FTA Report No. 0221

FTA RESEARCH
FEDERAL TRANSIT ADMINISTRATION

Rail Transit Agency Accident Investigations—Background Research

PREPARED BY

K&J Safety and Security Consulting Services

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

JUNE 2022

U.S. Department of Transportation
Federal Transit Administration

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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)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

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14. ABSTRACT
As part of FTA's effort to promote continuous safety improvement in the public transit industry, *Efffective Practices in Performing Rail Transit Agency Accident Investigations* were developed to provide public transit agencies that provide rail services practices for performing investigations. This supporting document provides a comprehensive examination of each SMS element to broaden the reader's understanding of how each component complements the others. The recommended practices 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.

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Abstract

As part of FTA's effort to promote continuous safety improvement in the public transit industry, *Effective Practices in Performing Rail Transit Agency Accident Investigations* were developed to provide public transit agencies that provide rail services practices for performing investigations. This supporting document provides a comprehensive examination of each SMS element to broaden the reader's understanding of how each component complements the others. The recommended practices 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

Introduction

The Federal Transit Administration (FTA) adoption of the Safety Management System (SMS) framework elevated the approach to safety in public transit, shifting the industry from a reactive stance to a more proactive one with a greater focus on event prevention. SMS is "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]

Title 49 Code of Federal Regulations (CFR) Part 673 requires that each transit agency establish and implement an SMS, appropriately scaled to the size, scope, and complexity of the agency, that includes the following elements:

- Safety Management Policy (SMP)
- Safety Risk Management (SRM)
- Safety Assurance (SA)
- Safety Promotion (SP)

SMS brings management and labor together to build a safety culture in transit dedicated to controlling and reducing risk and detecting and correcting safety issues in their early stages. This data-driven approach aids in developing Corrective Action Plans (CAPs) to address safety concerns and establishes safety goals, safety performance targets, and safety performance indicators. These metrics are used to measure the effectiveness of risk mitigations, and CAPs are monitored to ensure the organization is achieving the intended outcomes.

Accident investigation, which falls under the SA component of SMS, is central to identifying causal or contributing factors in events. 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, and elevating the safety of employees and the riding public. This is achieved through the development and implementation of CAPs, which are then measured and monitored to ensure they are effective and tracked to closure.

Purpose

As part of FTA's effort to promote continuous safety improvement in the rail transit industry, this technical memorandum provides the background research in support of FTA's *Effective Practices in Rail Transit Accident Investigations*. It provides a comprehensive examination of each SMS element to broaden the

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

understanding of how components complement each another. Each rail transit agency (RTA) is responsible for tailoring its processes to its unique operating environment, the complexity of its operation, and the mode of transportation provided.

The primary purpose of conducting investigations of undesirable events is to determine the cause so corrective actions can be put in place that prevent future similar events. 49 CFR §673.27(b)(3) requires transit agencies to conduct investigations of safety events to identify causal factors as part of their SA process in the Public Transportation Agency Safety Plan (PTASP). An investigation evaluates the effectiveness of safety risk control methods, identifies causal factors, and may result in corrective actions to improve control methods where gaps are identified.

Background

Accident investigations are event investigations performed as part of SA activities within the SMS framework:

- Analyze data and information obtained through the investigation process, proactively and predictively to identify where and when a similar event could occur.
- Identify changes to facilities, vehicles, equipment, and systems that were not effectively managed to ensure safety.
- Use lessons learned from event investigations to promote continuous improvement in safety performance.
- Enter hazards identified from data analyses during investigations into the SMS SRM Process (SMS Component 2).

Accident investigation practices, although typically used in response to an incident, may also identify and diagnose the present state of early warning methods that allow management to harvest leading indicators to significant events. One of these methods is non-punitive employee safety reporting programs. Many public transit agencies have instituted these programs and found them to be more effective and successful due to the protections granted reporters.[2] Safety efficiency testing is another early warning system that flags employee non-conformance to existing procedures, which can also be the precursor to more serious operational violations. Auditing is another early warning approach. These components of the agency's safety defenses can identify significant safety concerns and a systemic safety problem before an

[2] Staes, L., and Godfrey, J., 2020, "Characteristics and Elements of Non-Punitive Employee Safety Reporting Systems for Public Transportation," Pre-publication draft, TCRP Research Report 218, Transportation Research Board, Washington, D.C., National Academies Press, https://www.nap.edu/catalog/25852/characteristics-and-elements-of-non-punitive-employee-safety-reporting-systems-for-public-transportation.

accident. Identification of a significant hazard often requires recognition of the seriousness of the hazard by senior management, which leads to the safety issue receiving the appropriate level of mitigation resources. Effective accident investigation promotes the organization's capability to institute a strong response to often very indistinct stimuli to prevent a more serious event from occurring.

Accident investigation activities benefit from an in-depth understanding of not only the technical aspects of an investigation but also non-technical aspects of organizational performance. To effectively investigate an event, agencies may want to consider both aspects, and conduct investigations in a comprehensive manner. Agencies may want to avoid investigation outcomes that assign individual or organizational blame for major incidents; otherwise, relevant, and important aspects of the event may not be revealed, opportunities for safety performance improvement may be missed, and risks to the agency will not be sufficiently remediated. There are challenges to investigation techniques that are focus on both technical and non-technical elements. Non-technical organizational challenges generally stem from issues such as inadequate succession planning, ineffective recruitment and retention strategies, procurement obstacles, poor safety culture, organizational blindness to risk, failure to learn from past events, an imbalance in the normal tension that exists between operations and maintenance personnel for track time allocations, inadequate funding for capital investments, or the failure to maintain agency assets in a State of Good Repair (SGR).

As noted, effective investigation practices often leverage the knowledge of Subject Matter Experts (SME) to aid in identifying deviations from current operating or maintenance practices identifying opportunities to make the agency more effective and efficient to reduce risk. These opportunities may include improving system designs, procedural modifications, quality assurance activities, identifying new technologies, being cognizant, implementing best industry practices suited for the agency's unique environment, and adapting and effectively using maintenance management systems to collect data that informs maintenance and investment decisions. Additionally, medical expertise is often needed to evaluate human factors that can influence performance, such as the proper screening for medical conditions such as Obstructive Sleep Apnea (OSA) that can result in fatigue.

RTAs may find it beneficial to ensure that their frontline workforce is equipped with the required tools, training, and knowledge to diagnosis and mitigate severe conditions that require immediate attention. Often, frontline employees know about existing hazards, but they may need access to portals or other reporting platforms to report these hazards. Further, organizational commitment toward hazard identification and mitigation should be communicated to employees to build a safety culture of trust that will safeguard their fellow employees and the riding public.

This research and the corresponding *Effective Practices in Rail Transit Accident Investigations* describe the SMS background and the elements that support it. The guidelines are meant to inform and improve an investigator's critical thinking skills, which are necessary to accurately identify root causes and contributing factors, thus leading to short-term, intermediate, and long-range CAPs to address their key findings.

Report Organization

This report is organized by each SMS element, as follows:

- Section 1 – Safety Management Policy
- Section 2 – Safety Risk Management
- Section 3 – Safety Assurance
- Section 4 – Safety Promotion

Each section includes a description of the organizational accountabilities, recommended policies and procedures, and the components of each SMS element that support, direct, and further the accident investigation process. The report provides the steps and considerations that will direct an agency past the investigation process toward various methods of safety assurance, promotion, and continuous improvement based on SMS principles and includes case study examples presented to impart experiential knowledge. Appendices provide topical supplemental information and include resources for transit agency investigation and management personnel who are tasked with investigation and close-out activities.

Section 1

Safety Management Policy

FTA Safety Management System Framework and Safety Management Policy Directives

The Federal Transit Administration (FTA) Safety Management System (SMS) framework requires a transit agency to establish its organizational accountabilities and responsibilities and have a written statement of safety management policy that includes the agency's safety objectives. The agency must establish a process that allows employees to report safety conditions to senior management, protects employees who report safety conditions to senior management, and describes employee behaviors that may result in disciplinary action. At the center of an agency's SMS is the communication of the policy throughout the organization.

The transit agency must establish the necessary authorities, accountabilities, and responsibilities for the management of safety among the following individuals within its organization as they relate to the development and management of the transit agency's SMS:

- **Accountable Executive** – The Accountable Executive should be a transit operator's chief executive; this person is often the President, Chief Executive Officer, or General Manager.[3] A transit agency must identify the Accountable Executive who will be responsible for ensuring that the agency's SMS is effectively implemented throughout the agency's public transportation system. The Accountable Executive is accountable for ensuring action is taken, as necessary, to address substandard performance in the agency's SMS. The Accountable Executive may delegate specific responsibilities, but the ultimate accountability for the transit agency's safety performance cannot be delegated and always rests with the Accountable Executive.
- **Chief Safety Officer or SMS Executive** – The Accountable Executive may designate a Chief Safety Officer (CSO) or SMS Executive who may be given authority and responsibility for the day-to-day implementation and operation of an agency's SMS. The CSO or SMS Executive should hold a direct line of reporting to the Accountable Executive. A transit agency may allow the Accountable Executive to also serve as the CSO or SMS Executive.
- **Agency leadership and executive management** – A transit agency must identify those members of its leadership or executive management, other than an Accountable Executive, Safety Officer, or SMS Executive, who have authorities or responsibilities for day-to-day implementation and operation of an agency's SMS.

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

- Key staff – A transit agency may designate key staff, groups of staff, or committees to support the Accountable Executive, CSO, or SMS Executive in developing, implementing, and operating the agency's SMS.

This section includes the following topics that are central to SMS and Safety Management Policy:

- Organizational Factors and Safety Culture
- Employee Safety Reporting
- Management/Labor Relations

Organizational Factors and Safety Culture

One characterization of an organization is "a unit of people that is structured and managed to meet a need or to pursue collective goals." All organizations have a management structure that determines relationships between different activities and members and subdivides and assigns roles, responsibilities, and authority to conduct various tasks. Organizations are open systems; they affect and are affected by their environment.

An organization's culture can have as significant an influence on safety outcomes, including the prevalence and severity of safety events, including accidents. Without directed guidance and appropriate and applicable policies, organizational culture may divert from the organization's goals and mission. Understanding culture and how it aligns with the organizational strategy is critical in the development, implementation, and maturation of a robust SMS. A successful culture balances people's focus on achieving results and looks both internally and externally to maximize a positive impact on all stakeholders. An ideal organizational culture is one that is stable in terms of mission and values yet flexible enough to adapt to changes in the external and internal environments.

Organizational Risk Factors

As a part of an SMS structure, specifically the development of the Safety Management Policy and associated procedures and processes, transit agencies may benefit from proactively evaluating factors that can impact organizational safety and determining what actions, if any, it will take to mitigate those risks. Organizational risk factors can include, but may not be limited to:

- Compliance
- Laws and regulations
- Cumbersome, outdated, or non-existent crisis/emergency management policies
- Agency safety procedures and policies
- Personnel

- Management and staff attitudes toward workplace safety
- Staff training and preparedness
- Succession planning
- Recruitment and retention of qualified employees
- Insufficient resources to effectively monitor and address significant organizational changes
- Staffing levels, extended shifts, and overtime requirements
- Procurement obstacles, which may include an inadequate zero-based budget (ZBB)[4]

Identifying and evaluating organizational risk factors and establishing policies and procedures to address and mitigate those factors can reduce the likelihood that an "organizational accident" will occur. In general terms, organizational accidents result from actions or inactions of companies or organizations. As noted author James Reason stated,

Organizational accidents are the comparatively rare, but often catastrophic, events that occur within complex modern technologies such as nuclear power plants, commercial aviation, the petrochemical industry, chemical process plants, marine and rail transport, banks, and stadiums. Organizational accidents have multiple issues involving many people operating at different levels of their respective companies. By contrast, personal accidents are ones in which a specific person or group is often both the agent and the victim of the accident. Organizational accidents, on the other hand, can have devastating effects on uninvolved populations, assets, and the environment.[5]

Examples of Organizational Accidents and Incidents

The following examples of organizational accidents and incidents highlight the failures of organizations, specifically organizational procedures and policies and the ineffectiveness of management:

- **British Petroleum (BP) Refinery Accident, Texas City, Texas.** On March 23, 2005, the BP Texas City Refinery suffered one of the worst industrial disasters in recent U.S. history. Explosions and fires killed 15 people and injured another 180 individuals, alarmed the community, and resulted in financial losses exceeding $1.5 billion. The accident was investigated by the U.S. Chemical Safety and Hazard Investigation Board (CSB),[6] which found, among several significant safety issues identified and investigated in its extensive report, the following:

[4] ZBB is a method of budgeting in which all expenses must be justified and approved for each new period. ZBB starts from a "zero base" at the beginning of every budget period and analyzes needs and costs of every function within an organization and allocates funds accordingly, regardless of how much money has previously been budgeted to any given line item.
[5] Reason, J., *Managing the Risks of Organizational Accidents*, Ashgate Publishing, 1997.
[6] For additional information, see CSB report 2005-04-I-TX, March 2007.

  - BP lacked focus on controlling major hazard risks. BP management paid attention to, measured, and rewarded personal safety rather than process safety.
  - BP and Texas City managers provided ineffective leadership and oversight; they did not implement adequate safety oversight, provide needed human and economic resources, or consistently model adherence to safety rules and procedures.
  - BP and Texas City managers did not effectively evaluate the safety implications of significant organizational, personnel, and policy changes.

- **New York Metropolitan Transportation Authority (MTA), Results of Blue-Ribbon Panel Report, August 27, 2014.** In August 2013, the Chairman/ Chief Executive Officer of MTA assembled a Blue-Ribbon Panel (BRP) of transportation safety officials and railroad industry leaders following mainline derailments at the Long Island Rail Road (LIRR), Metro-North Railroad (MNR), and New York City Transit (NYCT) that had track-related defects identified as either a potential cause or a contributing factor to these events. Several BRP members were tasked with reviewing non-technical aspects of the rail properties, such as their safety climate,[7] organizational, funding, management issues, and the overall policy setting and oversight. A specific concern that emerged focused on the need to modify the organizational structure that had existed between the safety function and the rail agency's leadership at LIRR and MNR. The BRP emphasized that this relationship must assure that a clear communication channel exists between these parties and send the message throughout the organization that safety is not subsidiary to other departments. The Chairperson/CEO acted upon the finding by directing the presidents of MNR and LIRR to designate a lead safety individual at each agency to report directly to the CEO to ensure that the CSO had no job responsibilities other than safety; this reporting structure already existed at NYCT and was used as a model. An interim report by the BRP identified that organizational changes were needed to assure that safety groups were seen by all as "clear and effective champions" of safety with the tools and support necessary to do their job well.

[7] Safety climate refers to the perceived value that is given to safety considerations within an organization, a holistic term that includes corporate policies, management attitudes, and worker beliefs about safety within the workplace. The concept of safety climate is similar to the concept of safety culture; however, the latter term refers more specifically to the individual attitudes toward safety practice that exist within an organization, whereas safety climate refers to how those attitudes are collectively understood. The two terms are sometimes contrasted as referring to an organization's "personality" (safety culture) and "mood" (safety climate). The safety climate, like a mood, exists at a given point of time and can change significantly based on the circumstances. The safety culture refers to a more durable set of beliefs and practices that may persist even as the safety climate changes.

Safety Culture

Whereas there are various definitions of what constitutes safety culture, an accepted and recognized meaning is that safety culture is how safety is managed in a workplace, a combination of beliefs, perceptions, and attitudes of employees toward the safety of workers and the overall safety of the work environment. Cultivating a safety culture is a crucial aspect of maintaining workplace safety.

Just as every organization has a structure, every organization has a safety culture. In a strong safety culture, safety is the top priority. At all times, across all levels of the organization, safety is placed above all other priorities. If hazardous, potentially harmful safety concerns are identified, operations affected by the hazard that pose an imminent safety risk do not continue until the safety concerns have been resolved. Competing demands, such as productivity, profitability, and on-time performance, are not prioritized above safety. When competing demands are prioritized over safety, a favorable, proactive safety culture suffers.

Considerable research was conducted to identify indicators of a positive safety culture. Reason[8] identified five main components of a strong safety culture on a generic basis, and many of the guidelines in industries have been adapted from this model.

- An **informed** culture is one in which "those who manage and operate the system have current knowledge about the human, technical, organizational, and environmental factors that determine the safety of the system."
- A **reporting** culture is one that allows and encourages people to report their errors and near misses. This can often be difficult to achieve but can be helped by using a confidential reporting system, keeping a separation between those who collect information and those who would implement sanctions, providing fast and useful feedback, and making the reporting system easy to use.
- A **learning** culture is evident when an organization has the willingness and competence to learn from its safety information and will include this when implementing safety reforms.
- A **flexible** culture is a culture that can re-configure itself and respond to change and may change from a conventional hierarchical structure to a flatter one. A flexible culture also encourages people to adapt and allows people regardless of their position to have an active role in the overall organizational safety.
- A **just** culture avoids apportioning blame on an individual, which, in turn, facilitates a focus on systemic deficiencies rather than on individual failings. In a just culture, there will be an atmosphere of trust and a clear understanding of the difference between an error and a violation for all involved.

[8] Reason, 1997.

Employee Safety Reporting

An agency's SMS and its Safety Management Policy should include an employee safety reporting process.[9] A non-punitive safety reporting system has proven to be an effective method for improving safety in the chemical process, nuclear, and transportation industries. A non-punitive safety reporting system typically uses a collaborative problem-solving approach that encompasses all stakeholders. The success of such a program requires a focus on precursor events that may lead to accidents, use of data and SMEs to determine corrective actions, allows cooperative, cross-functional problem solving, and an organizational setting capable of implementing corrective actions.

Although there are several types of reporting systems, the essential components of a non-punitive safety reporting system include the following:

- **Voluntary reporting** of incidents/safety concerns.
- **Confidential reporting** that ensures that the identities of reporting individuals cannot be disclosed.
- A **non-punitive approach** that protects employees from disciplinary action; however, the process also defines actions that are not exempt from discipline.
- **Third-party data collection and de-identification** to ensure confidentiality; most, but not all, close-call safety reporting systems employ a third-party agency to receive, process, and, in some cases, investigate the reports.
- **Analysis** that may involve a Peer Review Team (PRT), which uses either staff SMEs or access to SMEs, to ensure that the reported safety concern is fully understood and to assist in developing CAPs to address the problem effectively.
- Although safety concerns may be made in a confidential or anonymous manner, the organization should develop methods of providing **feedback to all employees** on the actions taken to address reported problems. This can be done by posting updates on the agency's intranet or in monthly news bulletins, discussions at safety forums, and routine safety meetings. If the reporting employee chooses to provide their identity, then direct feedback can be provided to that individual. People are more prone to report issues if they believe that problems will be addressed in a prompt, effective manner.
- **Stakeholder involvement and empowerment** that engages personnel at all levels of the organization, i.e., frontline employees, union representatives, supervisors, and management, and allows all parties to participate in the decision-making process.

[9] §673.23(b) – "A transit agency must establish and implement a process that allows employees to report safety conditions to senior management, protections for employees who report safety conditions to senior management, and a description of employee behaviors that may result in disciplinary action."

Examples of Employee Safety Reporting Programs

FRA's Confidential Close Call Reporting System (C^{3}RS)

An example of a non-punitive confidential close call reporting system is the Confidential Close Call Reporting System (C^{3}RS), a partnership between National Aeronautics and Space Administration (NASA) and the Federal Railroad Administration (FRA) in conjunction with participating railroad carriers and labor organizations. It is designed to improve rail and transit safety by studying near-miss incidents and unsafe situations by identifying their root causes and developing preventive measures or corrective actions. As envisioned, the C^{3}RS reporting program has fostered a safety culture in which employees feel they can report without the threat of discipline or retaliation. It is designed to improve railroad safety by collecting and analyzing reports that describe unsafe conditions or events in the railroad industry. There are over 21,000 frontline railroad employees who are eligible to report safety incidents through the C^{3}RS program. These employees can report safety issues or "close calls" voluntarily and confidentially. By analyzing these events, potential lifesaving information can be obtained to help prevent more serious incidents in the future.

NASA uses the expertise it has gained from developing and managing the successful Aviation Safety Reporting System (ASRS) to administer the C^{3}RS program. NASA has operated ASRS since 1976 and has received over one million reports from the aviation community. ASRS has made numerous contributions to aviation safety without violating the confidentiality of any reporter. NASA is an independent and respected research organization that does not have a regulatory or enforcement interest; It, therefore, serves as an "honest broker" that is an objective and trustworthy recipient of reports submitted by railroad professionals.

The FRA and NASA collaborate with rail carriers, labor representatives, and frontline personnel to implement C^{3}RS at the nine participating sites and all partake in the process. A rail carrier may establish a Peer Review Team (PRT) to promote C^{3}RS at the site, identify why close calls may occur, recommend corrective action, and evaluate the effectiveness of any such action that was implemented. The carrier reviews PRT recommendations and may take corrective action.

In a February 2019 report,[10] the FRA attempted to determine if close call reporting systems such as C^{3}RS are effective in the railroad industry. The C^{3}RS evaluation was designed to answer three major questions:

- What conditions are necessary to implement C^{3}RS as planned in a demonstration?

[10] "Confidential Close Call Reporting System (C^{3}RS) Lessons Learned Evaluation, Final Report," USDOT, Federal Railroad Administration, DOT/FRA/ORD-19/01.

- What is the impact of C^3RS on safety and safety culture?
- What factors help to sustain C^3RS long-term, beyond the demonstration?

To address these questions, FRA implemented a "lessons learned" evaluation over a 12-year duration across four demonstration pilot sites. The report describes the final answers to the evaluation questions. In summary, implementing C^3RS as planned is possible within transportation departments in the railroad industry. Bottom-line impacts were achieved in the presence of C^3RS in areas such as reduced derailments (three sites), injuries (one site), discipline hearings (two sites), and improved safety culture (four sites). C^3RS can be sustainable in railroad transportation when enlisting the support of local labor, management, national labor, and FRA.

Bureau of Transportation Statistics (BTS)

Another close call reporting program is operated by the Bureau of Transportation Statistics (BTS) under an agreement with WMATA, which allows its employees to report close call events voluntarily without the threat of disciplinary action. The BTS protects data and information collected for statistical purposes under the Confidential Information Protection and Statistical Efficiency Act of 2002, which established uniform confidentiality protections over disclosure and use. The BTS also has agreements with the Department of the Interior in a C^3RS program pertaining to the offshore gas and oil industry.

FTA's Employee Safety Reporting Activities

In 2012, the Transit Advisory Committee for Safety (TRACS) published a report[11] that recommended that FTA pilot a close call, a non-punitive reporting system for transit. The report stated, in part:

> … The primary purpose of a close call safety reporting system is to improve overall safety by encouraging employees to report unsafe conditions or acts voluntarily that would otherwise not be known or detected by transit agency management…. There is strong potential for a confidential, non-punitive, close call safety reporting system to build trust between labor and management and to help establish a just safety culture throughout a rail transit enterprise. Establishing a robust safety culture where all stakeholders work together to continually improve safety is the ultimate goal of a confidential, non-punitive, close call safety reporting system.

Among other topics, the TRACS report identifies and discusses elements of existing systems, funding, pilot sites, Memoranda of Understanding (MOU), criteria for successful implementation, and examples of unsafe incidents. It

[11] TRACS Working Group 11-01 Report, "Establishing a Confidential, Non-Punitive, Close Call Safety Reporting System for the Rail Transit Industry," 07/16/12.

also proposed recommendations for the establishment of a close call reporting system in the rail transit industry.

