2010 NTD data. The proposed application safety area accounts for the following Top 20 Ranked Collision Types:

- **Frequency Rankings.** #6, 7, and 20
- **Total Cost Rankings.** #6, 7, and 26
- **Average Cost per Collision Rankings.** #10, 11, and 14

Table 7-5: Collision Types Addressed by Angle Collisions at Intersections Warning Applications

Category	Collisions Group	Collision With	Figure #	Frequency Ranking	Cost Ranking	Average Cost per Collision Ranking
Intersection – Motor Bus Going Straight	Motor Vehicle Approaching from Right – Going Straight	Motor Vehicle	Figure 5-10	6	6	11
Intersection – Motor Bus Going Straight	Motor Vehicle Approaching from Left – Going Straight	Motor Vehicle	Figure 5-9	7	7	10
Intersection – Motor Bus Turning Left	Motor Vehicle Approaching from Left – Going Straight	Motor Vehicle	Figure 5-9	20	26	14

7.6 Blind Spot Warning/Lane Change Warning Applications

Blind Spot Warning/Lane Change Warning Applications warn drivers when they try to change lanes if there is a car in their blind spot. These applications would use V2V communications to continuously calculate the rear blind spots on both sides of the vehicle – both the motor bus and the motor vehicle. These applications would help reduce collisions where a vehicle attempts to overtake another vehicle. For example, a driver may look in the side mirror to confirm that the lane is free, but suddenly a car comes into the visual field from behind, just when the driver is about to change lanes. Such critical situations often arise in urban traffic and result in a collision if the vehicle in the blind spot is overlooked. When the turn signal is activated indicating that the driver is about to change lanes, these systems may warn the driver if changing the lane is not safe at that moment.

Looking at the Top 20 rankings by frequency, cost, and average cost per collision, Blind Spot Warning/Lane Change Warning Applications have the potential to address several collision types, as depicted in Table 7-6. These collision types accounted for 221 collisions with an estimated cost of

$40,863,595 based on 2010 NTD data. The proposed application safety area accounts for the following Top 20 Ranked Collision Types:

- **Frequency Rankings.** #5 and 13
- **Total Cost Rankings.** #12 and 19
- **Average Cost per Collision Rankings.** N/A

Table 7-6: Collision Types Addressed by Blind Spot Warning/Lane Change Warning Applications

Category	Collision Type	Collision With	Figure #	Frequency Ranking	Cost Ranking	Average Cost per Collision Ranking
Mid-Block – Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Switching Lanes	Motor Vehicle	Figure 5-13	5	12	25
Intersection – Motor Bus Going Straight	Motor Vehicle Driving in Same Direction – Switching Lanes	Motor Vehicle	Figure 5-5	13	19	33

8 Next Steps

This report provides a detailed analysis of 2010 NTD transit collisions focused primarily on motor bus collisions using normalized/extrapolated numbers as described in Section 4 of this report. Understanding that there are additional transit modes, next steps for analysis may include a more detailed analysis of light rail/streetcar collisions and demand response vehicle collisions. Additionally, further analysis could be performed to look into motor bus collisions with bicyclists. Collisions with bicyclists were included as collisions with pedestrians, but were not called out specifically. To perform these analyses, the analysis team would need to review the free form incident descriptions for these collisions.

In addition to performing additional analysis, this report will be used by the Connected Vehicle Transit Program as input for defining future transit safety applications and prioritizing those applications. This report will help ensure that collisions occurring more frequently, and are more costly, are given a higher priority as transit stakeholders begin focusing on defining, prototyping, and implementing safety applications for transit.

