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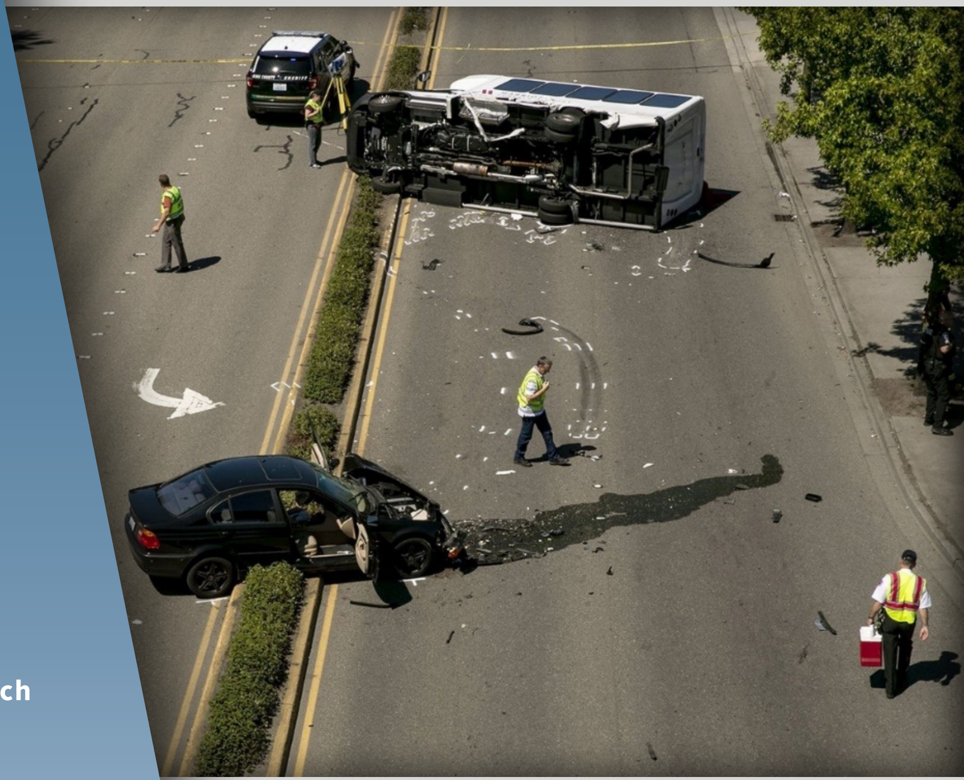

Effective Practices in Bus Transit Accident Investigations

PREPARED BY
K&J Safety Consulting Services

Center for Urban Transportation Research (CUTR)
University of South Florida

NOVEMBER
2021

U.S. Department of Transportation
Federal Transit Administration

COVER PHOTO

Courtesy of National Transportation Safety Board (NTSB)

DISCLAIMER

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3257 Elcano Lane
Cantonment FL 32533-6876

Center for Urban Transportation Research (CUTR)
University of South Florida
4202 E. Fowler Avenue, CUT100
Tampa FL 33620

SPONSORED BY

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Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

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As part of FTA's effort to promote continuous safety improvement in the public transit industry, these Effective Practices in Bus Transit Accident Investigations were developed to provide bus transit agencies leading transit industry practices for performing investigations. The supporting Bus Transit Accident Investigations—Background Research provides a comprehensive examination of each SMS element to broaden the reader's understanding of how each component complements the others. The recommended practices described in this document and emphasized through the background research are not intended to be prescriptive in nature. Each public transit agency is responsible for tailoring its event investigation processes to its unique operating environment, the complexity of the operation, and the transit modes provided. These locally-developed processes should correspond to a transit agency's existing Standard Operating Procedures (SOPs) or emergency plan.</td></tr>
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Abstract

As part of FTA's effort to promote continuous safety improvement in the public transit industry, these *Effective Practices in Bus Transit Accident Investigations* were developed to provide bus transit agencies leading transit industry practices for performing investigations. The supporting *Bus Transit Accident Investigations—Background Research* provides a comprehensive examination of each SMS element to broaden the reader's understanding of how each component complements the others. The recommended practices described in this document and emphasized through the background research are not intended to be prescriptive in nature. Each public transit agency is responsible for tailoring its event investigation processes to its unique operating environment, the complexity of the operation, and the transit modes provided. These locally-developed processes should correspond to a transit agency's existing Standard Operating Procedures (SOPs) or emergency plan.

Executive Summary

Background

The Federal Transit Administration's (FTA) adoption of the Safety Management System (SMS) framework elevated the approach to safety in public transit. FTA defines SMS as "… a formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of the transit agency's safety risk mitigation. SMS includes systematic procedures, practices, and policies for managing risks and hazards."[1]

Event investigation, which falls under the Safety Assurance (SA) component of SMS, is central to identifying causal or contributing factors in events, including accidents. They are conducted for early detection and identification of hazards, addressing safety concerns in a permanent and effective manner, reducing the agency's exposure to risk, promoting continuous improvement, as well as elevating the safety of employees and the riding public. Effective accident investigations can lead to the institution of modified policies, procedures, and practices that can prevent future transit accidents.

49 Code of Federal Regulations (CFR) § 673.27 requires transit agencies to include the investigation of safety events as part of their safety assurance process in the Public Transportation Agency Safety Plan (PTASP). An investigation evaluates the effectiveness of safety risk control methods and should result in corrective actions to improve those control methods where gaps are identified, providing a platform for continued monitoring, modification, and continuous improvement.

Whereas other functions within the transit agency may develop information to implement disciplinary action, manage claims, or defend litigation, the safety investigation should be independent of these interests and focused on developing the facts, determining the probable cause, and—most importantly—identifying corrective actions that can prevent future accidents.

Purpose

As part of FTA's effort to promote continuous safety improvement in the public transit industry, these *Effective Practices in Bus Transit Accident Investigations* were developed to provide bus transit agencies leading transit industry practices for performing investigations. The supporting *Bus Transit Accident Investigations—Background Research* provides a comprehensive examination of each SMS element to broaden the reader's understanding of how each component complements the others. The recommended practices described in this document and emphasized through the background research are not

[1] *Federal Register*, Vol. 83, No. 139, July 19, 2018. Pg. 34428; 49 CFR Part 673, Public Transportation Agency Safety Plan Final Rule. § 673.5, Definitions.

intended to be prescriptive in nature. Each public transit agency is responsible for tailoring its event investigation processes to its unique operating environment, the complexity of the operation, and the transit modes provided. These locally-developed processes should correspond to a transit agency's existing Standard Operating Procedures (SOPs) or emergency plan.

Document Organization

This document is intended to improve the investigator's analytical and critical thinking skills, which are necessary to accurately identify root causes and contributing factors leading to short-term, intermediate, and long-range Corrective Action Plans (CAPs) to address key findings in accident investigations. These practices are based on the background research presented in *Bus Transit Accident Investigations – Background Research*. An expanded SMS presentation and detailed accident investigation processes and methods are included within that technical memorandum.

This document includes the following sections and supporting appendices:

- Section 1 presents the accident investigation perspective and includes statutory requirements.
- Section 2 presents the accident scene process.
- Section 3 presents the activities that should occur after the on-scene investigation has concluded.
- Section 4 discusses report preparation and the development of CAPs.
- Appendix A provides recommended investigator "Go-Bag" contents.
- Appendix B provides information on documenting the scene, including photography and field sketching to assist the on-site investigation process.
- Appendix C includes key points that should be considered when conducting interviews and recommended processes.
- Appendix D is a Survival and Witness Statement and Questionnaire for events that result in an injury or fatality.
- Appendix E is a pre-event history checklist to assist in obtaining, in as much detail as possible, information on the operator's activities during the 72 hours before the event.
- Appendix F presents the Safety Risk Management process, including hazard identification and tools that can assist in performing hazard analyses.
- Appendix G provides a detailed investigation report outline and discusses content.
- Concluding the document are acronyms and abbreviations, traffic investigation terminology, and a glossary of terms.

Section 1 Investigation Perspective

The primary purpose of conducting investigations of undesirable events, including accidents, is to determine the cause so corrective actions can be put in place that prevent future similar events. For the purpose of this guidance document, the terms “event” and “accident” are defined in accordance with 49 CFR § 673.5:

- *Event* – an accident, incident, or occurrence
- *Accident* – an event that involves any of the following: a loss of life; a report of a serious injury to a person; a collision of public transportation vehicles; a runaway train; an evacuation for life safety reasons; or any derailment of a rail transit vehicle, at any location, at any time, whatever the cause.

A transit agency can use accident investigation outcomes to inform its Safety Management System (SMS) processes. The analyses performed and information obtained through the investigation process can be used to proactively and predictively identify where and when a similar event may occur. It can result in process improvements from lessons learned and the identification of system changes that were made with no change management process, resulting in unintended consequences.

The American Public Transportation Association’s (APTA) RT-OP-S-002-02 Rev. 3, Standard for Accident/Incident Notification and Investigation Requirements, defines the purpose of an investigation as “... to gather and assess facts in order to determine cause(s), and to identify corrective measures to prevent recurrence. Accident/incident investigation is not intended to affix blame, or subject people to liability for their actions, or to recommend disciplinary action.”

Although other functions within the transit agency may develop information to implement disciplinary action, manage claims, or defend litigation, a safety investigation should be independent of these interests and focused on developing the facts, determining the probable cause, and, most importantly, identifying corrective actions that can prevent future accidents.

During the investigation of an undesirable safety event such as a bus accident, a variety of factual operating information is developed around the circumstances of the event. This information is then compared with the programs, procedures, and practices that should have been in place and followed in the particular event. Investigation findings are noted where there is a gap between what should have been and what was. Gaps are analyzed to determine the probable cause and other factors contributing to the event.

If no gaps between existing requirements and actual performance are identified in an accident investigation, the adequacy of agency policies, procedures, training, and equipment should be assessed. In both safety auditing and safety investigation, findings are analyzed, and corrective actions are developed to address gaps that are identified, and CAPs are tracked, monitored, and managed.

FTA Regulations

FTA specifies requirements for transit accident investigations in 49 CFR 673; § 673.27, which requires transit agencies to include the investigation of safety events as part of their safety assurance process in the Public Transportation Agency Safety Plan (PTASP). An investigation evaluates the effectiveness of safety risk control methods and should result in corrective actions to improve those control methods where gaps are identified.

Working with FTA on Investigations

FTA, under the authority provided in 49 USC § 5329(f), may conduct independent investigations. When these occur, agencies should plan to coordinate their activities to minimize confusion or miscommunication.

Notification

All safety events (including “near misses”), no matter how minor they may be perceived, should result in notification to key personnel and management so they can be investigated, assessed, and recorded in line with SMS data collection and analysis requirements. Although not all events will require notification and reporting to oversight bodies outside the transit agency, investigators should acquaint themselves with the specific regulations and requirements for notification applicable to their operations, which may include internal agency processes and procedures, or other regulations and requirements.

Investigation Plan and Procedures

Bus transit agency investigation plans and associated procedures should conform to their own well-established, documented internal processes. In states with a State Safety Oversight (SSO) bus program, there may be state requirements. Generally, the transit agency plan should identify thresholds for accidents that require an investigation and the level of investigation required based on the severity of the event. The plan should also address the procedures for protecting the confidentiality of investigation reports.

Significant or complex investigations may require the assembly of an investigation team or committee. Typically, internal support for the investigative process includes agency subject matter expertise in specific areas that may include:

- Bus vehicle (mechanical)/vehicle maintenance
- Infrastructure (e.g., bus stops, transit facilities, signaling, guardrails, busways)
- Transportation operations and operating rules, procedures, practices
- Training management personnel or instructors
- Human factors (e.g., medical, hours of service, training, distraction)
- Survival factors
- External expertise may also be required from vendors, manufacturers, or consultants
- Transportation planning (e.g., route and schedule planning)

Investigator Qualifications

Essential knowledge, skills, and abilities for investigators include:

- Knowledge of system operations
- Knowledge of accident investigation methods and requirements
- Understanding of equipment and subsystem functionality (transportation, vehicles, infrastructure, communications)
- Ability to read and understand procedures and drawings
- Knowledge of agency rules, procedures, and processes in place to prevent accidents
- Understanding of SMS and system safety principles
- Knowledge of incident scene management and Incident Command System/ National Incident Management System (ICS/NIMS)
- Interviewing skills
- Skills related to documenting an accident scene (e.g., photography, sketching, measurement, evidence)
- Report writing
- People skills

Title 49 CFR Part 672 establishes minimum training for personnel overseeing fixed-guideway transit systems and a voluntary training curriculum recommended to bus transit agency personnel. This training is offered by the US Department of Transportation (USDOT) Transportation Safety Institute (TSI). The voluntary curriculum for bus transit system personnel with direct safety oversight responsibility and state DOTs overseeing safety programs for sub-recipients includes the following:

- SMS Awareness – e-learning delivery (all required participants) (1-hour course)

- Safety Assurance – e-learning delivery (all required participants) (2-hour course)
- SMS Principles for Transit (all required participants) (20 hours)
- Transit Safety and Security Program (TSSP) curriculum, minus Transit System Security (TSS) course (all required participants) – credit provided if participant has Course Completion Certificate of previous TSSP courses
- Bus Transit System Safety
- Effectively Managing Transit Emergencies
- Fundamentals of Bus Collision Investigations

In addition to the PTASP Safety Certification Training Program curriculum, there are several additional types of training investigators should consider. Potential topics/courses of value to investigators include:

- Advanced Problems in Bus Collision Investigation (TSI)
- Agency operating rules
- Agency maintenance training courses
- Agency bloodborne pathogens training
- Agency hazardous materials awareness
- Fatigue and Sleep Apnea Awareness (TSI-on-line)
- Curbing Transit Employee Distracted Driving (TSI-on-line)
- Transit Safety and Security Audit (TSI)
- Introduction to the Incident Command System, ICS 100 (Federal Emergency Management Agency (FEMA) On-line)
- Forensic photography (various commercial vendors)
- Interviewing skills (various commercial vendors)
- Root cause analysis (various commercial vendors)

Investigators should take every opportunity to undertake self-directed training by spending time with agency technicians, operators, controllers, and other personnel to better understand system operations and maintenance. This also allows investigators to establish good interpersonal relationships with key staff.

Section 2 Accident Scene

Agency Emergency Response

An agency's response to incidents should be established in advance in an existing Standard Operating Procedure (SOP) or emergency plan. Typically, the agency's dispatch or control center is directed to notify appropriate personnel and activate the response, including notifying investigators. This is where an agency's program of training, exercises, and debriefs with emergency responders pay dividends. It is essential that agency responders are aware of the priorities—rescue and public safety followed by preservation of evidence. Emphasis should be placed on preserving the integrity of data recorders, camera systems, and vehicle control compartments.

Inter-Agency Coordination/ICS

Source: istockphoto.com

Multiple agencies may be involved in an accident response, particularly a significant mass casualty event. The Incident Command System (ICS) is a standardized, on-scene, all-hazard incident management concept (Figure 2-1). ICS allows its users to adopt an integrated organizational structure to match the complexities and demands of single or multiple incidents without being hindered by jurisdictional boundaries. ICS is part of the National Incident Management System (NIMS) and has as its primary purposes:

- Safety of responders and others
- Achievement of tactical objectives
- Efficient use of resources
- Communication and coordination between responding agencies

FEMA offers free online training on ICS. Various transit specific emergency management documents are available on FTA's website at www.transit.dot.gov/regulations-and-guidance/safety/publications.

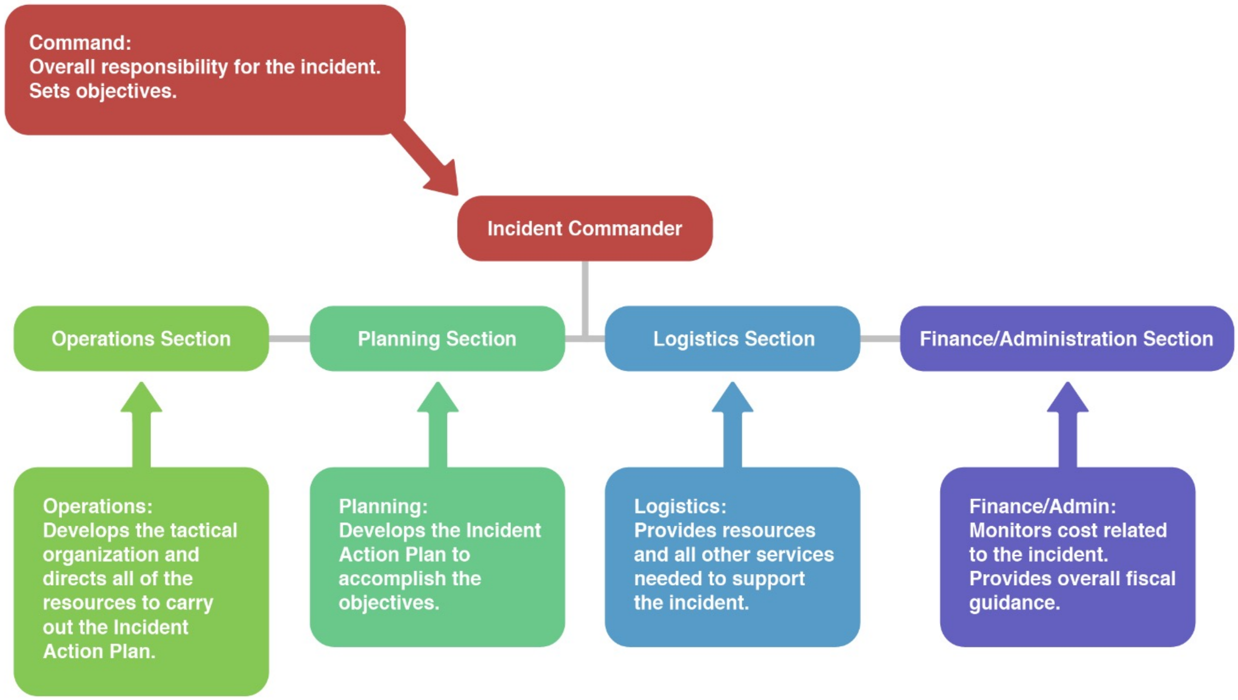


Figure 2-1 *Incident Command System (ICS) Structure, IC Organization*
Source: TSI

Typically, the first transit employee on the scene (often the bus operator) is the initial Incident Commander (IC). The IC position may transition to a more experienced agency employee until emergency responders arrive. When ICS is established by the response agency, the agency becomes part of the ICS and supports the IC.

The Federal Railroad Administration (FRA) regulates commuter rail, freight, and intercity passenger rail. Although the following FRA regulations do not apply to most transit systems, they do provide a useful model on coordination with emergency response agencies that can be adapted to transit:

- Title 49 CFR § 239.101(5) – establishing and maintaining a working relationship with emergency responders through training, exercises, and planning.
- Title 49 CFR § 239.103 – periodic full-scale simulations
- Title 49 CFR § 239.105 – debriefing and critique after each actual event and large-scale simulation
- Title 49 CFR § 239.105 (c) – purpose of debriefing and critique.

If there are multiple agencies involved in the investigation, business cards or contact information of people from other departments and outside agencies should be obtained. An investigator will invariably have additional questions or need documentation or further information.

Working with Law Enforcement

Local law enforcement agencies have independent authority at traffic accidents and criminal events and will oversee their investigation. Investigators need to forge cooperative working relationships with these local authorities, preferably in advance of the accident. Relationships can be forged through meetings, training, drills, and tabletop exercises.

Law enforcement traffic investigations focus on which party broke the law—i.e., who gets the citation. In severe accidents, law enforcement may conduct a criminal investigation of agency employees, or the agency itself. In some instances, the transit operator is judged not “at fault” by law enforcement, but the transit agency’s investigation may find the accident to have been preventable. (*Note*: An accident could be rated as non-preventable on the part of an employee by the transit agency, but still have organizational implications that need to be addressed to prevent similar future accidents, or that require the agency to analyze identified hazards, evaluate safety risk, and implement proactive or preventive action. The agency safety investigation is more focused on system issues and prevention than on fault.)

Scene Safety

When responding to a call to an accident scene, investigators should remember that they are not a police officer and must still obey all traffic laws. If law enforcement has not already set up traffic control, the investigator should park his official vehicle on the roadway and in such a manner as to provide a shield between the vehicles, the injured, the investigator, and traffic. Response vehicles should be equipped with cones and triangles to warn traffic also. The recommended signage placement based upon miles per hour (mph) is as follows:

Speed Limit	First Triangle or Cone
25 mph	68 ft
35 mph	112 ft
45 mph	167 ft
55 mph	227 ft
65 mph	301 ft

The first stop for investigators should be the IC. This person often will be with the fire department or police, as noted. For accidents entirely on agency property (such as a bus depot) and with no fire or injuries necessitating a response, the IC will be an agency employee. Before entering the scene, investigators should perform a hazard scan and participate in a safety briefing with the IC. Among the potential hazards that should be evaluated are fuel tanks, pressure vessels, batteries, unstable equipment, movement on adjacent roadways, hazmat spills, and biohazards spills.

Safety investigators should model appropriate behavior and lead by example. Clothing and Personal Protective Equipment (PPE) appropriate to the accident scene and agency protocols must always be worn while on-scene. Generally, at a minimum, this means long pants, safety footwear, eye protection, a hard hat, work gloves, and a reflective outer vest meeting agency requirements. Additional PPE may be required depending on the conditions at each accident scene.