Close call events cannot be investigated and understood if transit agencies are not aware that they occurred. Hence, the importance of non-punitive safety reporting systems and systems, allowing confidential reporting. The NYCT Track Safety Task Force survey reported that more than half of maintenance-of-way personnel had experienced a near miss or close call, but only one-third of those who had experienced them said they reported it.[12] This hesitancy to report could be the result of a blame culture.

Transit Cooperative Research Program (TCRP) Report 149 offers the following advice on reporting systems:

> A culture of blame will most certainly deter widespread safety reporting. Many reporting systems offer reporting incentives that minimize or eliminate any disciplinary action for an incident except for the most egregious.[13]

Management/Labor Relations

An effective SMS and the supporting Safety Management Policy recognize the importance of management/labor relations. This section examines some best practices for performing event investigations and implementing other safety initiatives where this cooperation can have positive safety effects. Although labor and management have distinct roles in an organization, both share the goal of making the enterprise successful and maintaining public support for the agency's mission. Part of attaining that goal is avoiding transit safety-related events, including accidents and the associated injuries and fatalities.

Joint Safety Investigations

Although transit management may not include union personnel as part of the investigation team for day-to-day event investigation, it may want to look for ways to maximize the resource that unionized employees and their leaders possess during the investigative process. In a Special Investigation Report examining Roadway Worker Accidents,[14] the National Transportation Safety Board (NTSB) described its investigatory process that includes incorporating union personnel as part of the investigation team. The report noted that "the NTSB has experienced that organizational and employee involvement in accident investigations is instrumental in investigative fact-finding." NTSB concluded that "union representation brings operations-specific knowledge to the accident investigation team and helps facilitate the cooperation of employees."

[12] NYTC Taskforce Report, Attachment A, p. 13.
[13] TCRP Report 149, p. 62.
[14] "Special Investigation Report on Railroad and Rail Transit Roadway Worker Protection," NTSB Special Investigation Report, NTSB/SIR 14-03, adopted September 24, 2014.

The NTSB Special Investigation Report elaborates:

> Another key perspective can be gained through employee involvement in the investigation process. Employees are the most knowledgeable about the human, technical, and organizational factors that determine the safety of the system as a whole. This leads not only to a more thorough investigation but also to employee buy-in, resulting in a stronger overall safety culture.[15]

Some agencies convene Boards of Inquiry or other committees, which include a representative from the union on the panel, to investigate serious events. In these serious events, the investigation may require specialized groups or task forces to examine organizational culture and root causes. Union representation can be helpful in such efforts. Therefore, while developing accident investigation protocols, agencies may want to consider ways to use represented employees and their union leaders as a resource to understand accident causation, to find potential links to organizational culture, and to find practical corrective actions to prevent recurrences. Some best practices are discussed below in which joint union-management efforts can improve an organization's safety performance.

During a one-week period in April 2007, NYCT experienced two roadway worker fatal accidents. These accidents led the President of NYCT to convene a Joint Track Safety Taskforce[16] "to identify system, cultural, and behavioral factors that negatively affect track safety and to make recommendations to neutralize or reverse those tendencies." The taskforce included management personnel from NYCT operations and safety departments as well as representatives from the Transport Workers Union (TWU) Local 100. The Task Force goal was not to investigate the details of the specific accidents but to dig deeper into root causes and conditions that could lead to similar events. As part of the Task Force effort, several previous Board of Inquiry reports were evaluated that determined that whereas in many cases rules were not followed leading to an accident, there was an absence of analysis on why the rules were not followed. The report made 63 recommendations grouped into the following categories: 1) General, 2) Training, 3) Routine Communications to Employees, 4) Rules and Regulations, 5) Safety Stand Down, 6) Board Inquiry, and 7) Job Preparation. Recommendations included continuation of joint labor-management inspections of work areas, analysis of inspection data to monitor the effectiveness of safety protocols, and joint labor-management quarterly audits of safety procedures.

Subsequently, TCRP Report 149[17] on rules compliance was published and provides a detailed description of the NYCT Joint Track Safety Taskforce, noting

[15] NTSB Special Investigation Report 14-03, p. 46
[16] New York City Transit, "Joint Track Safety Taskforce Final Report," November 20, 2007
[17] TCRP Report 149: "Improving Safety-Related Rules Compliance in the Public Transportation Industry," Transportation Research Board, 2011.

that since the joint audits were initiated, rules compliance violations declined. The Task Force effort is listed as an industry best practice in the TCRP Report.

Joint Union-Management National Safety Programs

There are several national safety programs with union and management participation that issue reports and other documents that can be helpful in conducting accident investigations and in supporting other safety efforts. The TRACS Safety Committee provides information, advice, and recommendations on transit safety and other issues. TRACS comprises a diverse panel of professionals representing a variety of stakeholders and interests to address issues cooperatively. The TRACS Committee roster[18] includes one member affiliated with the Amalgamated Transit Union, and two current TRACS Safety Focus Areas[19] are Right-of-Way Worker Protections and Accident/Incident Investigation.

The FRA established the Fatality Analysis of Maintenance-of-Way Employees and Signalmen (FAMES) Committee in collaboration with railroad labor and management representatives to review and analyze roadway worker fatalities. FAMES is a voluntary, consensus-based group focused on identifying risks, trends, and factors impacting roadway worker safety. FAMES periodically issues findings and recommendations based on its review of available safety data; its activities are focused on education and prevention.[20]

Transit agencies can support national efforts by assigning personnel and can also find ways to analyze their safety data at the local level using existing joint labor-management safety committees or form other labor-management committees to examine specific issues arising out of investigations or recurring events.

Peer Instructors/Mentors

Many transit agencies use line employees to serve as peer trainers or mentors for new hires. In this role, they can be a resource to other employees by conveying lessons learned from close calls, rules noncompliance, and accidents. The NYCT Task Force report includes a survey[21] taken during focus groups and telephone interviews that found that “over 4 in 10 respondents say communications (bulletins) are ineffective. The top suggestion for improving communication is to increase face-to-face interactions about rules.” The NYCT survey also found that “emphasizing more on-the-job training with a mentor for new workers” would support improvements in safe work practices. Peer trainers and mentors, with union-management backing, are ideally suited to

[18] TRACS Membership List March 2019, FTA public website.
[19] TRACS List of 25 Safety Focus Areas, March 2019, FTA public website.
[20] FRA public website.
[21] "New York City Transit Joint Track Safety Taskforce Final Report," Appendix A.

provide this face-to-face contact. NYCT built upon this initiative by performing activities such as joint labor/management safety audits. These interactions provide employees an opportunity to voice safety concerns with union representation present, which reinforces a positive safety culture. Negative audit findings are prioritized and promptly corrected.

Joint Safety Inspections/Audits of Workplaces

Many accidents involve incorrect execution of existing rules. In line with root cause analysis, investigators should think beyond proximate cause (someone broke a rule) and examine what James Reason would describe as the "defenses" and how they failed to prevent the undesirable event. One of those defenses is rules compliance auditing.[22] Joint union-management auditing can be an effective tool to improve safe work practices.

FTA's regulation at 49 CFR Part 673 is based on the SMS approach. A key element of SMS is Safety Assurance. 49 CFR § 673.27(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.

Dr. Richard Hartley, an expert in high-reliability organization theory, noted in NTSB's investigative hearing into MNR's accidents that "you have a safety management system (but) you have no idea how good that's working until you understand the gaps between how people do work and how you intend them to do work."[23]

Joint union-management monitoring can help to identify those gaps that monitoring conducted by managers alone may not find. Joint union-management compliance monitoring, with less emphasis on discipline and a greater focus on correcting unsafe work practices overcomes negative front-line employee perceptions and makes monitoring programs more effective.

A potential downside of safety compliance monitoring is that the educational and culture-changing potential of monitoring activities can be lost because it is perceived by employees as a "gotcha" program that is heavy on discipline and light on education, coaching, and improvement. It can be a difficult balance to maintain; however, effectively training auditors on employee coaching techniques can help remove negative perceptions. Another way to improve the reception is to make sure that employees are recognized and thanked for things they do correctly.

In 2010, the American Public Transportation Association (APTA) published APTA-RT-OP-S-11-10, Rule-Compliance Program Requirements, for rail transit systems. This voluntary standard requires, among other things, defining rules

[22] Reason, 1997.
[23] NTSB Investigative Hearing Transcript, p. 310, Docket No. DCA13MR003.

to be evaluated, identifying operating positions affected, determining the frequency of checks, establishing methods of verification and metrics, and validation/analysis of program effectiveness.

TCRP Report 149 identified two key factors explaining the success of NYCT's Safety Audit Teams—management support and adequate resources; the agency's CEO has supported this effort since its inception. That endorsement plus the willingness of NYCT's managers to support the findings of the safety audits have made the program a meaningful component of the agency's overall safety program.[24] Joint union-management compliance audits can grow out of accident investigations and CAPs (as in the NYCT example) or be a function of safety committee work or a standalone program.

The survey conducted as part of the NYCT Task Force found that among the top suggestions from employees for improving safety were frequent, unannounced safety audits, more safety training, and improved review and enforcement of safety rules.

[24] TCRP Report 149, p. 55.

Safety Risk Management

Safety Risk Management (SRM) is a process for identifying hazards and analyzing, assessing, and mitigating safety risk. The objective of SRM is to determine and classify system-wide safety risk to develop appropriate risk mitigation strategies.

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

SRM Process

The SRM process defines an RTA's approach and the implementation of an integrated systemwide safety risk mitigation 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 and the process by which an RTA will provide ongoing reporting of hazard identification, consequence, and risk mitigation activities. The SRM process has three primary elements—safety hazard identification, safety risk evaluation, and safety risk mitigation, illustrated in Figures 2-1, 2-2, and 2-3.

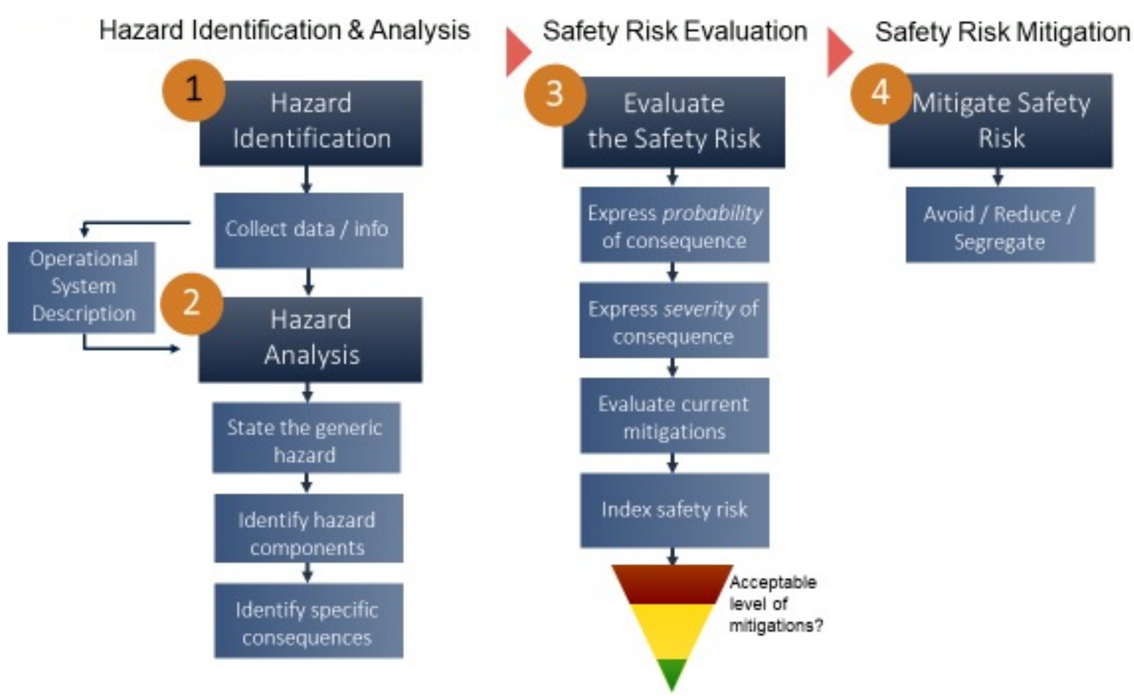

Figure 2-1 *Safety Risk Management Process*

Source: Transportation Safety Institute (TSI)

Transit agencies may find it beneficial to apply elements of the SRM process , either quantitatively or qualitatively, to the following:

- **Initial designs** of systems, vehicles, equipment, material, and organization.
  - Safety and Security Certification (SSC) is applied to projects that may be expected to pose hazards or security risks to the RTA's passengers, employees, and emergency response personnel. It is conducted through a collaborative effort between the safety department and the applicable project team, which may include representatives from other RTA departments as well as project contractors.
  - Procurement requirements include basic safety and user requirements in procurement specifications and coordinated with appropriate offices. As a new facility, system, or equipment specifications are proposed, responding contractors can resolve hazards, by the following prioritized list:
    1. Design for Minimum Hazard – The major effort during the design phase of a contract is to select appropriate safety design features (e.g., fail-safe, redundancy).
    2. Safety Devices –For hazards that cannot be eliminated through design, consider appropriate safety devices to reduce the consequences of hazards to an acceptable level with.
    3. Warning Devices – When it is not possible to preclude the existence or occurrence of a hazard, employ devices for the prompt detection of the condition and the generation of an effective warning signal.
    4. Special Procedure – When it is not possible to reduce the magnitude of an existing or potential hazard through design or the use of safety and warning devices, the development of special procedures to control the hazard may be required.
- **Safety operational procedures** by RTA management ensure that a safety risk assessment is conducted and used to prioritize the development, training, and compliance of rules and procedures.
- **Hazard identification** is addressed through safety assurance functions, such as hazards identified during accident investigations.
- **Planned changes** to the operational system include introduction of new equipment, material, systems, and procedures, to identify hazards associated with those changes.

Safety Hazard Identification

Each RTA must establish a process for safety hazard identification, including identification of the sources (predictive, proactive, reactive) for identifying hazards and their associated consequences (Figure 2-2). Consider a comprehensive list of sources, and ensure activities are documented. Training in hazard identification and reporting will improve an agency's data; hazard identification is ongoing. If the agency receives a hazard report, act and give feedback.

Figure 2-2 *Hazard Identification and Analysis*
Source: TSI

Hazard identification is data-driven—the use of data can facilitate hazard identification (Figure 2-3). Agencies can collect data and information from various sources; however, it is important 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 happening in the agency.

Figure 2-3 *Hazard Identification and Data Collection*
Source: TSI

Historically, an iceberg graph shown in Figure 2-4 can help to illustrate where the focus of hazard identification should lie (elements seen above the water line and what is hidden underneath the water surface). An iceberg graph is an operational depiction of a relationship established in the 1930s by H.W. Heinrich, an industrial safety engineer who demonstrated that for a specific operational work situation that led to highly-damaging outcomes (an accident) (top level), there was a large number of same-type, precursor specific work situations that led to less harmful outcomes (serious incidents) (second level), a more significant amount of same-type, precursor specific work situations that did not lead to damaging outcomes (incidents) (third level), and, at the bottom of the iceberg, an even more significant number of “normal” work situations where the precursors to harmful outcomes (hazards) could be identified.

Figure 2-4 *Iceberg Graph: Focus of Hazard Identification*
Source: TSI

The bottom of the iceberg is where hazard identification is most effective and where practical drift can be tracked. This is where hazard identification best operates through specific activities aimed at capturing both volume and variety of data on hazards identified while monitoring service delivery operations by a transit agency. Once hazards are identified and assessed, then safety risks can be evaluated, and mitigations can be proactively deployed to avoid the escalation of the potential consequences of hazards towards the accident at the tip of the iceberg. (*Note*: It might not be feasible to perform comprehensive safety risk assessments of all the precursors to damaging outcomes [hazards] at the bottom of the iceberg. Collection of and analysis of “occurrence” data would assist in identifying and prioritizing hazards that should be subject to comprehensive safety risk assessment.)

Hazard identification 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. The three methodologies for identifying hazards are:

- **Reactive** - involves analysis of past outcomes or events. Hazards are identified through event investigations. Incidents and accidents are clear indicators of system deficiencies and, therefore, 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, such as through an employee safety reporting program or monitoring service operations. 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.

Hazards may be identified through many sources, as illustrated in Figure 2-5. Categories of hazards, hazard aspects, and descriptions are listed in Table 2-1, and details of mechanical and overexertion hazards are listed in Table 2-2.

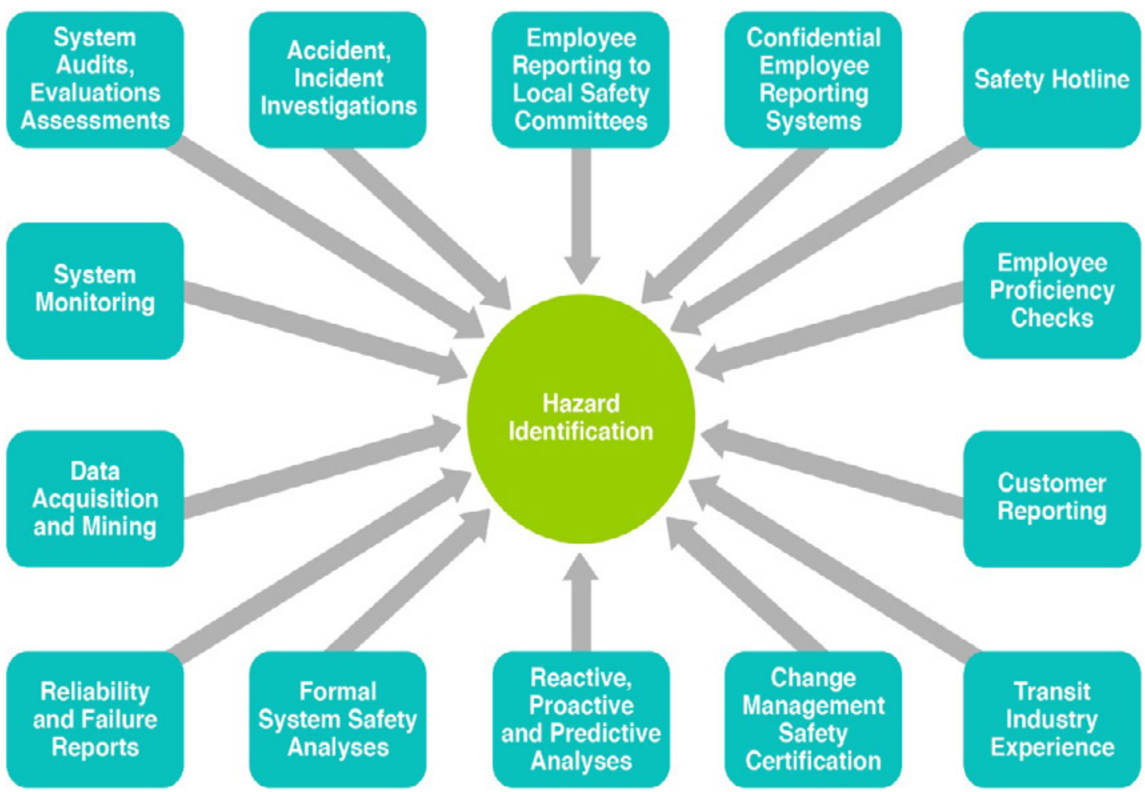

Figure 2-5 *Sources of Hazard Identification*

Source: TSI

Table 2-1 *Hazard Categories*

Hazard Category	Hazard Aspect	Description
Is there an environment capable of producing an unwanted release of energy?		
Unwanted Energy	Fire	Potential for exposure to a chemical or substance that can ignite if exposed to an ignition source, including power faults producing arc flashes.
	Loss of Power	Potential for exposure where safety critical equipment can fail due to loss of power or unexpected loss of power can endanger people in or ways.
	Shock, Short Circuit, Arc Flash,	Potential for contact with exposed conductors or device that is incorrectly grounded. Potential for arc flash.
	Static	Potential for exposure where static electricity is generated by rubbing of wool, nylon, or synthetic fibers (escalator handrail), or flowing liquids and can cause a spark to ignite combustible material; spark can ignite flammables, damage electronics, or affect body's nervous system.
	Radiation-Ionizing	Potential for exposure to alpha, beta, gamma, neutron radiation.
	Radiation-Nonionizing	Potential for exposure to electromagnetic fields or light (energy) sources.
	Chemical Reaction/ Deflagration	Potential for incompatible materials to mix, causing explosion or unwanted release of energy; may include explosions due to combustible dusts (brake/ tunnel dust).
	Over Pressurization	Potential for sudden and violent release of large amount of gas or energy due to significant pressure differences such as rupture in boiler, pipe, or compressed gas cylinder.
Is workplace configured so workers could be caught in, on, between equipment and that employees can strike an object?		
Configuration	Caught in on, between	Person becomes trapped in some enclosure or opening or caught on a protruding object or is exposed to irregularities in facilities design.
	Struck Against	Person could strike exposed object.
	Design	Workplace or facility is poorly designed, specifications are incomplete, and or maintenance requirements are not known, understood, or incomplete, which could contribute to injury or illness.
Can an employee be struck by an object or be struck by a moving mechanical object?		
Mechanical	Failure	Potential for excessive vibration or factors that could cause material fatigue that results in safety-critical failure (e.g., fasteners, abraded slings/ropes, weakened hoses/belts).
	Moving Vehicle	Potential to be struck by or collide with a moving vehicle.
	Struck/Caught By	Potential for a person or clothing to be struck or grabbed by a moving object.
	Transmission	Potential for signal loss, making transmission between equipment and or personnel difficult or not enabled.
Is there potential for slipping, tripping, or falling due to gravity?		
Gravity	Changing Levels	Potential for exposure to a fall from elevated work area.
	Overhead	Potential for objects to fall from heights, causing injury or property damage.
	Slips & trips (walking/working surfaces)	Potential for exposure to uneven floor or floor openings, with potential for slip or trip.