APPENDIX A. List of Acronyms

Acronym	Meaning
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
CPI	Consumer Price Index
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
EEBL	Emergency Electronic Brake Light
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FTA	Federal Transit Administration
GPS	Global Positioning System
HOV	High Occupancy Vehicle
HRI	Highway Rail Intersection
I2V	Infrastructure-to-Vehicle
IMA	Intersection Movement Assist
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
NHTSA	National Highway Traffic Safety Administration
NTD	National Transit Database
RITA	Research and Innovative Technology Administration
RLVW	Red Light Violation Warning
ROW	Right-of-Way
RSE	Roadside Equipment

Acronym	Meaning
SAE	Society of Automotive Engineers
SSGA	Stop Sign Gap Assist
SSVW	Stop Sign Violation Warning
TRP	Transit Retrofit Package
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
X2D	Vehicle of Infrastructure-to-Device

APPENDIX B. Terms and Definitions

The following terms and definitions were taken from the 2010 NTD Glossary.

- **Angle Collision.** A collision type involving an impact to anywhere on the side of a vehicle with the exception of a sideswipe.
- **At Grade, Exclusive Right-of-Way.** Railway right-of-way from which all other traffic, mixed and cross, is excluded. Median strip ROW is included provided all crossings of the right-of-way pass over or under the median.
- **Automated Guideway.** A transit mode that is an electric railway (single or multi-car trains) of guided transit vehicles operating without vehicle operators or other crew onboard the vehicle. Service may be on a fixed schedule or in response to a passenger activated call button. Automated Guideway transit includes personal rapid transit, group rapid transit, and people mover systems.
- **Bicyclist.** A person who rides a bicycle.
- **Cable Car.** A transit mode that is an electric railway with individually controlled transit vehicles attached to a moving cable located below the street surface and powered by engines or motors at a central location, not onboard the vehicle.
- **Commuter Rail.** A transit mode that is an electric or diesel propelled railway for urban passenger train service consisting of local short distance travel operating between a central city and adjacent suburbs. Service must be operated on a regular basis by or under contract with a transit operator for the purpose of transporting passengers within urbanized areas (UZAs), or between urbanized areas and outlying areas. Such rail service, using either locomotive hauled or self-propelled railroad passenger cars, is generally characterized by multi-trip tickets, specific station to station fares, railroad employment practices, and usually only one or two stations in the central business district. It does not include: heavy rail rapid transit, or light rail/streetcar transit service. Intercity rail service is excluded, except for that portion of such service that is operated by or under contract with a public transit agency for predominantly commuter services. Predominantly commuter service means that for any given trip segment (i.e., distance between any two stations), more than 50 percent of the average daily ridership travels on the train at least three times a week. Only the predominantly commuter service portion of an intercity route is eligible for inclusion when determining commuter rail route miles.
- **Demand Response.** A transit mode comprised of passenger cars, vans or small buses operating in response to calls from passengers or their agents to the transit operator, who then dispatches a vehicle to pick up the passengers and transport them to their destinations. A demand response operation is characterized by the following: (a) the vehicles do not operate over a fixed route or on a fixed schedule except, perhaps, on a temporary basis to satisfy a special need, and (b) typically, the vehicle may be dispatched to pick up several passengers at different pick-up points before taking them to their respective destinations and may even be interrupted en route to these destinations to pick up other passengers. The following types of operations fall under the above definitions provided they are not on a scheduled fixed route basis:
    - Many origins — many destinations

- Many origins — one destination
- One origin — many destinations, and
- One origin — one destination.