News media often stage cameras to record activities at accident scenes. The investigator should be aware that the behavior and appearance of investigators and other personnel may make the news. (*Note*: The media might have video equipment that might not appear to be in use [video cameras pointed to the ground]; however, video cameras may still be recording audio._

Experienced investigators maintain a "go bag" with PPE and investigative tools that are routinely needed. Gauges, meters, measurement devices, and publications maintained as part of a go-bag (see Appendix A) should be kept up to date and calibrated, and camera or video recorders should be charged and have available storage space (SD or memory card). Users should be appropriately trained and qualified. For investigators who do not routinely use an electrical meter or similar device, it is often better to have an experienced technician take the measurements while an investigator observes and records.

Exposure Potential – Bloodborne Pathogens

Transit accident investigators have the potential for exposure to bloodborne pathogens, including Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV). While on scene, investigators should assume that blood and other bodily fluids may be present and should use "universal precautions"—treat blood and bodily fluids as if they are infectious for HIV, HBV, and other bloodborne pathogens and take appropriate precautions. Transit accident investigators should receive initial and recurrent training on bloodborne pathogens as specified in applicable Occupational Safety and Health Administration (OSHA) regulations. Training is required to cover information on the HBV vaccine, which employers should provide at no charge if requested. (See 29 CFR §1910.1030)

Exposure Potential – Hazardous Materials

Transit accident investigators may be exposed to hazardous materials such as automotive fluids (gasoline, diesel fuel, hydraulic fluid, antifreeze), unique transit vehicle fuels (natural gas or fuel cell, as examples), and a wide variety of chemicals transported by commercial motor carriers. Some level of hazardous materials awareness training for investigators is appropriate. For example, NTSB rail accident investigators who respond to transit, freight, and passenger train accidents complete a 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) initial training with annual 8-hour refreshers. Some online courses are commercially available. Transit investigators should be provided with an appropriate level of hazardous materials training based on the operational characteristics and risk of exposure they may encounter. (See 29 CFR §1910.120)

Documenting and Managing the Accident Scene

A key element of scene management is the preservation of factual evidence. However, during the initial emergency response phase, rescue, recovery, and public safety will be priorities over preservation of evidence. Transit investigators should contact the IC as soon as possible to coordinate the needs of the investigation with the needs of immediate response. The goal of preserving, securing, and documenting the history of pieces of evidence is to protect the condition and integrity of evidence collected during an investigation. In most bus transit accidents on streets and highways, law enforcement will assume this responsibility. However, transit investigators may have specialized technical knowledge that will assist in identifying unique transit specific features. Elements of the investigation process, specifically in the area of documenting and managing the accident scene, are presented in the following section.

Chain of Custody

Chain of custody documents the movement and location of evidence and the history of persons and entities who had it in their custody from the time it is obtained until its final disposition. Transit agencies should have a chain of custody process in their accident investigation procedure.

Evidence Collection/Retention

Investigators should have an evidence control plan along with the appropriate chain-of-custody forms and containers. For agencies with dedicated transit law enforcement, these organizations will have established evidence control procedures and storage rooms that can be of help. Other agencies may find locations, such as a fare counting room, as a viable evidence storage location. If vehicles or larger components such as bus tires need to be preserved, a secure storage location in a bus depot or other fenced facility is needed, ideally with access control. Investigators should tag all evidence collected at the scene.

Typical investigative actions to collect and preserve evidence include:

- Extensively photographing and videoing scene documentation that allows the viewer to link specific shots of evidentiary items to be linked to the overall scene map.
- Field sketching with sufficient detail to show spatial relationship of collected items to overall scene.
- Photographing collected evidence *in situ* before collection.
- Tagging or bagging evidence items and complete chain of custody form for each item.
- Maintaining physical control of collected items until transferred to another custodian (storing items in a locked vehicle only accessible by the investigator satisfies this element).
- Tagging larger items and completing a chain-of-custody form; transferring control to the manager responsible for moving the item to a secure location after reaching an understanding on the secure storage requirements.
- Delivering smaller items under the investigator's control to the designated custodian (for example, if transit agency police are available for this function)
- In cases in which the investigator will be the custodian, bagged or tagged items can be stored in a secure location such as a locked storeroom, locked office, or locked cabinet with controlled access.

Event Recorder, Data Logger, Supervisory Control and Data Acquisition (SCADA), Camera System Analysis

Many transit systems have extensive data recording systems that provide invaluable information to the investigator. Data recorders may be installed on vehicles, traffic control devices, grade crossing warning equipment cases, and in the control center. Some transit operations use Automatic Vehicle Locator (AVL) systems that also record historical data. Most transit agencies have camera systems on vehicles, in transfer stations, and other locations. Private surveillance cameras may be installed at businesses and residences adjacent to the scene. Some agencies use automated driver behavior monitoring/coaching systems that produce valuable data for investigators.

Investigators need to become familiar with the various types of recorders and cameras in place on the system(s) for which they may be called on to investigate. If a delay in downloading data could result in data loss, the recorder should be downloaded on-scene and documented. The time of download should be noted against an accurate clock (such as control center time or time on a cell phone) for later time synchronization. Agencies should have written protocols in place for the protection, download, analysis, and retention of data generated by such systems. Investigators need to familiarize themselves with these systems and the protocols for download and analysis and should practice obtaining information in a low-pressure, non-accident environment. Some systems will require the assistance of technicians to obtain and explain the data. Investigators should get to know these technicians in advance to facilitate analysis when needed.

Forward-facing video from same-day previous trips performed on the vehicle involved in the accident may be useful and should be ordered in a timely way to avoid losing data. In addition, if other transit buses were in the area at the time and approached or drove near or past the scene, video recorders on those vehicles may also prove useful. The general rule for electronic data that is at risk of being overwritten is that it is better to have it and not need it than the other way around. Some local traffic departments collect recorded data from field devices and pole-mounted cameras. Investigators should become familiar with what is available and develop points of contact in advance.

Photographs, Videos, Sketches, and Measurements

Appendix B provides extensive instruction and pointers for documenting the scene through photographs and field sketches. In general terms, investigators should take many photographs and videos. Some investigators wear a "Go Pro" type device, so they are always recording on-scene. (*Note*: Investigators should exercise caution when using mobile phones to take accident photos; check local and state public record and evidentiary protection laws). It is better to have images and not need them than miss important photographic evidence.

Source: Pixabay

Before collecting small pieces of evidence, photo documentation should be made of the point of rest, orientation, and location relative to the overall scene. Unique identifiers on equipment and components such as serial numbers or model identification should be captured.

It is important to capture things that may change, such as debris location, tire marks, road scars, fluid spills, and bus operator controls, settings, and other device status. The investigator should start at a distance and move in closer. If documenting a vehicle, signal case, or other unique component, an image of the identification number (e.g., vehicle

Source: Shutterstock.com

number, VIN, license plate, signal number) should be captured before and after taking more detailed shots to enable easy linking of a close-up to the unique item at a later time.

Agencies may find it beneficial to have a drone operator/photographer on staff or under contract to record aerial images of a scene. An alternative is to ask for images from law enforcement or media who may have overflown the scene.

Documenting a bus transit accident includes sketching and diagramming the scene to scale, and measuring reference points, including tire marks, for example. Detailed instructions on this process are included in Appendix B.

Intersections/Grade Crossings

If the transit bus accident occurred at an intersection or in proximity to a grade crossing, position and condition of pavement markings, warning signs, and any special pedestrian enhancements (swing gates, pedestrian gates, Z approaches) should be documented, as should the functionality of traffic signals and warning devices, if possible. During the post-on-scene phase, scene conditions should be compared to as-built drawings, regulatory orders, and other criteria. If conditions permit, it is helpful to record a video from a motor vehicle driver/pedestrian perspective approaching the crossing/intersection in the same manner as during the event.

Source: CUTR

Witness Statements

Police or transit agency personnel should try to get as many witness statements ("courtesy cards") as possible along with contact information. Passengers often are anxious to leave the scene; at a minimum, contact information for later follow up should be obtained. Investigators may need to schedule follow up interviews depending on the nature of the event.

Weather and Environment

The first investigators to arrive on the scene should make notes on their observations of the weather and environment at the scene:

- Did weather conditions affect visibility?
- Is it dark (before sunrise or after sunset)?
- What was the direction of travel (to determine if glare may have been a factor)?

- Is artificial lighting present? Are all lights functional?
- Is any unusual noise present (such as construction activity)?
- Is there anything in the environment that may have created a distraction?

Source: CUTR

Local airports often will have a weather station and data on temperature, precipitation, and wind, that can be obtained at or near the time of the event. Information on times of sunset and sunrise can also be obtained.

Section 3 Post On-Scene Investigation

Fact-Finding Phase

Post on-scene activities include desk reviews of documentation, follow-up interviews, tests, and re-creations, described as the "fact-finding" phase of an investigation.

Timeline

Effective Investigation Practice

Once a "good" time is established for an event—for example, using a vehicle event recorder, forward-facing video, and/or signal system data that show the bus entering an intersection or leaving a stop—other recorders and associated data can be synced. Investigators should plan to budget enough time for this effort.

A timeline will form as the basis of laying out the accident sequence and helps to put precipitating events in order; therefore, early on, investigators should begin creating a timeline of Events relevant to the accident. This starts at the beginning of the accident trip or employee shift. However, investigators should also review and include operating cautions, special or temporary orders, procedures, and instructions that might have been in effect on the day of the accident. As much detail as possible should be developed around events relevant to the accident. Inputs for the timeline include vehicle and signal system event recorder data, video recordings, interviews, SCADA data, and control center logs.

Recorded Data

Recorded data are a crucial source for a complete timeline and for understanding the event. Synchronizing the times from multiple data recorders is an important step to ensure accuracy. Standalone cameras and data recorders typically have autonomous internal clocks. Over time, these clocks can deviate from the original time setting, and some equipment may have had clocks initially set inaccurately or to a different time zone. Aligning date/time stamps across various data sets to actual time can be a challenge. SCADA time is usually tied into an accurate clock, but this should be verified.

Video images can provide valuable data to the survival factors investigation on where individuals were located and the injury mechanisms involved. Forward-facing video can provide valuable information on the moments leading up to the accident and traffic, roadway, or environmental conditions.

Inward (operator)-facing video is becoming more common and has been recommended to the transit industry by the NTSB. APTA issued Recommended Practice RT-OP-RP-024-19, Crash and Fire Protected Inward and Outward Facing Audio and Image Recorders in Rail Transit Operating Compartments; although developed for rail transit vehicles, some practices may be adopted by bus transit agencies. Inward-facing video can provide the investigator with valuable information on operator actions, vigilance, and distractions that may have been factors in an accident.

Event recorders can provide time, distance traveled, and information on speed, braking, and other operational parameters. However, it is important to recognize that in a collision or bus-off-the-road scenario, the last few seconds of recorded data may be corrupted or inaccurate because of power interruption due to collision forces and electronic recording lag.

Some transit agencies have installed driving behavior management systems that monitor vehicle dynamics, provide inward- and forward-facing video, record specific parameters (including some vehicle dynamic events such as hard braking or aggressive maneuvers), may provide immediate feedback to drivers, and provide reports to managers for follow-up when problematic driving behaviors are detected. These devices are a valuable source of data for the accident investigator.

Source: NTSB

Most agencies record radio and telephone communications to/from the control center. In some cases, radio communication between field units is also recorded. Review and analysis of these communications will help nail down the timeline. They may provide important information about communication flow and on decisions made leading up to, during, and after the accident. As with other data sources, the time stamp needs to be verified for accuracy and synchronized with other recorded data. Investigators may find it helpful to have critical communications transcribed.

Document Reviews

Document review can be a daunting task; documents are selected by investigators based on the circumstances of the accident, as with an audit. Examined should be what the document says should be done and what was done. Discrepancies or "gaps" need analysis to determine their relevance. Overall, the document review and gap identification process should present opportunities to improve agency standards, update the training curriculum, and support assistance to frontline employees. The focus should be on documentation of procedures and policies that were intended to prevent the type of accident under investigation. For example, if operating rules violations were involved, training, rules and procedures, management oversight, and compliance monitoring would be key areas of documentation to review. Figure3-1 provides examples of documents that may be reviewed during this activity.

If mechanical failure of system components is involved, a review of maintenance inspections, preventive maintenance records, recall notifications, bus operator pre-/post trip inspection records that may indicate a defect or mechanical issue, technician qualifications and training, quality control, procedures, schedule, and history are critical areas of documentation review.

Transportation Department

- Vehicle operating documents
  - Run ID
  - Schedule/paddle
  - Bulletins or written instructions to operators
- Operational rules/procedures
- Operating rule book
  - SOP book
  - Operator manual
  - Troubleshooting guide
- Operational rules and testing records
- Pre-/post-trip inspection reports
- Transportation occurrence reports
- Supervisor reports
- Operator statements

Mechanical (Vehicle) Department

- Vehicle histories
  - Acquisition date
  - Initial certification
  - Rehab/rebuild information
  - Fleet modifications
- Vehicle inspection records
- Preventative maintenance records
- Post-event testing and inspection reports
- Vehicle repair records
- Event data recorder downloads
- Forward-facing and cab video downloads
- Interior security videos
- Detailed damage estimates

Figure 3-1 *Example Documents to Review*

Source: K&J and CUTR

Management Oversight and Rules Compliance

Operating rules are instructions to personnel covering bus operations and maintenance activities on vehicles. They include the agency's rulebook and other associated manuals, SOPs, bulletins, and operating documents or the equivalent issued to bus operators. Investigators should become familiar with the requirements in these rules and procedures.

It is not enough to have rules in place. Systems need to have quality control/ assurance programs to be sure rules are understood and complied with. Without management oversight, levels of compliance and uniform application of rules, there will be drift. In an SMS environment, this is called "practical drift," and an agency process should be in place to measure and control drift and bring procedures back in line with the agency's expected performance standards. Rules compliance monitoring programs provide this function.

Key Points on rule assessments:

- Determine if established practices were followed.
- If not, determine why, i.e., distraction, inadequate oversight, insufficient training or ineffective training, cumbersome procedures, practical drift, immature safety culture.
- If procedure/practice was followed, determine if it is effective.

FTA regulations at 49 CFR Part 674 are based on the SMS approach. A key element of SMS is safety assurance that includes rules compliance audits. 49 CFR §674.27(b)(1) requires that an agency's safety plan include provisions to "monitor its system for compliance with, and sufficiency of, the agency's procedures for operations and maintenance."

Evaluation of the operating rules is an essential part of the investigative process. Investigators need to be familiar with the rules and determine what was required and what transpired and be able to factually document and describe any deviations or anomalies. If rules were not followed, how did that affect the event? Was the training in conformance with the current rules and the existing equipment configurations? If not, what bearing did that have on the event?

Effective Investigation Practice

When reviewing the rules compliance program data relevant to the accident under investigation, investigators should consider the following:

- Is the program guidance to managers clear on what rules to check and how to perform checks?
- Are managers performing checks themselves qualified on the rules?
- Are reports produced showing compliance data over time? Examine how managers use the data.
- Red flags:
  - Compliance check results that are "too good," i.e., never any exceptions
  - Compliance checks not spread over days and times; should be unexpected.
  - Compliance checks not spread over all operational bases
  - Compliance checks limited to PPE, tardiness, and "easy" checks

It is important to determine what rules were clear and understood by those involved and if employees had received enough initial and refresher training on the rules. It is also essential to evaluate the compliance program conducted by managers. Finally, if there have been revisions to the rules involved in the event, investigators should look at the change management process, stakeholder involvement, and how rules revisions were communicated to those affected.

Interviews

Conducting interviews is one of the most important responsibilities in the investigation process. In addition to immediate on-scene interviews, it is often desirable to conduct follow-up interviews during the post-on-scene phase of the investigation, particularly with key individuals who may have played a role in the event, such as the bus operator, control center personnel or dispatchers, and maintenance technicians. Information obtained after the on-scene phase may identify new individuals who can shed light on the event. The following section discusses who should be interviewed and why. (See Appendix C for recommended processes.)

Key Points for conducting interviews:

- Who will be interviewed? Interviewees who meet the objectives of filling in the blanks or clarifying events should be included, such as:
  - Eyewitnesses
  - Bus operator
  - Other employees
  - Passengers
  - Managers
  - First responders
  - SMEs

One-on-one interviews may be necessary, particularly when obtaining witness statements after an event, as witnesses may be anxious to leave. An interview team of two is preferred—one to conduct the interview and the other to take notes or operate recording devices. Having a second person as a witness may also be desirable in some cases. Larger groups of interviewers can be challenging and require a leader to set clear ground rules about questions and the interview process.

Effective Investigation Practice — Approach to Interviews

When reviewing the rules compliance program data relevant to the accident under investigation, investigators should consider the following:

- Interview, not an interrogation.
- Cooperative and informal, yet structured conversation.
- Usually conducted informally and voluntarily.
- Recorded and transcribed.
- No "off the record" interviews.
- Interrogation approach is counterproductive.
- Interviewee can have one representative present.
- Interviewee is an equal partner.
- Interviewee is encouraged to cooperate.
- Interviewee allowed to relate observations without interruption or intimidation.
- Appeal to interviewee emphasizing need for transportation safety and prevention.
- Most people want to help and share their observations.

Some critical points for team interviews that may lead to greater success include having one person designated as the lead interviewer, maintaining a professional and non-judgmental demeanor, not allowing other interviewers to interrupt each other or the interviewee, and establishing a code of conduct that includes an agreement not to interrupt the questioning and establishing that each interviewer should wait their turn. Other contributors to interview success include the following:

- **Identify the interviewee.** Who will be interviewed? When? Why? If possible, select a time and place for the interview that will put the interviewee most at ease. Set goals for the interview. Identify some of the critical areas you hope to understand better.

- **Acknowledge interviewee concerns.** Be aware of concerns the interviewee may have and be ready to discuss and address as much as possible. Eyewitnesses may fear seeing their name in media or be reluctant to get involved or may fear "getting it wrong." Those involved in the accident may be concerned with the effect on those individuals, the agency, and themselves.
- **Prepare.** Do your homework; know the operating rules and method of operation involved as much as possible. Review the circumstances of the accident—the rules and procedures involved, witness statements, timeline, video, event recorder, and other recorded data.
- **Identify information to be obtained.** Determine the order in which information is to be obtained and the general questions that will elicit the information to be obtained for each topic. Establish ground rules for conducting the interview, and ensure that the interviewee is as comfortable as possible.
- **Follow common sense rules.** Do not conduct an interview alone, particularly with someone who may have been involved in the event. Ensure that notes are taken during the interview, interview only one person at a time, and allow no interviewee to observe other interviews or talk to each other between interviews. Separating multiple interviewees reduces the likelihood of them influencing each other's recollection of events.
- **Do not permit interruptions** to either questions or answers, but allow follow-up questions. One person should be responsible for taking notes during the interview, and notes should be agreed to and signed by all interviewers present in the interview as soon as possible.
- **Allow an interviewee representative.** In some cases, interviewees may want a representative. Unionized agencies typically provide for a union representative if requested. The representative may not answer questions for the interviewee. Just as it is important to establish rapport with the interviewee, the interviewer should try to develop a rapport with the representative.
- **Take notes or record the interview.** The interviewee should be informed if the interview will be recorded. Some agencies record interviews, others do not. Recording has obvious advantages in terms of accuracy. Even with a recorder, someone should be taking good notes, as recorders can fail, and there

Effective Investigation Practice

For transcribed recordings:

- Word for word, no interpretation.
- Note time stamps on transcript.
- Record actual language or lack of words.
- Who initiated?
- Whose words were "stepped on"?
- Who acknowledged the information provided?
- Were readbacks repeated word for word?
- Have a second set of ears verify accuracy.

may be nuances, such as body language, that a recording will not capture. An interviewee may object to recording; the objective is to make the interviewee comfortable. Conducting an interview without a recorder is preferable to a confrontational interview or no interview at all.

- **Set the stage.** Develop a rapport with the interviewee, even if it takes an extended amount of time. Find some common ground. This should be done before beginning the interview. Developing rapport will set the stage for the rest of the interview.

Reenactments and Sight Distance Evaluations

Reenactments and sight distance observations often are done to verify the conditions at the time of the accident. The goal is to come as close as possible to duplicating the accident conditions and when participants could have seen a hazard before the accident.

Effective Investigation Practice

Reenactments should be done as soon after the accident as possible and at the same time of day with the same lighting and weather conditions. The same equipment or the same type of equipment should be used. Equipment operators/train operators should be qualified on the equipment, and their observations and insights should be noted. In measuring sight distance, investigators should note in documentation that everyone was focused on identifying the item (bus, auto, worker, pedestrian, or bicyclist), creating an artificiality from normal operations.

Tests

Agencies typically have existing test criteria that are used on a routine basis in preventive and running maintenance or when subsystems or components are replaced. Post-incident testing can use the same tests to verify the operating condition of vehicle braking and any other subsystem or component that may be relevant to the event under investigation. For example, if traffic signal system performance needs to be validated, it may require a simple, functional verification or complex software analysis.

Most investigators usually will need to rely on technical staff to perform many of the tests, but they may need to witness the test performance. Any test not already covered by an internal maintenance procedure should have a written test plan developed and reviewed by agency technical and investigative staff.

Laboratory Testing

A contract laboratory may be needed for specialized tests beyond the capability of the agency—i.e., metallurgical analysis, materials testing, software testing, etc. Investigators will need engineering support from within agency or specialized consultants to help organize and select appropriate labs and testing protocols. The transit agency may already have some contracts in place.

Drug/Alcohol Testing

> **Effective Investigation Practice**
>
> For an impairment to be considered a cause or contributor to an accident following a positive test result, the investigator needs to determine that vigilance, reaction time, perception, or decisionmaking was a factor in the accident and was influenced by the substance involved. The agency medical officer may be of help in making this determination.