Hazard Category	Hazard Aspect	Description
Does presence of chemicals or substances pose a threat to safety and health of workers and customers?		
Chemicals/ Substances	Biological	Exposure to or contact with contaminated or pathogenic products or materials or potent compounds.
	Toxic	Potential for exposure to chemical through inhalation, absorption, or ingestion that causes illness, disease, or death.
	Corrosive	Potential for exposure to chemical that can cause skin and eye damage; typically, pH at 11 or more or a pH of 2 or less.
	Vegetation	Potential for adverse reactions to contact with vegetation.
Could employee overexert from pushing, pulling, bending, twisting, repetitive motion, vibration, or lifting?		
Overexertion	Acute	Potential for exposure to non-contact injury/illness such as bodily strain or sprain from lifting, bending, twisting, pulling, pushing.
	Chronic (Repetitive Motion)	Potential for exposure to non-contact injury/illness such as bodily strain or sprain from repetitive motion, prolonged inactivity; potential exposure to excessive vibration, causing nerve-ending damage. (e.g., power tools, jackhammers, rock hammers, tampers).
	Vibration	Potential for exposure to excessive vibration, causing nerve-ending damage. (e.g., power tools, jackhammers, rock hammers, tampers).
Is working or operating environment hazardous to safety and health?		
Environmental	Atmosphere	May include lack of oxygen or environmental factors not directly a result of substances in workplace (see substances above if mold, dust).
	Excavation (Collapse)	Potential for collapse or engulfment, e.g., in dirt from trenching or excavation as result of improper or inadequate shoring or steep edge based on soil characteristics or in a confined space.
	Noise	Potential for exposure to noise levels above 85 dBA, 8-hour TWA, or 140 dBA impact noise resulting in hearing loss or interference with communication or noise at lower levels may interfere with verbal, critical communication.
	Temperature Extreme (Heat/ Cold)	Potential for exposure to fire, burns, heat stress/exhaustion, cryogenics, hypothermia.
	Visibility	Potential for incidents or errors because of insufficient lighting or obstructed view.
	Wildlife	Potential for wildlife to encounter workers and cause injury or illness (e.g., spiders, stinging insects, ticks, mosquitos, snakes, bears).
	Wear	Changes in wear may cause flooding, ice or snow accumulations, wind hazards, electrical hazards, arc flash.
Is task designed to be either too complicated, too simple, or contribute to human error?		
Human Factors	Task Design or Complexity	Potential for system design, procedure, or system/equipment design that is error provocative (e.g., switch must go up to turn off device, conflicting color codes, or labeling, task is monotonous). Can include physical and social environment, resources, tools, incentives, equipment problems, obstacles to performance, staffing.
	Communication	Instructions required to perform a task where communication is ambiguous, vague, conflicting, and or incomplete. Communications can be verbal (including over radio net) or documented.
	Experience	Includes insufficient experience, training or knowledge, proficiency, skills, experience, physical readiness, attitudes, or motives.

Source: American Society of Safety Professionals (ASSP)

Table 2-2 *Details of Mechanical and Overexertion Hazards*

Mechanical Detailed List (To be performed in addition to general hazard list). Evaluate point of operation, power transmission, other moving parts, and safeguard(s) itself.	
Parts or work pieces	Shape; relative location; mass and stability (potential energy of elements which may move under the effect of gravity); mass and velocity (kinetic energy of elements in controlled or uncontrolled motion; chemical strength limitations).
Potential energy	Elastic elements (springs); liquids and gasses under pressure, vacuum effects.
Other mechanical	Crushing; shearing; cutting or severing; entanglement; drawing in or trapping; impact; stabbing or puncture; friction or abrasion. High-pressure fluid injection or ejection.
Electrical	Contact with live parts; contact with parts that have become live under fault conditions; approach high voltage; arc flash; electrostatic and thermal (molten or heated particles or substances).
Thermal	Burns, scalds, or other injuries with contact of objects or materials in extremely high or low temperatures, arc flash, flames or explosions, heat source radiation.
Unexpected start-up, Overrun or over-speed	Failure of a control system, restoration of energy after interruption, external influences on electrical equipment, other external influences (gravity, wind), errors in software, man-machine interface errors.
Operational	Variations in rotation speed of tools; failure of power supply; failure of control circuit; errors of fitting; break-up during operation; falling or ejected objects or fluids; loss of stability or overturning of machine; person might slip trip or fall into a machine.
Safeguards	
Safeguard design and Construction	Pinch, shear, or crush; loosening or fracturing of bolts, fasteners, or components; loss or disturbance of external power sources; failure of electrical pneumatic or hydraulic components; hazardous energy, electromagnetic, or electrostatic interferences, shock, vibration; humidity, contaminated air, ambient noise, light, temperature, liquids; human factors, electrical shock, arc flash.
Safeguard installation	Work area layout, hazardous energy; work surfaces; housekeeping; accessibility limitations.
Start-up (safeguard)	Pinch, shear, or crush between safeguard and machine; improper mounting or positioning; power source interference, machine interface errors; machine motion; electrical shock; safeguard proximity to other tools, equipment, and materials, human factors.
Safeguard use	Set and adjustments; function; limited application; proximity to other tools, equipment, and materials; housekeeping, human factors.
Safeguard maintenance	Motion, stored energy, improper testing procedures, work procedures, housekeeping, human factors.
Overexertion	
Repetition	Repeating same motion every few seconds or repeating cycle of movements involving repetition of affected body part more than twice per minute for more than two consecutive hours in a workday.
Force - 25	Lifting more than 25 lbs below knees, above shoulders, or at arm's length more than 25 times per day.
Force - 55	Lifting more than 55 lbs more than 10 times per day.
Force - 75	Lifting more than 75 lbs at any one time.
Force - push/pull	Pushing/pulling with more than 20 lbs of initial force (e.g., equivalent to pushing a 65 Force pushing/pulling box across tile floor or pushing shopping cart with five 40-lb bags of dog food) for more than 2 hours per day.

Grip	Gripping unsupported object weighing 10 lbs or more per hand or use of an equivalent force (e.g., crushing sides of aluminum can with one hand) for more than two hours per day.
Pinch	Pinching unsupported object weighing 2 lbs or more per hand or using an equivalent pinch-ing force (e.g., holding small binder clip open) for more than 2 hours per day.
Postures/twisting	Repeatedly raising or working with hand(s) above head or elbow(s) or above shoulder(s) for more than 2 hours total per day. Kneeling or squatting for more than 2 hours total per day. Working with back, neck, or wrists bent or twisted more than 20 degrees for more than 2 hours per day, squatting or kneeling more than 4 hours per day, or body bent or twisting for or 30 degrees more than 4 hours per day.
Impact	Using body part as a hammer once per minute for more than 2 hours in a day.
Vibration	Either local or whole-body vibration.
Contact stress	Repeated or continuous contact with hard or sharp objects such as non-rounded desk edges or unpadded, narrow tool handles creating pressure over one area of body; can inhibit nerve function and blood flow.

Source: ASSP

Practical Drift

Part of the SRM process is the evaluation of existing systems, policies, and procedures to ensure that "practical drift"[25] is not a contributor to risk. Practical drift is the slow and inconspicuous, yet steady, uncoupling between written procedures and actual practices during the provision of services (Figure 2-6).

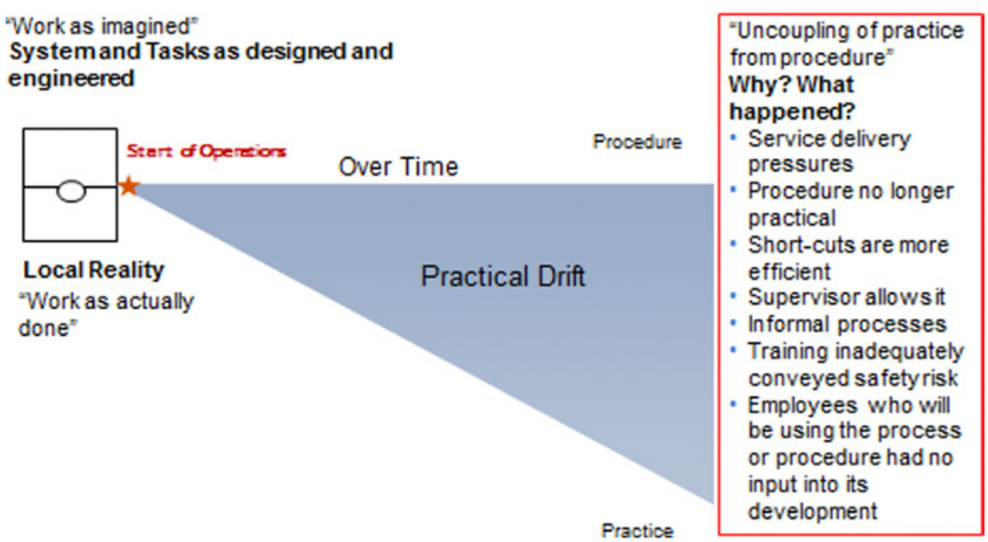

Figure 2-6 *Practical Drift*

Source: TSI

A robust data collection and analysis process may enhance practical drift identification. Figure 2-7 illustrates data needs.

[25] Snook, Scott, A., *Friendly Fire: The Accidental Shootdown of U. S. Blackhawks over Northern Iraq*, Princeton University Press, 2000, Digital Location 5234.

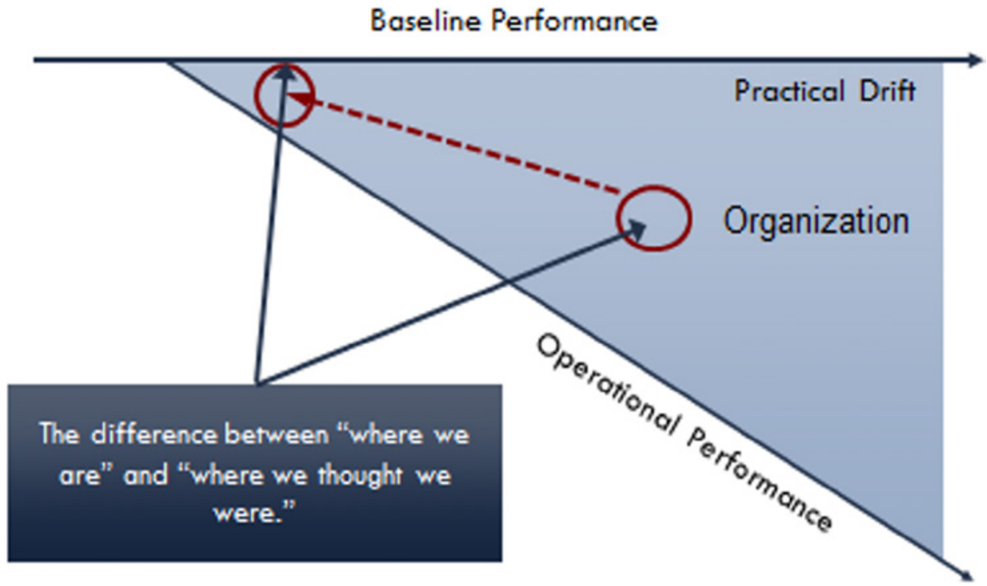

Figure 2-7 *Navigating Practical Drift – Need for Data*
Source: TSI

A practical drift from baseline performance to operational performance is unavoidable in any system's operations or maintenance functions, no matter how careful and well thought out its design planning may have been. There can be multiple reasons for the practical drift, including technology that does not always operate as predicted, procedures that cannot be executed as planned because of changes in operating conditions, the addition of new components to the system without an appropriate safety assessment of the problems that such components might introduce, and employee adaptations to procedures to make their job easier, improve the effectiveness of a procedure, or provide some perceived positive organizational benefit. In its simplest form, practical drift is based in human nature.

Practical drift is not always negative. The adaptation may be more productive, save time and energy, or be easier or safer. However, practical drift potentially can put an employee, passengers, or the agency at a higher safety risk. A shortcut to a procedure or practice that seems harmless could have negative or unsafe impacts on another facet of the agency's operations. This goes back to the interconnectivity of transit systems—one small change in practice could lead to unsafe circumstances and outcomes. It is critical to know where, how, and how much drift has occurred. Data are necessary to navigate the practical drift successfully. The only way to tell whether the drift is positive or negative is to gather information through monitoring what is happening versus what was planned, required, or expected.

Managing Practical Drift

Managing practical drift begins with recognizing that it will occur in an organization; it is human nature. The process to manage drift is as follows:

- Explore how employees come to believe that not following procedures makes more sense than systematic and principled series of activities directed to an intended completion.
- Involve knowledgeable and respected front-line employees in the development of agency policies and procedures.
- Acknowledge that, ideally, the right way to accomplish a task should also be the easiest.
- Conduct supervisory monitoring of how employees do their work, identify how tasks are being conducted rather than how they were initially designed to be conducted.
- Update procedures in line with safe, effective, current practice.

For example, a transit agency provides sufficient time for an employee to perform a comprehensive pre-trip inspection in accordance with agency policies. However, shortcuts are taken by some operators due to inclement or severe weather, fatigue, or the assumption that "everything was fine yesterday, so it is good-to-go today." If the operator "gets away" with it, i.e., takes shortcuts, and they do not result in incidents or the operator is not noticed taking shortcuts by a supervisor, then the shortcuts continue, and perhaps, the shortcutting behavior is acquired by other operators. In the extreme, pre-trip inspections might eventually degenerate into a "pencil whipping exercise." This would be a form of practical drift.

Safety Deficiency

Identifying safety deficiencies of the system is part of the safety risk management process. Safety deficiencies could be the source of hazards or allow for the perpetuation of hazards in time; these are the products of organizational processes and can include:

- Unclear management support for the employee safety reporting system
- Deficiencies in documented key activities, such as hazard identification
- Shortcomings in personnel resources or training in safety-critical areas
- Incomplete certification of equipment and facilities
- Ambiguous operational procedures
- Staffing key operational positions with personnel not meeting the required qualifications
- Practical drift

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. Examples include:

- Grade crossings
- Unclear roadway signage/traffic patterns
- Worn vehicle brake assembly
- Narrow traffic lanes

A consequence is the potential outcome(s) of the hazard. Figure 2-8 shows the transition of a hazard to a consequence. For this transition to occur, there needs to be present a form and magnitude of energy and a trigger event, i.e., exposure to or proximity to the hazard. Energy is the property of objects that can be transferred to other objects or converted into different forms but cannot be created or destroyed; it gives a hazard the ability to cause harm. A trigger is a pathway of exposure to hazards, including direct or indirect contact with or proximity and duration, magnitude, and concentration or dose of exposure. The following are causes or triggers that could result in exposure to a hazard:

- Machinery – design, fabrication, selection, use, maintenance, state of good repair
- Human – actions, inactions, knowledge, skill, capability, attention, interaction, communication, practical drift
- Management – direction, supervision, instructions, inconsistencies in enforcement, communication
- Methods – design, system, process, procedure, task, consistency
- Materials – elements, constituents, selection, handling, storage, use, disposal
- Work and operating environment – design/layout, condition, external factors

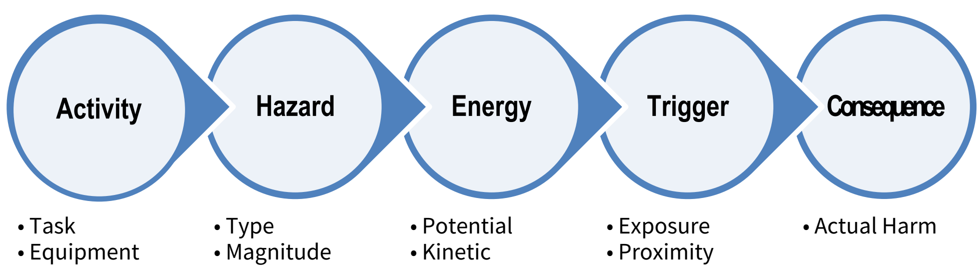

Figure 2-8 *Necessary Elements for Hazard to Result in Consequence*
Source: TSI

Hazards within the transit rail environment can exist due to several factors; the failure mode of the system, equipment, products, or elements exists when these components fail to perform as expected or deviate from design tolerances. Failures may present (or have the potential to present) hazardous events or harm. Examples include:

- Premature operation of a system, vehicle, or equipment (e.g., unexpected activation or energy release)
- Failure to start operation (e.g., drainage pump fails to operate, and water levels rise above the third rail in underground portions of the rail system)
- Failure to stop operation (e.g., vehicle braking fails when train door interlocks fail)
- Failure during operation (e.g., tunnel ventilation system fails when tunnels are filling with smoke)
- Degradation or deterioration of an operation (e.g., accumulating snow covers third rail or the combination of leaves, and wet tracks cause slippery conditions on the track)
- Exceeded capability or capacity of an operation (e.g., over-crowding on escalators fail to result in activation of escalator glide-stop)
- Foreseeable uses and misuses of an operation (e.g., heavy equipment transported on escalators)

It is critical to understand the difference between a hazard and a consequence. Confusing the two will limit the ability to effectively mitigate the multiple, potentially dangerous consequences of a hazard, including describing consequences as a hazard, and can disguise potential consequence(s) of the hazard and interfere with identifying other significant consequences. Accurately describing hazards allows for identification of their components, proper evaluation of the consequence(s), including the magnitude, and effective mitigation of the consequence(s). Examples of hazards and consequences include the following:

- Unclear roadway signage (hazard) that may lead to erratic vehicle speeds (consequence)
- Worn bolts on brake assembly (hazard) that may lead to a collision (consequence)
- Narrow traffic lanes (hazard) that may lead to collisions with other vehicles, pedestrians, bicyclists, or road structures (consequence)
- Grade crossings (hazard) that may lead to collisions with vehicles, pedestrians, bicyclists, or grade crossing arms and other structures (consequence)

Consequences are often assessed for severity, frequency of occurrence, and cost feasibility of remedial action required to mitigate the consequences of a hazard.

Operational System Description

An operational system description can be used to examine critical operational interactions that could generate hazards and determine mitigations that may safeguard against the consequences of potential or existing hazards. The primary purpose of the operational system description is to define the contextual boundaries where hazard identification will be conducted, the components in the operational system that will be considered, and the interactions between the selected elements. This can be an effective early step of an accident investigation.

An operational system description may not need to be developed every time a hazard is identified, which could be potentially paralyzing to the agency. Documented system descriptions can serve as an ongoing record of hazard analysis and safety risk evaluation activities as well as a reference if any hazards are identified. If well-documented, they also provide one way to measure the effectiveness of the SRM process. If a transit agency is continuously reinventing or modifying the operating system description as hazards are identified, perhaps the activity is not comprehensive enough.

The operational system description focuses on what the operating system looks like currently or immediately before an accident or incident and during response and recovery. An accurate system description may lead to identification of hazards, evaluation of safety risk, and identification of safety risk mitigations.

The operational system description is meant to describe reality, not what the agency would like the system to be. It can serve as a menu, detailing the technical components, the activities around the components, and the interactions between operational components and activities. The system description also encompasses the applicable regulatory requirements under which the operations take place and any mitigations in place to make the system safer and more efficient. Elements and sub-elements of an operational system description are presented in Figure 2-9.

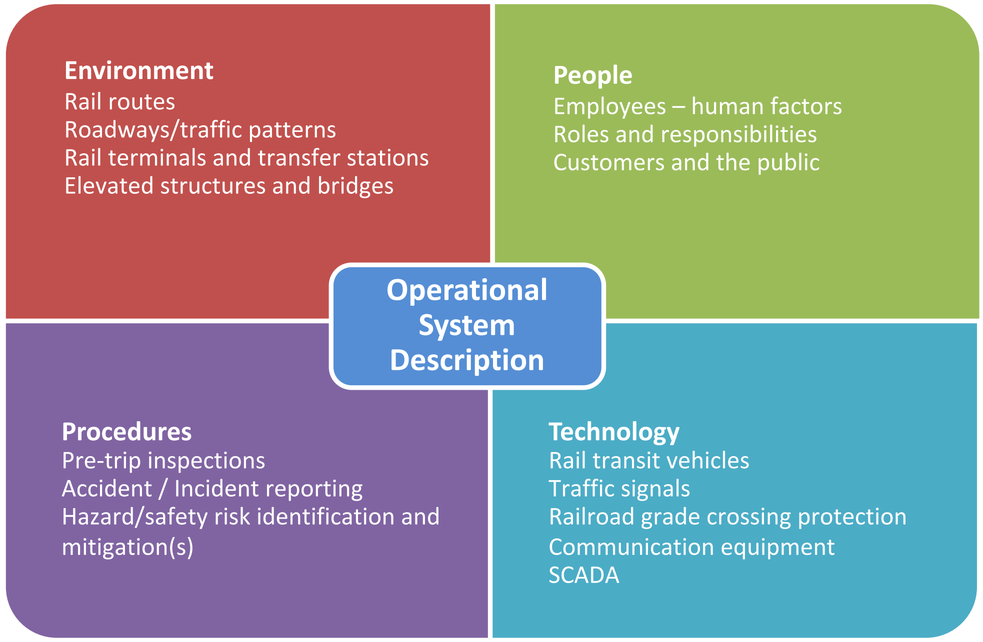

Figure 2-9 *Operational System Description*

For each operating system described, an agency may establish a team to perform the analysis and include all levels of labor that perform the work, along with management and safety representation, to develop the operating system description. The agency may appoint an SME to lead the team (e.g., a senior signal engineer to lead the team conducting an analysis for a signal system or a superintendent of track maintenance to lead the track team). In some situations, the operational system description may require only a reliable SME, but most often it is best served by a team representing a cross-section of employees. Qualities of the process include:

- Scalable depending on size of agency
- Encouraging State Safety Oversight Agency (SSOA) participation
- Clarifying roles of operating and maintenance functions to take clear accountability for safety performance under SRM
- Introducing multiple layers of SMEs

Members of the operating and maintenance functions are an important part of the operational system description team, as SMEs in these functions often have an essential role in safety performance. Frontline employees have excellent subject matter expertise in conducting their safety-related responsibilities and in identifying hazards inherent in those responsibilities. Transit agencies may want to consider giving them, their supervisors, and operating and maintenance managers a voice on these teams. Safety staff have a significant role to play in this process; however, the team's effectiveness relies on input from multiple layers of organizational expertise. The team needs to be well-rounded and inclusive of people with technical specialties and broader knowledge. It is also important to keep the size of the team in perspective and scale it to fit the area addressed. Some areas may need more involvement and others less. Be mindful to avoid burdening the process with teams that are too inclusive.

Once assembled, the team can identify the operational elements for which they are responsible and address tasks performed by employees to operate and maintain the system for which they are responsible and the interactions critical for the successful performance of that system, such as standard operating procedures (SOPs), rules, and processes. The team can then look at the scenarios used to clarify interactions among elements and sub-elements during service delivery operations as part of the SRM activities and then prioritize the mitigations as part of SRM—identify those already in place that ensure the safety of the operational elements and sub-elements in the system based on the scenarios.

The Safety department's role in operational system description team activities may be to support the respective departmental activities, including but not limited to those of the maintenance, plant, transportation, and operation departments. This may include providing templates to develop meeting agendas and document the results of those meetings as well as carrying forward any required SRM hazard analysis processes based on hazards identified during team discussions.

Each team can submit a final report to the Safety department that supplies the operational system description for their functional area of responsibility and includes a prioritized list of safety mitigations in place and those recommended because of the safety risk evaluation to safeguard safety success within their functional areas of responsibility. The SRM report could then be incorporated into the accident investigation report.

Hazard Identification

After hazards have been identified, they should be analyzed for their consequences. Analysis may best be performed by SMEs from appropriate departments, individuals who know the technical aspects of the equipment, systems, vehicles, facilities, or the issue at hand. SMEs are experienced personnel that may have experience in addressing a similar issue. The transit agency may need to bring in outside expertise, as external assistance can bring fresh eyes and a new perspective on an issue.

Hazard Identification is a three-step process:

1. **Identify the generic hazard.** This provides focus and perspective on a safety issue while also helping to simplify the tracking and classification of many individual hazards flowing from the generic hazard.

2. **Break down the generic hazard into specific hazards or hazard components.** Each component will likely have a different and unique set of causal factors, thus making each component different and unique in nature.
3. **Link the hazard components to potentially specific consequences,** such as specific events or outcomes.