- **Employee.** An individual who is compensated by the transit agency as follows: (a) for directly operated services, the labor expense for the individual is reported in object class labor or (b) for purchased transportation service; the labor expense for the individual meets the same criteria as object class labor.
- **Fatality.** A death or suicide confirmed within 30 days of a reported incident. Does not include deaths in or on transit property that are a result of illness or other natural causes.
- **Ferryboat.** A transit mode comprised of vessels carrying passengers and/or vehicles over a body of water that are generally steam or diesel powered. Intercity ferryboat service is excluded, except for that portion of such service that is operated by or under contract with a public transit agency for predominantly commuter services. Predominantly commuter service means that for any given trip segment (i.e., distance between any two piers), more than 50 percent of the average daily ridership travels on the ferryboat on the same day. Only the predominantly commuter service portion of an intercity route is eligible for inclusion when determining ferryboat route miles.
- **Fixed Object.** A collision in which the primary collision involved a single vehicle and a fixed object.
- **Fixed Route Service.** Transit service using rubber tired passenger vehicles operating on fixed routes and schedules, regardless of whether a passenger actively requests a vehicle.
- **Guideway.** A public transportation facility using and occupying a separate right-of-way or rail for the exclusive use of public transportation including the buildings and structures dedicated for the operation of transit vehicles such as at grade, elevated and subway structures, tunnels, bridges, track and power systems for rail modes, and paved highway lanes dedicated to bus mode. Guideway does not include passenger stations and transfer facilities, bus pull-ins or communication systems (e.g., cab signaling and train control).
- **Head-on Collision.** A collision type where two vehicles coming from opposite directions impact each other straight on in the front; or in a T-bone or broadside collision, where the front of a vehicle (head-on) impacts the side (angle) of another vehicle.
- **Heavy Rail.** A transit mode that is an electric railway with the capacity for a heavy volume of traffic. It is characterized by: (a) high speed and rapid acceleration passenger rail cars operating singly or in multi-car trains on fixed rails, (b) separate rights-of-way from which all other vehicular and foot traffic are excluded, (c) Sophisticated signaling, and (d) high platform loading.
- **Injury.** Any physical damage or harm to persons as a result of an incident that requires immediate medical attention away from the scene.
- **Jitney.** A transit mode comprised of passenger cars or vans operating on fixed routes (sometimes with minor deviations) as demand warrants without fixed schedules or fixed stops.

- **Light Rail.** A transit mode that typically is an electric railway with a light volume traffic capacity compared to heavy rail. It is characterized by: (a) passenger rail cars operating singly (or in short, usually two car, trains) on fixed rails in shared or exclusive right-of-way, (b) low or high platform loading, and (c) vehicle power drawn from an overhead electric line via a trolley or a pantograph.
- **Mode.** A system for carrying transit passengers described by specific right-of-way, technology and operational features.
- **Motor Bus.** A transit mode comprised of rubber-tired passenger vehicles operating on fixed routes and schedules over roadways. Vehicles are powered by diesel, gasoline, battery, or alternative fuel engines contained within the vehicle.
- **Motor Vehicle.** A self-propelled wheeled vehicle that does not operate on rails, such as trains or trolleys. The vehicle propulsion is provided by an engine or motor, usually by an internal combustion engine, or an electric motor, or some combination of the two, such as hybrid electric vehicles and plug-in hybrids.
- **Other Vehicle Occupant.** A person who is inside the other vehicle than a transit vehicle collided with.
- **Paratransit.** Types of passenger transportation which are more flexible than conventional fixed-route transit but more structured than the use of private automobiles. Paratransit includes demand response transportation services, shared-ride taxis, car-pooling and vanpooling, and jitney services. Most often refers to wheelchair-accessible, demand response service.
- **Passenger.** An individual on board, boarding, or alighting from a revenue transit vehicle. Excludes operators, transit employees, and contractors.
- **Passenger Stations.** A passenger boarding/de-boarding facility with a platform, which may include: stairs, elevators, escalators, passenger controls (e.g., fare gates or turnstiles), canopies, wind shelters, lighting, or signs. It also may include buildings with a waiting room, ticket office or machines, restrooms, or concessions. Includes all fixed guideway passenger facilities (except for on-street cable car and light rail stops), including bus way passenger facilities; underground, at grade, and elevated rail stations; and ferryboat terminals. It includes transportation/transit/transfer centers, park-and-ride facilities, and transit malls with the above components, including those only utilized by motor buses. It does not include stops (which are typically on-street locations at the curb or in a median, sometimes with a shelter, signs, or lighting) for bus, light rail, or cable car.
- **Property Damage.** The estimated dollar value of all property that is damaged in a Reportable Incident. Property damage considers transit-owned property and other vehicles property involved in the incident that are not owned by the transit agency. It excludes personal property such as cell phones and computers. Property damage also includes the cost of clearing wreckage.
- **Rear-ended.** A collision type where a vehicle is impacted on its back end by the front of another vehicle.
- **Rear-ending.** A collision type where the front of a vehicle impacts the back end of another vehicle.
- **Revenue Facility.** A location or an area within a location that is used to enable individuals to board or alight transit vehicles and that is controlled by the transit system.