FTA drug-alcohol testing requirements are found at 49 CFR Part 655. In addition to alcohol testing, FTA requires tests for marijuana, cocaine, opioids, amphetamines, and phencyclidine. Specific protocols will be spelled out in the agency's testing program. A post-accident test needs to be done within two hours. Some agencies may have testing programs that screen for additional substances. Investigators should know what the specific requirements are for their agency. (See the Human Factors section of this document for more detail). If the accident conditions triggered employee post-accident or probable-cause drug and alcohol testing, results will come back negative or positive; a positive result will need some analysis to determine if it is relevant to the accident.

Before ruling out impairment as a factor following a negative test, remember that federally-required protocols test only for a limited number of substances. A negative test result for FTA test criteria does not necessarily mean impairing drugs were not tested for by the FTA panel and were not involved.

Emergency Response Documents and Debrief

On-scene investigators should attend a "hot wash" session with responders documenting what went right and what challenges were encountered. Documentation produced by response agencies is valuable and should be obtained. Emergency response documentation may include:

- 911 call center logs showing time and source of initial notification and who was notified/dispatched.
- Fire department/Emergency Medical Services dispatch logs that show when the notification was received, when units were dispatched. and when they arrived on-scene.
- EMS triage logs that indicate how many people were triaged, color-coded tag counts, lists of names, and disposition of injured.
- IC log and notes, if available.
- Photographs and videos from response agencies and other parties.
- Control center or dispatch records, recorded transmissions, and any other event records.

Challenges or problems identified in the hot wash and debrief should result in a review of the agency SOPs and emergency plan resulting in revisions where warranted.

The goal of the emergency response element in a survival factors investigation is to determine if the response contributed positively or negatively to the event. It is safe to say that a delayed or substandard response by emergency responders coupled with severe passenger/operator injuries could result in additional fatalities or more severe injuries to passengers and the bus operator.

Effective Investigation Practice

For major events, responders will often hold a more formal debrief one or two weeks after the event. Investigators should attend and participate. Valuable information for the survival factors investigation will be covered at the debriefing.

An evaluation of medical response should be provided that includes a list of agencies involved in the response (transport agency, hospitals), number of individuals transported, and where they were transported.

Law enforcement response should be assessed to include which jurisdictions responded, when and how they were notified, when they arrived on the scene, how they assisted with the evacuation, crowd control, and information on who collected witness statements. It is important to debrief with as many emergency response, police, and medical staff to determine what problems were encountered while responding to the event.

Investigating Injury and Fatality Events

In a mass casualty event on a public transit system, cataloging injuries can be challenging. as uninjured passengers and "walking wounded" with minor injuries may walk away to continue their journey. Even determining the number of passengers involved can be difficult, as most transit agencies do not maintain a passenger manifest like some other modes of transportation. Some sources that investigators can use to catalog injuries and fatalities include:

- Vehicle interior video recorders
- Interior conditions that may include biological residue or impact deformations
- Claims
- Interviews
- Statements
- Triage logs
- Other emergency responder records

Based on these sources, investigators should prepare a simple grid cataloging the numbers and types of injuries (see example below). A detailed list of all fatal injuries should also be provided. Detail on where the individual was sitting during the event is significant to the investigation as is all pathological information relating to the individual's injuries.

Injuries and Fatalities at Scene*

	Employees	Responders	Passengers	Total
Fatal				
Serious Injury				
Non-Serious Injury				
Other Injuries				
Total				

*Includes individuals who stated they sustained injuries but *did not* seek immediate assistance and who were not transportation away from the scene.

Injured passengers and employees should be interviewed to document as much information concerning their actions just before, during, and after the event. Additional information should be collected, such as where the passenger was sitting at the time of the event and what they noticed about what other passengers around them were doing just before, during, and after the accident (see Survivor and Witness Questionnaire in Appendix D.) Injuries can be classified according to *NTD Safety and Security Manual* requirements.

Effective Investigation Practice

When interviewing individuals who were in accident vehicles, equipment layouts, photos, and scene diagrams should be available to help interviewees identify their location and the location of others for whom they may have information.

Survivability Factors[2]

The survival factors element of an investigation seeks to understand why some people were killed and injured and others walked away unscathed. Not every accident will need full-scale survival factor investigation; however, investigators should be aware of what is involved and assess whether such an evaluation is appropriate.

Understanding survival factors can lead to improvements in procedures and equipment design that save lives and reduce injury severity. Past survival factors investigations have resulted in many safety improvements that are now commonplace, such automotive seat belts, airbags, seating improvements, and emergency lighting. Survival factors investigations involve an examination of the following:

[2] National Transportation Safety Board Investigator's Manual Volume III – Regional Investigations.

- Evacuation of ambulatory passengers
- Evacuation or extraction of persons with disabilities, including persons in mobility devices
- Operator workstation and transit vehicle interior configurations
- Vehicle operator workstation and passenger area damage
- Fatal and nonfatal crash injuries
- Emergency response
- Disaster preparedness planning and training

A critical element of a survival factors investigation is documenting the response and actions of the emergency response and emergency responders. Several key facts need to be documented; information will come from emergency responder records and interviews with responders and persons attending post-event debriefings:

- Number of emergency responders on the scene
- Agencies represented
- Time of notification
- Delays in arriving at site
- Time ICS established
- Responder familiarity
- Command post
- Equipment used
- Adequacy of communication protocols and equipment

Survival factors investigations look closely at the preparedness training and exercises that have occurred in the past to understand how well transit agency personnel have been prepared.

Human Factors

The objective of the human factors (HF) portion of an investigation is to understand the nature and scope of human and organizational factors as they relate to transportation accidents. The methodology for conducting the investigation involves assessing information pertaining to the circumstances and conditions of an accident, operator background and performance, psychological and physiological sub-disciplines that can offer analytic explanations for operator performance (human and organizational), and the ergonomic and environmental issues affecting operator behavior.[3]

[3]The term “operator” may also include but is limited to dispatchers, MOW personnel, and others whose actions or inactions are of interest to the investigator.

The investigator is responsible for documenting and analyzing various HFs within the disciplines of engineering, physiology, and psychology. They should understand how these factors interrelate and interact and how they influenced the perceptions, decisionmaking, and actions of individuals involved in an accident.

Experience/Familiarity/Background

The investigator should determine an operator's experience and familiarity with both the equipment and the territory. Inquiries could include the following:

- Was this your first time operating this type of vehicle? If not, how much experience do you have with this type of equipment?
- Was this your first time in this vehicle? If not, how much experience do you have with this vehicle?
- Do you ever drive a different vehicle? How often? What is the difference between the two vehicles?
- Have you operated over this territory before? How often? Have you operated it under similar conditions? When was the last time you operated over this territory before the accident?
- For a route or planned trip, have you operated over this route/trip before? How often? When was the last time before the accident?

Distraction

Distraction, in simple terms, is the bus operator's attention on or to something other than the operating task. As research has shown, distraction can be a factor in accidents. The investigator should determine if the operator was distracted at or near the time of the event and should be cognizant that an operator may be reluctant to divulge information due to a fear of punitive actions. Inquiries could include the following:

- What were you doing just before the accident?
- What were you thinking about just before the accident?
- Were you mentally preoccupied with something just prior to the accident?
- Was there anything interesting or unusual outside the vehicle before the accident?
- Was there anything interesting or unusual inside the vehicle just before the accident?
- Did you have any special concerns about operations just before the crash?
- Did you have any special concerns about the state of the equipment just prior to the crash? Was anything inoperable or not working correctly just prior to the crash?

- Were you dealing with a customer, supervisor, or central/dispatch just before the incident?
- Were you listening to the radio? Did you change the channel/volume before the accident?
- Were you using or manipulating any device, such as the radio or a technology device, before the accident? (*Note*: Investigator should determine agency's electronic device policy.)
- Were you eating or drinking anything at the time of the accident? If so, what/when?
- Were you smoking or chewing tobacco at the time of the accident? If so, when?
- Were you adjusting any of the vehicle controls – A/C, heat, seat, windows, doors, before the accident?
- Do you have a cell phone? What is the number? Were you using/on a mobile telephone before or at the time of the accident (phone call, e-mail, text)? If yes, obtain complete details.
- Were you engaged in any personal grooming activities?

Task–Time Relationships

Not only is it essential to determine what the bus operator was doing at the time of the accident, but it is also necessary to decide on what time pressure, if any, the operator may have been under and how his or her activities relate in time to other activities or events. Inquiries could include the following:

- How long had you been operating at the time of the accident? How long had you operated that day? Did you take any breaks? When and how long? When was your last break before the accident?
- Were you operating on a deadline? Did you need to be anywhere at a particular time? If so, were you on time/on schedule? What would have been the consequences of being late? Of being early?
- If the accident had not happened, when would have been your next change—i.e., making a stop or a turn? How far in distance and time were you from that change when the accident occurred?
- Are you working a split shift?

In addition to a description of the task is the bus operator's perception of their workload. When assessing workload, typical and event-specific workload should be considered. Inquiries could include the following:

- How would you describe your typical workload when operating the vehicle (1–10 scale, light/medium/heavy)?

- How would you describe your workload just before the accident (1–10 scale, light/medium/heavy)?
- Do you typically perform any non-operational activities? What activities, how often, for how long, and why?
- Were you performing any non-operating activities before the accident? If so, what were they, when, and why?
- Do you remember what you were thinking about just before the event (i.e., was it related to the task – possible heavy workload – or not –possible lighter workload)?

Environmental Factors

Environmental factors include both external and internal conditions. Inquiries related to external conditions include the following:

- What was the weather like at the time of the accident (cloudy, sunny, raining, windy, snowing, clear)? (The investigator should remember to obtain weather condition reports as an independent verification of the operator's statement.)
- Had the weather changed recently?
- What were the surface conditions at the time (icy, wet, dry)?
- Had the road conditions changed recently?
- Had there been any changes in the type or configuration of roadway or intersection?

Questions related to the conditions inside the vehicle at the time of the accident should begin with the following:

- Describe any noise in the vehicle just before the accident.
- What was the temperature in the vehicle? Was the heat or A/C on?
- Were any of the windows or doors open? Which ones? How far?
- Were there any audible alarms or any illuminated warning indications on the bus operator's dashboard/console?

Illumination

The purpose of this questioning is to determine the level of illumination at the time of the accident. This will help the investigator determine how far the bus operator could see, what they could see, and if glare was a factor. Inquiries could include the following:

- Did the accident occur in the daytime or the nighttime?

- What was the direction of travel? Glare could have been a contributing factor to the event.
- Where was the sun/moon—overhead, setting, rising?
- Did the sun/moon cause you any problems?
- Did the headlights of other vehicles, reflections, or lights from the environment cause you any problems?
- Could you see and read your instrument panel?
- How well could you see other vehicles?
- Did the visibility or illumination level change before the accident?
- Was/were your headlight(s) on?
- Were you wearing sunglasses?
- How clean was your windshield? Any problems seeing through it?
- Were any of your vehicle's interior lights on? If so, why?
- If the accident occurred in a tunnel, how was the lighting/illumination, i.e., what was the condition of the tunnel lighting? Was the lighting sufficient for you to see everything?

Noise/Vibration/Motion

Noise/vibration questions help to determine if noise may have played a part in the accident. Also, by asking about vibration and motion, the investigator may be able to determine if a mechanical failure occurred or if some feature contributed. Questions could include the following:

- What did you hear just before the accident?
- Were there any new or unusual noises, either from the roadway or from the bus?
- Did you notice any unusual motion or vibration in the vehicle?
- Describe the vehicle's motion during the accident.

Training

Documenting bus operator training in the wake of an accident is of interest to the investigator. The following questions should initially be asked of an operator, tailored as needed and based on their level of experience and education and their familiarity with equipment, procedures, policies, and systems:

- What operator education classes or training have you had? List when and where you had the training, including the most recent training (before the accident) and describe it. Who offered/provided the training? What was your opinion of the quality of training?

- Have you had any on-the-job training? If so, provide details.
- Have you had any technical training? If so, provide details.
- Do you take any annual or recurrent training? If so, provide details.
- Have you ever been required to take re-training? If so, provide details.
- Have you ever taken any simulator training? If so, provide details.
- When did you receive your first license/certificate?
- What license/certificate do you currently hold?
- Based on your training, how confident are you in effectively and safely performing your duties?

The investigator should confirm the training completed by the operator. Sources of training information may include:

- Company records and company training personnel
- Personnel records
- Operational training procedures
- Simulator records
- Licenses/certificates
- Logbooks
- Fellow operators who may know the operator's skills and abilities

Health Factors

Health factors include the employee's general health, sensory acuity, and ingestion of drugs or alcohol including over-the-counter (OTC) and prescription (Rx) medication, and fatigue.

Source: Pixabay.com

General Health

The NTSB has subpoena authority to obtain medical records; however, a transit agency is restricted by HIPAA regulations, which were enacted to safeguard an individual's medical information. As such, the investigator will have difficulty determining the operator's state of general health unless the individual voluntarily provides this information. The investigator should discuss this issue with agency legal and medical personnel to ensure alignment regarding the proper protocols to follow during an event to ensure that HIPAA regulations are not violated. In many instances, the agency's human resources staff can be relied upon to review the employee's medical work history to determine if preexisting medical conditions were known and adequately controlled.

The investigator should evaluate the transit agency's medical screening process for medically-based conditions such as sleep disorders. Some transit agencies attempt to elicit this information from questionnaires, which may not be successful in identifying at-risk employees. Effective measures include such things as obtaining body mass index (BMI) or having an employee suspected of having a sleep disorder undergo a polysomnography (sleep study). An investigator should ask the employee questions about overall health, including the date of his last physical examination, results, or any problems or issues noted.

Sensory Acuity

An operator's sensory acuity may play a vital role in an accident; however, information on both vision and hearing may be protected by HIPAA regulations. This information may not be available to the investigator unless volunteered by the individual. Questions to ask the operator (or his/her family) include the following:

- How is your vision generally?
- How was your vision at the time of the accident?
- Do you have, or what you ever, had problems with your sight?
- Do you wear glasses/contacts? If yes, were you wearing them at the time of the accident?
- Do you see an optometrist/ophthalmologist?
- How is your hearing generally?
- How was your hearing at the time of the accident?
- Do you have, or have you ever had problems with your hearing?
- Do you wear a hearing aid? Were you wearing it at the time of the accident? When was the last time you had it serviced or changed the batteries? (An investigator should obtain the make/model/date of hearing aid manufacture)
- Are you under the care of an audiologist or another doctor for your hearing?

Drug/Alcohol Ingestion

A post-accident examination of drug and alcohol consumption should be compliant with FTA post-accident regulations found at 49 CFR § 655.44. This regulation requires that an alcohol test must be documented within two


Source: CUTR

hours, i.e., if an alcohol test required is not administered within two hours following the accident, the employer must prepare and maintain on file a record stating the reasons the alcohol test was not promptly administered. If an alcohol test required is not administered within eight hours following the accident, the employer must cease attempts to administer one and maintain the record. Also, regulations require that a drug test must be administered within 32 hours of the accident.

Unfortunately, many OTC medications are not currently part of the standardized testing panel. The investigator should determine and document the applicable transit agency policy or lack thereof on self-reporting the use of all medications by covered employees. Also, it is important to determine what drugs the operator did NOT take—regular or prescribed medications that the operator missed or chose not to take; the absence of a drug could be just as important as its presence. Areas of inquiry include the following:

- Do you drink alcohol? How much? How often?
- When was the last time you drank alcohol before the accident? How much?
- Do you use illicit drugs? Which, and how often? When was the last time you used illegal drugs before the accident?
- Do you take prescription medications? Which? How often? What doctor prescribed them (contact information needed?) What conditions do they treat?[4]
- Did you take your prescribed drugs in the three days before the crash? At what times? Did you forget to take any, or miss any doses?
- Did you take any over-the-counter drugs (aspirin, Tylenol) in the three days before the accident? When? Why did you take them?
- Did you take any herbal supplements, homeopathic remedies, or vitamins in the three days before the accident? When and why?

Fatigue

Fatigue is a significant problem across all modes of transportation. Fatigue can be defined as a subjective feeling of tiredness that has a gradual onset and can have physical or mental causes. For the purposes of this document, the focus is on mental fatigue—a temporary inability to maintain optimal cognitive performance. The onset of mental fatigue during any cognitive activity is gradual and depends upon an individual's cognitive ability and other factors, such as sleep deprivation and overall health, which can reduce mental and

[4] This is HIPAA protected information; however, the investigator may wish to discuss the employee's medical history with trained RTA Medical personnel, while following defined protocols.

physical functioning. Although the level of fatigue varies, causes of fatigue in a work context may include the following:

- Long work hours
- Split shifts or night shifts
- Long hours of physical or mental activity
- Insufficient break time between shifts
- Changes to jobs or shift rotations
- Inadequate rest
- Excessive stress
- Having multiple jobs
- Changes to home environment, such as new baby, change in patterns and routines, new or changing caregiver roles
- Changes in home relationship status such as divorce or separation
- A combination of factors

Effects of Fatigue	
Reduced decision-making ability	Increased tendency for risk-taking
Reduced ability to do complex planning	Increased forgetfulness
Reduced communications skills	Increased errors in judgment
Reduced productivity or performance	Increased sick time, absenteeism, turnover
Reduced attention and vigilance	Increased medical costs
Reduced ability to manage stress on the job	Increased incident rates
Reduced reaction time – both in speed and thought	Increased risk-taking behavior
Reduced memory/ability to recall details	Impaired judgment
Failure to respond to changes in surroundings	Lowered motivation
Unable to stay awake	Slow reaction time

The investigator should always try to obtain information on both the quality and quantity of an operator's sleep. The time of the accident should be noted for comparison to known circadian low points. Sources of information other than the operator include work schedules, work cellphone records, and logbooks. A baseline for on- and off-duty days should be established if possible, as well as specifics for the 72 hours before the incident and the two compared. Specific information to obtain includes the following:

- Times the operator awoke/went to bed each day
- Commute distance and duration
- Times, content, and duration of meals, including snacks
- Step-by-step recounting of activities, including times and durations

- Relationship between that day's activities and their normal ones—anything missing, anything new, anything odd
- People they saw or spoke with and times
- Time, duration, and location of any naps
- Any medications that are taken, including prescription, OTC, or herbal, including time and dose
- Time and amount of any intoxicant ingestion, including alcohol and illegal drugs

If granted an interview with the surviving bus operator, the most effective way to obtain this information may be to have them describe the events and actions that occurred beginning three days (72 hours) before the accident and move step-by-step through the days. The more detail that can be obtained, the better the investigator will be able to determine if fatigue did or did not play a role in the accident. If an operator declines to be interviewed or did not survive the accident, the investigator should attempt to obtain this information from family members, roommates, neighbors, co-workers, or other sources. The goal of the 72-hour history is to obtain, in as much detail as possible, information on the operator's activities in the three days before the accident. Information from this history will touch on every area of the HF investigation, making it one of the most important activities the investigator will undertake. It may be beneficial to go back slightly farther than 72 hours, to the time the operator awoke. (See 72-Hour Pre-Incident History Checklist in Appendix E.)

Change/Configuration Management (CM)

Source: Pixabay.com

When accidents are investigated, it is essential to understand what has changed or may have changed related to the various elements associated with the system being analyzed and the undesirable event being investigated. Failure to plan for and manage change may be part of the root cause of an accident. Configuration Management (CM) is a process for establishing and maintaining consistency of a product's performance and functional and physical attributes with its requirements, design, and operational information.

CM applies to both hardware and software[5] components, including operating rules, procedures, and drawings). Change to hardware and software needs to be evaluated and approved by affected agency departments and documented and

[5] "Software" is used in the generic sense to include written procedures, training plans, and other documents.

evaluated to ensure that changes do not adversely impact safety. Most agencies have a CM or change control board to monitor this process.

Types of change include:

- Climatic
- Operational
- External influences
- Personnel
- Maintenance Activities
- Technological
- System
- Budget for agency or unit

Climatic changes include variations in temperature, season precipitation, and acts of God. Investigators should be familiar with any special procedures triggered by temperature fluctuations. For example, in cold weather, there may be restrictions related to ice buildup on roadways; conversely, heavy rain may lead to traction issues or decreased visibility.

Operational changes include increased service (closer headways) to meet growing ridership demands, route changes such as timing or location, competition between maintenance forces and transportation personnel for access to revenue equipment, increased turnaround of transit vehicles, and new service modes (BRT for example) or new fuel or propulsion system (compressed natural gas [CNG], hybrid electric, or electric, as examples).

External changes include but may not be limited to:

- Increased ridership
- Shifts in populations
- Land-use change (zoning, development)
- Increased urbanization
- Population/demographic changes
- Land-use changes
- Regulatory changes

Examples of external changes that may impact system operation are transfer center issues with increased patronage and trespassing in busways. Regulatory changes may include changes to state commercial driver license requirements, hours of service, traffic codes, or vehicle equipment.

Personnel changes may include a high rate of attrition/retirement resulting in a significant loss of institutional knowledge, i.e., “brain drain,” along with inadequate succession planning for the organization. Other personnel changes may include recent hires and changes in senior management or political leadership. As attrition occurs, employee development is a vital component of a productive workforce; therefore, training programs should always be evaluated as part of the investigation process. Absence or inadequate programs for development of talent management to address brain drain can be at the root or contributory cause of an incident.