Safety-Critical Systems

Specific systems and subsystems in the design and development of a transit system are safety-critical and may present potential safety hazards:

- Train control
- Traction power
- Communications
- Signal systems
- Track and infrastructure
- Material selections
- Fire and emergency management systems (EMS)
- Ventilation systems

Hazard Identification Methods

Processes used to analyze safety critical systems are identified below and include those considered "inductive" and "deductive." An inductive analysis is one that determines the effect of a specific event or component failure on a system. This is a bottom-up approach—for example:

- Component – headlight switch
- Problem – fails
- Hazard/effect – strike unseen object on track

Analyses that may be used to support this process include:

- Operating Hazard Analysis (OHA)
- Preliminary Hazard Analysis (PHA)
- Subsystem Hazard Analysis (SSHA)
- System Hazard Analysis (SHA)
- Software Safety Analysis (SSA)

A deductive analysis will examine the undesired event to determine the plausible causes of that event. This is a top-down approach—for example:

- Hazard/effect – Strike unseen object on track

- Problem – no headlight
- Component – failed headlight switch

A Fault Tree Analysis is an example of a deductive method of hazard analysis. A description of each of these analysis methods is provided in the following section. Associated forms are included in Appendix A.

An Operational Hazard Analysis (OHA) is used to identify and analyze hazards associated with personnel and procedures during production, installation, testing, training, operations, maintenance, and emergencies. The OHA will provide for corrective or preventive measures to be taken to minimize the possibility that any human error or procedure will result in injury or system damage. It provides inputs for recommendations for changes or improvements in design or procedures to improve efficiency and safety, development of warning and caution notes to be included in manuals and procedures, and the requirement of specialized training of personnel who will carry out the operation and maintenance of the system. It will result in outputs presented in Figure 2-10.

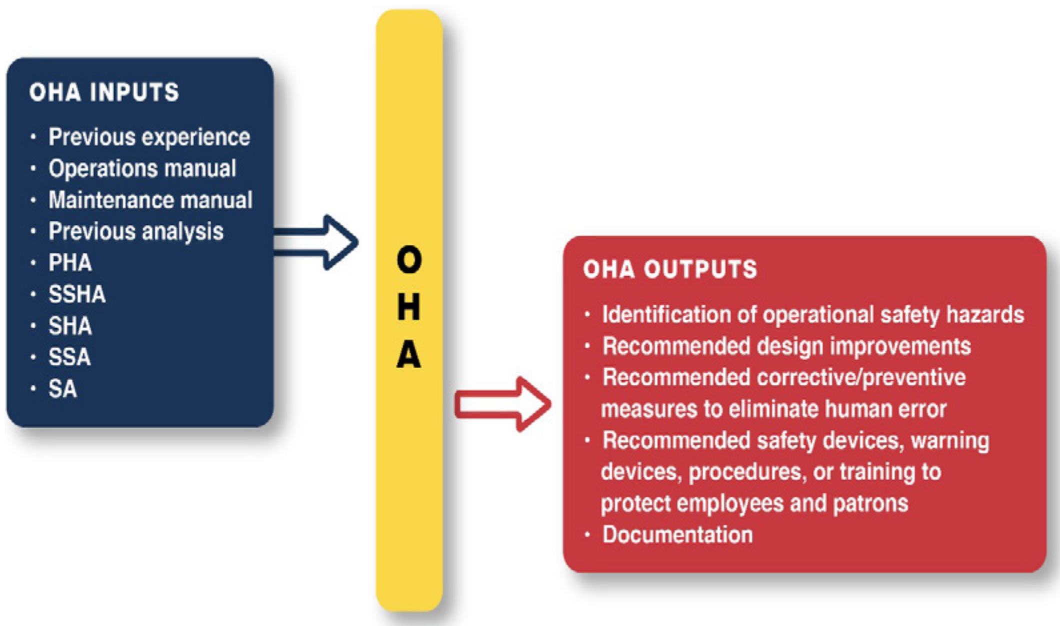

Figure 2-10 *Operational Hazard Analysis*
Source: TSI

The OHA analyzes hazards as described above, specifically:

- Tasks
- Human/machine interface
- Operation sequences
- Instructions

- Warnings/cautions
- Mental/physical demands
- Time requirements

The purpose of a Failure Modes and Effects Analysis (FMEA)[26] is to determine the results or effects of sub-element failures on system operation and to classify each potential failure according to its severity. FMEA is used to identify and analyze failures early in the design and major retrofit phases so that appropriate actions are taken to eliminate, minimize, or control safety. FMEA also has an application to manufacturing, construction, and the operating phases of a system.[27] The FMEA process is illustrated in Figure 2-11. The FMEA can be used to:

- Assist in selecting effective, reliable design alternatives
- Ensure that failure modes of system and processes and their effects on operations have been evaluated
- Identify human error modes and effects
- Establish a basis for planning, testing, and maintenance of systems
- Enhance the development of procedures and processes
- Provide both qualitative and quantitative data for analysis methods and safety risk evaluation

FMEA will examine the system element by element, using deductive logic to evaluate a system or process for safety hazards and to assess risk. An FMEA identifies:

- Potential failure modes of parts and subsystems of a system (failure mode is what is observed to fail or to perform incorrectly)
- Effects of failures on system
- Failure mechanisms
- Mitigation of effects of failure on system

Inputs[28] to an FMEA include:

- System drawings and a flow chart that depicts system and its components undergoing analysis
- Understanding of function of each step in the process or each component of system
- Details of conditions and other factors that might affect system operation
- Grasp of consequences of specific failures
- Historical agency and transit industry failure and failure rate data

[26] USDOT, Federal Transit Administration, *Hazard Analysis Guidelines for Transit Projects*, January 2000.
[27] American National Standards Institute (ANSI)/American Society of Safety Professionals (ASSP), ANSI/ASSP Z690.3-2011, Risk Assessment Techniques, Des Plaines, IL, 2011, p. 56.
[28] *Ibid*., p. 57.

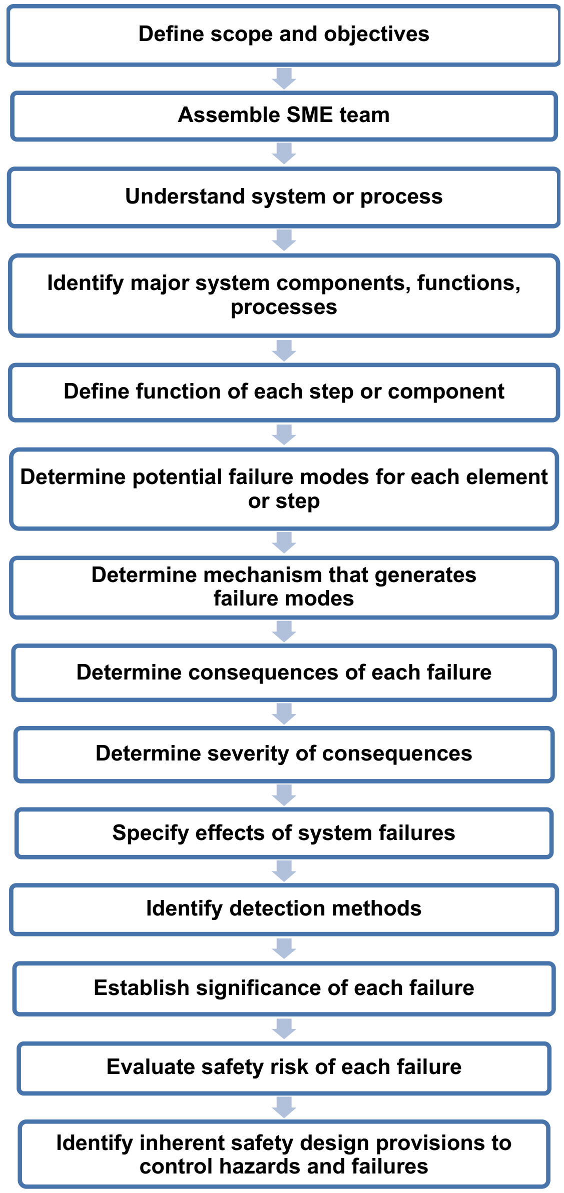

Figure 2-11 *FMEA Process*

The output of the FMEA is a comprehensive report that contains:

- Operational system description
- Methodology
- Analytical hypothesis and conventions
- Data sources
- List of failure modes, failure mechanisms, causes, effects, and consequences a failure of each component or step of a system or process and consequences on the system or process as a whole

- Test results and calculation worksheets
- Recommendations for additional analyses, mitigations, and corrective actions for each failure if necessary
- Data from FMEA entered into a Safety Risk Assessment Matrix to determine level of safety risk and safety risk priority

A Failure Mode, Effects and Criticality Analysis (FMECA) can be used to classify each identified failure mode according to its criticality. The classification can be performed by determining the level of risk or the risk priority number.

FMEA Strengths

- Widely applies to system, process, equipment, hardware, software, procedures, and human failure modes
- Identifies and organizes component failure modes, and causes and effects on system or process
- Identifies single point failure modes and requirements for design redundancy and mitigation via safety systems
- Identifies key features and controls that need to be evaluated in a safety assurance, safety performance monitoring plan

FMEA Limitations

- Can identify and evaluate only single failure modes
- Process must be directed and focused to avoid uncontrolled expenditure of resources
- Analysis of multi-layered, complex systems, and processes can become tedious and abstruse

Figure 2-12 *FMEA Strengths and Limitations*

Fault Tree Analysis[29] is both an analytical method to assist in determining accident causes and a hazard identification method. It provides a standardized discipline to evaluate and control hazards. The Fault Tree Analysis process is used to solve a wide variety of problems ranging from safety to management issues. A Fault Tree Analysis is used by the professional safety and reliability community to prevent and resolve hazards and failures. Both qualitative and quantitative methods are used to identify areas in a system that are most critical to safe operation; either approach is effective. The output is a graphical presentation providing technical and administrative personnel with a map of “failure or hazard” paths. The reviewer and the analyst must develop insight into system behavior, particularly those aspects that might lead to the hazard under investigation.

[29] USDOT, Federal Aviation Administration, *FAA System Safety Handbook*, Chapter 9, Analysis Techniques, December 30, 2000.

Qualitative Fault Tree Analyses are cost-effective and valuable safety engineering tools. The generation of a qualitative fault tree is the first step. Quantitative approaches multiply the usefulness of the Fault Tree Analysis but are more expensive and often difficult to perform.

A Fault Tree Analysis (like a logic diagram) is a deductive analytical tool used to study a specific undesired event such as "train car door relay failure." This approach begins with a defined unwanted event, usually a postulated accident condition, and systematically considers all known events, faults, and occurrences that could cause or contribute to the occurrence of the undesired event. Top-level events may be identified through any safety analysis approach, through operational experience, or a "could it happen?" hypothesis. The procedural steps of performing a Fault Tree Analysis are as follows:

1. Assume a system state and identify and document the top-level undesired event(s). This is often accomplished by using a PHA. Alternatively, design documentation such as schematics, flow diagrams, level B & C documentation may be reviewed.
2. Develop upper levels of trees via a top-down process—determine intermediate failures and combinations of failures or events that are the minimum to cause the next higher-level event to occur. The logical relationships are graphically generated, as described below, using standardized Fault Tree Analysis logic symbols.
3. Continue the top-down process until the root causes for each branch are identified and until further decomposition is not considered necessary.
4. Assign probabilities of failure to the lowest level event in each branch of the tree; this may be through predictions, allocations, or historical data.
5. Establish a Boolean equation for the tree using Boolean logic and evaluate the probability of the undesired top-level event.
6. Compare to the system level requirement. If the requirement is not met, implement corrective action. Corrective actions vary from redesign to analysis refinement.

The output of the Fault Tree Analysis is a graphical logic representation of fault events that may occur to a functional system (see Figures 2-13 and 2-14). This logical analysis must be a functional representation of the system and must include all combinations of system fault events that can cause or contribute to the undesired event. Each contributing fault event should be further analyzed to determine the logical relationships of underlying fault events that may cause them. This tree of fault events is expanded until all "input" fault events are defined in terms of primary, identifiable faults that may then be quantified for computation of probabilities if desired. When the tree has been completed, it becomes a logic gate network of fault paths, both singular and multiple, containing combinations of events and conditions that include primary, secondary, and upstream inputs that may influence or command the hazardous mode.[30]

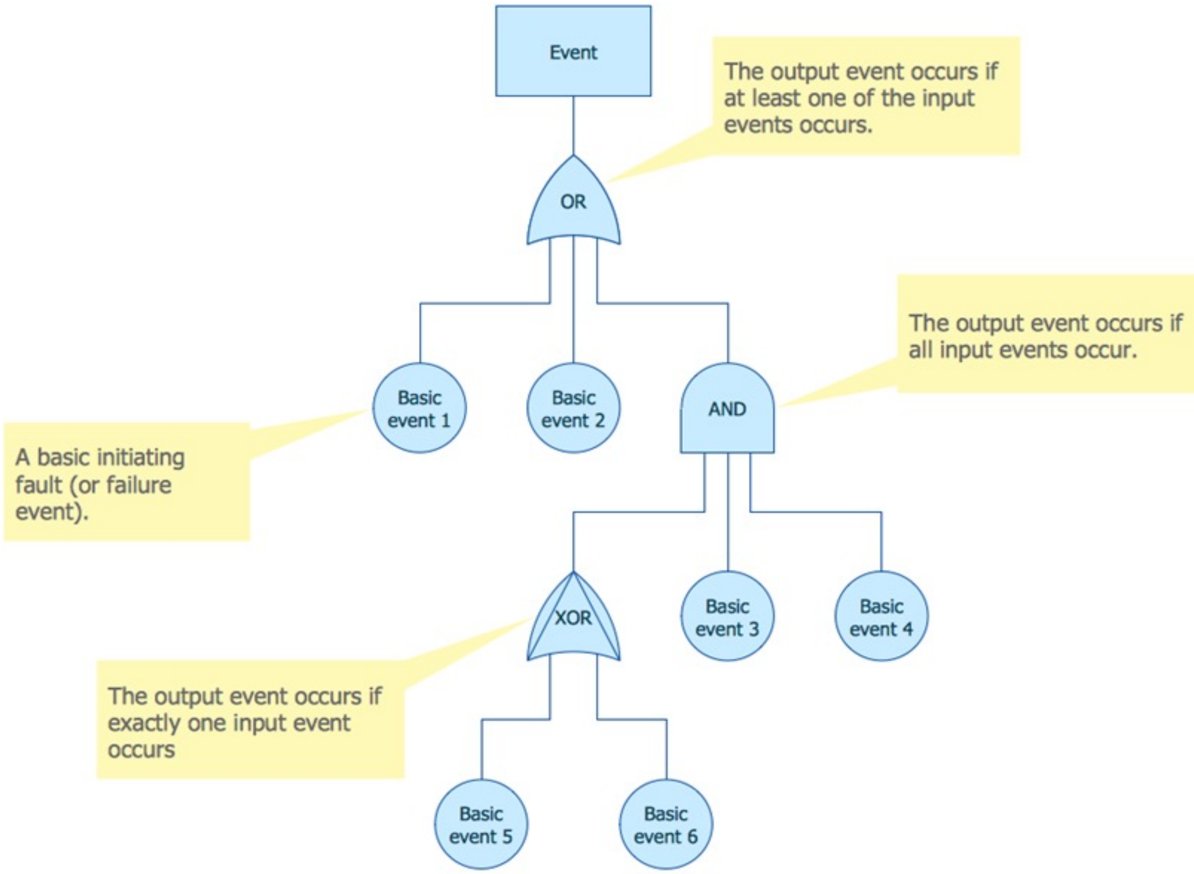

Figure 2-13 *Example Fault Tree*

[30] *Ibid*., p. 9-5.

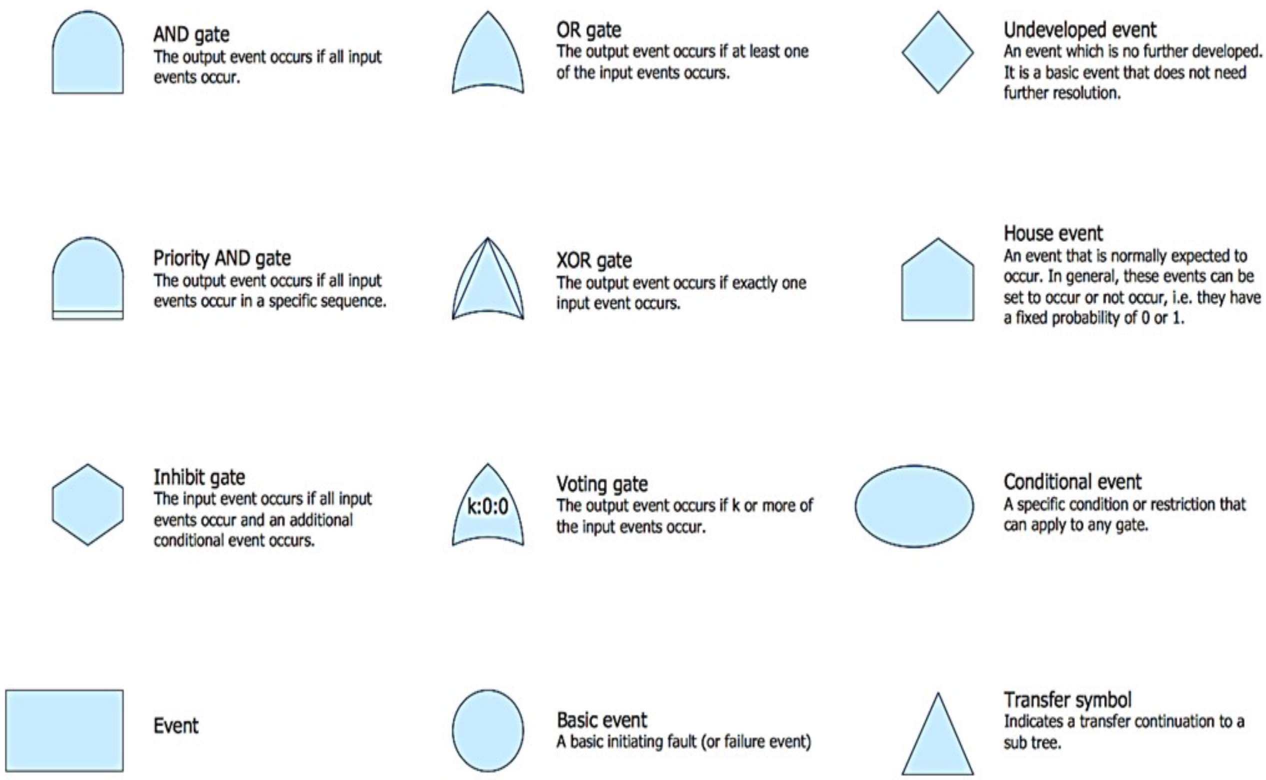

Figure 2-14 *Fault Tree Symbols*

Figure 2-15 Illustrates the strengths and limitations[31] of Fault Tree Analysis.

Fault Tree Analysis Strengths

- Provides a highly systematic approach to analyze multiple factors contributing to a top event.
- Is used for analyzing systems with many interfaces and interactions.
- Graphical representation facilitates understanding of behavior of factors of system.
- Logic analysis is useful to follow failure pathways in a complex system

Fault Tree Analysis Limitations

- Can be uncertainties of probability of base events that can cause uncertainties in probability of top event.
- Is a static model; time interdependencies not addressed; only failed or not failed states can be addressed.
- Human error modes can be included in a qualitative fault tree, but degree or quality of human error cannot easily be added.
- Conditional failures cannot be easily included

Figure 2-15 *Fault Tree Analysis Strengths and Limitations*

[31] ANSI/ASSP, Z690.3-2011 : Risk Assessment Techniques, Des Plaines, IL, 2011, p. 62.

A Software Safety Analysis can identify the hazards associated with the growing use of software to analyze, evaluate, and specify the control of system hazards. It includes software associated with train control, identifying defective systems, train door failures, Closed Circuit Television (CCTV), Communication Based Train Control (CBTC), and other systems with computer interface. It is recommended that an agency (or contractor) use Section 4.4 and Appendix B (adapted as necessary) of the Military Standard (MIL-STD)-882 E[32] to perform a Software Safety Analysis. If contracted, the transit agency should require a comprehensive formal report that includes analyses, results, findings, conclusions, and recommendations that, at a minimum:

- Define software hazards that will prevent hardware from operating
- Identify security-type problems that will have operational impact on transit system
- Detail importance level of automated equipment failures
- Develop items for emergency procedures to control emergencies and manual operation of equipment

Safety Risk Evaluation Process

Once a hazard has been identified and an analysis of its potential consequences has been completed, two possible scenarios exist—the transit agency has enough resources to address all likely consequences, or it does not. The second scenario is the critical one to be managed in SMS. The Safety Risk Assessment process (Figure 2-16) provides the RTA with a basis for making decisions about allocating resources to contain the damaging potential of hazard consequences.

The evaluation is performed objectively by assessing the probability of consequences occurring and the seriousness of the consequences if they do occur. This is the essential contribution of safety risk evaluation to the safety risk management process. Evaluation helps quantify the number of hazard consequences and provides a basis for making decisions about allocating resources to contain the damaging potential of hazard consequences.

Safety risk assessment provides a way to measure the potential consequences of identified hazards and includes evaluating how existing defenses mitigate the consequences of those hazards. Assessment helps determine whether certain consequences have an acceptable level of safety risk and which require additional safety risk mitigation. Safety risk assessment within SMS is data-driven; therefore, safety resource allocations are more logical and defendable. This helps a transit agency allocate its finite resources to address the mitigation of consequences in a prioritized way.

[32] US Department of Defense, Standard Practice, System Safety, MIL-STD-882E, May 2012.

The term safety risk means the composite of predicted severity and likelihood of the potential effect of a hazard. It is based on both the chance that people or equipment could be harmed by the potential consequences of a hazard and how serious the harm could be. After a hazard has been identified and consequences envisioned (hazard identification step), the safety risk assessment process can begin.

It is often easy to jump to the worst possible probability and severity during this assessment process, which could lead to the conclusion that the activity is just too dangerous to continue. The purpose of the safety risk management is to enable agencies to continue delivering transit services but at an acceptable level of safety risk. Safety risk can be managed through the implementation of effective safety risk mitigation. Five assessment steps are included in Figure 2-17 and further described below.