- **Revenue Facility Occupant.** An occupant at a location or an area within a location that is used to enable individuals to board or alight transit vehicles and that is controlled by the transit system.
- **Sideswipe Collision.** A collision type in which two vehicles traveling in the same direction or opposite directions contact each other along the side in a scraping-type action, or a moving vehicle scraping its side against a stationery object.
- **Transit Employee/Contractor.** An individual who is compensated by the transit agency as follows: (a) for directly operated services, the labor expense for the individual is reported in object class 501 labor or (b) for purchased transportation service; the labor expense for the individual meets the same criteria as object class 501 labor.
- **Transit Facility Occupant.** A person who is inside the public passenger area of a transit revenue facility. Employees, other workers, or trespassers are not transit facility occupants.
- **Transit Passenger.** A person who is on board, boarding, or alighting from a transit vehicle for the purpose of travel. Operators, transit employees, and contractors are excluded.
- **Trolleybus.** A transit mode comprised of electric rubber-tired passenger vehicles, manually steered and operating singly on city streets. Vehicles are propelled by a motor drawing current through overhead wires via trolleys, from a central power source not onboard the vehicle.
- **Vanpool.** A transit mode comprised of vans, small buses and other vehicles operating as a ride sharing arrangement, providing transportation to a group of individuals traveling directly between their homes and a regular destination within the same geographical area. The vehicles shall have a minimum seating capacity of seven persons, including the driver. Vanpool(s) must also be in compliance with mass transit rules including Americans with Disabilities Act (ADA) provisions, and be open to the public and that availability must be made known. Other forms of public participation to encourage ridesharing arrangements, such as:
    - The provision of parking spaces
    - Use of high occupancy vehicle (HOV) lanes
    - Coordination or clearing house service, do not qualify as public vanpools.

APPENDIX C. Summary of 2010 NTD Transit Collisions

The tables in Appendix C provide the detailed breakdown of all 2010 NTD transit collisions. This table depicts the collision numbers from the data obtained directly from the NTD (depicted in the column labeled ‘sample’) and also shows how those numbers were extrapolated or normalized. Included in this table is the normalized number of collisions, the percentage of those collisions by category, and the percentage of the total number of collisions. As shown in this table 14% of collisions involved motor buses and pedestrians, 49.8% of collisions occurred between motor buses and motor vehicles at intersections, and 31.9% of collisions occurred mid-block between motor buses and motor vehicles. The table also includes the percentage of that collision type for its category (e.g., motor bus collisions with pedestrians) and percentage of all motor bus collisions (column labeled % Total). These data are explored in more detail in the body of this report.

Table C-1:Summary of 2010 NTD Motor Bus – Pedestrian Collisions

Category	Collision Type	Number of Collisions in Sample	% Category of Sample	% Total of Sample	Multiplier	Normalized Number of Collisions	% Category of Normalized Data	% Total of Normalized Data
Collisions at Intersections	Motor Bus Going Straight	107	28.9%	4.8%	1.20	130	28.9%	4.0%
Collisions at Intersections	Motor Bus Turning Left	60	16.2%	2.7%	1.20	73	16.2%	2.3%
Collisions at Intersections	Motor Bus Turning Right	24	6.5%	1.1%	1.20	29	6.5%	0.9%
Collisions at Intersections	Motor Bus Leaving a Bus Stop	15	4.1%	0.7%	1.20	18	4.1%	0.6%
Collisions at Intersections	Motor Bus Making a Bus Stop	11	3.0%	0.5%	1.20	13	3.0%	0.4%
Mid-Block Collisions	Motor Bus Going Straight	96	25.9%	4.3%	1.20	117	25.9%	3.6%
Mid-Block Collisions	Motor Bus Leaving a Bus Stop	33	8.9%	1.5%	1.20	40	8.9%	1.2%
Mid-Block Collisions	Motor Bus Making a Bus Stop	24	6.5%	1.1%	1.20	29	6.5%	0.9%
Total		**370**	**100.0%**	**16.5%**	**-**	**451**	**100.0%**	**14.0%**