Maintenance-related changes include but may not be limited to:

- New power systems such as hybrids my require new equipment and processes
- Introduction of a new product that changes maintenance procedures
- Replacement of components, which results in the disarraying of wiring, leading to potential incorrect rewiring of circuitry
- Unauthorized substitution of parts or components
- Revised procedures that may have not been fully distributed to all departments
- Maintenance work on the CNG systems that may require new procedures and safeguards

Technology changes and other changes associated with the update of existing technologies or the testing and/or integration of new technologies may include:

- Lane departure and back-up warning systems
- Collision warnings and automatic emergency braking
- Traffic signal preemption
- Camera based driver monitoring/coaching systems
- Exterior camera obstacle detection and alerting systems
- Autonomous vehicle technology
- Alternative fuel, hybrid, or battery power
- AVL and route direction systems
- Other external or internal audio announcements or alerts

Investigators should evaluate the potential unintended consequences of technology changes. Agencies may adopt new technology for a variety of reasons, including the following:

- Improve performance
- Meet increased ridership demands
- Reduce accident claims
- Address retiring legacy systems that have exceeded their useful life

- Increase current system efficiency, i.e., track bus locations, control bus connections, alternative service needs
- Replace, recondition, retrofit equipment that has exceeded its life expectancy
- Component obsolescence
- Lack of support by manufacturer of equipment, or high expensive to repair and maintain
- Change-out of equipment at end of life cycle
- Legislative mandate, environmental regulation, or emissions control upgrades
- Design modifications and retrofits
- Upgrades as part of SGR initiatives

Key Points—Investigators should evaluate the potential unintended consequences of technical change. System changes may include new BRT lines or extensions, new bus schedules and/or new or modified routes, added transfer centers or other facilities; facility improvements, and new buses.

Acquisition of additional buses from other manufacturers may create compatibility problems concerning operational characteristics of different fleets such as brake and acceleration rates, operator interface, customer interface, and maintenance capacity and training. The need for the system to consolidate, accept, and operate more effectively may lead the agency to operate more than one type of bus service or bus equipment on any one line. The acquisition of new vehicle equipment or the mixing of different fleets needs to be thoroughly evaluated.

Budget changes include but may not be limited to the following:

- Procurement Department may order a part at a significant cost savings to the agency, not realizing that it is inadequate and could cause a malfunction or an incident leading to a major bus incident
- Budget constraints that may adversely impact maintenance and inspections and training.
- Low-bid requirements that may result in parts and materials that do not meet agency needs.
- Equipment specifications that may be rewritten to reduce costs at the risk of reducing safety and impacting warranty period performance.
- Labor costs that impact the budget, driving the need for increased productivity and greater mechanization without corresponding training.

The system may have changed because the Purchasing Department accepted the lowest bid. Those deciding to accept the lowest bid may not fully understand the operating needs of the new equipment, systems, or service procured. Part of the problem may be that the specification used was too general and did not specify the system performance requirements. Even if the specification was sufficiently detailed and accurate, the number of bidders might have been too low due to the difficulty of the project. (*Note*: This emphasizes the importance of including safety in the procurement process. If a specification is changed or a procurement in undertaken that does not meet the established specification, hazard analysis and safety risk evaluation would be required to ensure that the proposed change does not adversely affect the safety of the system.)

Analysis Phase

There is no obvious line that separates the fact-gathering phase from the analysis phase of an investigation. In the on-scene and early stages of the investigation, investigators are cautioned about reaching conclusions. This is important because they need to keep an open mind and not close off lines of inquiry that may yield valuable information.

At some point, usually days or weeks into the investigation, it is appropriate to begin analyzing the factual information developed. This serves to focus the investigation on relevant areas. For example, investigation of an intersection collision between two buses will concentrate more on signals, braking, operational performance, and human performance than on roadway conditions on a clear, dry day.

Analysis can be described as separating the significant few (facts) from the trivial many. The facts and necessary analysis will vary from event to event, but the process is the same. There are several analytical tools that may assist in determining cause, including the “5 Whys,” the Ishikawa Chart, Fault Tree Analysis, the SHEL model, and Root Cause Analysis. These methods are further described in Appendix F.

Section 4

Report Development and Corrective Action Plans

Report Timing

Generally, agencies have internal requirements to produce a preliminary summary report on the incident along with any recommended immediate actions within 24–36 hours. The agency policy may also contain timelines for interim and final reports. Although developing the report promptly is essential, the quality of the investigation and analysis should remain the top priority. Production of quality preliminary and interim reports can help assuage the impatience of those anxious for a final product in a complex investigation.

Report Format and Organization

The agency's report format will likely be driven by agency policy, unless there are state requirements. The report format in this manual uses an NTSB report format for convenience, and it is not intended to supplant what may be required by agency policy. Report headings may vary slightly based on the circumstances of the individual accident, agency standard, or the standard prescribed by any Federal or state oversight agency, if applicable. Appendix G – Bus Investigation Report Organization provides a suggested outline and contents of the report.

The *Chicago Manual of Style* is a useful standard for stylistic formatting (punctuation, numbering, references), unless otherwise directed by the agency style manual. Reports should be written in plain English; jargon and obscure technical terms should be avoided unless they are critical to an understanding of the event, in which case they should be defined or explained.

An investigation report should provide all the information necessary to reconstruct the accident later (e.g., for audit purposes or litigation discover and response). It should present specific findings and recommendations that should drive the development and content of CAPs.

Report contents should include the following items (see details in Appendix G):

- Acronyms and Abbreviations
- Executive Summary
- Factual Information
- Analysis
- Conclusions
- Recommendations

Report headings may vary slightly based on the circumstances of the individual accident. Less complicated and more minor accidents may use a more abbreviated format depending on the circumstances.

Accident Investigation Report Recommendations

Once the cause and contributing factors have been determined, the investigators, together with the associated agency departments, should develop a realistic and practical remedy to prevent a similar accident from happening again. The Recommendations section of the report should provide a set of actions that should be taken to prevent recurrences of the accident. These recommended improvements should be organized by time so that those requiring immediate action can be implemented and others requiring more time and funding can be scheduled for a permanent fix for the elimination of the problems leading to this accident. Long-term recommendations may require capital budgets, re-design, or extensive system modifications, i.e., retiring legacy vehicles or upgrading them with newer components.

Recommendations are action items. Each should begin with an action verb (e.g., conduct, revise, modify) that will result in measurable action. There should be a distinct logic chain from the facts to the analysis to the conclusions to the recommendations.

Recommendations will drive corrective actions, so they need to be worded in a way that supports the corrective action format and have identifiable and measurable outcomes. For example, a recommendation reading “improve emergency responder safety training” would not meet this test. A more focused approach is needed, such as “revise the emergency responder training program to cover the use of agency-supplied keys to open vehicle doors from the outside.” Recommendations should logically link to the corrective action plans.

Corrective Action Plan (CAP)

Corrective actions need to be linked to the investigation report and associated recommendations and developed in a way that is achievable and measurable. As with any action plan, a CAP should explain the action being taken, the reason, the person responsible for making it happen, and a realistic schedule. Without these key elements, an action plan is likely to fail.

Key CAP Elements	
What	What are the specific actions and measurable results?
Why	Links back to the accident investigation and recommendations
Who	Who (job title) is responsible for shepherding the action to completion?
When	Identify a realistic time frame and set a date.

The CAP should be developed by the department responsible for implementation of the CAP item in conjunction with the investigators (usually the Safety Department). The State Safety Oversight Aforgency (SSOA) is the regulatory body that will approve the CAP and approve and verify the closure. The SSOA should also be involved in CAP development.

Effective Investigation Practice

Example of Washington Metrorail Safety Commission required CAP elements include:

- Date CAP generated
- Unique CAP identifier
- Source
- Description
- Hazard rating
- Estimated cost and funding strategy, if known
- Interim mitigations in place (if applicable)
- Anticipated completion date
- Responsible party/department

The CAP puts the action into an actual implementation plan—how it will be done, who will be responsible for doing it, and when it will be completed. Complex CAPS may have interim milestones and multiple tasks under the control of different personnel.

Most agencies use a CAP database or spreadsheet as a tracking tool and to provide periodic reports on CAP status. It should be easy to use and allow for generating reports on current status. Additionally, CAPs should be monitored through regular status meetings, at which problems can be identified and resolved. Monitoring can also ensure that the implementation of a CAP is effective and allows for the identification and resolution of unintended consequences.

Some agencies have found that color-coding the CAP items is helpful, with green meaning satisfactory progress, yellow meaning falling behind schedule, and red meaning a risk of not meeting the schedule. This can also serve as motivation for responsible managers to stay on task.

The responsible manager will report that a CAP item has been completed. Before closure, the CAP item's satisfactory completion should be verified and appropriate signoffs documented.

Continuous Improvement – Tracking CAPs through Closeout

Continuous Improvement[6] is a process by which a transit agency examines safety performance to identify safety deficiencies and conduct a plan to address those identified. Continuous improvement auditing function allows the agency to:

- Assess the effectiveness of the SMS to determine if it was performing as intended.

[6] Federal Transit Administration, *SMS Safety Assurance Participant Guide*, v12_09282018.

- Assess adherence to the agency's written and intended SMS policy, procedures, and processes
- Identify causes of sub-standard performance.
- Develop, monitor, and modify CAPs to address sub-standard performance, including those identified through an accident investigation.
- Close CAPs once the effectiveness has been determined and there are no unintended consequences.

Even when fully implemented, the continuous improvement sub-component of SMS is always relevant and always improving to meet the needs of the agency; it should never be viewed as complete. The transit industry is never static; personnel, equipment, technology, routes, and the operating environment change constantly.

Appendix A

Investigator Go-Bag Contents

Investigators typically customize their go-bags (resource kit) to include items they anticipate using or have found useful in the past. The following are items that investigators should consider for their go-bags as they develop a resource kit for when duty calls.

Safety Equipment

- Reflective vest
- Eye protection – safety glasses, chemical splash goggles, chemical face shield
- Hard hat
- Gloves – vinyl/latex/nitrile examination gloves, chemical resistant gloves
- Bloodborne pathogens protection kit
- Cones/reflective triangles for traffic warnings
- Heavy duty flashlights (and batteries)
- Appropriate footwear

Investigative Tools

- Video recorder
- Tape recorder
- Camera, charged batteries, memory cards
- Flashlights, extra batteries
- Notepads, pens, graph paper pad, memory sticks
- Wireless electronic devices (tablet, laptop, smartphone)
- Templets for sketches
- Chalk, paint pens, spray paint
- Measuring wheel, non-metallic tape measure, other measuring devices
- Evidence control kit (containers/forms/tags/markers)
- Calibrated gauges[7]
- Drag sled

Pre-Identified and Up-to-Date Agency Manuals/Documents

- Schematics
- Rule books
- Other specialized documents and plans specific to agency operations

[7] Specialized tools should be kept calibrated, and users should be trained and familiar with their use. Some agencies choose to rely on technical staff to bring tools, make measurements, and record data while the investigator observes.

Appendix B

Documenting the Scene: Photography and Field Sketching

Photographs taken at the scene of the event can provide significant evidence to support the investigation process. An investigator should take photos as soon as possible after arriving at the accident scene and should focus immediately on things that may change quickly. It is important that agency investigators or photographers supporting the investigation have a plan prior to arriving on the scene, focusing on:

- Elements of the scene that should be documented through photographic evidence
- Relationships of objects to each other and photo angles required to capture sufficient evidence to support the investigation process
- Vehicles – damage (internal and external), location of each, vehicle identification numbers
- Location of vehicles to each other
- Overall accident scene (approaching the scene)
- Standards for photographs, e.g., avoiding angles that may result in distorted photos

Before collecting small pieces of evidence, photo document the point of rest, orientation, and location relative to the overall scene (Figure B-1) should be photo-documented. Unique identifiers on equipment and components such serial numbers or model identification should be captured.

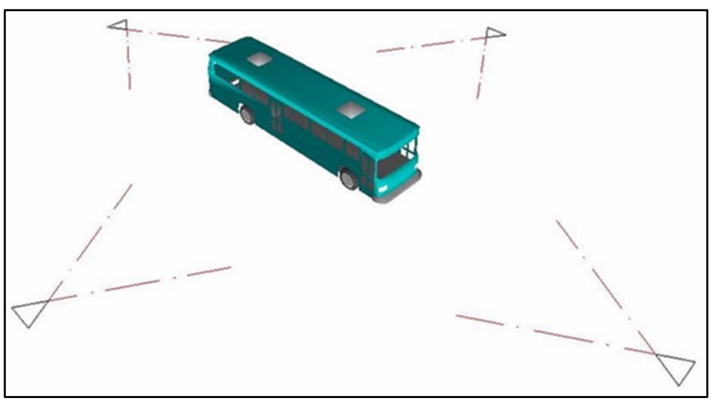


Figure B-1 *Standard Photographic Record (4-sided view of vehicle damage)*

Source: TSI

Occupant Compartment

Photographs of the occupant compartment in each vehicle should include:

- Instrument panel/dashboard:
  - Position of switches, levers, buttons
  - Readings on dials and gauges
- Contact damage inside vehicle
- Evidence of food, beverages, tobacco products, electronic device use, reading material
- Restraint devices
  - Seatbelts (worn, frayed, broken, cut)
  - Airbags (deployed, imprints including blood)
  - Infant/child seats (potential installation errors or other evidence of improper use)
  - Wheelchair restraint systems or other assistive devices (bent, broken, cut, or signs of mechanical failure)
- Evidence of occupant injuries (blood, hair, tissue, contact damage)

Photographs of vehicle features should include:

- External vehicle damage to each vehicle involved
- Relationship of vehicles to each other
- Point(s) of impact
- Tires

Marking and Measuring

After the initial response, arrival, and scene management responsibilities are carried out, the next step of the investigative process is to decide what items of physical evidence should be located, marked, and documented. The following is a guide but is not by any means all-inclusive:

- Determine if measurements are necessary.
- Photograph the scene.
- Locate transient evidence.
- Locate and mark each point to be measured, including:
  - Start of skid marks
  - Skid mark direction changes
  - Vehicle wheel positions at final rest
  - Gouges in roadway
  - Major debris points

- Note the location of fixed references such as adjacent buildings, traffic signage/signals, utility poles (note pole number if visible) or other objects.
- Make a field sketch of the scene.

After the decision is made on what items will be marked and recorded in the accident diagram how many marks or spots on the road surface should be addressed. Generally, if an accident is severe enough to warrant diagramming, the police will place their marks. Their measurements should be checked if it is anticipated that a piece of evidence was mismeasured. Many transit systems issue ordinary spray paint and lumber crayons to their supervisors for marking purposes. Bright orange or yellow paint is the most common, as it is easily visible and located for subsequent measuring. In the case of paint, less is usually best; there is no need to deface the roadway with colorful "art"—a simple paint dot to locate an item is sufficient. Paint is of little use on unpaved or dirt roads.

An alternative method for use on these surfaces is small flags or streamers, small (4–6 in.) pieces of wire to which bright streamers or flags are attached. Wire coat hangers and engineering tape (found at large hardware stores) are handy materials to make these flags; they can be used at every spot where paint would ordinarily be used and are easy to locate later, particularly across rough or uneven fields.

Marking tools and devices should be carried in investigation vehicles for when they are needed. It is the responsibility of each investigator to ensure that all necessary supplies are in the vehicle at the beginning of each shift. A professional transit investigator always knows what equipment they have and need. After determining what the investigator will want to measure, a decision has to be made on how many marks or spots will be used for each item. For vehicles, bodies, long tire marks, or large debris areas, one mark is insufficient. Figure B-2 shows an example of how one mark will not locate a vehicle's specific location and heading, as it can be facing in any direction if a single mark is used. If something large is measured with only one mark, its orientation will be unknown.

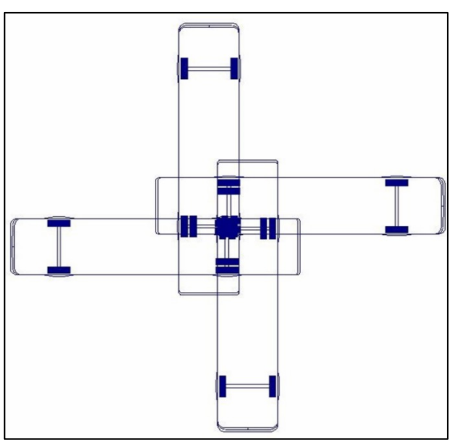


Figure B-2 *Marking Large Objects*

Source: TSI

Two or more points or marks are needed for items such as vehicles, bodies, skid or scuff marks, and large areas of debris. A marking on the front and rear tire (same side) of an automobile is usually sufficient. An articulated coach should be marked as if it were two separate vehicles. For a person, one mark at the head of a body and one at the navel are sufficient.

Straight skid marks are marked by a single spot at each end of the skid; this is repeated for every skid mark. A two-wheel vehicle such as a bicycle or motorcycle is marked by placing a paint or crayon spot at each wheel, as shown by the arrows in Figure B-3. For small objects such as gouges, minor scuff marks, or small debris areas less than 3 ft in diameter, a single mark or spot to the center of the object is sufficient. On curved tire marks such as yaw marks, stations along the mark should be located at 5-, 10-, 15-, or 20-ft intervals, depending on the length and sharpness (radius) of the mark. Large debris areas can be located by placing marks along its perimeter; 4–8 marks are usually sufficient.

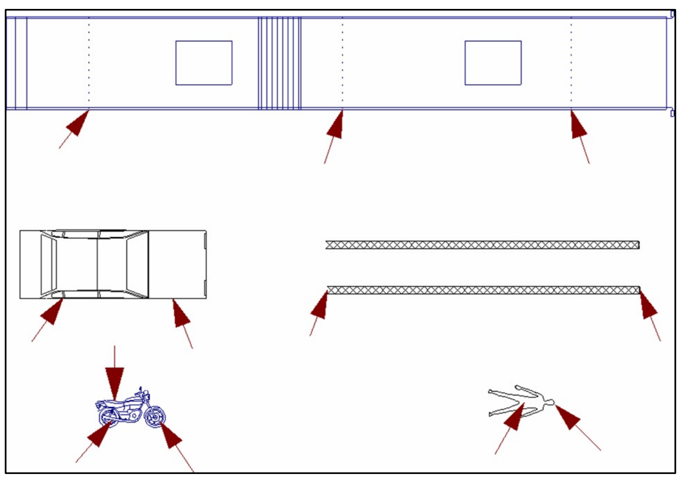


Figure B-3 *Where to Measure*

Source: TSI

Tire Marks, Scrapes, and Gouges

Marks on the roadway left by tires and vehicle components during the accident sequence need to be carefully measured and documented. Forensic analysis of these marks can aid specialists in reconstructing the movements of vehicles leading up to impact and provide information on vehicle speed and other operating parameters.

Tire marks fall into three categories—skids, yaws, and prints. Tire marks and roadway evidence are extremely important in determining how vehicles moved into the impact point and from impact to final resting locations. Before being able to adequately analyze tire marks, it is important to first understand how they are made and the braking mechanism involved. Most automobiles and paratransit vehicles use a standard hydraulic braking system for their primary braking systems and mechanically-activated brakes for their parking brakes. Transit buses use air brake systems, which are much more effective at stopping larger vehicles.

When brakes are applied, the vehicle tends to shift forward; this results in a weight transfer from the rear wheels to the front wheels. Although every vehicle is different, there are some generally accepted guidelines. Typically, 60% of the total weight of a rear-wheel-drive automobile rests on the front wheels during braking, leaving 40% of its weight applied to the rear wheels; this ratio changes for front-wheel drive vehicles and rear-engine buses. For front-wheel drive vehicles, the ratio is 70/30 front/rear and for rear-engine buses, the ratio is 40/60 front/rear. There are complex weight-shift equations that can provide an exact percentage of weight shift for a given vehicle; however, they are a bit more complex and beyond the scope of this guide.

When the brakes are applied, the kinetic energy of motion (as a result of the vehicle's mass times velocity) is transformed into heat by friction. If the brakes are applied strongly enough, the tire will lock. This is sometimes referred to as a 100% slip. The kinetic energy, or energy of motion, is then dissipated between the tires and the roadway surface in the form of heat. It is this heat that dissolves or melts the tars and oils on the roadway surface, thus creating a distinctive dark smear commonly referred to as a tire mark or skid mark.

Skid Marks

Although some small particles of tire rubber separate from the tire itself, a skid mark is primarily composed of asphalt tar. On concrete surface roads, skid marks are lighter in color. They are made by the rough concrete surface actually "grounding up" the tire or melting it. Sometimes the "squeegee" effect of the tire will clean the dirty road surface, resulting in a skid mark lighter in color than the surrounding surface. When a vehicle travels with its tires locked (sliding) through a soft or loose surface, it will plow through the loose material, pushing it out to the sides and ahead of the tire.

Skid marks show evidence of:

- Location and direction of vehicle travel
- Driver intention to stop
- Possible vehicle speed
- Area of impact by skid offsets

The skid mark shown in Figure B-4 was created by a tire that is locked, i.e. sliding, and not rolling. Skid marks tend to be straight, although they can exhibit some curvature due to asymmetrical braking (not all brake pads locking simultaneously) or the crown of the road. This can make the vehicle depart from a straight-ahead path. Front tire skid marks tend to be darker than rear tire marks (weight shift), and the outside edges of the mark may be darker than the inside area due to over-deflection of the tire (weight shift). The tire grooves are generally visible and easy to see in a skid mark. Rear-tire skid marks tend to be even in appearance, i.e., no dark outside edges.

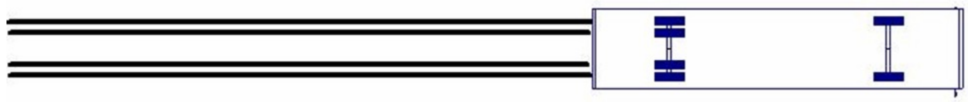


Figure B-4 *Skid Marks*
Source: TSI

Skid marks are an extremely important piece of physical evidence to the accident investigator. They can be used to determine the speed and establish the path of the vehicle while skidding. Unfortunately, tire mark evidence has a life span—it is affected by weather, sunlight, and traffic. Tire marks can be obscured by the movement of other vehicles at the accident scene (very common on gravel roads). Therefore, tire marks should be located, measured, and properly documented before their disappearance.