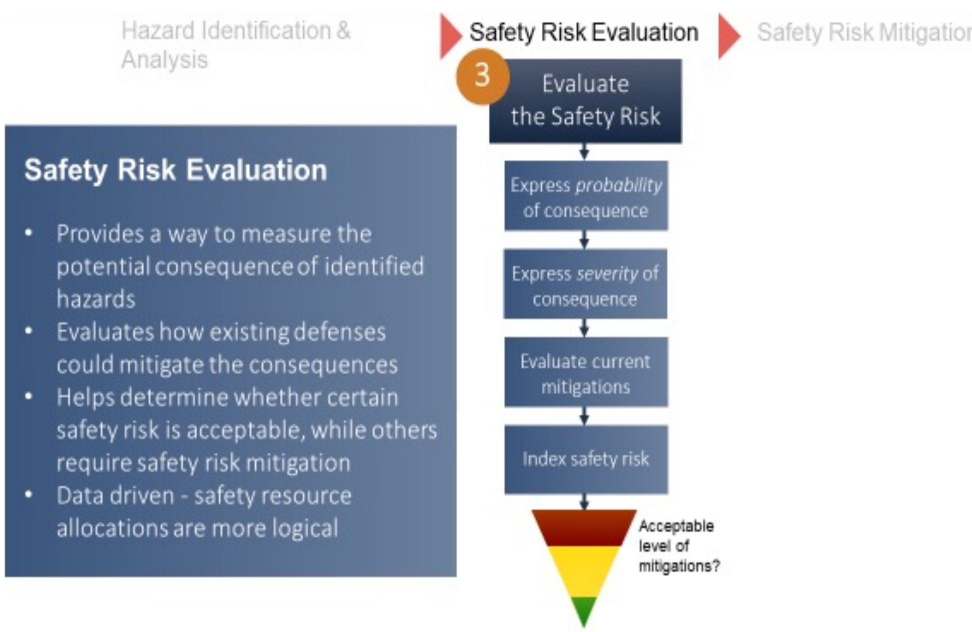

Figure 2-16 *Safety Risk Assessment Process*

Source: TSI

Figure 2-17 *Safety Risk Assessment Steps*
Source: TSI

Step 1: Express Probability of Consequence

Probability in this case is the likelihood that a consequence might occur. Emphasis is placed on the worst foreseeable, but credible, condition. The worst predictable condition might be based upon the judgment of an SME. When establishing the probability of the consequence of a hazard, the more data available to determine probability, the higher the degree of confidence achieved. If no data exist, then a qualitative probability evaluation may have to be based on the judgment of SMEs. However, with 3–5 years of pertinent and reliable agency accident and incident data, the agency may consider using quantifiable data to determine probability. If a transit agency possesses reliable data that suggests the lesser likelihood of a consequence occurring, it may choose to apply such data. Reliable data may outweigh an individual's subjective judgment regarding the probability of occurrence.

Table 2-3 presents event probability levels, as used by many transit agencies. The values are alphabetic in order and range from A to F, with A being frequent or likely to occur frequently and E being improbable or expected that this event will never happen. F is used when potential hazards are identified and eliminated.

Table 2-3 *Event Probability Levels*

Probability Levels			
Description	**Level**	**Specific Individual Item**	**Fleet or Inventory**
Frequent	A	Likely to occur often in life of an item.	Continuously experienced.
Probable	B	Will occur several times in life of an item.	Will occur frequently.
Occasional	C	Likely to occur sometime in life of an item.	Will occur several times.
Remote	D	Unlikely, but possible to occur in life of an item.	Unlikely, but can reasonably be expected to occur.
Improbable	E	Very unlikely, can be assumed that occurrence may not be experienced in life of an item.	Unlikely to occur, but possible.
Eliminated	F	Incapable of occurrence; used when potential hazards identified and later eliminated.	Incapable of occurrence; used when potential hazards identified and later eliminated.

Source: TSI

Credibility is critical and essential to Safety Risk Assessment and works in two ways—within the assessment process itself and for sustaining SMS. Whether using data or SME judgment, the condition must be credible, and the data for assessment must be reliable. If circumstances demonstrate that the evaluation of the condition is either too extreme or too lax, the credibility of the SRM process will suffer. Credibility of the analysis and assessment is essential.

Step 2: Express Severity of Consequence

Step 2 is to assess the severity of the consequence and could leverage severity categories such as those categories provided in Table 2-4. The assessment determines how harmful a given consequence would be if it became a reality. Determining the severity of a consequence may require a detailed knowledge of operations and the environment. Transit agencies may benefit from examining safety risk from the perspective of what could occur should the potential consequences materialize and looking at the impacts on people/personnel, system elements, equipment, and the operating environment. Safety risk severity can involve an assessment of the damaging potential of the consequence of the hazard under the worst foreseeable—but credible—condition, not merely a worst-case condition.

Table 2-4 *Event Severity Categories**

Description	Severity Category	Event Result Criteria
Catastrophic	1	Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
Critical	2	Could result in one or more of the following: permanent partial disability, injuries, or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
Marginal	3	Could result in one or more of the following: injury or occupational illness resulting in one or more lost workday(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M.
Negligible	4	Could result in one or more of the following: injury or occupational illness not resulting in a lost workday, minimal environmental impact, or monetary loss less than $100K.

**Note: Transit agencies may adapt property damage values to their specific operating environments. Larger agencies may be able to absorb higher damage costs.*

Source: TSI

Like the probability table, the Severity of Consequence chart (Table 2-5) presents a typical safety risk severity table (MIL-STD- 882E). It includes four categories to denote the level of severity of the occurrence of a consequence, the meaning of each category, and the assignment of a value to each category using numbers. In this table, 1 is considered catastrophic, meaning possible deaths and equipment destroyed, or system loss and 4 is considered negligible or of little consequence with two levels in between.

Table 2-5 *Qualitative Severity of Consequence*

Category	Catastrophic (1)	Critical (2)	Marginal (3)		Negligible (4)
Personal injury	Fatality	Serious injury	Non-serious injury	Minor injury	Less than minor injury
Environmental	Severe environmental damage, violation, law, regulation	Reversible environmental damage, violation, law, regulation	Reversible moderate environmental impact	Minor environmental impact	Superficial environmental impact
System	Severe effect – single point failure initiating catastrophic event	Serious effect – significant safeguard initiating concurrent failure event	Moderate effect – prolonged disruption initiating secondary hazard event	Minor effect – brief disruption initiating potential for secondary hazard event	Insignificant event – no impact, non-event
Emergency	Evacuation for life safety reasons	Evacuation because of event (serious non-life threatening)	Fire, smoke, irritant	Minor fire, smoke, irritant	Less than minor irritant, inhalation

Source: TSI

Step 3: Evaluate Current Mitigations

A process to evaluate current mitigations is illustrated in Figure 2-18. It begins by establishing a baseline—what is the initial risk if there are no mitigations in place? Then, evaluating the current mitigations of a given circumstance or concern. This can be done by assessing the existing safety risk and determining the probability and severity of a consequence based on the examples above.

The SMS SA process calls for evaluation of the effectiveness of a mitigation in correcting a deficiency or other risk and ensuring no unintended consequences. Agencies will benefit from accounting for existing defenses or mitigations when looking at probability and severity. To get a good measure of the effectiveness of existing defenses, it may be best to turn to the data received through SA activities. The consequences of the hazard can be reassessed once mitigations are developed and then continuously monitored once they are implemented. With properly recorded mitigation activities, the review will disclose whether the mitigation is effective or not.

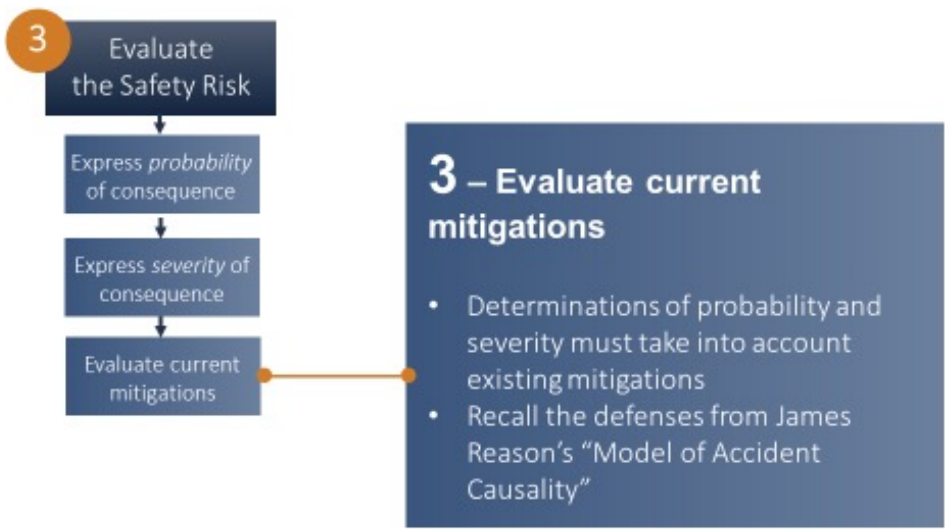

Figure 2-18 *Evaluation of Current Mitigations*
Source: TSI

There are different strategies for mitigating or controlling the consequences of a hazard. The first and most effective method is to eliminate the hazard at the design phase—prevent it from ever existing in the system. However, not all hazards can be designed-out of a system. Therefore, there are other ways to reduce safety risks through mitigations that might include:

- Installation of safety devices, equipment, and tools such as signage and interlocks
- Installation of warning systems such as guardrails and grade-crossing warning devices

- Implementation of effective administrative actions such as procedures and rules
- Proper selection and use of personal protective equipment (PPE)

Administrative action can be used as a quick fix in response to incidents or safety concerns because it may be the easiest and most cost-effective way to respond—send out a memo, update an SOP, or modify training. However, administrative action can also be effective and useful once higher-level mitigation has been implemented; it is often used as the only mitigation when higher-level mitigation may be necessary. Over-reliance on administrative action can lead to the appearance that something has been done and as a check in the box, but it does not resolve the problem.

Step 4: Index Safety Risk

Next, agencies can combine the values of safety risk probability with the safety risk severity values given the mitigations in place. This step determines the measure or index that will be assigned to the hazard and related consequence to prioritize the safety risk (Figure 2-19).

Figure 2-19 *Indexing of Safety Risk*
Source: TSI

The Safety Risk Assessment Matrix presented in Figure 2-20 provides a platform for the comprehensive examination of the level of probability that there will be an occurrence with the level of severity of that occurrence. The risk assessment code (RAC) or risk index (RI) is then calculated using Probability X Severity = RAC or RI with a descriptor.

Once the safety risk of a consequence has been assessed in terms of probability, severity, and considering current mitigations, the next step is establishing a safety RI for the residual risk of the consequence. This is achieved by combining the values for residual safety risk probability and residual safety risk severity tables into a residual safety risk matrix.

MIL-STD-882E	Safety Risk Assessment Matrix			
Severity / Probability	Catastrophic 1	Critical 2	Marginal 3	Negligible 4
A - Frequent	1A	2A	3A	4A
B - Probable	1B	2B	3B	4B
C - Occasional	1C	2C	3C	4C
D - Remote	1D	2D	3D	4D
E - Improbable	1E	2E	3E	4E
F - Eliminated				

1A, 1B, 1C, 2A, 2B	High	**Unacceptable**
1D, 2C, 3A, 3B	Serious	**Undesirable** with management decision required
1E, 2D, 2E, 3C, 3D, 3E, 4A, 4B	Medium	**Acceptable** with review by management
4C, 4D, 4E	Low	**Acceptable** without review

Figure 2-20 *Qualitative Safety Risk Matrix*
Source: TSI

If a safety risk probability has been assessed as occasional (C) and the safety risk severity has been evaluated as critical (2), the composite of probability and severity (2C) is within the orange zone (serious safety risk). This evaluation system assigns an actual value to the hazard and consequence of concern. The color-coding in the matrix reflects the tolerability regions in the inverted safety risk tolerance triangle. Red is unacceptable (or high), orange is serious, yellow acceptable (or medium) with mitigation, and green acceptable (or low). (*Note*: This safety risk matrix is presented as an example. SMS is scalable and every organization will want to perform the safety risk evaluation process in a way that works for it. What works at one organization may not work at another – but the point is to establish an evaluation system that assigns value to the consequence of a hazard so that it can be ranked and prioritized.)

A semi-quantitative risk model uses qualitative data to express risk values with numerical ratings utilizing a formula to produce a risk score.[33] This model is intended to facilitate understanding of the effectiveness of various mitigation methods for those who are responsible for developing, implementing, and monitoring the effectiveness of mitigations to reduce safety risk. The semi-

[33] Lyon, B. K., and Popov, G., "Risk Management Tools for Safety Professionals," Part I, Chapter 3, American Society of Safety Professionals, 2018.

quantitative risk model adds a degree of objectivity to the more subjective qualitative safety risk analytical method. An example of these models, including sample worksheets, and scoring is provided in Appendix A.

The Semi-Quantitative Safety Risk Probability Table (Table 2-6) assigns a numeric value to the probability of occurrence of a consequence. The probability of "Frequent" is assigned a value of "5." The probability ranges descend to "Improbable," which is assigned a value of "1." (*Note*: Each probability level is also assigned a scientific notation value under the "Meaning" column, which would be utilized when reliable data is available regarding the frequency of occurrence of a consequence.)

Table 2-7 provides the four commonly-used semi-quantitative safety risk severity categories that denote the level of severity of the occurrence of a consequence, the meaning of each category, and the assignment of a numerical value to each category. In this table, 4 is considered catastrophic, meaning possible fatalities, system loss, and equipment destroyed, and 1 is considered negligible or of little consequence with two levels in between.

Table 2-6 *Semi-Quantitative Safety Risk Probability*

Probability of Occurrence of the Consequence		
Probability	**Meaning**	**Value**
Frequent	Likely to occur frequently (> 10^{-1})	5
Probable	Likely to occur several times (< 10^{-1} but > 10^{-3})	4
Occasional	Likely to occur sometime (< 10^{-3} but > 10^{-6})	3
Remote	Very unlikely to occur (< 10^{-6} but > 10^{-8})	2
Improbable	Almost inconceivable that event will occur (< 10^{-8})	1
Eliminated	Incapable of occurrence; used when potential hazards identified and later eliminated.	0

Source: TSI

Table 2-7 *Semi-Quantitative Safety Risk Severity Categories**

Description	Severity Category	Event Result Criteria
Catastrophic	4	Could result in one or more of following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
Critical	3	Could result in one or more of following: permanent partial disability, injuries, or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
Marginal	2	Could result in one or more of following: injury or occupational illness resulting in one or more lost workday(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M.
Negligible	1	Could result in one or more of following: injury or occupational illness not resulting in a lost workday, minimal environmental impact, or monetary loss less than $100K.

**Transit agencies may adapt property damage values to their specific operating environments. Larger agencies may be able to absorb higher damage costs.*
Source: TSI based on MIL-STD-882E Table 1, Severity Categories.

Figure 2-21 provides a comprehensive illustration of the merging of risk potential and severity. The Semi-Quantitative Safety Risk Matrix can be used to identify risks deemed unacceptable to those that may be acceptable with or without management review.

	Semi-Quantitative Safety Risk Assessment Matrix			
Severity / Probability	Catastrophic 4	Critical 3	Marginal 2	Negligible 1
Frequent 5	High-20	High-15	Serious-10	Medium-5
Probable 4	High-16	High-12	Serious-8	Medium-4
Occasional 3	High-12	Serious-9	Medium-6	Low-3
Remote 2	Serious-8	Medium-6	Medium-4	Low-2
Improbable 1	Medium-4	Medium-3	Medium-2	Low-1
Eliminated 0				

High (>11)	Unacceptable
Serious (7-11)	Undesirable
Medium (>3 and < 7)	Acceptable with review
Low (<=3)	Acceptable no review

High	Unacceptable
Serious	Undesirable with management decision required
Medium	Acceptable with review by management
Low	Acceptable without review

Figure 2-21 *Semi-Quantitative Safety Risk Matrix*

Source: TSI

Determining the final score or rank of the safety risk helps to prioritize items, elevating those that need immediate attention to the forefront for action. This helps the agency decide where to focus resources against established criteria, determines the safety risk the agency will need to act upon, and defines priorities for safety risk mitigation efforts.

Step 5: Determine Safety Risk Tolerability

Step 5 of a safety risk assessment establishes the agency's tolerance for a given safety risk against established criteria (Figure 2-22). It determines the safety risk level upon which an agency will act and defines safety risk mitigation priorities. The triangle is a visual representation of safety risk in three broad categories—Acceptable, Acceptable with Mitigation, and Unacceptable (Figure 2-23). In determining what is "reasonably practicable" in the context of SRM, consider both the technical feasibility of further reducing the safety risk and the cost. Showing that the safety risk is As Low as Reasonably Practicable (ALARP) means that any further safety risk reduction is either impracticable or grossly outweighed by the cost. However, a transit agency "accepting" a safety risk does not mean that the potential consequences of hazards have been eliminated. Instead, it means that the possible consequences of a hazard are either low enough or have been mitigated by the transit agency so that any further effort would not be practical or beneficial. However, the effectiveness of the mitigations must be continually monitored through SA activities.

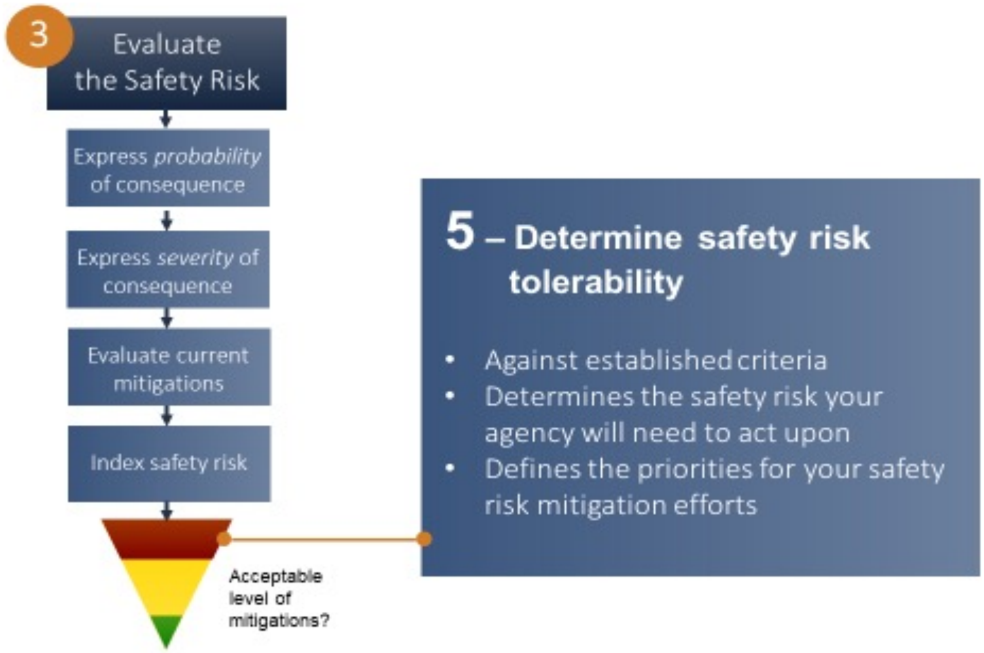

Figure 2-22 *Determination of Safety Risk Tolerability*
Source: TSI

The triangle in Figure 2-22 is presented in an inverted position, suggesting that the transit industry (like any other mass transportation industry) is "top-heavy" from a safety risk perspective. There could be a significant number of safety risks evaluated as being within the Unacceptable region (red), but this evaluation could change after staff better understand the process of evaluating safety risk. Nevertheless, safety risks evaluated as falling in the Unacceptable region are unacceptable under any circumstances—the consequences of the hazards are of such a magnitude and the damaging potential of the hazard poses such a threat to the viability of the transit agency to deliver its services that immediate mitigation is required.

Hazards evaluated as falling in the Acceptable region are acceptable provided mitigation already in place suggests that the consequences of the hazards have been effectively mitigated. The same criteria applies to a hazard evaluated initially in the Unacceptable region and mitigated to the Acceptable region. A hazard initially evaluated as unacceptable that is mitigated and slides down to the Acceptable region must remain "protected" by mitigation. If the safety risk is not effectively protected continuously by mitigation, it is unacceptable. Hazards evaluated as falling in the Acceptable region are acceptable as they currently stand and require no action other than monitoring.

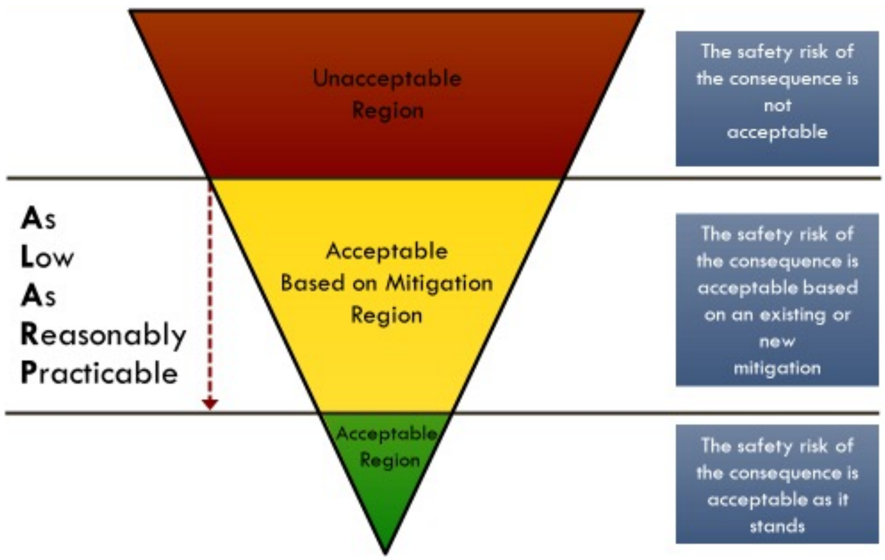

Figure 2-23 *Safety Risk Tolerability*
Source: TSI

Safety Risk Mitigation

Following safety risk assessment, hazards ranked as Acceptable or Unacceptable with mitigation may require management. Step 4 of the SRM is to Mitigate Safety Risk (Figure 2-24), a step that if effectively conducted will help address safety risk while balance the issue of “management dilemma” of protection/safety versus productivity/service delivery. It enables transit agencies to manage safety risk with balanced mitigation strategies that reduce risk to an acceptable level. Agencies may find it beneficial to align strategies with their safety performance objectives.

Figure 2-24 *Safety Risk Mitigation Process*

Source: TSI

Safety risk mitigation strategies (Figure 2-25) must be monitored for effectiveness and can be aligned with agency safety performance objectives. There are three common strategies of safety risk mitigation—avoid the hazard, reduce the hazard, and segregate the hazard. Safety Risk Mitigation includes initial, ongoing, and revised mitigation strategies. The SA function provides ongoing monitoring of these strategies.

Transit agencies are familiar with the concept of safety risk mitigation during the building or major extension/rehabilitation of new systems and with processes already in practice. These mitigations are often tied to MIL-STD-882E and are reflected in the design, engineering, and construction of transit systems. MIL-STD-882E system safety design order of precedence (most to least effective) identifies alternative mitigation approaches as follows:

- Eliminate hazards and consequences through system design and redesign.
- Mitigate hazards and consequences through system design and redesign.
- Incorporate engineered features or devices.
- Provide warning systems.
- Apply low technology and administrative mitigations (signage, PPE, work methods, rules and procedures, and training).

Figure 2-25 *Safety Risk Mitigation Strategies*

Source: TSI

Safety Risk Avoidance as a mitigation strategy is an essential safety risk management concept. It means avoiding, canceling, or delaying the operation or activity that presents the consequences of the hazard. The objective is to avoid the consequences, not the hazard (for example, rain/snow cannot be avoided). For example:

- Cancel – a defective transit vehicle is removed from service and decommissioned.
- Delay – suspension of transit service in adverse weather and resuming it only when conditions improve.

Safety Risk Reduction (Figure 2-26) mitigation methods reduce the safety risk associated with the consequence of the hazard to ALARP. It allows the agency to bring the safety risks to a level acceptable to management and is the most common safety risk mitigation strategy—operation or activity is subject to limitation, thus reducing the probability or severity to reach an acceptable region in ALARP.