Table C-2: Summary of 2010 NTD Motor Bus - Motor Vehicle Collisions at Intersections

Category	Collision Type	Number of Collisions in Sample	% Category of Sample	% Total of Sample	Multiplier	Normalized Number of Collisions	% Category of Normalized Data	% Total of Normalized Data
Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left - Going Straight	16	1.7%	0.7%	3.44	55	3.4%	1.7%
Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left- Turning Left	1	0.1%	0.0%	3.00	3	0.2%	0.1%
Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Left- Turning Right	0	0.0%	0.0%	-	0	0.0%	0.0%
Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Right	0	0.0%	0.0%	-	0	0.0%	0.0%
Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Going Straight	19	2.0%	0.8%	3.42	65	4.0%	2.0%
Intersection - Motor Bus Turning Left	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Left	2	0.2%	0.1%	3.50	7	0.4%	0.2%
Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Right - Going Straight	4	0.4%	0.2%	3.50	14	0.9%	0.4%
Intersection - Motor Bus Turning Left	Motor Vehicle Approaching from Right- Turning Left	0	0.0%	0.0%	-	0	0.0%	0.0%
Intersection - Motor Bus Turning Left	Motor Vehicle Driving in Same Direction - Turning Left	11	1.2%	0.5%	3.45	38	2.3%	1.2%

Category	Collision Type	Number of Collisions in Sample	% Category of Sample	% Total of Sample	Multiplier	Normalized Number of Collisions	% Category of Normalized Data	% Total of Normalized Data
Intersection - Motor Bus Turning Left	Motor Vehicle Driving in Same Direction - Going Straight	10	1.1%	0.4%	3.40	34	2.1%	1.1%
Intersection - Motor Bus Turning Right	Motor Vehicle Approaching from Left - Going Straight	0	0.0%	0.0%	-	0	0.0%	0.0%
Intersection - Motor Bus Turning Right	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Left	1	0.1%	0.0%	3.00	3	0.2%	0.1%
Intersection - Motor Bus Turning Right	Motor Vehicle Driving in Same Direction - Turning Right	5	0.5%	0.2%	3.40	17	1.0%	0.5%
Intersection - Motor Bus Turning Right	Motor Vehicle Driving in Same Direction - Going Straight	5	0.5%	0.2%	3.40	17	1.0%	0.5%
Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Left - Going Straight	82	8.7%	3.7%	1.63	134	8.4%	4.2%
Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Left - Turning Left	8	0.9%	0.4%	1.63	13	0.8%	0.4%
Intersection - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Going Straight	8	0.9%	0.4%	1.63	13	0.8%	0.4%
Intersection - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Left	45	4.8%	2.0%	1.64	74	4.6%	2.3%
Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Going Straight	88	9.4%	3.9%	1.64	144	9.0%	4.5%

Category	Collision Type	Number of Collisions in Sample	% Category of Sample	% Total of Sample	Multiplier	Normalized Number of Collisions	% Category of Normalized Data	% Total of Normalized Data
Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Turning Right	19	2.0%	0.8%	1.63	31	1.9%	1.0%
Intersection - Motor Bus Going Straight	Motor Vehicle Approaching from Right - Turning Left	4	0.4%	0.2%	1.75	7	0.4%	0.2%
Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction - Motor Bus Rear Ending	101	10.7%	4.5%	1.64	166	10.3%	5.1%
Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction - Motor Bus Rear Ended	256	27.2%	11.4%	1.64	420	26.1%	13.0%
Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction - Vehicle Switching Lanes	46	4.9%	2.1%	1.63	75	4.7%	2.3%
Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus	79	8.4%	3.5%	1.65	130	8.1%	4.0%
Intersection - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus	10	1.1%	0.4%	1.6	16	1.0%	0.5%
Intersection - Bus Stop	Motor Bus Leaving a Bus Stop	61	6.5%	2.7%	1.08	66	4.1%	2.1%
Intersection - Bus Stop	Motor Bus Making a Bus Stop	59	6.3%	2.6%	1.08	64	4.0%	2.0%
Total		**940**	**100.0%**	**41.9%**	**-**	**1606**	**100.0%**	**49.8%**