When looking for skid marks, it is of extreme importance to determine the point where the skid marks begin. This beginning point is a relatively faint mark compared to the rest of the dark tire mark. During the initial brake application, there is a short time delay between the time the braking system/tire combination locks the wheel and the point at which the tire heats up sufficiently to begin leaving a mark. This faint beginning is called the skid mark shadow. To locate this shadow, the investigator should kneel or bend down to the roadway level 20–30 ft ahead of the mark and look towards the apparent beginning of the skid mark. A second person is needed to assist the investigator in marking the beginning point of the shadow with a crayon or paint.

The location and inclusion of this faint beginning of the skid mark are extremely important for future use in speed determination. As much as 10% of a skid mark can be in this shadow, and overlooking it can underestimate the speed of the skidding vehicle considerably.

Curved skid marks indicate that the vehicle that made them was rotating while simultaneously skidding. When this occurs, all four tire marks can be observed. This rotation during a skid can be initiated by the driver beginning a turning maneuver; as the wheels are locked in braking, the vehicle continues in rotation. Curved skid marks can also be indicators of unequal braking. If left-side tires are braking with greater force than right-side tires, the vehicle will tend to rotate counterclockwise in the direction offering the higher resistance.

Curved skid marks can also be indicative of a half spin; this is a rotation of the vehicle 180° from its original direction of travel. This is caused by the rear tires locking up before the front wheels. A vehicle is less stable in terms of directional control when the rear tires lock up before the front ones. Rear tires will then lose the necessary lateral forces, which are essential to directional control of the vehicle. When this occurs, the vehicle will "switch ends."

If there is a question as to the operational status of all or any brakes, an examination of every tire should be conducted to reveal the presence or absence of abraded areas at the road/tire interface, also known as skid patches.

When skid marks are not continuous but are intermittent, they may have been made by a vehicle bouncing along on the roadway (Figure B-5). In this situation, the length of the skid mark and the length of the space between them is uniform and consistent, and less than 3–4 ft apart. This condition can result when the wheel strikes a pothole or bump on the roadway which starts the vehicle bouncing.

Figure B-5 *Skip Skid Marks*

Source: TSI

Skip skids should be measured for total length so the gaps are included in the finished measurement; these gaps are part of the skid mark. Vehicle braking is not reduced during the skip portion of the skid by virtue of the wheels being off the ground for such short distances. Although actual braking does not occur during these short intervals when the wheel leaves the ground, heavier braking occurs when it returns to the ground to compensate for the missing distance. This effect tends to average the energy lost and results in valid speed estimations from skip skids. Skip skids, like any tire mark, should be documented accurately and photographed for further evaluation of the skid mark.

Skip skids are different from the marks made by antilock brakes, although they are measured the same. Antilock brake marks show a consistent width while with skip skids, the width varies as the tire bounces. Many times, skid marks are observed when there is a gap between the termination of the skid marks on the roadway and a re-initiation of the skid mark some distance down the road (Figure B-6). This is the result of the driver applying the brakes and subsequent release and re-application.

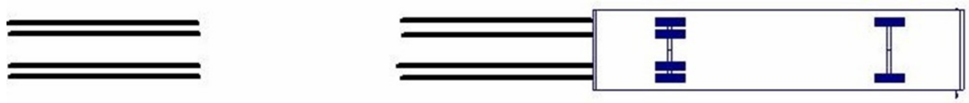


Figure B-6 *Gap Skid Marks*
Source: TSI

Sometimes the driver will momentarily release the brakes because they believe that the conflict situation ahead, in which an accident appears imminent, has passed, only to re-apply them again when they realize that the initial judgment was incorrect. This is a typical situation in accidents with pedestrians or bicyclists, where the slower movement of the person or bicycle can change suddenly from what the driver anticipates. Unlike skip skids, such gaps in skid marks are not included in the overall measurement of the skid mark. Gap skids are measured separately as if they were made by two separate vehicles. A combined speed approach is then used to calculate a speed. The following section on speed calculations presents the mathematical approach for this situation.

Acceleration Marks

Often, tire marks that look like skid marks are acceleration marks (Figure B-7), which are created when a vehicle accelerates rapidly from a stopped position or moves at a slow speed to make dark tire marks. These acceleration marks closely approximate skid marks in their appearance, beginning as heavy dark marks and slowly disappearing as the rotational velocity of the tire starts to approach the linear velocity of the vehicle. One characteristic common to acceleration marks is their linearity. When rapidly accelerating a vehicle under maximum forward acceleration, some steering is necessary to maintain a straight path. This is because the torque from each wheel may not be equal at each rear tire because of road-tire interface differences. This small difference should then be corrected by steering. This results in a curved or "wavy" appearance.

Figure B-7 *Acceleration Marks*
Source: TSI

Tire Tread Prints

Tire tread prints can illustrate:

- Location and direction of vehicle travel
- Driver's intention not to brake
- Driver's intention to steer the vehicle

An imprint of the tire tread pattern indicates that the wheel was rolling (Figure B-8) and not skidding. The effect created is much like an ink stamp, in which the pattern of rubber is imprinted on a flat surface without smearing. The print may be the result of loose matter picked up by the tire as it rolled on the roadway. Tire prints are different from skid marks in that they convey the tire tread pattern of the tire without any of the slick or smoothly-worn features characteristic of a skid mark. In addition, the print pattern is uniform in contrast and noticeably similar to other print marks left by tires on other wheels of the same vehicle.

Figure B-8 *Tire Tread Print*
Source: TSI

Yaw Marks

Scuff marks, also known as yaw marks or critical speed scuffs, are tire marks left on the roadway by wheels that are sliding and rolling simultaneously (Figure B-9); the wheel is rolling and slipping sideways at the same time. Yaw marks are always curved and have very distinctive striations. As evidence, yaw marks show that the vehicle was traveling too fast to negotiate a curve, the vehicle's location and direction on the roadway, and the driver's intention to steer rather than stop and are very accurate in determination of vehicle speed.

When a vehicle "spins out" or "slips out" while cornering or is oriented in a direction different from its direction of travel, scuff marks will be deposited. Often, they are in the form of light parallel grooves, referred to as striations or hash marks, which run straight but are diagonal to the outline of the continuous scuff mark. They are made by the sidewall or rib of the tire. An important piece of information from scuff marks is that the vehicle was taking a turn at a critical cornering speed. Critical cornering speed is the speed at which the vehicle is on the threshold of spinning out or slipping laterally.

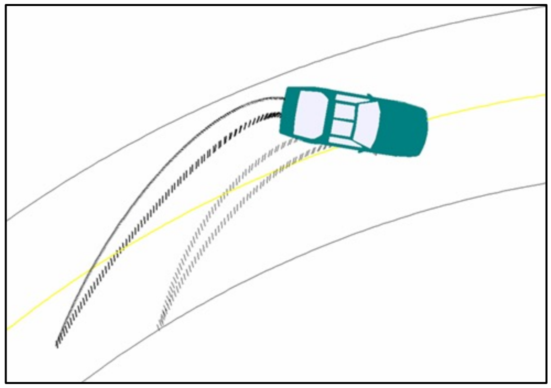


Figure B-9 *Typical Curved Scuff Mark Appearance*
Source: TSI

Tire scuff marks that occur under these circumstances are critical speed scuffs made by tires sliding as the vehicle traverses a curve and are made by the outside edges of the tires. The scuff mark left by the rear tire will fall outside the scuff mark made by the front tire for that side of the vehicle tending to slip off the roadway as a result of centrifugal force. It is important to remember that scuff marks are made by steering or slightly oversteering, as opposed to skid marks, which are made by braking. Two important characteristics to look for when examining scuff marks are their curved path and the striations (see Figure B-10).

Figure B-10 *Close-up View of Scuff Mark with Striations*
Source: TSI

Metal Scars

When a moving vehicle is damaged in such a way that metal parts come in contact with the roadway surface, scars or scratches are left. Scars are helpful in indicating the direction of movement of the vehicle on impact. When correlated with the parts of the vehicle that made the scars, they can also confirm the position of the vehicle on the roadway at impact.

Scars resulting from rollovers may indicate where the vehicle initiated its rollover movement. A vehicle sliding along the pavement on its side or top leaves distinctive scratches made by sharp sheet metal edges or other protruding parts. Scars may also indicate the direction of impact and the relative force of the impact. This is true when the scar can be matched with the undercarriage portion of the vehicle (engine, frame, transmission, differential, or other components) that made the scar.

There are also some instances in which scratches on pavement before impact are indicative of a failure of vehicle components. An example of this is when scratches occur from the rim of a wheel, which sustained a flat tire before the accident. This can be confirmed by the distinctive pattern of a wobbly flat tire as it moves across the pavement.

Gouges can be distinguished from scratches, in that they are much deeper and broader and tend to chip or chop chunks of road surface material. Examination of the undercarriage of the vehicle can indicate abraded areas that may have gouged the pavement. Deep gouges are characteristic of severe head-on accidents, where the front ends of one or both vehicles are driven down into the road surface with tremendous force. These deep road gouges are good indicators of the point of impact or area of the accident.

Field Sketching and Diagramming the Scene

All investigators should feel comfortable sketching an accident scene, capturing the important aspects of vehicles, debris, marks, as surface gauges, as examples. The template shown in Figure B-11 is a useful tool for developing field sketches.

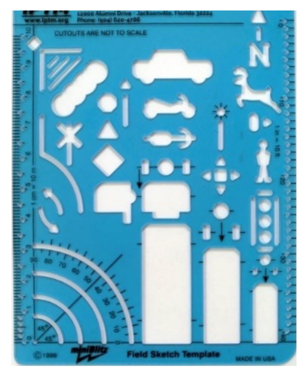


Figure B-11 *Field Sketching Template*

Source: CUTR

An accident scene diagram is of the highest importance, as it assists in the visualization of what the scene looked like. A useful diagram helps the investigator later if it is necessary to testify in court with precision and confidence. A diagram also helps in the reconstruction of the accident if it becomes necessary later. Many transit agencies use the diagrams prepared by local law enforcement and may not be required to develop field diagrams.

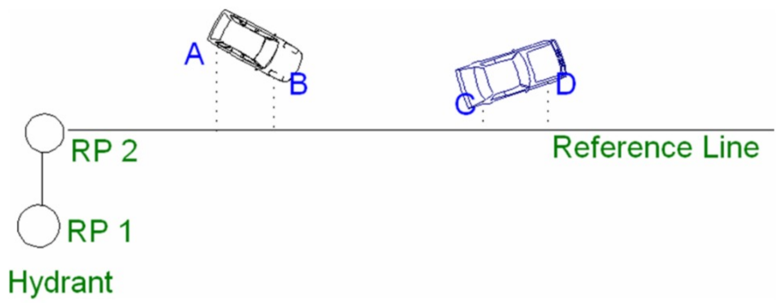
For transit agency investigators who are required to diagram an accident scene, there are several methods that have been developed over the years and are in widespread use. Some of these techniques are simple to learn and use, and others are somewhat complex and require considerable amounts of training.

There is very little doubt that traffic accident investigation is, by its nature, a technical task. However, most on-scene investigative work is often carried out by field supervision; this is particularly so in smaller transit systems.

With the above in mind, it is easy to understand the need for transit systems to teach their investigators simple yet effective accident mapping techniques. Two of these methods are coordinate and triangulation techniques.

Coordinate Method

The coordinate method (Figure B-12) is based on locating specific spots using distances from a fixed reference point (RP), along a reference line (RL). In using this method, a vital ingredient to accurate measurements is the selection of a good RP. If future reconstruction of the accident is necessary, the RP becomes the key from which the scene is mapped. Some examples of good RPs are highway mileposts or mile markers, utility poles, fire hydrants, culverts and bridges, intersections of roadways, and any other artificial or natural point of a permanent nature.



Point	From "0" or RP	From Ref Line	Description
A	25'6"	18'3"	Acura RR Tire
B	36'8"	14'2"	Acura RF Tire
C	45'5"	6'9"	Mercury RR Tire
D	57'9"	9'9"	Mercury RF Tire
Legend. Location: Continental Way near Storch Blvd. RP 1 Fire Hydrant. The street is 36' wide			

Figure B-12 *Coordinate Method*

Source: TSI

When selecting an RP, keep in mind that if the RP is destroyed, then surveyor plans, street maps, engineering drawings, and other resource documents should be available that will enable the reconstructionist to "place" the RP back at its original location. The RP is the keystone from which the entire accident is measured and drawn; an incorrect RP selection would make exact reconstruction of the accident at a later date difficult, if not impossible, to the degree of accuracy required.

To use the coordinate method, as with any other technique, the accident investigator first prepares a field sketch of the scene showing all important items and then assigns each significant item a letter of the alphabet starting with "A." The investigator draws a table where all measurements will be recorded, which can be next to the field sketch or on a separate page. The table should include a legend and consist of geographical location of the accident, scene, weather, and roadway width, complete description of the RP, and investigator name, as well as date the diagram was prepared and an explanation of any non-standard symbols used. Figure 14 (above) shows a simple scene sketch, including a measurement table and legend. The legend will show the accident measurement data in four separate columns: point, from “0” or RP, from roadway edge, and an identifying description of each item or point. The first column is the alphabetical listing of all significant items marked at the accident scene. After reaching the letter “Z,” the investigator can go on to “AA,” “BB” or an alphanumerical system such as “A-1,” “A-2” can be used. The next column (from "0" or RP) will show the distance from the RP along the RL to a point abreast or perpendicular to each significant item. At each point, the investigator places a mark (paint, crayon) and continues to measure up to the next point. The “0” designation is used when the RP does not lay directly on the RL, such as when using a telephone pole as the R. This is commonly referred to as "bringing" the RP to the roadway edge by measurement. This distance is not part of the table, but it should be shown in the legend. It should be noted that the coordinate method should not be used when significant items are more than 35–40 ft from the roadway edge, as accuracy begins to suffer beyond this distance. In such a situation, a triangulation-based method is recommended.

After this process has been completed, the investigator then measures the distance from the roadway edge out to each significant item. This information is recorded under the "From Roadway Edge" column next to its corresponding letter. Thus, a set of measurements or coordinates is established for each significant item. The last column, "Identification," is a short description of each item in the diagram.

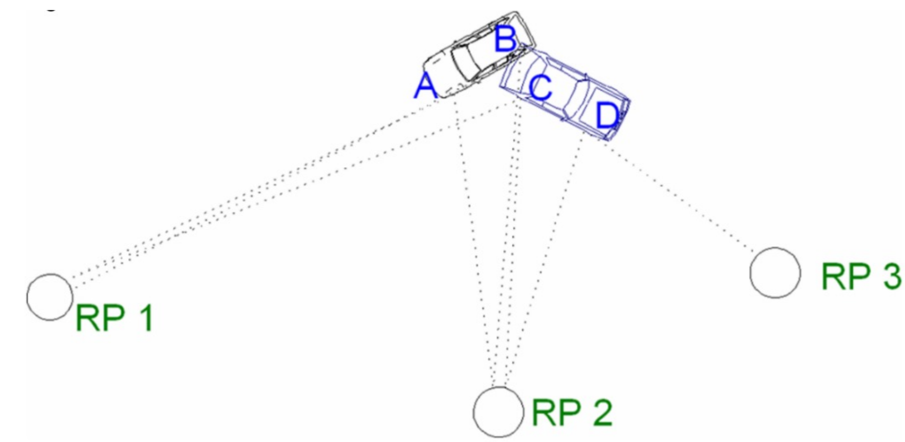
Equipped with this information, the investigator is now ready to prepare a post-accident or final position diagram. If the diagram is to be to scale, then they will need additional information such as radii of any curves.

Triangulation Method

Often, the final rest positions of vehicles involved in accidents, particularly in rollovers, are too far from any convenient roadway edge RLs, rendering the coordinate method somewhat inaccurate when distances beyond 30-40 ft from roadway edge are involved. This is a common occurrence along county and state highways, where the high velocities involved sometimes cause the accident vehicle to arrive at its final rest at a considerable distance from the roadway.

This inability to determine right angle straight lines out to an object is due to parallax error, an apparent change in position of an object when viewed from two or more positions not precisely in line with the object—the greater the distance, the more significant the margin of error.

In these cases, the triangulation method (Figure B-13) presents a much more accurate alternative. When using triangulation, each significant item is located by establishing fixed distances from two RPs along a RL. In the example, point "A" is determined by (1) measuring the distance from the first RP (RP 1) to "A," (2) measuring the distance from RP 1 to RP 2, and (3) measuring the distance from RP 2 to "A." The investigator can use as many RPs as necessary; the only criterion to keep in mind is selecting RPs that will maintain an evenly-spaced or equilateral triangle.



Point	RP 1	RP 2	RP 3	Description
A	65'7"	65'0"		Acura LF Tire
B	78'2"	71'3"		Acura LR Tire
C	78'3"	66'9"		Mercury RR Tire
D		52'1"	42'11"	Mercury RF Tire
Note: RP1 to RP2 65'4". RP 2 to RP 3 49'5"				

Figure B-13 *Triangulation Method*
Source: TSI

Each of these steps is repeated for every significant item in the diagram. The accompanying table shows the recommended method of documenting these measurements. Two measurements should be obtained for each significant item.

To draw the diagram to scale, a standard compass, previously adjusted to the distance required using the scale on the template, is used to draw an arc from each of the RPs. The point at which they intersect is the location of the significant item.

The coordinate and triangulation methods are simple, easy to learn, and do not require a large amount of equipment or time to use. They are accurate and will cover every accident diagramming an investigator is asked to perform, with minor modifications. The coordinate method is easier to use and can be applied to about 90% of all accident scenes, and the triangulation system is available for those few times it is required.

Drawing the Scale Diagram

The last step in the measuring and diagramming process is to prepare a scale diagram. This is a representation of the accident scene, which is proportionate to the actual scene, based on a given scale. Most accidents investigated by supervisors will require no more than a simple, not-to-scale diagram showing final vehicle positions and other physical evidence. Scale scene diagrams are time-consuming and not necessary for most accidents. Local law enforcement officers and investigation units may be collecting the measurements and diagramming the scene as described in the following section. The investigator should communication with local law enforcement agencies to determine if they are performing these steps and if access to the investigation drawings and diagrams is available.

To draw an accurate and technically-acceptable scale accident diagram, the following are needed:

- Field sketch
- Field notes
- Table of measurements and legend information
- Paper and fine point pencil
- Template with 1–10 and 1–20 scales
- Compass

Source: istock.com

The first step in drawing a scale diagram is to determine which items are going to be included. It would be technically possible but extremely time-consuming to attempt to add every single item at the accident scene, such as sidewalks, poles, street signs, bushes, and other items commonly found on or near the scene; only items that are relevant to the accident should be included.

All roadway evidence, such as skid marks, should be included in the drawing. The final positions of the vehicles are critical to an understanding of the accident and are also shown. The roadways involved should be shown, but sidewalks and gutters are not included unless they are of relevance, i.e., in the case of a bus jumping a curb and striking a pedestrian on a sidewalk.

In drawing the diagram, a template designed for accident mapping is essential. Two templates commonly used by investigators are the Traffic Template and Calculator from Northwestern Traffic Institute and the Blue Blitz from the Institute for Police Technology and Management; both are plastic, have a nomograph for speed calculations, include unique cut-outs for drawing cars and trucks, and have the two most commonly-used scales—1 in. = 10 ft and 1 in. = 20 ft, or 1=10 / 1=20. These scales are printed on either edge of the template.

The selection of scale to be used in the diagram will determine how large the final product will be. A standard 8.5 x 11-in. sheet of paper will accommodate an accident scene of approximately 160 ft x 135 ft on a 1=20 scale and 81 ft x 68 ft on a 1=10 scale. If a larger diagram is necessary, flip chart paper can be used or additional sheets of paper can be taped together or a smaller scale can be used.

In drawing the diagram (Figure B-14), include a North arrow towards the top of the page, an accepted rule in mapmaking that should be complied with whenever possible.

To show intersection curves or other roadway curves to scale, certain measurements have to be obtained at the scene:

- Chord – straight line intersecting a curve at two points (tangent)
- Middle Ordinate (M.O.) – shortest distance from center of chord out to point on its perimeter
- Radius – distance from center of a circle to a point on its perimeter

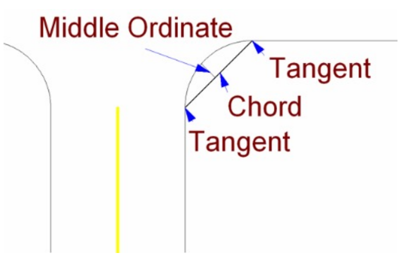


Figure B-14 *Intersection Curve Diagram – Chord Line, Middle Ordinate, and Tangent Points*

Source: TSI

The first step in calculating the radius of a curve is to measure its chord line. This is done by stretching a 100-ft tape from tangent point to tangent point; at the midpoint, the middle ordinate is then measured out to the curve. For example, if the curve chord measurement is 50 ft, then the middle ordinate measurement would be taken at the 25-ft mark. (*Note*: Law enforcement on the scene may be completing these calculations and documenting them in the accident record.)

Once the chord and middle ordinate measurements are recorded and roadway width measurements are taken, then all necessary information is available to go to the next step in the process. A mathematical calculation using the radius of a curve equation must be completed before using a compass to draw the curve:

$$R = \frac{C^2}{8M} + \frac{M}{2}$$

Where R = radius of curve, C = chord measurement, M = middle ordinate measurement, and 8 & 2 are constants (in a mathematical equation a constant is a value that never changes its value; i.e., in this equation, 8 and 2 are always used as such.])