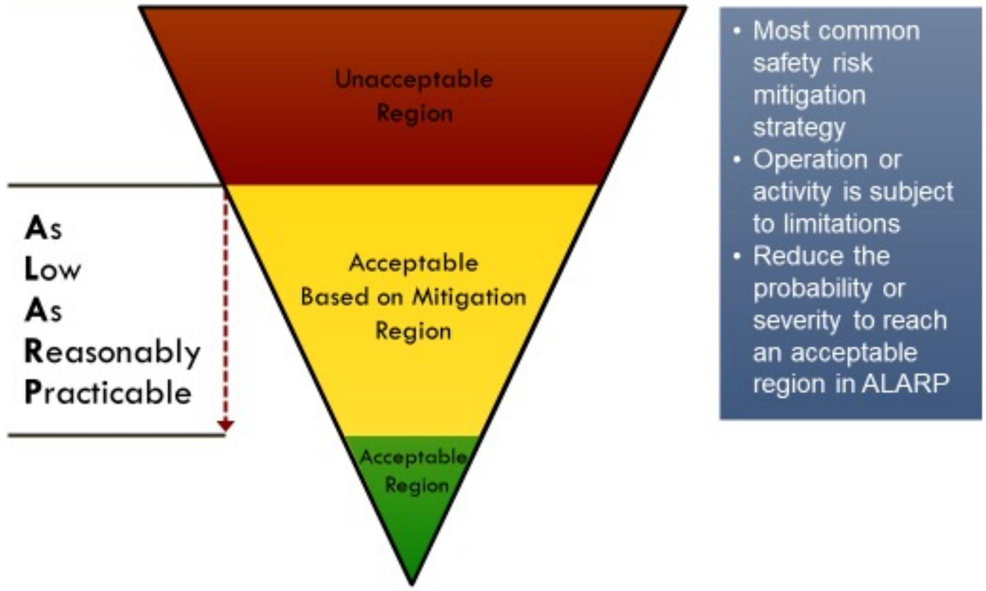

Figure 2-26 *Safety Risk Reduction*
Source: TSI

Safety risk reduction-related mitigation examples include the following:

- Reducing operating speeds over track in poor condition.
- Requiring specific certifications and protective equipment for personnel working under specific operational conditions.
- Requiring additional inspections.
- Placing restrictions on sections of track prone to slip/slide conditions, particularly prevalent in Fall when leaves accumulate on tracks.
- Increasing frequency of track inspections based on pre-determined temperature during periods of excessive heat.
- Highlighting safety topics to increase employee awareness of certain safety risks; examples include Signs and Symptoms of Heat Exhaustion, Signs and Symptoms of Cold Emergencies.
- Conducting job safety briefings intended to provide site-specific safety advice and guidance specific to hazards in work area; attentive employees may increase their awareness and thus lower their safety risk.
- Convening task forces to address requiring hazards.
- Implementing strategies to mitigate a malfunctioning switch—impose speed restrictions, perform temporary field repair, conduct additional inspections, supervisors walk train over switch, hand-throw or crank switch.

Segregation of exposure is a mitigation strategy that involves limiting the exposure to the consequences of hazards by isolating the effects of the consequences of the hazard or building in the redundancy of protection against the consequences of the hazard. Examples of segregating exposure by limiting the exposure of people, assets, or operations and activities to the consequences of the identified hazards include the following:

- Isolating rail cars due to malfunctioning doors (some railcars can mechanically lock out doors and lock end doors to keep the public from accessing car until train can be pulled from service. Each agency has different procedures about isolating cars—some offload entire train, some keep train in service until it reaches end of line, some will leave train in service until end of run)
- Ensuring that two-person dispatch teams always include a veteran controller/dispatcher whenever an inexperienced controller/dispatcher is working during rush hour and special events; inexperienced controllers are segregated from exposure to consequences of hazards resulting from lack of operating experience (isolation)
- Using trip stops or train control lockouts to provide redundant protection for work zones and roadway workers on right-of-way (redundancy)
- Providing multiple mitigations on rail transit vehicle in case one fails (redundancy)
- Providing cell phones programmed with restriction to call dispatch only for radio communication dead spots within service area (redundancy)
- Providing additional transit rail personnel at stations during rush hour to manage crowding (and platform loading)
- Limiting access to right-of-way to only those who meet established levels of training
- Allow access to right-of-way after rush hour to minimize exposure of roadway workers to moving railcars
- Single-track around malfunctioning switch so it is completely separated from track used for revenue operation

Categories of Mitigations

Mitigations can be grouped into two broad categories—Engineering and Personnel. Engineering mitigations either eliminate a hazard or its potential or adjust the operation to reduce the consequence(s) of the hazard to a manageable level. Engineering mitigations are considered "hard" mitigations because they do not rely on flawless human performance. Personnel mitigations rely on personnel interventions to cope with the consequence(s) of a hazard—for example, by adding warnings, revised checklists, standard operating procedures, and training. Personnel mitigations are considered "soft actions" because they require flawless human performance. For example, an automated blocking device that operates under specified operational conditions without need for human intervention is a hard mitigation;

a reminder to (or training) operator to be careful under same specified operational conditions is a soft mitigation. The most effective mitigations are hard mitigations. Because hard mitigations are often expensive, however, soft mitigations (such as training) are more commonly proposed. For soft mitigations, safety staff often work with operating and maintenance functions to ensure that the organization is taking responsibility for SRM and monitoring front-line employee performance.

Not all mitigation strategies have the same potential safety effect. The effectiveness of each specific alternative needs to be evaluated before a decision can be made. Safety and operational SMEs could be involved in this evaluation. There might be multiple alternative mitigation strategies, and some may be more effective than others. This evaluation of alternative strategies is an essential step in the mitigation process because only after this is done can final decisions be made about the safety risk mitigation strategies that will be implemented.

Operations and maintenance managers have ownership because they will implement and track the safety risk mitigation strategies. The Safety department has ownership for monitoring the effectiveness of safety risk mitigation strategies through the SA function. Everyone involved in interacting with the safety risk mitigation strategies once they are implemented has ownership.

Mitigations, Recommendations, and Corrective Action Plans

Safety risk mitigations derived from SA activities (event investigations) will be developed and tracked in the form of investigation recommendations, which drive corrective actions. Guidance is provided in the SA section of this document under Accident investigation procedures and further delineated in the *Effective Practices in Rail Transit Accident Investigations*.

Section 3

Safety Assurance

Transit agencies should develop and implement a safety assurance process that includes safety performance monitoring and measurement activities. This section focuses on the following elements of safety assurance:

- Safety objectives, safety performance targets, and safety performance indicators
- Event investigations
- Continuous improvement
- State of Good Repair (SGR) and Transit Asset Management (TAM)

A transit agency should perform the following activities in support of its safety assurance process:

- Monitor its system for compliance with and sufficiency of its procedures for operations and maintenance
- Monitor its operations to identify any safety risk mitigations that may be ineffective, inappropriate, or were not implemented as intended
- Investigate safety events to identify causal factors
- Monitor information reported through any internal safety reporting programs

Included within SA is Management of Change. Transit agencies should establish a process for identifying and assessing changes that may introduce new hazards or impact the transit agency's safety performance. If it is determined that a change may impact its safety performance, it must evaluate the proposed change through the SRM process.

Continuous Improvement is central to SA. Transit agencies should establish a process to assess their safety performance. If a transit agency identifies any deficiencies as part of its safety performance assessment, it must develop and carry out, under the direction of the Accountable Executive, a plan to address the identified safety deficiencies.

Safety Objectives, Safety Performance Targets, and Safety Performance Indicators

The safety performance monitoring and measurement subcomponent of SA details activities an RTA should establish to:

- Monitor its system for compliance with, and sufficiency of, the agency's procedures for operations and maintenance

- Monitor its operations to identify any safety risk mitigations that may be ineffective inappropriate, or were not implemented as intended
- Investigate safety events to identify casual factors
- Monitor information reported through any internal safety reporting programs

There are three key terms for establishing performance measurement criteria are the following:

- Safety Objective – A quantifiable statement regarding safety achievements to be accomplished by an organization regarding its safety performance
- Safety Performance Target – A specific, quantifiable level of performance for a given performance measure over a specified timeframe related to safety management activities
- Safety Performance Indicator – A data-driven, quantifiable parameter used for monitoring and assessing safety performance

Once established, the safety objectives must be formally communicated throughout the agency. Transit agencies will benefit from the periodic review and update (as appropriate) of safety performance indicators and targets and may use them to inform the allocation of resources.

SMS generates data and information that the Accountable Executive and other senior management can leverage to establish safety objectives, safety performance targets, and safety performance indicators and provides a mechanism to evaluate whether implemented safety risk mitigations are appropriate and effective. Safety performance monitoring does not focus on monitoring individuals but on monitoring the safety performance of a transit agency itself through routine monitoring of operations and maintenance activities. FTA provides full details of the practices described below in its TSI training programs.[34]

Although establishing safety performance targets and safety performance indicators is a good thing, Andrew Hopkins provides cautionary comments regarding performance indicators, which may be manipulated, especially when financial incentives are involved:

> When deciding on the performance indicators to be included in pay schemes, it is essential to recognize that the moment there are consequences attached to performance with respect to an indicator, there is an incentive to manage the indicator itself rather than the phenomenon of which it is supposed to provide an indication. This is apparent in the case of lost-time

[34] *FTA SMS-Safety Assurance: Participant Guide*, v.12_09282018.

> injuries. For instance, if people are brought back to work the day after an accident and placed on alternative duties, hey presto, a potential lost-time injury is no longer a lost-time injury. While this can often be justified from an injury management point of view, there is plenty of anecdotal evidence of people being brought back to work purely as a means of managing the measure…. The problem is so severe that a review sponsored by the New South Wales mining industry recently recommended that the industry should no longer pay bonuses based on injury outcome data, such as lost-time or medical treatment injuries.[35]

A similar position has been adopted by the Occupational Safety and Health Administration (OSHA)[36] to ensure that disincentives are not created for private sector employees to report illnesses or injuries. Reporting a work-related injury or illness is a core employee right, and retaliating against a worker for reporting is a violation of Section 11c of the OSH Act. Section 11c prohibits a private sector employer from discriminating against an employee because the employee reports an injury or illness. Other whistleblower statutes enforced by OSHA also may protect employees who report workplace injuries. The National Transit Systems Security Act (NTSSA), 6 U.S.C. § 1142, provides public transportation employee protections to those reporting the violation of any Federal law, rule, or regulation related to transit safety or security, or fraud, waste or abuse of Federal grants or other funds, or for reporting hazardous safety or security conditions. However, although NTSSA provides protections to employees, it does not address injury reporting in the same way as the Federal Railroad Safety Act (FRSA). In particular, the FRSA prohibits traditional railroad carriers and their contractors and subcontractors from discriminating against employees for reporting injuries under 49 U.S.C. 20109(a)(4).

OSHA identified several workplace policies and practices that could discourage reporting and could constitute unlawful discrimination:

> Incentive programs that discourage employees from reporting their injuries are problematic.… If an employee of a firm with a safety incentive program reports an injury, the employee, or the employee's entire workgroup, will be disqualified from receiving the incentive, which could be considered unlawful discrimination. One crucial factor to consider is whether the incentive involved is of sufficient magnitude that failure to receive it "might have dissuaded reasonable workers from reporting injuries."[37]

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[35] Hopkins, A., "Failure to Learn, the BP Texas Refinery Disaster."

[36] US Department of Labor, Occupational Safety and Health Administration, Memorandum, March 12, 2012, Employer Safety Incentive and Discrimination Policies and Practices.

[37] *Burlington Northern & Santa Fe Railway Co V. White*, 548 U.S. 53, 68 (2006).

Therefore, before implementing safety performance targets and safety performance indicators employers may find it beneficial to ensure that they do not create inappropriate financial incentives, especially for those specific to employee or contractor Lost Time Accident (LTA) rates.

Safety performance monitoring and measurement have four essential activities that must occur:

- Mitigation monitoring – This verifies that mitigations are implemented and are effective/appropriate and performing as intended. This helps to confirm safety risk management and verifies that new hazards have not been introduced. Mitigations can be fed into the SRM review process. Unimplemented or ineffective mitigations, along with new hazards, can be returned to the SRM function for follow-up activities.
- Monitoring of regular operations – Field observations that fall under monitoring of regular activities differ significantly from auditing and inspections, as they are designed to promote the collection of safety data by simply watching employees work in their normal work settings. Field observations also highlight compliance with actual agency policies and practices and are critical to ensuring that mitigations are working as intended. Transit agencies may choose to regularly report the results of observations to management for review.
- Employee safety reporting – SMS and SA activities are heavily dependent on effective employee safety reporting to collect critical safety information, and employees should be encouraged to use these programs. The effectiveness of the employee reporting system should be monitored. The data can be used to identify hazards, assess the performance of safety risk mitigation, capture previously identified safety deficiencies, and confirm the effectiveness of existing safety risk mitigations and that they are performing as intended.
- Event investigations – An essential activity for effective data analysis is identifying root causes and contributing factors that lead to events. Any hazards identified in the investigation can be fed into the SRM process for hazard analysis, safety risk assessment, and development of mitigation.

Performing these activities aids in risk-informed decision making and allows top management to prioritize organizational actions and allocations of resources more effectively.

Case Studies

Fire/Smoke Events

The following case study describes the application of the SMS framework to reduce the frequency and severity of smoke/fire events. The discussion is intended to stimulate investigator critical thinking skills, provide a limited introduction into the complexity of accident investigations, and increase awareness that events that can impact normal operations can have secondary effects that increase organizational risk and can potentially have significant fiscal implications that adversely affect the agency. The discussion mirrors strategies that have been tried and had varying degrees of success at different RTAs; however, investigators are cautioned that while many RTAs face very similar challenges, each agency must thoroughly evaluate its own risk and tailor solutions based upon its unique operating environment, organizational characteristics, complexity, and mode of transportation.

Case Study of Safety Objectives, Performance Targets, and Indicators

The goal was to improve employee and passenger safety by reducing fire/smoke events through the implementation of preventive maintenance programs and component replacement. Safety objective and performance targets included:

- Decrease frequency and severity of fire/smoke events
- Produce 25% decrease in incidents within one year, 50% decrease in incidents within two years, and 75% decrease in incidents within three years.

Sample indicators included the following:

- Number of smoke/fire events reported per month, categorized by all sources
- Number of Preventive Maintenance and Inspections (PMIs) conducted per month associated with roadbed cleaning and drain maintenance vs. established goals per month
- Number of power PMI inspection actions related to fire/smoke prevention
- Number of completed maintenance actions resulting from PMI findings
- Required maintenance back-log related to required fire/smoke prevention actions
- Supply system fire/smoke related component floats and lead times
- Number of third rail insulators replaced per month vs. established goal per month
- Third rail insulators cleaned by linear third rail linear feet per month vs. established goal

- Number of traction power feeder cables inspected/replaced per month vs. established goal per month
- Number of traction power feeder cables meggered per month vs. established goal per month
- Number of linear feet of tunnel treated with curtain grouting as part of water intrusion abatement activities vs. the established goal per month

Case Study – RTA

An RTA is plagued with recurring fire/smoke events that are negatively impacting the agency in a variety of ways. These events create employee and passenger safety concerns, degrade on-time performance (OTP), and contribute to a decline in ridership due to the transit system's lack of reliability for daily commuters. Fortunately, the organization implemented a global Fire Incident Reporting System (FIRS) that required employees to enter pertinent data regarding the fire/smoke events into a central database.

The Safety Department, in collaboration with operation personnel, conducted an in-depth trend analysis of wayside fire/smoke events to harvest information to aid in developing strategies to combat this systemic problem. This effort resulted in a "heat map" or a graphical representation of the rail system that depicted a subset of three segments of the system that were experiencing the most frequent fire/smoke events. The data further reflected that the most frequent type of fire/smoke event involved the failure of contact rail (third rail) insulators.

The account of events contained in the database records described multiple contributing factors that led to the contact rail insulators fire/smoke incidents. The failures were specifically attributed to the contact rail insulators being coated in dense layers of brake shoe dust and steel dust that has conductive properties; in some instances, debris and trash had accumulated around them and overhead leaks were prevalent due to water intrusion flooding the track. There were several locations where accumulations of standing water and mud were present due to clogged drains. These individual factors and a combination of many conditions induced the transfer of electrical energy from the positive traction power energy feeding the contact rail to earth ground via the contact rail insulators, which ultimately resulted in the insulators over-heating and emitting smoke and igniting.

The agency's strategy to address these failures included implementing preventive maintenance programs such as replacing severely fouled contact rail insulators with new ones, insulator cleaning programs, deploying track cleaning crews to remove debris and unclog drains to abate standing water and mud, implementing water remediation programs such as curtain grouting to mitigate leaks penetrating the tunnel ceilings and walls, as well as prioritizing the most problematic sections of system based upon the heat maps. As part of these activities, the agency established safety performance indicators for each one of these tasks, i.e., “replace 500 contact rail insulators per month in a defined segment of the track(s).”

This example highlights the importance of comprehensive trend analyses, not only identifying failures that occur most frequently but establishing the specific component(s) and modes of failure that pose the most significant safety risk. These analyses supported the immediate mitigation of defects. Assuming that the trend analysis identified that a minimal number of traction power positive feeder cable fires were occurring, the failures are commonly attributed to the cables chafing against the concrete track surface or conduit entrance points, and eventually, arc tracing to earth ground, resulting in the cables igniting. Other causes include cable insulation damage due to age, improper boot “O-ring” installation, and undersized cabling due to higher power load demands resulting from an increase in the amount of train cars running on the line.

The narratives in the data reflected that a contributing factor in the failures was cables being coated in conductive steel dust and other containments and laying in standing water. Although the data reflected that these incidents are relatively rare, the consequence of a traction power feeder cable fire occurring, especially in an underground section of track, poses a much more significant threat to human life than a contact rail insulator fire. Therefore, when an agency performs its risk assessment, this component (power cable) and mode of failure should receive a higher hazard ranking. In a resource-constrained environment, addressing traction power feeder cable fires will take priority; however, ideally, the agency will develop and implement CAPs to simultaneously mitigate risk in each failure mode.

A RTA’s strategy to address the traction power positive feeder cable failures may involve conducting a systemwide inspection to identify and suspect cables. Hazard analysis and safety risk evaluation should be performed to assist in prioritizing cables for refurbishment. They may also have to take immediate mitigating actions such as disconnecting and electrically isolating any cables found to be compromised until permanent repairs can be executed. Also, the agency may have to take interim measures such as implementing “Slow Speed” restrictions on train movement in areas where cables have been isolated because the capacity to supply traction power is diminished or the agency may even have to suspend train service temporarily until emergency repairs are made. These actions should be performed based upon recommendations of SMEs and applicable engineering codes and drawings.

Longer-term solutions may require an RTA to develop and fund capital investments, such as a traction power positive/negative cable renewal program based upon an assessment of a cable’s useful life, the physical condition of the cable as identified during inspections and the results of cable insulation megger testing.[38] In addition, this circumstance may present an agency with the opportunity to further reduce risk by retiring the legacy cables and replacing them with cables manufactured with insulation that meets current smoke, flame, and toxicity rating requirements, which can help to reduce the severity of inhalation injuries should a future cable fire occur.

Although all actions noted should help to reduce risk, the investigator, with the support of the appropriate SMEs, should continue attempting to identify contributing factors that are promoting these events. The review could start with a focus on the RTA's current inspection and maintenance processes, as these deficiencies should have been identified, scheduled for repair, and remedied before failure. One possibility for this situation could be inspectors having an unrealistic workload associated with their daily work assignments, which effects the periodicity and caliber of inspections. For example, inadequate inspections may be the result of employees having to rush to complete their task because the length of the territory that they must traverse is excessively long, or worse, certain areas may be going uninspected for prolonged periods because the assignment cannot be accomplished in the time period allocated to perform the task. In extreme circumstances, conditions could lead to inspectors' "pencil-whipping" inspection reports and submitting reports for inspections that were not performed.

Investigators typically do not have SME-level knowledge of all aspects of an RTA's operations; therefore, a comprehensive investigation often hinges on knowing what questions to ask respective system SMEs:

- Did one or more steps in the responsible department's inspection procedure not occur?
- What percentage of the required inspections are being performed on time?
- Are the inspection procedures ineffective or flawed and can the procedures be improved?
- Were the defects—standing water and mud, fouled insulators, overhead water leaks—adequately identified, documented, and cataloged by inspectors in their respective maintenance databases?
- Were identified defects correctly hazard ranked based upon the likelihood and severity of the condition?
- Was the hazard ranking of the defect elevated if a combination of conditions was present, i.e., a fouled contact rail insulator sitting in standing mud and exposed to an overhead leak?

[38] A megger is a portable instrument used to measure the insulation resistance of electrical wiring. RTAs typically establish defined thresholds in which a low insulation resistance reading will mandate that the cable be replaced.

- Were the defective components scheduled for repair/replacement?
- Is there a large backlog of work orders waiting to be performed?

The analysis should also attempt to determine what organizational factors may be influencing these events. For example, if the analysis identifies that there is a large backlog of work orders, this circumstance should raise additional questions:

- Is this situation the result of inadequate track access for maintenance forces to perform the work?
- Is the backlog due to a lack of human capital to complete the work?
- Are work orders prioritized to address the most hazardous conditions first?
- Are there more pressing priorities that are competing for resources?
- Is there a process to issue emergency work orders based upon risk?
- Is material to complete repairs available, or are there procurement challenges?
- Can work across separate disciplines be ganged to achieve maintenance efficiencies?
- Is the training adequate so that employees can perform work efficiently and effectively?
- Do employees have the correct tools to do the job?
- Is any combination of these factors and others at play?

Once the investigator has a good understanding of the causal and contributing factors that are driving the agency's undesired events, they are better prepared to formulate and implement CAPs. The agency must establish safety performance targets and may also establish safety performance indicators so that the effectiveness of CAPs can be measured and monitored to ensure they are achieving their intended outcomes. Also, focusing on the effectiveness of the CAP is beneficial as it shifts the agency's attention away from fixating on how many CAPs are "open" vs. "closed" and forces senior management to concentrate on measuring performance, i.e., is this activity improving safety? If not, then the CAP must be sent back through the SRM process and adjustments made to improve performance.

Fire/smoke events require a variety of actions to be performed by Rail Operations Control Center (ROCC) personnel to manage the situation, such as the possible evacuation of a train or passenger station, ensuring that all trains in the affected area are accounted for and routed out of the vicinity of the fire/smoke condition, coordinating the safe removal and restoration of the electrical power feeding the contact rail or Overhead Contact Systems (OCS), interacting with external first responders and accounting for their whereabouts, establishing alternative travel arrangements such as bus bridges, and coordinating with agency personnel as they inspect the track, diagnose the problem, execute temporary repairs, and clear the track.

Disruptions to train service such as fire/smoke events often result in abnormal operating conditions, i.e., single-track operations or diverting train service to adjacent rail lines. These situations have secondary effects that can significantly increase organizational risk. Train operators can be diverted to adjacent rail lines where they may be somewhat unaccustomed to the route's characteristics, which can lead to operational violations such as red signal overruns, platform overruns, or train doors opening on the wrong side of a platform, as some examples.

These activities typically are managed by an ROCC Controller; as the cognitive loading of this individual builds, opportunities for miscommunication increase. The ROCC Controller will usually have to give instructions to multiple train operators during the event, as they are also simultaneously coordinating with first responders, power operations personnel, and field personnel to resolve the problem. This high-pressure situation can result in a serious operational incident happening, such as an unintended wrong rail train movement leading to a head-to-head train collision or the premature restoration of OCS or contact rail power. Also, if these events take place during peak service hours when ridership is at its highest levels and train service is at its most intense, the situation is further compounded by cascading effects such as platform overcrowding and potential emergency egress issues. Therefore, the prevention of these unplanned service disruptions is essential to reducing risk.