Table C-3: Summary of 2010 NTD Motor Bus – Motor Vehicle Collisions at Mid-Block

Category	Collision Type	Number of Collisions in Sample	% Category of Sample	% Total of Sample	Multiplier	Normalized Number of Collisions	% Category of Normalized Data	% Total of Normalized Data
Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction - Transit Bus Rear Ending	126	15.8%	5.6%	1.29	163	15.8%	5.1%
Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction - Motor Bus Rear Ended	304	38.2%	13.6%	1.29	393	38.2%	12.2%
Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction - Vehicle Switching Lanes	113	14.2%	5.0%	1.29	146	14.2%	4.5%
Mid-Block - Motor Bus Going Straight	Motor Vehicle Parked - Same Direction	18	2.3%	0.8%	1.28	23	2.3%	0.7%
Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Going Straight	38	4.8%	1.7%	1.29	49	4.8%	1.5%
Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching the Motor Bus from the Opposite Direction - Turning Left	17	2.1%	0.8%	1.29	22	2.1%	0.7%
Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Right in Front of Bus	20	2.5%	0.9%	1.30	26	2.5%	0.8%
Mid-Block - Motor Bus Going Straight	Motor Vehicle Driving in Same Direction and Turning Left in Front of Bus	9	1.1%	0.4%	1.33	12	1.1%	0.4%
Mid-Block - Motor Bus Going Straight	Motor Vehicle Approaching from Left or Right	28	3.5%	1.2%	1.29	36	3.5%	1.1%

Category	Collision Type	Number of Collisions in Sample	% Category of Sample	% Total of Sample	Multiplier	Normalized Number of Collisions	% Category of Normalized Data	% Total of Normalized Data
Mid-Block - Bus Stop	Motor Bus Leaving a Bus Stop	44	5.5%	2.0%	1.30	57	5.5%	1.8%
Mid-Block - Bus Stop	Motor Bus Making a Bus Stop	78	9.8%	3.5%	1.29	101	9.8%	3.1%
Total		**795**	**100.0%**	**35.4%**	**-**	**1029**	**100.0%**	**31.9%**

Table C-4: Summary of 2010 NTD Motor Vehicle Collisions with Fixed Objects

Category	Collision Type	Number of Collisions in Sample	% Category of Sample	% Total of Sample	Multiplier	Normalized Number of Collisions	% Category of Normalized Data	% Total of Normalized Data
Collisions with Fixed Objects	Collisions with Fixed Objects	80	100.0%	2.9%	1	80	100.0%	2.5%
Total		**80**	**100%**	**2.9%**	**-**	**80**	**100%**	**2.5%**

Table C-5: Summary of 2010 NTD Other Collisions

Category	Collision Type	Number of Collisions in Sample	% Category of Sample	% Total of Sample	Multiplier	Normalized Number of Collisions	% Category of Normalized Data	% Total of Normalized Data
Collisions with Other	Collisions with Other	10	100.0%	0.4%	-	10	100.0%	0.3%
Total		**10**	**100.0%**	**0.4%**	**-**	**10**	**100.0%**	**0.3%**

Table C-6: Summary of 2010 NTD Miscellaneous Motor Vehicle Collisions (Data that could not be categorized)

Category	Collision Type	Number of Collisions in Sample	% Category of Sample	% Total of Sample	Multiplier	Normalized Number of Collisions	% Category of Normalized Data	% Total of Normalized Data
Miscellaneous Motor Vehicle Collisions	Miscellaneous Motor Vehicle Collisions	48	100.0%	1.7%	-	48	100.0%	1.5%
Total		**48**	**100.0%**	**1.7%**	**-**	**48**	**100.0%**	**1.5%**

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