For example, the next series of steps will show how the equation is worked out, using a value of 50 ft for the hypothetical roadway curve and 7 ft for the middle ordinate. The final result of the equation is a radius of the curve of 48.14 ft. In actuality, 1/10 of a foot is a little over 1 in., which is impossible to discern in a 1=10 or 1=20 scale diagram, so the measurement can be rounded down to an even 48 ft.

$$R = \frac{50^2}{56} + \frac{7}{2}$$

$$R = \frac{2550}{56} + 3.5$$

$$R = 48.14 \text{ ft}$$

Step 1 in the process of drawing the curve is accomplished using the template and an ordinary drawing compass. Two straight, intersecting lines are drawn, as shown in Figure B-15, with the “cross” on the side of the page where the curve will be. This can be a trial-and-error process, and the investigator will improve with skill with practice. After determining the scale for the diagram (1=20 for most diagrams), the compass gap is adjusted to the distance calculated in the radius of a curve equation using the template—in this case adjusted to 48 ft. The sharp metal point of the compass is placed at the intersection of the two lines, and two short arcs are drawn, intersecting each line, as shown in Step 2.

In Step 3, the sharp point of the compass is placed at the intersection of each arc made in Step 2, and two additional arcs are drawn towards the side the final roadway curve will be. Step 4 consists of placing the sharp point of the compass at the intersection of the last two arcs drawn, then drawing the curve from one side to the other (Step 5). The straight lines are erased, leaving a perfect, to-scale roadway curve (Figure B-16).

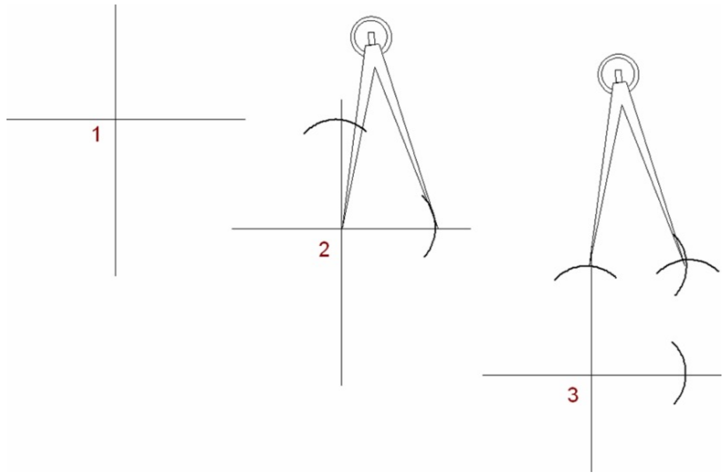


Figure B-15 *Drawing Curves to Scale – Steps 1 through 3 Used in Drawing Intersection Curves to Scale*

Source: TSI

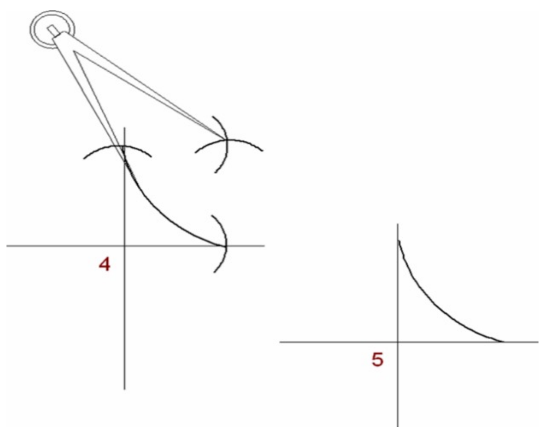


Figure B-16 *Final Steps in Curve Drawing Process (Steps 4 and 5)*

Source: TSI

The process is completed by extending all lines and measuring the space between the lines with the template to match the roadway widths at the accident scene (Figure B-17). Once the curve drawing procedure is carried out three more times, a four-way scaled intersection is finished. The investigator should keep in mind that, although all four curves at an intersection are generally of the same radius, this is not always so; each curve should be measured to ensure accuracy.

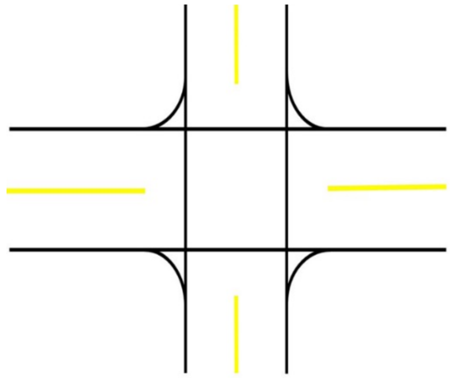


Figure B-17 *Four-way Intersection with Curves Drawn to Scale (Before Erasure of Roadway Edge Lines)*

Source: TSI

Not all intersections are four-way or T-bone, meaning they do not all meet at easy-to-draw 90° angles without measuring the actual angles. Many roadways join at acute or obtuse angles, such as depicted in Figure B-18. If the investigator guesses and draws the intersection freehand, it is no longer a scale diagram. The investigator should first determine the angle at which one roadway meets the other.

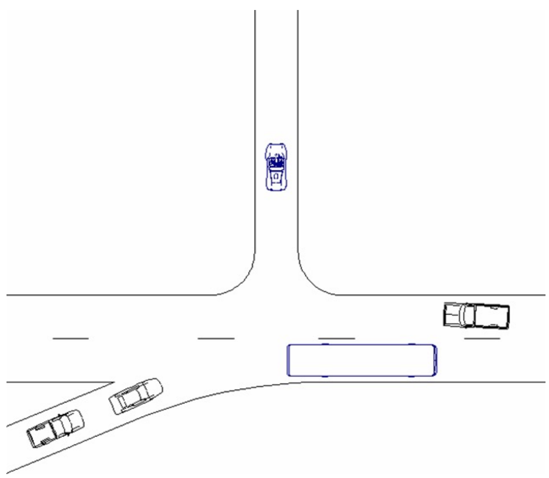


Figure B-18 *When Angles are Not 90°*

Source: TSI

To do this, the investigator first should visually extend the roadway edges and mark the point at which the two meet (apex). Then, an arbitrary but equal distance is measured and marked from the apex along each roadway edge (A and B in Figure B-19). The distance between A and B is recorded, along with the first distance measured.

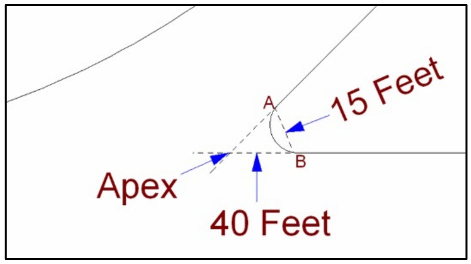


Figure B-19 *Measuring Intersection Angle – Establish Apex and Mark Off Point along Each Side*

Source: TSI

For example, assume that the first distance is 40 ft and the second is 15 ft. The investigator begins by drawing a straight line across the page, keeping in mind where the intersection will come in. Using a compass/template and adjusting the gap to the first distance (40 ft), the investigator then draws an arc with the sharp point of the compass at the apex. The arc will cross the first line drawn, as shown in Figure B-20 (Step 1). The compass is removed and adjusted to the second measurement (15 ft), and the sharp point is placed at the intersection of the straight line and the arc. A second arc is drawn intersecting the first arc (Step 2).

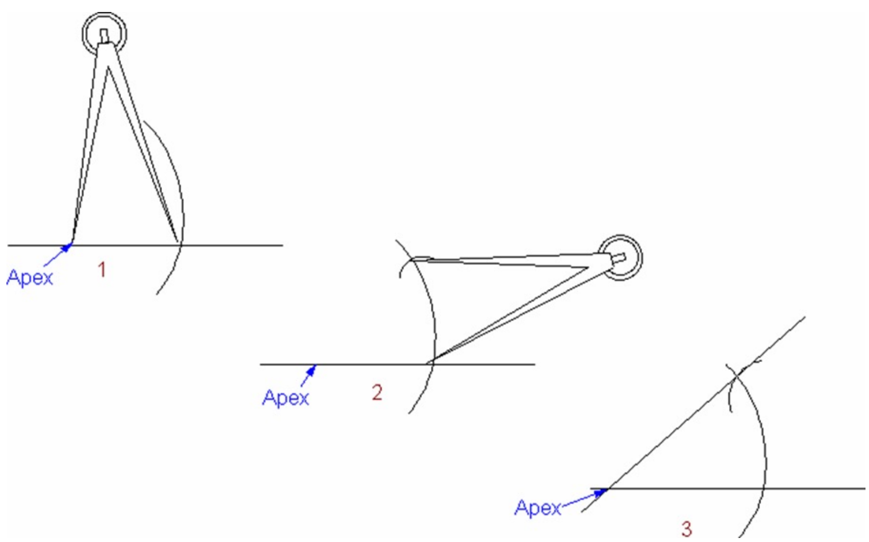


Figure B-20 *Steps to Draw Angled Intersection to Scale*

Source: TSI

The next step is to connect the apex and the intersection of the two arcs using a straight edge; this will provide the angle of the intersection. To complete the drawing, the other two roadway edges should be added in accordance with the actual roadway width measurements. The last step required is to draw the radius of each curve. The mathematical equation is the same as that used for 90° intersections, but the process to draw the curves is slightly different.

Once the angle intersections have been drawn to scale, the radius of each curve is added. Two parallel lines are measured, one on each side of the angle and to the distance of the radius obtained from the equation. Where these lines cross, the sharp point of the compass is placed to draw the curve. This process is repeated for the opposite curve, using the radius calculated for that curve. Figure B-21 shows how to complete these steps.

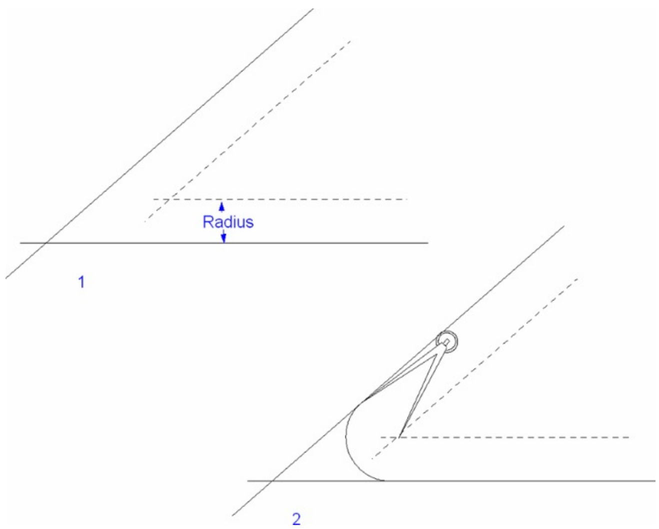


Figure B-21 *Drawing Curve Radius to Scale (Angled Intersection)*

Source: TSI

Appendix C

Key Points for Conducting Interviews

One-on-one interviews may be necessary for the investigation, particularly when obtaining witness statements after an event, as witnesses may be anxious to leave the scene. An interview team of two is preferred, one person to conduct the interview and the other to take notes or record the interview. Approval should be obtained from witnesses prior to recording the conversation. Having a second person as a witness may also be desirable in some cases. Larger groups of interviewers can be challenging and require a leader to set clear ground rules about questions and the interview process.

Key points for team interviews:

- Designate one person as the lead interviewer.
- Maintain a professional and non-judgmental atmosphere; an interview is not an interrogation.
- Do not allow other interviewers to interrupt each other or the interviewee.
- Agree not to interrupt the questioning; each interviewer should wait their turn.
- Establish when follow-up questions to an interviewer's initial question will be addressed.

Interviews are conducted to obtain factual information to verify other data already obtained and to understand different perspectives of the same event. People involved may have information not obtained; information is needed to develop a factual record, and interviewee cooperation is needed. Some people may be compelled to be interviewed but cannot be compelled to be helpful; establishing rapport is key to success. Also, interview objectives may change.

Potential interviewees include:

- Operating & maintenance personnel
- Supervisors/managers
- Victims
- Bystanders
- Residents
- People familiar with potential participants
- Friends
- Coworkers
- Managers
- Emergency crews such as fire and EMS
- Hospital staff

- Law enforcement
- News media
- Walk-ups

Key interview points before the interview starts:

- Introduce yourself, present identification, and chat with the interviewee.
- Explain the process, your role, and the identity of others who are present.
- Put the interviewee at ease as much as possible.
- Explain that they can call for a break anytime.
- Identify their concerns and try to address them.
- Answer any questions they may have.
- Explicitly instruct them to generate information—explain the ground rules.

Key points on question sequence:

- When there are two or more interviewers, follow a predetermined order of questioning; do not interrupt each other.
- Begin with open-ended questions—What happened? Walk me through it in detail.
- Determine beforehand the order of issues to be addressed in questioning each interviewee.
- Guide the interviewee back to areas of interest where more detail is needed.
- Introduce new issues after each issue has been addressed in turn.
- Use one of two types of sequences of issues with interviewees—chronological order or order of importance.
- Address issues that the interviewee may have raised while discussing another issue, even if it means going out of sequence.

Key points on attending to the interviewee:

- Always show attention to the interviewee.
- Be aware of and avoid non-verbal interviewer cues that may unwittingly be sent to the interviewee.
- Ensure that the interviewee is comfortable and that the interview location is free of distractions. Stop the interview if the interviewee appears uncomfortable or begins to lose their composure; this is especially important if interviewing a victim of the event.
- Do not offer the interviewee career or personal assistance but demonstrate concern for the interviewee. Suggest a break if the interviewee becomes emotional or seems stressed.

- Have paper or whiteboard available in case the witness wants to draw a diagram. Also have a scene sketch available so that the witness can point to what they have seen.
- Have a passenger car interior layout available to aid an interviewee in recalling locations of people or events.

Key points on follow-up questions:

- Use follow-up questions when one of several interviewers has not pursued an issue that an interviewee has raised or when an interviewee has raised multiple issues in response.
- Ensure that other interviewers wait until their turn to follow up on an issue rather than disrupt other interviewers.
- Allow each interviewer at least two opportunities to ask questions, one to ask the initial questions and a second for follow-up questions.

Key points on false responses:

- Rephrase or refocus questions if there is a reason to believe the interviewee has answered questions falsely.
- If there is contradictory factual information available, ask the interviewee to explain the discrepancy in a non-confrontational way.
- Do not express disapproval or attempt to coerce a truthful response from the interviewee.
- Do not use a prosecutorial tone in asking questions.

Key points on concluding the interview:

- Ask the interviewee if they have anything else to add or change.
- Ask if there are any questions they have that should have been asked.
- Ask for any suggestions for preventing a recurrence.
- Ask if they can think of anyone else that should be interviewed to understand what happened.
- Give interviewees business cards and ask them to contact you later if they have additional recollections or further information to provide.
- Let the interviewee know that they can contact you with any questions that they may have; this will also allow you to collect any follow-up information.
- Thank interviewees for their cooperation.

Appendix D

Survivor and Witness Statements and Questions

Injured passengers and employees should be interviewed to document as much information concerning their actions just before, during, and after the event. Additional information should be collected, such as where the passenger was sitting at the time of the event and what they noticed about what other passengers around them were doing just before, during, and after the accident.

Persons who can provide information and who should be interviewed include:

- Passengers
- Vehicle operators
- Dispatchers
- Other agency employees
- Responders
- Witnesses

Be sensitive to interviewee injuries. Request permission to record the interviews. If a recorder is used, the interviewer and interviewee should identify themselves as well as the date, time, and location of the interview and others present.

A technique that has been successful in interviewing survivors is to permit the interviewee to discuss their observations without interruption. The person designated as note-taker writes down only pertinent information. At the conclusion of the interviewee's statement, some specific questions noted below may be asked if they were not covered and to clarify certain areas of interest. It is useful to have available copies of seating diagrams of the vehicle type occupied by the interviewee. Allow the interviewee to mark their location and other relevant information on the copy:

- What position/seat/location did you occupy?
- Describe the vehicle occupancy level.
- Were you seated or standing?
- Can you recall anything prior to the accident once you boarded the vehicle?
- Can you describe any impact forces (direction, magnitude)?
- (If injured): Can you describe your injuries and how they were sustained?
- Did you observe other passengers who were injured?
- Where were they located?
- Describe the injury mechanism if you observed.

- Can you describe your escape (method, time, difficulties, smoke, fire, egress routes)?
- Were there any difficulties during escape/rescue?
- Was there any difficulty opening doors/windows/emergency exits?
- Can you recall any observations of trapped passengers after the accident and during egress?
- Can you describe rescue/firefighting activities (location of fire, smoke)?
- Did you take any photographs/video after the accident? (if yes, ask for copies)
- Do you know how the vehicle was evacuated?
- Was any emergency equipment used, i.e., flashlights, megaphones, loudspeakers, PA?
- Did you observe any floor path emergency lights?
- Did you recall seeing/reading any safety card or other safety information?
- For passengers with disabilities: (if possible), obtain name, address, (age, weight, height), disability, mobility impairment.
- Were you using a mobility aid (walker, wheelchair)?
- What was the status of the mobility device during the evacuation and after?

Injuries and fatalities can occur under certain conditions; as a result, there are key questions that should be answered and conditions that should be documented associated with the vehicle interior and vehicle exterior.

Documentation and key questions regarding vehicle interior:

- Location of seats and equipment outside vehicle
- Description of thermal and smoke damage
- Description of vehicle(s) damage as it relates to interior structural deformation (location/dimensions), fire pattern, egress
- Documentation of evidence of firefighting/rescue activity pertaining to all vehicles
- Condition of windshields, wipers, lights
- Did seats or other interior equipment become unsecured? Did any sharp edges show evidence of impact with vehicle occupants?
- Did windows and doors stay secured?
- Evidence of difficulty removing emergency egress windows or using emergency door releases
- Documentation of condition of debris, signage, emergency lighting, exits, carry-on baggage and mobility devices
- Seat belt and shoulder harness conditions before and after impact (if applicable)

- Difficulty releasing restraints (if applicable)
- Were any injuries the result of passenger ejection or penetration by outside objects?
- Did doors function as intended for emergency access or passenger evacuation?
- Did emergency lighting function?
- Was fire involved? How did interior furnishings perform?
- Was the required emergency equipment in place (ex: fire extinguishers)? Were any used?
- Were instructions provided over vehicle intercom?

Documentation and key questions regarding the vehicle exterior:

- Were there external factors involved relative to the accident site? Document and supplement with photographs, videos, sketches, drawings
- Site description including final rest position of all vehicles
- Distance, heading, and relative bearing of evidence (e.g., ground scars, skid marks) and vehicle components from main wreckage
- Description of vehicle(s) damage as it relates to exterior structural deformation (location/dimensions), fire pattern, egress
- Description of group scars (length, width, depth, distance, bearing, and heading path and to from main wreckage site)
- Description of obstacles/structures struck (height, construction)
- Description of terrain (elevation, slope/grade, soil)
- Were emergency egress windows/door releases used? Issues?
- Did responders encounter difficulty accessing equipment? Did they have keys or know how to trigger door release mechanisms?
- If applicable, did fuel tanks leak? Was fire involved?
- Was survivable space maintained in passenger areas and control cab?
- Was vehicle equipped with crash protective features like corner posts, accident posts, or crumple zones? Did they function as designed?

Appendix E

72-Hour Pre-Incident History Checklist

The goal of the 72-hour pre-incident history is to obtain, in as much detail as possible, information on the operator's activities in the 72 hours prior to the accident. Information from this history will touch on every area of the investigation, making it one of the most important activities the investigator will undertake. It may be beneficial to go back slightly longer than 72 hours. Initial questions to ask include, but are not be limited to the following:

- When do you normally go to sleep and get up on your days off?
- How much sleep do you normally get?
- When do you normally go to sleep and get up on days you have to work?
- How long does it take to travel home at the end of your shift?
- How much sleep do you normally get on those days?
- Do you normally take naps? When, for how long, and why?
- How would you describe the general quality of your sleep?
- Can you estimate how long it normally takes you to fall asleep after you go to bed?
- Do you wake during the night? If so, how often, for how long, and how long does it take you to get back to sleep?
- Specifically, when did you go to sleep and get up the three days before the accident?
- Did you nap any of the three days before the accident? If so, when and for how long?
- Did you wake during the night any of the three days before the accident? If so, why?
- How long were you awake?
- How long did it take you to get back to sleep?
- How long did it take you to fall asleep initially the three days before the accident?
- Do you take any medications to help you fall asleep or stay asleep? What medications? (contact prescribing doctor) Did you take them three days before the accident?
- Do you take any medications that make it difficult to fall asleep? Did you take them in the three days before the accident?

The human factors investigator should also try to obtain information on both the quality and quantity of an operator's sleep. Note the time of the accident for comparison to know circadian low points. Sources of information other than the operator include work schedules, cellphone records, logbooks, alarm clock settings, and hotel wake-up calls. A baseline should be established for on- and off-duty days and for specific of the 72 hours before the accident and the two compared. Specific information to obtain includes the following:

- Times the operator awoke/went to bed each day
- Times, content, and duration of meals, including snacks
- Step-by-step recounting of activities, including times and durations
- Relationship between that day's activities and their normal ones—anything missing, anything new, anything odd
- People they saw or talked to, and times
- Time, duration, and location of any naps
- Any medications that are taken, including prescription, OTC, or herbal, including time and dose
- Time and amount of any intoxicant ingestion, including alcohol and illegal drugs

Appendix F

Safety Risk Management Process

Hazard identification is a prerequisite to the Safety Risk Management (SRM) process and is further described in the companion resource *Bus Transit Accident Investigations – Background Research*. A formal safety risk management process 1) describes a system, 2) identifies hazards, 3) assesses hazards, 4) identifies consequence(s) that the hazard could trigger, 5) analyzes those consequences to evaluate the safety risk, and 6) establishes controls to manage those safety risks. The objective of SRM is to assess the risks associated with the consequences of identified hazards and develop and implement effective and appropriate mitigations. Therefore, SRM is an essential component of the SMS process. SRM includes three elements:

- Safety Risk Management Process
- Safety Hazard Identification
- Safety Risk Evaluation and Mitigation

During an investigation, it might be suspected that existing safety risk controls or mitigations are ineffective due to a change in conditions, inappropriateness, or were not implemented as intended. The investigation might also identify new or previously-unidentified hazards. These circumstances require that the transit agency evaluate through its SRM process existing safety risks and mitigations, newly-identified hazards, and any resultant risk.