There are many potential adverse agency financial implications of not adequately addressing safety risk beyond those associated with civil lawsuits stemming from personal injuries. For example, agencies attempt to accommodate customers via alternative service options such as bus bridges. The implementation of bus bridges can require the agency to incur overtime/personnel costs to support the operation and backfill vacancies on bus lines and at bus depots where bus operators have been pulled away from their regular duties. The fiscal impact on the organization is dependent upon how often these alternative forms of transportation have to be deployed as the result of unplanned service disruptions. The dollars spent on this activity can divert scarce agency funds away from investments intended to maintain an SGR for critical system assets.

Additionally, the reality of the situation is that a bus bridge typically cannot manage the volume of passengers that a fully-loaded train can carry. This circumstance can further frustrate passengers—after their commute on the rail line is disrupted, they wait for a bus to arrive, and when it finally does, they are not able to board due to capacity issues. In addition, providing unplanned bus service in heavily congested urban traffic can result in an arduous journey for the customer to reach their final destination. Therefore, these events also have a significant impact on customer satisfaction and if they occur on a repetitive basis, it can result in a permanent loss of revenue due to customers abandoning the RTA and adopting other long-term methods of transportation, which further reduces the pool of money that can be used to invest in the system's assets. Other financial repercussions include having to schedule major shutdowns due to excessive deferred maintenance and expending resources to constantly address emergent issues due to poor pro-active hazard prevention maintenance actions.

Effectively implementing the SMS framework can result in a significant reduction in events and promote continuous improvement. The goal of data collection and trend analysis is to identify causal and contributing factors leading to failures. By applying traditional accident investigation techniques and aggressively tackling precursors, the transit agency has a better opportunity to avoid a serious accident and be positioned to more economically and effectively deploy resources to mitigate risk. Also, agencies may consider establishing safety performance targets to monitor and measure the effectiveness of CAPs.

Case Study – Metro-North Railroad (MNR)

Over a 10-month period in 2013 and 2014, MNR experienced a series of five undesirable events that resulted in 6 fatalities, 126 injuries, and over $28 million in damages. The accidents were investigated by the NTSB and, after the fourth accident, a focused audit was initiated by FRA. This case study illustrates how effective accident investigation can surface significant safety concerns. To aid in this examination, researchers used the following two reports:

- Federal Railroad Administration Report to Congress: Operation Deep Dive MNR Commuter Railroad Safety Assessment, March 2014 – 28-page report to Congress presents results of Operation Deep Dive assessment.
- NTSB Special Investigation Report: Organizational Factors in MNR Railroad Accidents, NTSB/SIR-14-04, adopted November 19, 2014 – 135-page Special Investigation Report covering all five accidents, discusses the organizational factors involved.

The **first accident** involved derailment of an MNR passenger train in Bridgeport, Connecticut, and a subsequent collision with another MNR passenger train on an adjacent track. On May 17, 2013, eastbound MNR Train 1548 derailed at a broken joint bar and subsequently collided with westbound MNR Train 1581. In total, 65 passengers were injured, and the damage was $18.5M.

The NTSB determined that the probable cause was an undetected broken pair of compromised joint bars on the north rail of track four on the MNR New Haven subdivision at milepost 53.25 resulting from lack of a comprehensive track maintenance program that prioritized the inspection findings to schedule proper corrective maintenance, a regulatory exemption for high-density commuter railroads from the requirement to traverse the tracks they inspect, and MNR's decisions to defer scheduled track maintenance.

The **second accident** involved a roadway worker fatality when an MNR passenger train was routed into an out-of-service track where maintenance work was underway in West Haven, Connecticut. On May 28, 2013, MNR Train 1559 was routed into Track #1 and struck and killed a track supervisor and narrowly missed a crane boom that had been fouling the track moments before the train passed. The probable cause, as determined by NTSB, was the student rail traffic controller's removal (while working without direct supervision) of signal blocking protection for the track segment occupied by the track foreman and the failure of MNR to use any redundant feature to prevent this single point failure. Contributing to the accident was FRA's failure to require redundant signal protection, as recommended by NTSB Safety Recommendation R-08-6.

The **third accident** involved derailment of a CSX freight train on MNR-owned and maintained tracks in the Bronx, New York. CSX Train Q70419 derailed cars 11–20 of the 24-car train at a location with fouled ballast, center cracked concrete ties, and wide track gauge. The damage was estimated at $877,700. The probable cause, as determined by NTSB, was excessive track gauge due to a combination of fouled ballast, deteriorated concrete ties, and profile deviations resulting from MNR's decision to defer scheduled track maintenance.

The **fourth accident** involved the derailment of an MNR passenger train in the Bronx, New York. On December 1, 2013, MNR Train 8088 derailed on a 30-mph curve while traveling at 82 mph. In total, 4 passengers were killed and 61 were injured. The damage was estimated at $9 million. The probable cause, as determined by NTSB, was the engineer's non-compliance with the 30-mph speed restriction because he had fallen asleep due to undiagnosed severe OSA exacerbated by a recent circadian rhythm shift required by his work schedule. Contributing to the accident was the absence of an MNR policy or an FRA regulation requiring medical screening for sleep disorders. Also contributing to the accident was the absence of a positive train control (PTC) system that would have automatically applied the brakes to enforce the speed restriction. Contributing to the severity of the accident was the loss of the window glazing that resulted in the fatal ejection of four passengers from the train.

The **fifth accident** involved a roadway worker fatality when a worker was outside a designated work area. On March 10, 2014, an MNR electrician was struck and killed at a control point in Manhattan, New York, while working outside an adjacent exclusive use work area within the control point. The probable cause, as determined by NTSB, was a miscommunication of the limits of on-track protection resulting from incomplete and inaccurate roadway worker job briefings. Contributing was the use of a reference point (“AB Split") that was poorly understood by some workers.

Although each accident had unique factors discussed in the individual accident reports, several overarching themes are highlighted in both the FRA Deep Dive Report and the NTSB Special Investigation Report.

FRA Deep Dive Report[39]

FRA, with assistance from FTA, fielded a 60-person team to assess “MNR’s safety-related processes and procedures, its compliance with safety regulations and requirements, and its overall safety culture.”[40] This report identified three “overarching safety concerns”—overemphasis on on-time performance, ineffective safety department and poor safety culture, and ineffective training program. The report outlined findings and FRA directed actions in eight technical areas:

1. Track safety standards
2. Operating rules
3. Qualifications/certifications of train operating personnel
4. Workplace safety
5. Train control systems
6. Blue signal protection
7. Operations control center
8. Maintenance-of-Way employee fatigue

The report also detailed three FRA comprehensive directed actions:[41]

1. Effective immediately, MNR’s senior leadership must prioritize safety above all else and communicate and implement that priority throughout MNR.
2. Within 60 days, MNR shall submit to FRA a plan to improve the Safety Department’s mission and effectiveness. MNR must evaluate the structure, organization, and responsibilities of the Safety Department to ensure that it is communicating effectively throughout MNR and that it is providing effective leadership and oversight on safety issues. MNR must ensure that the staff of the Safety Department conducts safety meetings at all levels of the organization and provides appropriate in-person monitoring of field activities and personnel.
3. Within 60 days, MNR shall submit to FRA a plan to improve the training program. The senior leadership of MNR must evaluate the structure,

[39] FRA Report to Congress, "Operation Deep Dive, MNR Commuter Railroad Safety Assessment,” March 2014, www.fra.dot.gov/Elib/Document/3586.
[40] "FTA Report to Congress, Operation Deep Dive, Metro North Commuter Railroad Safety Assessment,” March 2014, p. 2.
[41] *Ibid*., p. 4.

organization, and responsibilities of the Training Department to ensure that it develops, implements, and leads an effective training program for all operating departments. MNR shall evaluate the existing recordkeeping system and take corrective action to ensure that accurate records are created, maintained, and readily accessible to appropriate employees.

NTSB Special Investigation Report

This report discusses each of the five accidents, their unique aspects, and MNR organizational factors related to the accidents. The report made 17 new recommendations to MNR, LIRR, MTA, FRA, various railroad and transit industry associations, the American College of Physicians, and the American Academy of Family Physicians. NTSB conclusions and examples were as follows:

- **Ineffective system safety program** – MNR's CSO acknowledged that the program was of "limited effectiveness" and that other than when distributed and updated as part of periodic APTA/FRA audits, the program documents "just reside(d) out in the hallway there in the file cabinet."[42]
- **Ineffective incident and close call investigations** – a precursor close call event to the West Haven roadway worker fatality occurred less than one month before the accident received a cursory investigation and was documented in a one-page memo with a timeline of events.[43]
- **Ineffective collection and monitoring of safety data** – NTSB investigators were able to pull broken joint bar incidents from MNR supplied data to demonstrate a clear upward trend that had not been identified by MNR.[44]
- **Emphasis on personal injury monitoring masked operational safety risks** – an MTA Board Member and chair of the MNR Committee described the safety program as a product "of what DuPont made it" and expressed alarm "that our infrastructure is as bad as it is."[45]
- **Lack of safety incident reporting** – over 12 months, there was only one report recorded for the MNR safety hotline (a missing first aid kit).[46]
- **Ineffective management oversight and enforcement of safety rules** – the supervisor who conducted the bulk of operational compliance testing on the engineer in the December 1 derailment had never been trained on the program and was not qualified on MNR operating rules. Additionally, most operating rule compliance testing was conducted in yards "where

[42] NTSB Special Investigation Report, "Organizational Factors in MNR Railroad Accidents," NTSB/SIR-14-04, adopted November 19, 2014, pp. 47-48.
[43] *Ibid*., p. 51.
[44] *Ibid*., Figure 27, p. 52.
[45] DuPont provides safety consulting focused on personal injury prevention.
[46] NTSB/SIR 14-04, p. 64.

revenue service would not be impacted or the cab where engineers would likely be aware of being observed."[47]

- **Ineffective medical monitoring of operations personnel** – MNR "medical protocols lacked appropriate guidance regarding sleep disorders and medications."[48]
- **Ineffective MTA safety oversight** – the MTA Board-level Safety Committee was discontinued in 2011. "The NTSB identified inconsistencies among these properties (MNR, LIRR, NYCT) that could have been identified and addressed by an MTA Board-level safety committee." Further, "LIRR and MTA subways owned track geometry vehicles and routinely used data in their track maintenance programs. MNR contracted this function and stated at the NTSB investigative hearing that they did not fully use the data generated by the contractor."[49]
- **Ineffective FRA regulation and oversight** – there was lack of regulations on sleep disorder screening, redundant track protection (for roadway work areas), and the regulatory exception for commuter railroads allowing multiple tracks to be inspected from a single track, as well as limited MNR track maintenance oversight: "The FRA did not conduct any visual or track geometry car inspections for the years 2012 and 2013 on MNR prior to the Bridgeport derailment."[50]

Additional NTSB public report documents associated with these MNR events are included in Table 3-1.

Table 3-1 *Individual NTSB Public Documents – Five MNR Accidents*

Accident Location	Date	Type	Docket Number
Bridgeport, CT	5/17/2013	Collision	DCA13MR003
West Haven, CT	5/28/2013	Roadway Fatality	DCA13FR005
Bronx, NY	7/18/2013	Derailment	DCA13FR009
Bronx, NY	12/1/2013	Derailment	DCA14MR002
Manhattan, NY	3/10/2014	Roadway Fatality	DCA14FR006

Accident Investigation

The following section presents suggested practices for performing accident investigations and the underlying SMS principles of this function.

Part 1: Investigation Perspective

An investigation of an undesirable safety event is a focused safety audit. During a safety audit, a variety of criteria, based on programs, procedures, and

[47] *Ibid.*, pp. 60-61.
[48] *Ibid.*, p. 63.
[49] *Ibid.*, pp. 64-65.
[50] *Ibid.*, p. 78.

practices, are compared with factual operating information. Audit findings are noted where there is a gap between what should be and what is. Similarly, during the investigation of an undesirable safety event, 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. In the event that no gaps are identified between existing requirements and actual performance in an accident investigation, the adequacy of agency policies, procedures, and equipment must be assessed. In both a safety audit and safety investigation, findings are analyzed, and corrective actions are developed to address gaps that are identified.

Purpose of Conducting Investigations

The primary purpose of conducting investigations of events is to determine the cause so corrective actions can be put in place that prevents future similar events. Title 49 CFR § 673.27 requires transit agencies to include the investigation of safety events to identify causal factors as part of their safety assurance process. An investigation evaluates the effectiveness of safety risk control methods and may result in corrective actions to improve those control methods where gaps are identified.

Safety investigations, as a part of safety assurance, are central to an effective SMS. The investigation process and the benefits of that process includes:

- Analysis of data and information obtained through the investigation process to proactively and predictively identify where and when a similar event could occur
- Identification of changes to facilities, vehicles, equipment, and systems that were not effectively managed to ensure safety
- Use of "lessons learned" from event investigations to promote continual improvement in safety performance
- Identification and logging of hazards identified from data analyses during investigations into the SRM Process (SMS Component 2).

Both NTSB and APTA provide resources through investigation reports and guidance documents. The NTSB "investigates(s) accidents to determine the probable cause, identify safety issues, and devise recommendations to prevent recurrence."[51] These reports are available on NTSB's website and can prove useful in understanding a robust investigation process.

[51] NTSB FY 2018–2022 Strategic Plan.

APTA RT- OP-S-002-02 Rev. 3, Standard for Accident/Incident Notification and Investigation Requirements, defines 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, 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.

Investigation Plan and Procedures

RTA investigation plans and procedures must conform with the requirements in the State Safety Oversight (SSO) program standard. Title 49 CFR § 674.27 (a) (7) Investigations, states that the SSO program standard must identify thresholds for accidents that require the RTA to investigate. Also, the program standard must address how the SSOA will oversee an RTA's internal investigation, the role of the SSOA in supporting any investigation conducted or findings and recommendations made by the NTSB or FTA, and procedures for protecting the confidentiality of the investigation reports.

Typically, an investigation plan may include the following:

- Format and content conforming to SSO Program Standard
- Policy statement with Accountable Executive approval
- Composition and organization of an agency inter-departmental investigation team
- Criteria for when use of a team investigation is required
- Investigation management procedures – who is in charge, roles and responsibilities of participating department personnel
- Notification procedures, internal and external, if the agency event investigation plan can reference SOPs that address who to notify and when that would be preferable; otherwise, the investigation plan would need to be updated every time a notification procedure is changed
- Coordination with public safety agencies – the agency's emergency response plan can be referenced; this details the incident command structure and other interfaces
- Scene management procedures, evidence collection, and preservation; the plan should detail scene security and evidence collection/preservation
- Established protocols for SSO investigations or SSO participation in an agency investigation

- Procedures for working with FTA or NTSB should they perform separate investigations
- Procedures and policies on conducting ongoing investigation and writing the report; process starts with occurrence and continues through SSOA acceptance and publishing the report

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

- Car equipment (mechanical)
- Track/infrastructure/power
- Signals/communication
- Transportation
- Operating rules, procedures, practices, bulletins
- Training
- Human factors (medical, hours of service, training)
- Survival factors

External expertise may also be required from vendors, manufacturers, or consultants.

Notification

Management may want to be notified of all safety events (including near misses), no matter how minor they may be perceived, so they can be investigated, assessed, and recorded in line with SMS data collection and analysis requirements. 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. The following information is based on regulations and guidance in effect as of the date of publication of this document; it is not intended to substitute for a careful reading of the current applicable regulations.

SSOAs, FTA, FRA, and NTSB have established that rail transit events meeting established criteria must be formally reported within specific timelines. Note that rail transit operations on shared-use or shared-corridor alignments may also fall under FRA accident notification requirements.

Notification Contacts	
FTA	TOC-01@dot.gov, (202) 366-1863
NTD	http://www.ntdprogram.gov
SSOA	As specified in agency's state's program standard
NTSB	(800) 424-0201, National Response Center
FRA	(800) 424-8802 or (800) 424-0201

Notification to FTA

Title 49 CFR § 674.33 provides notification requirements for FTA grantees. Appendix A describes the types of events that must be reported, using the definitions in § 674.7. RTAs must notify FTA within two hours of the following events:

- Fatality
- Serious injury
- All collisions
- Runaway trains
- Evacuations for life safety reasons
- All derailments
- Fires resulting in serious injury or fatality
- Any event requiring notification to FRA

Similarly, 49 CFR Part 630 and NTD reporting manuals require the reporting of incidents to NTD within 30 days of the following events:

- Personal injuries
- Injuries requiring medical transport
- Damage that disrupts operations
- Evacuations into right-of-way or adjacent track
- Collisions
- Damage to catenary or contact (third) rail that disrupts operations
- Fires resulting in a non-serious injury or property damage
- Trains stopping due to obstructions
- Most hazardous material spills

Notification to SSOA

Title 49 CFR § 674.27 requires the SSOA to establish accident notification requirements that must specify time limits, notification methods, and information requirements. The requirements will be published in a program standard. Investigators must familiarize themselves with the notification and reporting requirements in the program standard applicable to their state.

Notification to FRA

FRA has established reporting and recordkeeping requirements for accidents and injuries. Rail transit operations do not fall under these regulations; however, in the case of shared-use/shared-corridor operations, waiver agreements may require reporting of specified transit events. Investigators dealing with shared use/shared corridor operations must familiarize themselves with the specific reporting requirements (if any) in the waiver agreement(s) applicable to their operation.

Title 49 CFR Part 225 requires telephonic reporting of the following events to FRA:

- Fatalities
- Serious injuries
- Evacuation of a passenger train
- Train accidents resulting in > $150,000 damage
- Train accidents resulting in > $25,000 damage to a passenger train
- Collisions/derailments (or blockage) on main tracks used for passenger service

There may be additional reporting requirements for OSHA, EPA, and state and local agencies, depending on the circumstances of the accident.

Notification to NTSB

Title 49 CFR § 840.3 requires notification to the National Response Center NTSB

- Within two hours of the following events:
  - Passenger or employee fatality or serious injury to two or more crew members or passengers requiring admission to a hospital
  - Evacuation of a passenger train
  - Damage to a tank car or container resulting in release of hazardous materials or involving evacuation of the public
  - Fatality at a grade crossing
- Within four hours of the following events:
  - Damage (based on preliminary gross estimate) of $150,000 or more for repairs or current replacement cost to railroad and non-railroad property
  - Damage of $25,000 or more to a passenger train and railroad and non-railroad property

NTSB Investigations

NTSB was originally part of the USDOT, but Congress later established it as an independent accident investigation agency. NTSB has broad investigative authority but no regulatory authority; its single focus is on gathering facts, determining causes, assisting victims, and making recommendations to improve transportation safety. Title 49 CFR Parts 800–850 established how NTSB performs its responsibilities.

The NTSB Rail Division has 12–18 investigators and does not launch to most rail transit accidents. Accident notifications are passes to an investigator/duty officer who assesses the likelihood that NTSB will investigate and who may reach out to the agency's point of contact to obtain additional information. Information is then passed up the management chain where the decision to/not to send investigators is made.

If NTSB will be sending investigators, the agency point of contact will be informed by the duty officer or the NTSB Investigator-in-Charge (IIC). Expectations of the agency include the following:

- Provide telephone number of on-scene contact to NTSB IIC.
- Ensure preservation of evidence and scene in accordance with instructions and requirements of NTSB, which may supersede or supplement RTA’s actions to secure scene.
- Identify and make available personnel to represent agency and SSOA on technical (discipline) investigative teams.
- Establish points of contact to discuss appropriate responsibilities and roles for scene management and evidence preservation.
- Provide name and telephone number of agency and SSOA Public Information Officer (PIO).
- Refer all press inquiries on investigation to PIO for NTSB.

The seriousness and complexity of an accident will determine the size of the NTSB team. A Board Member may or may not arrive with the team. When NTSB arrives on the scene, technical workgroups will be formed to develop factual information relevant to the accident. The NTSB on-scene investigative team for a more substantial accident typically consists of an IIC and technical specialists to lead the investigative groups. Technical groups may include:

- Mechanical (vehicles)
- Operations
- Signals
- Track
- Human performance
- Survival factors
- Other specialized groups may be formed as needed

NTSB leverages its limited resources using technical staff from party organizations. Typically, the RTA and SSOA will be asked to provide senior managers as the primary contacts and technical specialists for the various investigative groups. Party participation is at the discretion of the NTSB IIC; party organizations are those that have people, procedures or equipment involved in the accident and can provide technical expertise to assist NTSB. Party participants may not make public comments on the investigation and may not distribute information outside the investigation. Parties may include:

- Railroad/transit agency
- FRA/FTA/SSOA
- Labor organizations
- Emergency responders
- Equipment manufacturers
- Persons with a connection to the event who bring technical expertise to investigation

Attorneys, claims agents, PIOs, and media are not permitted to participate in investigative activities.

The on-scene phase of an NTSB investigation focuses on developing facts and kicks off with an organization meeting at which party organizations and individual roles are established. Each following day, a progress meeting is held at which information is shared among the technical groups and work for the next day is planned. All information is shared; it cannot be withheld. At the end of the on-scene phase, a closeout meeting is held that involves the final exchange of factual data and field notes from each technical group. Follow-on activities may include additional interviews, laboratory exams, testing, or equipment teardowns. Each technical group will produce a factual report that is reviewed by the group members to ensure factual accuracy. Sometimes, the Board holds investigative hearings to develop the facts further. NTSB staff independently perform the analysis and complete the full report. Parties can provide their analysis and suggest probable cause and recommendations for NTSB consideration. The final report is presented at a public meeting at which Board Members discuss it and may adopt it or make their edits.

Investigator Training

Essential knowledge, skills, and abilities for investigators include the following:

- Knowledge of system operations
- Knowledge of accident investigation methods and requirements
- Understanding of equipment and subsystem functionality (track, vehicles, signals, power, 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 (ICS/NIMS)
- Interviewing skills
- Skills related to documenting an accident scene (photography, sketching, measurement, evidence)
- People skills

FTA's Public Transportation Safety Certification Training Program (Title 49 CFR Part 672) establishes minimum training for personnel who conduct safety audits and examinations of public transportation systems operated by public transportation agencies and those who are directly responsible for safety oversight of public transportation agencies. The agency's lead investigator and SSOA investigators fall under this requirement; depending on other investigator roles in the organization, they may or may not fall under this definition. The training curriculum provides a useful background for anyone involved in rail transit investigations. The required curriculum is as follows:

- SMS Awareness (1-hour course) – e-learning delivery (all required participants)
- Safety Assurance (two 2-hour courses) – e-learning delivery (all required participants)
- SMS Principles for Transit (20 hours) – (all required participants)
- SMS Principles for SSO Programs (16 hours) – FTA/SSOA/contractor support personnel only
- Transit Safety and Security Program (TSSP) curriculum minus Transit System Security course – all required participants; credit provided if participant has Course Completion Certificate of previously-completed TSSP courses
- Rail System Safety (36 hours)
- Effectively Managing Transit Emergencies (32 hours)
- Rail Incident Investigation (36 hours)

Title 49 CFR Part 672, Appendix A provides a list of technical training plan elements for SSOA personnel who oversee transit operations. This list is also a good benchmark for internal investigator training.