The SRM process defines a transit agency's approach and the implementation of an integrated systemwide safety risk resolution process. It specifies the sources of and the mechanisms to support the ongoing identification of hazards and defines the process by which identified hazards, resulting consequences, and level of safety risk will be evaluated and prioritized. It identifies the mechanism(s) that will be used to notify and report hazards to oversight agencies, as applicable, and the process by which a transit agency will provide ongoing reporting of hazard identification, consequence, and risk mitigation activities. This process is illustrated in Figure F-1.

The elements of this process should be applied, either quantitatively or qualitatively, to:

- Initial system, vehicle, equipment, and material designs
- Development of safety operational procedures
- Planned changes to the operational system, including the introduction of new equipment, material, systems, and procedures to identify hazards associated with those changes.

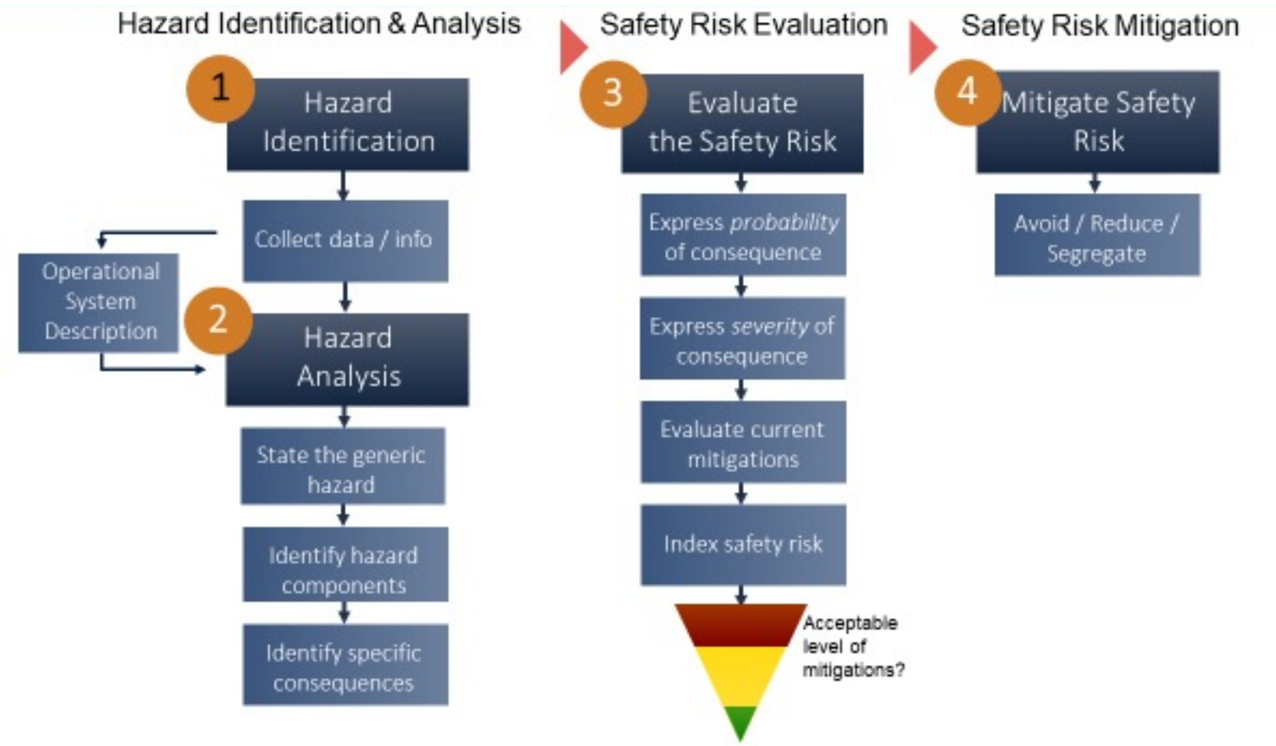


Figure F-1 *Safety Risk Management Process*
Source: TSI

A hazard is any real or potential condition that can cause injury, illness, or death; damage to or loss of the facilities, equipment rolling stock, or infrastructure of a public transportation system; damage to the environment; or reduction of the ability to perform a prescribed function (e.g., unclear/non-existent roadway signage or unnoticed traffic pattern notifications; vehicle system deficiencies, such as worn vehicle brake assemblies; other forms of infrastructure design or deficiencies, such as narrow traffic lanes and grade crossings). The hazard identification process is described in the following section.

Hazard Identification

Each transit agency should establish a process for safety hazard identification, including the identification of the methodologies—predictive, proactive, and reactive—for identifying hazards and their associated consequences. This process is presented in Figure F-2 and includes the steps to both hazard identification and analysis.

Figure F-2 *Hazard Identification and Analysis*

Source: TSI

The steps for hazard identification and data collection are shown in Figure F-3. Hazard identification is data-driven; data facilitate hazard identification. Although data will identify hazards, collection and analysis of data may disclose further/deeper safety concerns worth further examination. Data and information should be collected from various sources. However, it is of the utmost importance that the quality and integrity of the data be maintained. Inaccurate data, whether false or otherwise compromised, will not provide an accurate representation of what is occurring in the agency. Identification of hazards is the responsibility of all departments, offices, branches, and individual employees, and continual management of hazards is the key to an effective safety risk management program.

Figure F-3 *Hazard Identification and Data Collection*

Source: TSI

Hazards are identified through several sources:

- System inspections, audits, evaluations, assessments, regulatory inspections, and observations
- Accidents, incidents investigations
- Employee reporting to local safety committees
- Confidential employee reporting systems
- Safety hotline
- Ride checks and proficiency checks
- Customer reporting
- Transit industry experience
- Change Management and Safety Certification
- Reactive, proactive, and predictive analyses
- Formal system safety analysis
- System reliability and failure reports
- Data acquisition and data mining
- System monitoring

The three methods used to approach hazard responses are described below and presented in the order of an agency's SMS maturity (Figure F-4).

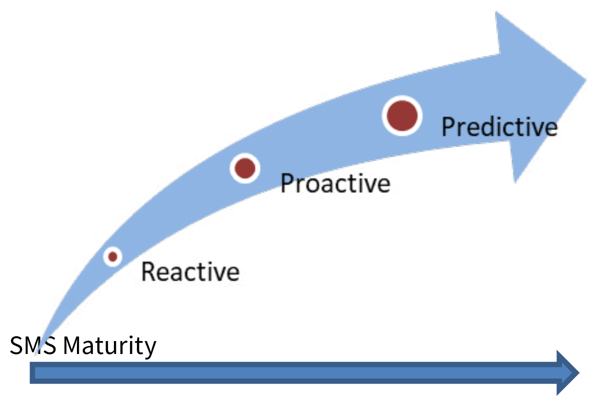


Figure F-4 *Approach to Hazard Response*

- **Reactive** involves analysis of past outcomes or events. Hazards are identified through an investigation of safety occurrences. Incidents and accidents are clear indicators of system deficiencies and can be used to determine the hazards that either contributed to the event or are latent.
- **Proactive** involves analysis of existing or real-time situations, which is the primary job of the safety assurance function with its audits, evaluations, employee reporting, and associated analysis and assessment processes. This involves actively seeking to identify hazards in the existing processes.

- **Predictive** involves data-gathering to identify possible adverse future outcomes or events, analyzing system processes and the environment to identify potential future hazards, and initiating mitigating actions.

Analytical Tools to Aid the Investigation Process

The "5 Whys"

A simple method of getting to the root cause of an accident is often referred to as the "5 Whys." This system involves asking "why" until the root cause of an event is determined, as in the following simplified example:

- Why did the vehicle veer off the road? Because the left front rim and tire separated from the hub.
- Why did the left front rim and tire separate from the hub? Because the lug nuts came loose.
- Why did the lug nuts come loose? Because they were improperly torqued.
- Why were they improperly torqued? Because the torque wrenches were out of calibration.
- Why were the torque wrenches out of calibration? Because the organization lacked an effective calibration policy and procedure.

Stopping at 1 or 2 fixes only the immediate problem on the accident vehicle—the out-of-calibration torque wrench remains in service awaiting the next accident. Stopping at #5 fixes only the individual torque wrench and does not entirely solve the problem.

Proceeding with more "why" levels can help get at a root cause related to organizational policy, procedures, management oversight, quality control, training and not stopping short so the underlying problem can be identified and addressed. The analysis logically links to cause and lays the foundation for recommendations to address the deficiencies and lead to corrective action plans. The following tools can help the investigator organize his thinking and assist in determining the critical factors in the accident scenario.

Fishbone Charts

Ishikawa or fishbone charts (Figure F-) aim to help list all possible causal factors. The categories in the boxes can change as needed for the investigation. The items listed under each category can help the investigator make sure that all potential causal factors have been examined.

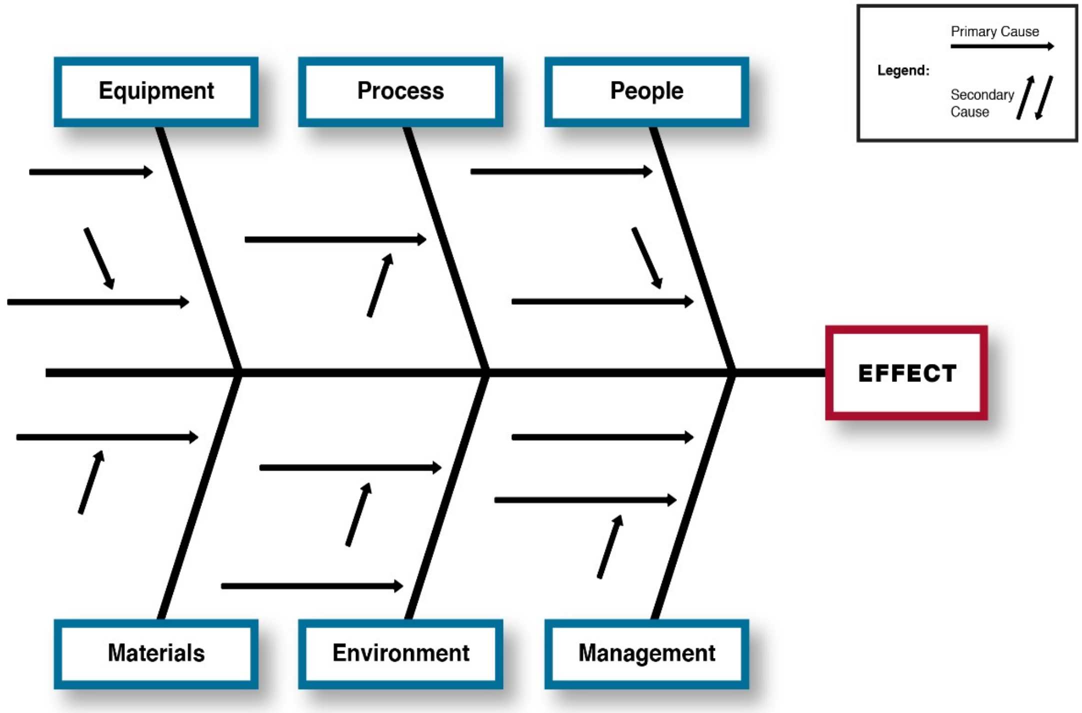


Figure F-5 *Fishbone Chart*

Source: TSI

Fault Tree Analysis

Fault tree tools are designed to help the investigator dig deeper beyond proximate cause and identify more fundamental or "root" causes. Fault tree analysis allows an investigator to map out possible causal scenarios in a graphic manner and imposes a logic flow that can help to support the probable cause of an event. A simplified example is shown in Figure F-6. At the top of the chart is the "event"—in this case, no light in a room. Two logical explanations are provided—no natural light and no artificial light. These are proximate causes, and these conditions are linked to the event box by an "and" gate meaning both conditions should exist together. Possible causes are in circles at the bottom of the graphic, which are connected to the logical explanations by "or" gates, meaning that any one of these causes would be sufficient to result in the event.

Further analysis of factual information developed in an investigation will help to rule in or out the bottom level causes. For example, if the light bulb tests okay, light bulb failure can be ruled out from the equation. The bottom level of a fault tree is the root cause. The above example can include going deeper (e.g., "5 Whys"); for instance, if a fault in the electric circuit is verified, the question is why— was there a maintenance issue, an overload issue, a training issue, a parts issue?

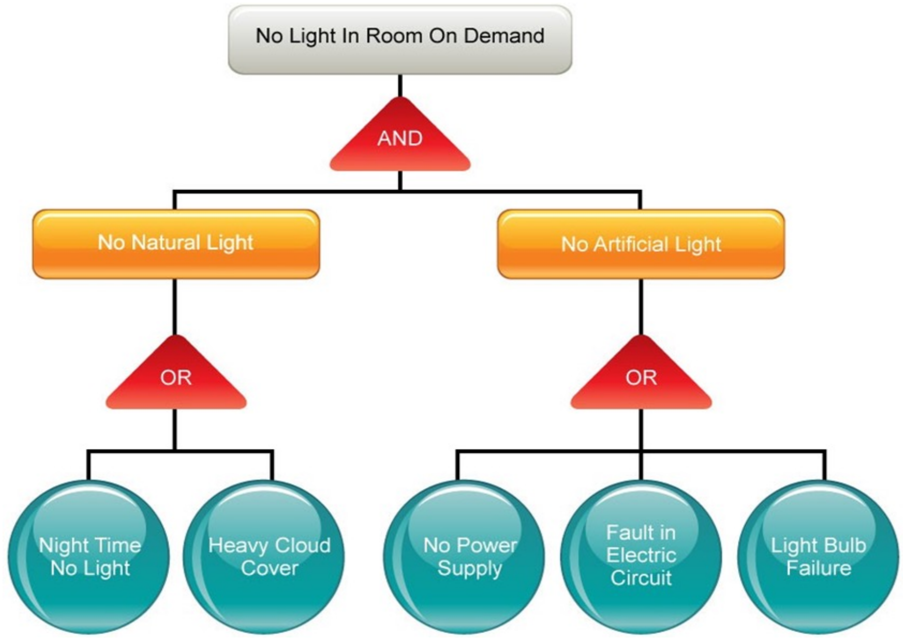


Figure F-6 *Fault Tree Analysis*

Source: TSI

Several commercial vendors produce proprietary root cause analysis tools and training classes. A free root cause analysis tool can be obtained from the National Aeronautics and Space Administration (NASA) at http://nsc.nasa.gov/RCAT/.

SHEL Model

The International Civil Aviation Organization (ICAO) SHEL Model (Figure F-7) is a conceptual tool used to analyze the interaction of multiple systems. It was first introduced by Edwards in 1972 and modified by Hawkins in 1975.

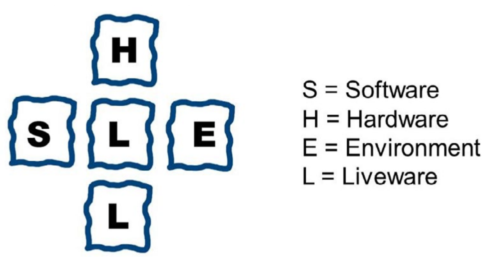


Figure F-7 *SHEL Model*

Source: ICAO 9859, Safety Management Manual

According to the SHEL Model, a mismatch between the Liveware and the four other components contributes to human error and groups factual material as follows:

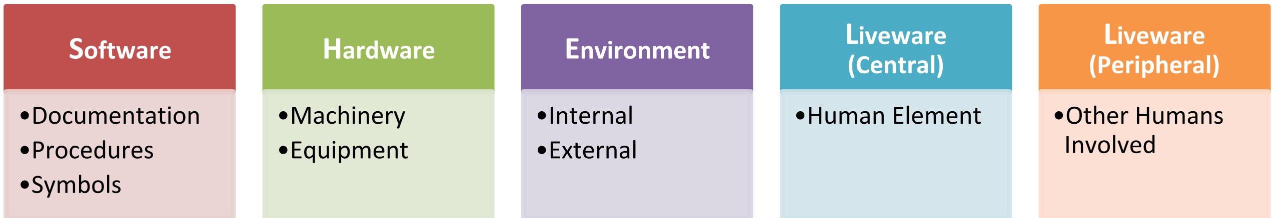


Figure F-8 *Components of SHEL Model*

Source: CUTR

Appendix G

Bus Investigation Report Organization

Transit agencies can use the template described below for its accident investigation report. Sections of the report should include the following, further described below:

- Section 1: Acronyms and Abbreviations
- Section 2: Executive Summary
- Section 3: Factual Information
- Section 4: Analysis
- Section 5: Conclusions
- Section 6: Recommendations

Section 1: Acronyms and Abbreviations

A general report writing convention is to spell out the complete acronym or abbreviation for the first use in the text and include the acronym or abbreviation in parenthesis. After that, the acronym or abbreviation should be used. Only acronyms and abbreviations used in the report should be included in this section.

Section 2: Executive Summary

The Executive Summary is a condensed version of the full report that is intended to allow readers to get acquainted with a large body of material without having to read the entire document. It is an essential section of a major report, as many readers will rely on it for a "big picture" view of the accident and may not read many other parts of the report. The Executive Summary typically will contain a brief description of the accident, pertinent background information, concise analysis, main conclusions concerning causal and contributing factors in the accident, and any corrective actions already undertaken.

Section 3: Factual Information

This section starts the full report and provides a detailed factual account of the accident without providing an analysis. It provides an overview of the accident and focuses on areas that are relevant to the cause of the accident and lead to the recommendations. The facts support the analysis, which supports the cause and recommendations; the factual portion of the report is the foundation. The factual section does not need to address every fact developed over the course of the investigation; however, there should be a clear logic chain between facts, analysis, conclusions, and cause.

Accident Description

The accident description provides the basic facts of the accident, telling the reader the “who,” “what,” “where,” and “when”; the “why” is reserved for the analysis section. Maps or photographs of the scene are helpful here.

Accident Narrative

This section tells the factual story of the accident. The timeline is significant here—usually, the “story” begins at the start of the trip or shift and leads up to and includes the accident sequence.

Agency Background

This section explains organizational relationships and how the agency's (or agencies’) safety plan ties it all together. With a single owner/operator, it is relatively straightforward, but some agencies have more complicated arrangements, with multiple contractors operating transit buses and maintaining rolling stock and infrastructure.

Operations

This section lays out the operating scheme—bus routes, governing operating documents, operating rule book, and any other operations manuals or guidance. Any discrepancies between requirements and what happened during the accident sequence should be explained. For example, hypothetically, the posted speed was 25 mph. Event recorder data indicated that the accident bus was traveling at 35 mph just before the event. Based on recorder data or analysis of tire marks, factual calculations of speed and stopping distance belongs in this section. Discussion of the significance of these facts should be presented in the Analysis section.

Oversight

This section explains the SSO relationship (if there is state oversight of agency bus operations), when and how the event was reported, and involvement of the oversight agency in the investigation. Depending on the circumstances of the accident, the agency may discuss the agency safety plan, rules compliance programs, and other relevant management programs. Any other agency that may be involved should be explained here; for example, if FTA had a role or OSHA is involved in an employee injury event.

Personnel Information

This section includes the relevant key players in the accident, such as bus operators, maintenance technicians, controllers, or supervisors. Personnel information might consist of fitness-for-duty checks, training and experience, disciplinary record, and promotion history. No personally identifiable information such Social Security number, phone number, or address should be included.

Damages

Dollar damages should be presented, broken down by category (e.g., infrastructure, transit agency vehicles, private vehicles) in a simple table format.

Equipment Information

This section lays out the necessary information on the bus or other equipment involved, including pre-departure inspection of the equipment and any anomalies discovered. Factual information that is relevant to the accident—for example, weight, crashworthiness design features, rehabilitation history, or age—should be included, and the post-accident positions of equipment and a factual description of damages should be described, including photos and diagrams.

Survival Factors

This section focuses on the issues related to the survivability of the passengers and bus operator (or any other agency personnel), as well as the ability of the passengers and crew to safely evacuate. Factual information should include survivable space, emergency exits, lighting, emergency information (signs and announcements), seat securement, emergency equipment, and injury locations within equipment. The size, scope, and content of this section will vary considerably based on the circumstances of each accident; some accidents may not need a survival factors discussion, but investigators should be alert to improvement opportunities that survival factors investigation can reveal.

Injuries

This section should include a simple injury table. More detailed injury information, if available, should be used to show injury locations within equipment and other details that may support recommendations for equipment improvements. The agency's legal department should be consulted on any health-related data to avoid sharing medical information in violation of HIPAA.[8]

Emergency Response

This section identifies response agencies that were involved. Factual information regarding time notified, time of arrival, and any delays or problems with evacuation, triage, or transport of injured should be included, and a response timeline table is helpful. Any factual information from the debriefing should be included.

[8] For specific details on HIPAA requirements, assistance can be found at the U.S. Department of Health & Human Services website at www.hhs.gov.

Traffic Control Systems

In an accident with no traffic signal connection to the cause, this section can be addressed by including a short description of the system. If the system was a factor in the accident, a detailed description of the condition, history, inspections, maintenance, and any discrepancies should be provided in sufficient detail to support any conclusions and causal statements in the analysis factually.

Other Infrastructure

This section discusses any other infrastructure or system that may have been a factor in the accident—for example, external intersection design elements, field of view constraints, agency communications, or SCADA. Any discrepancies between requirements and performance should be laid out factually to logically support the conclusions in the analysis.

Section 4: General Analysis

This section of the report is where the meaning of the facts is explained. When a discrepancy is found between what policy, procedures, specifications, or regulation requires in the accident, it is important to determine if the discrepancy is relevant. The analysis section is where the significance of the facts developed are explained. Some discrepancies may not be important—for example, a bus traveling 3 mph over the 40-mph speed limit is not likely a factor in an event, but a bus traveling 30 mph over the speed limit likely is. The logic chain should be present.

Introduction

Source: Pixabay

The introduction provides the opportunity to discuss the exclusions. Exclusions are the potential causal areas examined and found not to be factors in the accident. For example, in a possible collision, the report might note that investigators inspected and tested the braking system and examined maintenance records with no anomalies found. At the end of the introduction, a summary should note that the investigation concluded that the condition of the braking system was not a factor in this accident. That statement is then repeated in the conclusions section.

Specific Issues Identified in Accident

This section discusses and analyzes factors that were judged to be factors in the accident. For example, in a hypothetical collision, if it was found that the brakes were not applied before impact (or did not engage preventing impact), the report would provide a detailed analysis of the factors involved. This is where the "5 Whys" might come into play in examining procedures, equipment, communication between the bus operator and maintenance, maintenance and operations, and operations and the bus operator.

Effective Investigation Practice

Logic chain should strive for:

- Facts based on observable, verified, and accurate information.
- Analysis based on facts.
- Conclusions based on analysis.
- Causes and contributing factors output of logic chain.

Recommendations address cause and contributing factors.

At the end of each analysis discussion, conclusions reached should be specified and explained. There should be a clear logic chain between the facts, the analysis, and the conclusion.

Human Performance

Any human performance issues such as work environment, fatigue, experience, training, impairment, distraction, or medical conditions[9] are discussed here. (See the Human Factors section of this guidebook for more details.)

Survival Factors – Equipment Crashworthiness

If no crashworthiness issues were developed, this section may not be needed. Crashworthiness issues, such as loss of survivable space, windows that detached resulting in ejections, or interior amenities that broke loose resulting in injuries, should be discussed here.

Survival Factors – Emergency Response

This section evaluates the response and highlights any problems with the response. Areas that might be covered include:

- Delayed arrival/locating accident scene
- Access to scene and equipment
- Evacuations
- Agency employee performance and training
- Rescue and recovery
- Triage and transport of injured
- Communication and coordination between transit agency and first responders
- Responder training and familiarization provided by transit agency
- Past exercises, or lack thereof

[9] Ensure compliance with HIPAA requirements.

This may lead to recommendations on training, equipment, or procedures under agency control. Any problems discussed in this section should be supported by factual information.

Section 5: Conclusions and Findings

Findings are the logical outgrowth of the analysis, which is the logical outgrowth of the facts. This section repeats the conclusions developed and presents them in a list format.

Probable Cause and Contributing Factors

This section is in two parts—1) the primary cause, as determined by the facts and the analysis conducted by the transit agency investigator/investigative team, and 2) contributing factors discovered during the analysis of the facts without which the accident may not have occurred. Differences between probable cause and contributing factor may be gray rather than black & white areas. In NTSB reports, probable cause sometimes is the proximate (as opposed to root) cause with elements of the root cause listed as contributing factors. In other reports, the probable cause is a root cause with proximate causes listed as contributing.

As the more in-depth objective of the investigation is to identify preventive measures, report writers should consider the elements of the causal picture that best logically support the preventive recommendations. The primary causal and contributing factors of the accident should be clearly stated in the Conclusion section.

Once probable cause has been determined and contributing factors identified, the investigators, together with the associated departments, then develop a realistic and practical remedy to prevent a similar accident from occurring again.

Effective Investigation Practice: Example of Logic Flow*

- Fact: Vehicle brakes not applied before impact.
- Fact: Vehicle speed 30 mph at impact.
- Fact: Sight distance reconstructions indicate that obstruction at point of impact visible from 350 ft.
- Fact: Vehicle operator had approximately 8 sec to detect obstacle and apply brakes, but did not do so.
- Fact: Witnesses and inward-facing video showed vehicle operator looking downward and manipulating a smartphone.
- Analysis: Conclusion – had operator been alert and looking forward, obstruction would have been detected and vehicle stopped short of collision.
- Probable Cause: Operator distraction resulting from use of a cellphone for texting.

*Contributing factors in this hypothetical example would lay out relevant issues such as training and management oversight that were explained in the analysis.

Section 6: Recommendations

The Recommendations section should provide a set of actions that should be taken to prevent recurrence of the accident. These recommended improvements should be organized by time so those requiring immediate action can be implemented and others requiring more time and funding can be scheduled for a permanent fix to eliminate the problems leading to the accident. Long-term recommendations may require capital budgets, re-design, or extensive system modifications, such as retiring legacy vehicles or upgrading them with newer components or technologies.

Recommendations are action items. Each should begin with an action verb (i.e., conduct, revise, or modify) that will result in measurable action. There should be a clear logic chain from the facts to the analysis to the conclusions to the recommendation.

The recommendations will drive corrective actions and should be worded in a way that supports the corrective action format and identifies measurable outcomes. For example, a recommendation reading "Improve emergency responder training" would not meet this test. A more focused approach would be "Revise the emergency responder training program to cover the evacuation of passengers and personnel through transit vehicle emergency exits." Recommendations should logically link to the corrective action plans.

Key Point—The SMS process does not end with the completion and approval of the final accident investigation report. A complete SMS process includes ongoing tracking and monitoring of CAPs, including an evaluation of mitigation measures, actions, procedural changes, or training improvements and if these actions had any unintended consequences. Following the evaluation, the cycle begins again—monitoring, evaluation, and modifications, as needed.

Acronyms and Abbreviations

A/C	Air conditioning
APTA	American Public Transportation Association
AVL	Automatic Vehicle Locator
BMI	Body Mass Index
BRT	Bus Rapid Transit
CAP	Corrective Action Plan
CEO	Chief Executive Officer
CFR	Code of Federal Regulations
CM	Configuration/Change Management
CNG	Compressed Natural Gas
CSO	Chief Safety Officer
CUTR	Center for Urban Transit Research
EAP	Employee Assistance Program
EDR	Event Data Recorder
EMS	Emergency Medical Services
FAID	Fatigue Audit InterDyne
FAST	Fatigue Avoidance Scheduling Tool
FD	Fire Department
FEMA	Federal Emergency Management Agency
FMCSA	Federal Motor Carrier Safety Administration
FMEA	Failure Modes and Effects Analysis
FMP	Fatigue Management Program
FTA	Federal Transit Administration
FT/S	Feet per Second
HAZWOPER	Hazardous Waste Operations and Emergency Response
HBV/HIV	Hepatitis B Virus/Human Immunodeficiency Virus
HF	Human Factors
HIPAA	Health Insurance Portability and Accountability Act
HVAC	Heating, Ventilation, and Air Conditioning
IC	Incident Commander
ICAO	International Civil Aviation Organization
ICS/NIMS	Incident Command System/National Incident Management System
IPTM	Institute for Police Technology and Management
MAP–21	Moving Ahead for Progress in the 21st Century Act
MIL-STD	Military Standard
M.O.	Middle Ordinate
MPH	Miles per Hour
NASA	National Aeronautics and Space Administration
NATSA	North American Transit Services Association
NFPA	National Fire Protection Association

NHTSA	National Highway Traffic Safety Administration
NTD	National Transit Database
NTSB	National Transportation Safety Board
OEM	Office of Emergency Management
OHA	Operating Hazard Analysis
OJT	On-the-Job Training
ORA	Organizational Risk Assessment
OSA	Obstructive Sleep Apnea
OSHA	Occupational Safety and Health Administration
OTC	Over the Counter
PD	Police Department
PHA	Preliminary Hazard Analysis
PIO	Public Information Officer
PPE	Personal Protective Equipment
PRT	Peer Review Team
PTASP	Public Transportation Agency Safety Plan
RAC	Risk Assessment Code
RI	Risk Index
RL	Reference Line
RP	Reference Point
Rx	Prescription
SA	Safety Assurance
SAFTE	Sleep, Activity, Fatigue and Task Effectiveness
SCADA	Supervisory Control and Data Acquisition
SDP	Standards Development Program
SGR	State of Good Repair
SHA	System Hazard Analysis
SHEL	Software Hardware Environment Liveware
SME	Subject Matter Expert
SMS	Safety Management System
SOP	Standard Operating Procedure
SRM	Safety Risk Management
SSA	Software Safety Analysis
SSC	Safety and Security Certification
SSHA	Subsystem Hazard Analysis
SSO	State Safety Oversight
SSOA	State Safety Oversight Agency
TAM	Transit Asset Management
TSI	Transportation Safety Institute
TSS	Transit System Security
TSSP	Transit Safety and Security Program
U.S.	United States
U.S.C.	United States Code
VIN	Vehicle Identification Number

Traffic Investigation Terminology

Acceleration: Time rate of change of velocity; change of velocity divided by time; a vector quantity measured in feet per second per second (fps^2) or expressed as a decimal fraction of the acceleration of gravity (32.2 fps^2).

Apex: Point at which two sides of an angle meet or cross.

Area of Impact: Place on the roadway or ground closest to the first contact between colliding objects.

Arc: Part of a curve, especially a part of a circle, between two points on a curve.

Berm: See Shoulder.

Braking Distance: Distance through which brakes are applied to slow a vehicle; shortest distance in which a particular vehicle can be stopped by braking from a specified speed on a particular surface; distance from brake application to a collision.

Braking Skid Mark: See Skid Mark.

Centrifugal Force: Force of a body in motion, which tends to keep it continuing in the same direction rather than following a curved path.

Chord: Straight line connecting the ends of an arc or two points on a curve.

Coefficient of Friction: Dimensionless number representing the resistance to sliding of two surfaces in contact; drag factor of a vehicle or other object sliding on a roadway or other surface which is level.

Collision: Occurrence in a sequence of events that usually produces unintended death, injury, or property damage; has gained wider acceptance as a more accurate term for what used to be referred to as an accident.

Contact Damage: Damage to a vehicle resulting from the direct pressure of some foreign object in a collision or rollover; usually indicated by striations, rub-off of material, or puncture. Compare with Induced Damage.

Controlled Final Position: Final position reached because of the conscious effort of some person to modify the motion of a traffic unit after a collision.

Coordinate: Method of locating a spot in an area by measurements along and at right angles to a RL or by measurements of the shortest distances to each of two intercepting RLs; compare with Triangulation.

Critical Speed: Speed at which the centrifugal force of a vehicle following a specific curve exceeds the traction force of the tires on the surface, a velocity above which a particular highway curve could not be negotiated by a vehicle without yaw.

Critical Speed Marks: See Yaw Marks.

Crook: Abrupt change of direction of a tire mark due to collision forces. See Offset.

Debris: Loose material strewn about the road as the result of a traffic collision; dirt, liquids, vehicle parts, and other materials from the involved traffic units.

Deceleration: Rate of slowing; negative acceleration.

Disengagement: see Last Contact.

Drag Factor: Number representing the acceleration or deceleration of a vehicle or other body as a decimal fraction of the acceleration of gravity; when a vehicle slides with all wheels locked, the drag factor is the same as the coefficient of friction.

Energy: Ability to do work or produce an effect such as damage; a unit of force operating through a unit of distance; half the mass or weight times velocity squared; measured in foot-pounds (ft-lb).

Final Position: Location of a vehicle or body when it comes to rest after a collision; final positions may be controlled or uncontrolled.

First Contact: Initial touching of objects in a collision; the place on the road or ground where this touching occurs.

First Harmful Event: First occurrence in a traffic collision that results in appreciable damage or injury.

Flip: Movement of a vehicle, without touching the ground, from a place where its forward velocity is suddenly stopped by an object such as a curb or furrow-in below its center of mass with the result that the ensuing rotation lifts the vehicle off the ground. A flip is usually sidewise, but if it is endwise, it is a vault.

Fogline: Solid white line that separates drive lanes from the shoulder/berm area.

Furrow: Channel in loose or soft material, such as soil or dirt, made by a skidding or scuffing tire or some other part of a moving vehicle.

Gap Skid: Braking skid mark that is interrupted by release and reapplication of brakes or which terminates by the release of brakes before the collision. Compare with Skip Skid.

Gouge: Pavement scar deep enough to be easily felt with the fingers.

Grade: Change in elevation in the unit distance in a specified direction along the centerline of a roadway or the path of a vehicle; the difference in the level of two points divided by the level distance between the points.

Highway: Entire width between the boundary lines of every way publicly maintained when any part thereof is open to the use of the public for purposes of vehicular travel.

Imprint: Mark on road made without sliding by a rolling tire.

Induced Damage: Damage to a vehicle other than contact damage, often indicated by bending, braking, and distortion. Compare with Contact Damage, such as the impact of an individual's head against the windshield.

Intersection: When two or more roadways cross or connect, the area contained within the extension of curb lines, or if none, then the lateral roadway boundary lines are defined as the intersection.

Kinetic Energy: Amount of energy represented by a moving body; half of the mass times the square of the velocity.

Last Contact: Final touching of objects in a collision before separation.

Maximum Engagement: Greatest penetration of one body, such as a vehicle, by another during a collision; the moment of greatest force between objects in a collision.

Middle Ordinate: Perpendicular distance between an arc and its chord in the middle of the chord.

Nomograph: Graph on which three or more scales are arranged so that a straight line drawn through values on any two will cross the third at a corresponding value.

Radius: Distance from the center of a circle to a point on its perimeter (circumference); distance from a point on an arc to the center of the circle of which the arc is part.

Reference Line: Line, often the edge of a roadway, from which measurements are made to locate spots, especially spots along a roadway.

Reference Point: Point from which measurements are made to locate spots in an area; sometimes, the intercept of two reference lines; RP.

Road: Part of a traffic way that includes both the roadway, which is the traveled part and any shoulder or berm along the roadway.

Roadway: Portion of the highway improved, designed, or ordinarily used for vehicular travel, exclusive of the berm and shoulder.

Rollover: Situation where the vehicle rolls at least 90 degrees; also sometimes used to describe a pitch over (vault).

Scrape: Broad area of a hard surface covered with many scratches or striations made by a sliding metal part without significant pressure.

Scuff Mark: Friction mark on a pavement made by a tire that is both rotating and slipping.

Shoulder: That portion of the road contiguous with the roadway for the accommodation of stopped vehicles, for emergency use, and lateral support of the roadway structure.

Skid Mark: Friction mark made on a pavement by a tire that is sliding without rotation.

Skip Skid: Braking skid mark interrupted at frequent regular intervals; skid mark made by a bouncing wheel on which brakes keep the wheel from turning.

Traffic: Pedestrians, ridden or herded animals, vehicles, streetcars, and other conveyances either singly or together while using any highway for purposes of travel.

Trafficway: See Highway.

Triangulation: Method of locating a spot in an area by measurements from two or more reference points, the locations of which are identified for future reference.

Uncontrolled Final Position: Final position reached by a traffic unit after a collision without conscious human intervention.

Vault: Endwise flip.

Vehicle: Every device in, upon, or by which any person or property is or may be transported or drawn upon the highway, excepting devices moved by human power

Velocity: Time rate of change of position in which direction, as well as rapidity, is an element; distance divided by time if velocity is constant.

Yaw Mark: see Scuff Mark.

Glossary

Title 49 CFR §673.5 is the source of the definitions included within this glossary, unless otherwise indicated.

Accident: Event that involves any of the following: a loss of life; a report of a serious injury to a person; a collision of public transportation vehicles; a runaway train; an evacuation for life safety reasons; or any derailment of a rail transit vehicle, at any location, at any time, whatever the cause.

Accountable Executive: Single, identifiable person who has ultimate responsibility for carrying out the Public Transportation Agency Safety Plan of a public transportation agency; responsibility for carrying out the agency's Transit Asset Management (TAM) Plan; and control or direction over the human and capital resources needed to develop and maintain both the agency's Public Transportation Agency Safety Plan, in accordance with 49 U.S.C. 5329(d), and the agency's TAM Plan in accordance with 49 U.S.C. 5326.

Chief Safety Officer: Adequately trained individual who has responsibility for safety and reports directly to a transit agency's chief executive officer, general manager, president, or equivalent officer. A Chief Safety Officer may not serve in other operational or maintenance capacities, unless the Chief Safety Officer is employed by a transit agency that is a small public transportation provider as defined in this part, or a public transportation provider that does not operate a rail fixed guideway public transportation system.

Equivalent Authority: Entity that carries out duties similar to that of a Board of Directors, for a recipient or subrecipient of FTA funds under 49 U.S.C. Chapter 53, including sufficient authority to review and approve a recipient or subrecipient's Public Transportation Agency Safety Plan.

Event: Accident, incident, or occurrence.

FTA: Federal Transit Administration, an operating administration within the US Department of Transportation.

Hazard: Any real or potential condition that can cause injury, illness, or death; damage to or loss of the facilities, equipment, rolling stock, or infrastructure of a public transportation system; or damage to the environment.

Incident: Event that involves any of the following: a personal injury that is not a serious injury; one or more injuries requiring medical transport; or damage to facilities, equipment, rolling stock, or infrastructure that disrupts the operations of a transit agency.

Investigation: Process of determining the causal and contributing factors of an accident, incident, or hazard, for the purpose of preventing recurrence and mitigating risk.

National Public Transportation Safety Plan: Plan to improve the safety of all public transportation systems that receive Federal financial assistance under 49 U.S.C. Chapter 53.

Occurrence: Event without any personal injury in which any damage to facilities, equipment, rolling stock, or infrastructure does not disrupt the operations of a transit agency.

Operator of a public transportation system: Provider of public transportation as defined under 49 U.S.C. 5302(14).

Performance measure: Expression based on a quantifiable indicator of performance or condition that is used to establish targets and to assess progress toward meeting the established targets.

Performance target: Quantifiable level of performance or condition, expressed as a value for the measure, to be achieved within a time period required by the Federal Transit Administration (FTA).

Public Transportation Agency Safety Plan (PTASP): Documented comprehensive agency safety plan for a transit agency that is required by 49 U.S.C. 5329 and this part.

Public Transportation Safety Certification Training Program: certification training program for Federal and State employees or other designated personnel who conduct safety audits and examinations of public transportation systems and employees of public transportation agencies directly responsible for safety oversight, established through interim provisions in accordance with 49 U.S.C. 5329(c)(2), or the program authorized by 49 U.S.C. 5329(c)(1).

Rail fixed guideway public transportation system: Fixed guideway system that uses rail, is operated for public transportation, is within the jurisdiction of a State, and is not subject to the jurisdiction of the Federal Railroad Administration, or any such system in engineering or construction. Rail fixed guideway public transportation systems include but are not limited to rapid rail, heavy rail, light rail, monorail, trolley, inclined plane, funicular, and automated guideway.

Rail transit agency: Entity that provides services on a rail fixed guideway public transportation system.

Risk: Composite of predicted severity and likelihood of the potential effect of a hazard.

Risk mitigation: Method or methods to eliminate or reduce the effects of hazards.

Safety Assurance: Processes within a transit agency's Safety Management System that functions to ensure the implementation and effectiveness of safety risk mitigation, and to ensure that the transit agency meets or exceeds its safety objectives through the collection, analysis, and assessment of information.

Safety Management Policy: Transit agency's documented commitment to safety, which defines its safety objectives and the accountabilities and responsibilities of its employees in regard to safety.

Safety Management System (SMS): Formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of a transit agency's safety risk mitigation. SMS includes systematic procedures, practices, and policies for managing risks and hazards.

Safety Management System Executive: Chief Safety Officer or an equivalent.

Safety Performance Target: Performance target related to safety management activities.

Safety Promotion: Combination of training and communication of safety information to support SMS as applied to the transit agency's public transportation system.

Safety Risk Assessment: Formal activity whereby a transit agency determines Safety Risk Management priorities by establishing the significance or value of its safety risks.

Safety Risk Management: Process within a transit agency's Public Transportation Agency Safety Plan for identifying hazards and analyzing, assessing, and mitigating safety risk.

Serious injury: Any injury that 1) requires hospitalization for more than 48 hours, commencing within 7 days from the date of the injury was received; 2) results in a fracture of any bone (except simple fractures of fingers, toes, or noses); 3) causes severe hemorrhages, nerve, muscle, or tendon damage; 4) Involves any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface.

Small public transportation provider: Recipient or subrecipient of Federal financial assistance under 49 U.S.C. 5307 that has one hundred (100) or fewer vehicles in peak revenue service and does not operate a rail fixed guideway public transportation system.

State: US State, District of Columbia, Puerto Rico, Northern Mariana Islands, Guam, American Samoa, Virgin Islands.

State of Good Repair (SGR): Condition in which a capital asset is able to operate at a full level of performance.

State Safety Oversight Agency (SSOA): Agency established by a State that meets the requirements and performs the functions specified by 49 U.S.C. 5329(e) and the regulations set forth in 49 CFR part 674.

Transit agency: Operator of a public transportation system.

TAM (Transit Asset Management) Plan: Strategic and systematic practice of procuring, operating, inspecting, maintaining, rehabilitating, and replacing transit capital assets to manage their performance, risks, and costs over their life cycles, for the purpose of providing safe, cost-effective, and reliable public transportation, as required by 49 U.S.C. 5326 and 49 CFR part 625.

U.S. Department of Transportation
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East Building
1200 New Jersey Avenue, SE
Washington, DC 20590
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