In addition to the Public Transportation Safety Certification Training Program curriculum, there are several additional types of training investigators could consider. Potential courses of value to investigators include the following:

- Agency operating rules
- Agency roadway worker protection
- Agency maintenance training courses
- Agency bloodborne pathogens training
- Agency hazardous materials awareness
- Advanced Rail Incident Investigation (TSI)
- Rail Nomenclature (TSI-on-line)
- Fatigue and Sleep Apnea Awareness (TSI online)
- Curbing Transit Employee Distracted Driving (TSI online)
- Transit Safety and Security Audit (TSI)
- Introduction to Incident Command System, ICS 100 (Federal Emergency Management Agency (FEMA) Online)
- NTSB Accident Investigation Orientation (RPH-301, NTSB Training Center)
- Forensic photography (various commercial vendors)
- Interviewing skills (various commercial vendors)
- Root cause analysis (various commercial vendors)

Additionally, investigators may choose to 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 an investigator to establish good interpersonal relationships with key staff.

Part 2: Accident Scene

NTSB made the following recommendation to APTA: "Urge your members to conduct regular training exercises that use written ventilation procedures to provide ample opportunities for employees and emergency responders to practice those procedures." (R-15-12, Urgent). The National Fire Protection Association (NFPA) 130 9.11.3 states that "Critiques shall be held after the exercises, drills, and actual emergencies. APTA also provides a number of multimodal standards and recommended practices for emergency management."[52] The effectiveness of the response and coordination with responders is an element that needs to be assessed by investigators.

The agency's response to incidents should be established in advance in an existing SOP or emergency plan. Typically, the control center is responsible for notifying appropriate personnel and activating the response, including notifying investigators. This is where the agency program of training, exercises, and debriefs with emergency responders pay dividends.

[52] APTA Security and Emergency Management Standards, https://www.apta.com/research-technical-resources/standards/security/f.

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, signal cases, and vehicle control compartments.

Scene Safety

Investigators are on-scene to improve safety. If injured, an investigator will become part of the problem instead of part of the solution.

The first stop for investigators should be the Incident Commander (IC), who often is with the fire or police department. For accidents entirely on agency property (such as a yard) and with no fire or injuries necessitating a response, the IC will be an agency employee.

Before entering the scene, investigators must perform a hazard scan and participate in a safety briefing with the IC. Among the potential hazards that should be evaluated are traction power electrical status, unstable equipment, damaged catenary under tension, movement on adjacent tracks or of repair/re-railing equipment, biohazards, and Haz-Mat spills. Investigators need to request that the IC provide a representative with communication capabilities with the IC that can accompany them during the investigation.

Safety investigators must model appropriate behavior and dress. Clothing and PPE appropriate to the accident scene and agency protocols must always be worn while on-scene. At a minimum, this means long pants, safety footwear, eye protection, hard hat, work gloves, and a reflective outer vest meeting agency requirement. Additional PPE may be required depending on the conditions at each accident scene.

News media often stage cameras to record activities at accident scenes. Investigators should be aware that their behavior and appearance and that of other personnel may make the news. The media may have video equipment that may not appear to be in use (video cameras pointed to the ground); these video cameras may still be recording audio. If the NTSB is investigating, only an NTSB representative may talk to the media.

Experienced investigators maintain a "go-bag" with PPE and investigative tools that are routinely needed. PPE should include a bloodborne pathogen kit with gloves and other protective and sanitizing gear. Such kits are available commercially (see Appendix B).

Typical contents of an investigator's go-bag are PPE, flashlight (extra batteries), paint pens, marking chalk, cameras, electric meter, gauges, non-conductive measuring devices, bloodborne pathogens kit. Gauges, electric meters, measurement devices, and publications maintained as part of a go-bag must be kept up to date and calibrated. Users must be appropriately trained and qualified. For investigators who do not routinely use a track gauge, electrical meter, or similar device, it is often better to have an experienced technician take the measurements while an investigator observes.

Potential for Bloodborne Pathogen Exposure

Rail 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.” That means treating blood and bodily fluids as if they are infectious for HIV, HBV, and other bloodborne pathogens and to take appropriate precautions. Bloodborne pathogen kits should be part of an investigator’s go-bag.

Rail transit accident investigators should receive initial and recurrent training on bloodborne pathogens as specified in applicable OSHA regulations. The training is required to cover information on the HBV vaccine, which employers must provide at no charge if requested. (See 29 CFR § 1910.1030.)

Potential for Hazardous Material Exposure

Rail transit accident investigators have the potential for exposure to hazardous materials, particularly on systems that interface with highway vehicles. These materials may include automotive fluids (gasoline, diesel fuel, hydraulic fluid, antifreeze) as well as a wide variety of chemicals transported by commercial motor carriers.

Depending on the operational characteristics of the rail transit system and risk profile, 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 the 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) initial training with annual 8-hour refreshers. Some online courses are commercially available. Rail transit investigators must 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 preservation of factual evidence. However, rescue, recovery, and public safety supersede the preservation of evidence during the emergency response. Rail transit investigators should contact the IC as soon as possible to coordinate the needs of the investigation with the need for 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.

Chain of Custody

Chain of custody documents the movement and location of evidence and the history of those persons and entities who had it in their custody from the time it is obtained until its final disposition. Investigators must have an evidence control plan along with the appropriate chain of custody forms and containers. For agencies with dedicated transit law enforcement, these resources will have established evidence control procedures and storage rooms that can be of help. If vehicles or larger components such as switch machines need to be preserved, they need a secure storage location in a yard or other fenced facility, ideally with access control.

Event Recorder/Data Logger/SCADA/Camera System Analysis

Many rail transit systems have extensive data recording systems that provide valuable information to investigators. Data recorders may be installed on vehicles, wayside signal houses, grade crossing warning equipment cases, and in the control center. Camera systems may be on vehicles, in stations, or at other locations. Private surveillance cameras may be installed at businesses and residences adjacent to the scene. Onboard electronic data recorders are required in FRA-regulated environments and are becoming more common in transit.

Investigators should become familiar with the various types of recorders and cameras in place on the system(s) they investigate. If a delay in downloading data may result in data loss, the recorder should be downloaded on-scene and documented. The time of download should be noted against an accurate clock (like the control center time or the time on a cell phone) for later time synchronization. Some vehicle event recorders require a wheel measurement at the time of download. Agencies should have written protocols in place for the protection, download, analysis, and retention of data generated by such systems.

Investigators should 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 trains may be useful and should be ordered in a timely way to avoid losing data. 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.

Photographs, Videos, Sketches, and Measurements

Investigators should take numerous photographs and videos. Some investigators wear a "Go Pro" type device, so they are always recording on-scene. It is better to have images and not need them than vice versa. For evidence control purposes, unwanted images should not be deleted. Video recorders may also capture sound, so investigators should be aware of what is said during recording.

Investigators should capture things that will change, such as rail markings, track and switch conditions, signal relay positions, the operator's control handles, and cab breaker positions. They should start at a distance and move in closer. If documenting a vehicle, signal case, or another unique component, images should be captured of the identification number (car number, license plate, signal number, part number, asset number) before and after taking the more detailed shots to be able to link a close up easily to the unique item.

Before collecting small pieces of evidence, the point of rest, orientation, and location relative to the overall scene should be documented and unique identifiers on equipment and components such as serial numbers or model identification should be captured. Rail vehicles and maintenance equipment may have stenciling at various locations on (or under) the equipment that should be captured.

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.

In a derailment event, it is important to take as many images and measurements as possible before the derailed vehicle is moved. The area traversed before the derailment is of particular interest, as are the stationing markers along the right-of-way ahead of and throughout the derailment area, beyond the point of final rest and resulting property damage. It will be necessary to take additional photographs and measurements after the derailed vehicle is removed so that track structure is accessible. Post derailment track measurements are taken at stations of fixed distance (at 15.5-ft intervals, for example) where gauge, cross-level, and super-elevation are recorded. Conditions of ties, fasteners, and other track components are also recorded. Photos of conditions at each station can be useful.

Sketches should be marked "not to scale" and show a North arrow (does not have to point up). Measure from a fixed object that will not change like a stationing marker, the edge of a platform, or a traction power pole. Some vital measurements include point of impact, point of derailment, position of rest, and orientation of individual cars.

If multiple people are taking measurements, there are often natural discrepancies, particularly over long distances. Investigators should confer and agree on the numbers to be officially recorded, remeasuring if necessary. The goal with scene documentation is to have measurements and relative positions accurately recorded so that the investigator could theoretically put everything back in the same place after it has been removed.

Grade Crossings/Intersections

Investigators should document the position and condition of pavement markings, warning signs, and any special pedestrian enhancements (swing gates, pedestrian gates, Z approaches) as well as 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.

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:

- Do weather conditions affect visibility?
- Is it dark (after sunset or in a tunnel)?
- Is artificial lighting present? Are all lights working?
- Is any unusual noise present (such as ventilation fans)?
- Is there anything in the environment that may have created a distraction?

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

Witness Statements

Police or transit agency personnel should try to get as many witness statements as possible along with contact information. Passengers often are anxious to leave the scene and, at 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.

Inter-Agency Coordination/ICS

Multiple agencies may be involved in an accident response, particularly a significant mass casualty event. ICS is a standardized, on-scene, all-hazard incident management concept that allows its users to adopt an integrated organizational structure (see Figure 2-27) 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) with these defined purpose areas:

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

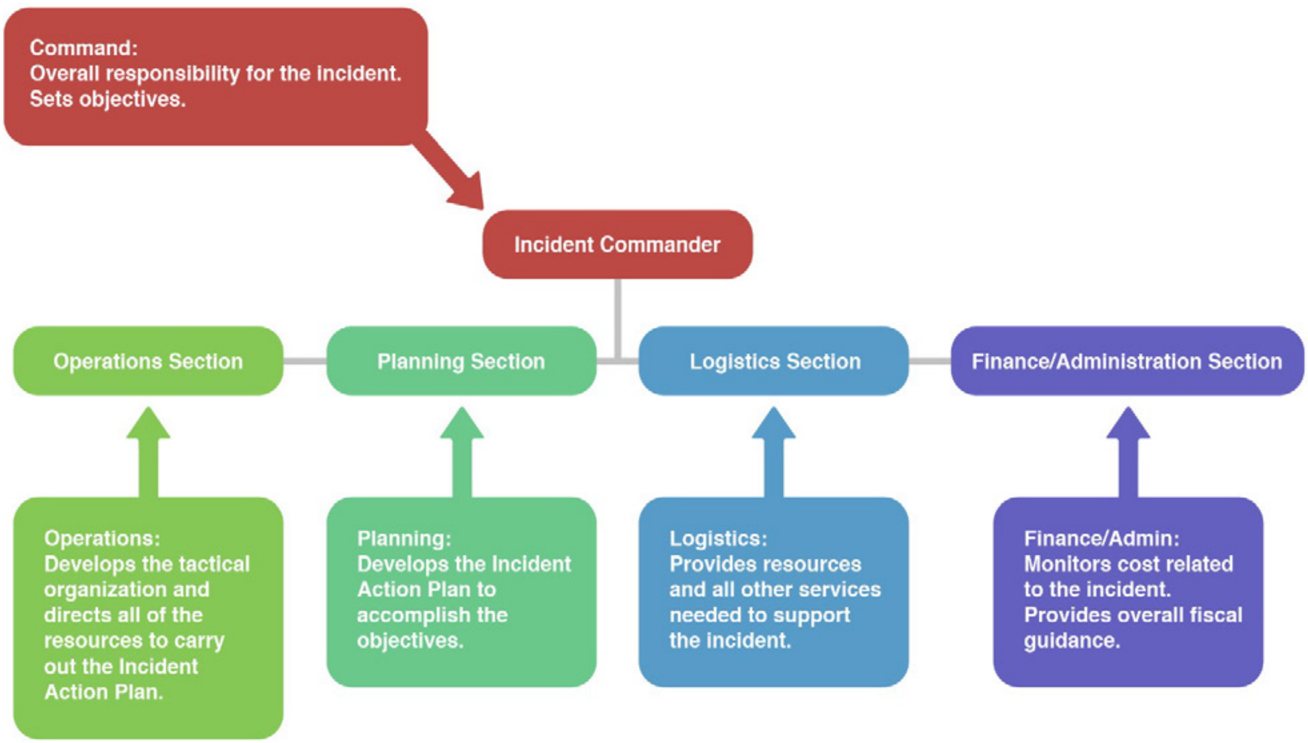

Figure 3-1 *Incident Command System (ICS) Structure*
Source: TSI

ICS objectives include the following:

- Operations – develop tactical organization and directs all resources to carry out Incident Action Plan
- Planning – develop Incident Action Plan to accomplish objectives
- Logistics – provide resources and all other services needed to support incident
- Finance/Administration – monitor costs related to incident, provide overall fiscal guidance.

Typically, the first transit employee on the scene (often a train operator) is the initial IC. The IC position may transition to a more senior agency employee until responders arrive. When ICS is established by the response agency, the agency becomes part of the ICS and supports the IC. Once the response has concluded, agency personnel and investigators should participate in a "hot wash" immediately after the response and participate in a more in-depth debrief after the event.

Working with Law Enforcement

State and local law enforcement agencies may have independent authority at traffic accidents and criminal events and may be in charge of the investigation. Investigators need to forge cooperative working relationships with these local authorities, preferably in advance of the accident. Agencies with their own police department or contracting with local police department for dedicated personnel often have an easier time. Relationships can be forged through meetings, training, drills, and tabletop exercises.

Law enforcement traffic investigations focus on which party broke the law—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 may be judged not "at fault" by law enforcement, but the agency's operations investigation may find the accident to have been "preventable" as defined by their agency procedures. (*Note*: An accident could be rated as "non-preventable" on the part of an employee by the RTA 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.)

Points of Contact

The investigator should obtain business cards or contact information of people from other departments and outside agencies. Invariably, there will be a need for follow-up questions or a need for documentation or further information.

Other Resources

FRA provides emergency management and related guidance to the rail industry. The following FRA regulations do not apply to most rail transit systems but can provide a useful model on coordination with emergency response agencies for the PTASP:

- 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. Debriefing and critique sessions should, at a minimum, determine:
  - Whether the on-board communications equipment functioned properly
  - How much time elapsed between occurrence of the emergency or full-scale simulation and notification to emergency responders involved
  - Whether the control center or the emergency response communications center promptly initiated required notifications, as applicable under the plan
  - How quickly and effectively emergency responders responded after notification
  - How efficiently passengers exited from the car through emergency exits, including passengers with disabilities or injuries (when RTA knows any such passengers).

These questions will also need to be explored as part of the survival factors investigation.

Part 3: Post On-Scene Investigation

Post-on-scene activities include desk reviews of documentation, follow-up interviews, tests and re-creations, and analysis of factual information.

Effective Investigation Practice

Investigators should plan sufficient time to established and confirm the time of the event. The approach should include the extraction and analysis of data from the vehicle event recorder, forward-facing video, and/or signal system data and syncing data time stamps.

Timeline

A timeline forms 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. Develop as much detail as possible 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.

Recorder Synchronization

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 have autonomous internal clocks. Over time, clocks deviate from their original time setting. Some equipment may have had clocks initially set inaccurately or to a different time zone. Synchronizing the times to reflect the accurate and precise time can be a challenge. SCADA time is usually tied into an accurate clock, but this should be verified.

Recorded Data

Video images can provide valuable data to the survival factors investigation on where individuals were located, and the injury mechanisms involved. The forward-facing video provides valuable information on the moments leading up to the accident and the conditions of track, structures, signals, and environment.

> **Effective Investigation Practice**
>
> In an accident in which the track, signals, power, or other infrastructure may play a role, forward-facing video from previous trains that operated over the territory just before the event can be valuable to review. Where relevant information is developed, it should be added to the timeline.

Inward (operator) facing video is becoming more common and has been recommended to the industry by 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. Inward-facing video can provide investigators with valuable information on operator actions, vigilance, and distractions that may have been factors in an accident.

SCADA system recorded data will provide information on the various systems and subsystems monitored. Potential SCADA data to review may include:

- Track circuit occupancy/non-occupancy
- Track switch position
- Signal indications
- Traction power status including breaker positions
- Alarms
- Ventilation fan status
- Controller inputs

Vehicle event recorders are increasingly common on rail transit vehicles. FRA regulations at 49 CFR § 229.135 require event recorders on locomotives. These regulations do not apply to most transit operations. The Institute of Electrical and Electronics Engineers (IEEE) issued the Standard for Rail Transit Vehicle Event Recorder, IEEE 1482.1-1999, and APTA issued a recommended practice for periodic maintenance and inspection of event recorders.[53] Event recorders will

[53] On-Board Recording Equipment Periodic Inspection and Maintenance, APTA RT-VIM-RP-015-03, Rev. 2, June 8, 2003.

provide time, distance traveled, and information on speed, braking, throttle, horn, and other operational parameters. In a collision or derailment scenario, the last few seconds of recorded data can be corrupted or inaccurate because of collision damage or the wheel providing speed/distance inputs being off the rail. If recorder data is based on wheel rotation, a wheel diameter measurement at the time of download is needed for the best accuracy. The point of rest of the rail vehicle following the accident is an essential measurement for calculating the location of vehicle data points approaching the accident location.

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 help nail down the timeline and may provide valuable information about communication flow, and on decisions that were 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.

Effective Investigation Practice: Transcribed Recording

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

Document Reviews

Documents for review will be selected by investigators based on the circumstances of the accident. These reviews are very "audit like"—what does the document say should be done, and what was done? Discrepancies or gaps need some analysis to determine their relevance. 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. Figure 3-2 provides examples of documents that may be reviewed during this activity.

Effective Investigation Practice

Questions document reviews should answer:

- Is the agency complying with internal and external standards?
- If no, what is the relevance to the accident sequence? What obstacles need to be addressed to bring practices into conformance?
- If yes, are the rail agency's current practices effective in identifying and addressing latent conditions and active failures that have the potential to result in the accident?

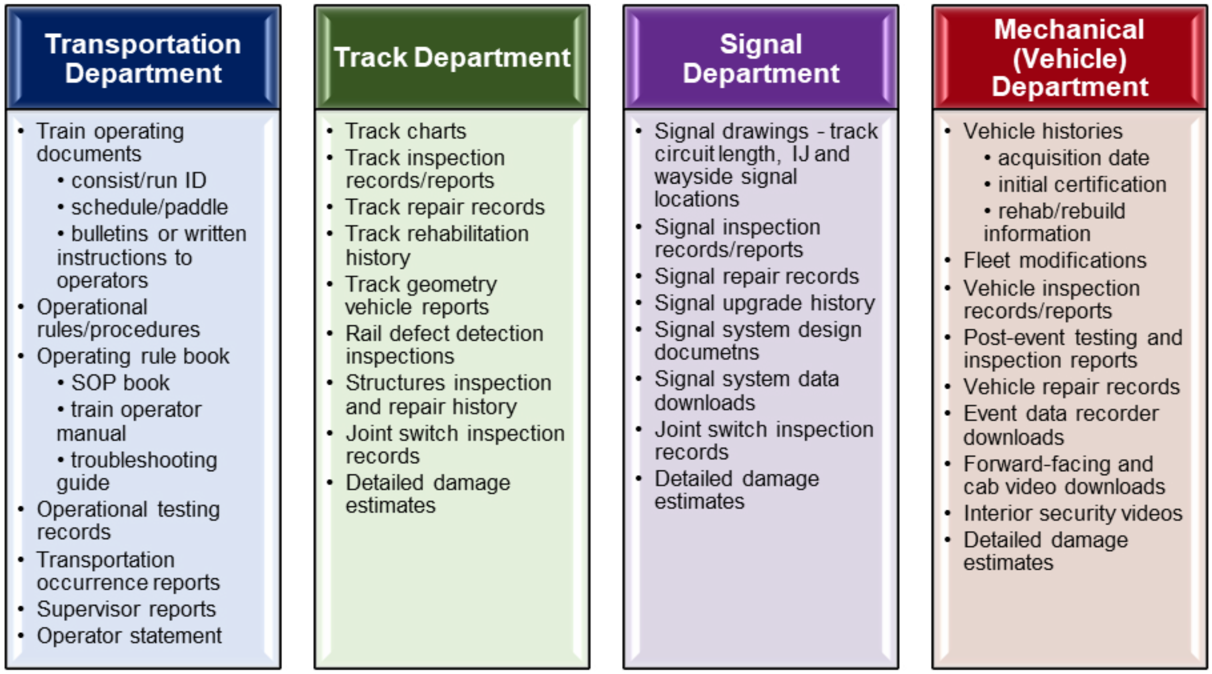

Figure 3-2 *Example Documents to Review*

Source: CUTR

If mechanical failure of system components is involved, a review of maintenance inspections, technician qualifications and training, quality control, procedures, schedule, and history would be critical areas of documentation review. FTA has produced a compendium of transit safety standards that contains potential external standards investigators can use as benchmarks.[54]

Management Oversight and Rules Compliance

Operating rules are the instructions to personnel covering train operations and maintenance activities on the right-of-way. Operating rules include the agency rulebook and other associated manuals, SOPs, bulletins, and operating documents (train orders or equivalent) issued to train operators. Investigators should become familiar with the requirements in these rules and procedures.

Key points on the assessment of rules:

- Determine if established practices were followed.
- If not, determine why, i.e., inadequate oversight, lack of training, cumbersome procedures promote practical drift.
- If procedure/practice was followed, determine if it is effective.

[54] https://www.transit.dot.gov/regulations-and-guidance/safety/compendium-transit-safety-standards.

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. As Ben Franklin said, “A little neglect may breed much mischief.” 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 has to be in place to measure the drift, control it, and bring it back in line with the agency's expected performance standards. Rules compliance monitoring programs provide this function.

FRA has requirements for programs of operational tests and inspections (49 CFR § 217.9) that require railroads to “conduct operational tests and inspections to determine the extent of compliance with its code of operating rules, timetables, and timetable special instructions.” Further, railroads must analyze program results and address trends. Rail transit systems do not fall under these FRA regulations. However, they provide an excellent benchmark to assess the adequacy of agency programs.

FTA requirements are more general. FTA regulations at 49 CFR Part 674 are based on the SMS approach. A key element (one of the four components) of SMS is safety assurance, which 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.”

APTA published a standard on rules compliance for rail transit systems, APTA-RT-OP-S-11-10. This voluntary (unless adopted by state regulation) standard requires, among other things, defining rules to be evaluated, operating positions affected, cycles, and determining the frequency of checks, establishing methods of verification, metrics, and validation/analysis of program effectiveness.

Evaluations of the operating rules are an essential part of the investigative process. Investigators need to be familiar with the rules and determine what was required, 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?

It is important to determine what rules were clear, were understood by those involved, and whether employees had received adequate training on the rules. It is also essential to evaluate the compliance program conducted by managers. Lastly, 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.

APTA-RT-OP-S-001-02 Rev. 2, the APTA standard for rail transit rule books, includes a suggested change management process. Part of the recommended operating rules change management process involves a committee structure, including a general Rulebook Committee with a chairperson and composed of senior managers from operating, maintenance, safety, labor, risk, security, and law offices. The objective of this committee structure is to make sure that all departments affected by changes understand and approve the changes.

Effective Investigation Practice

Reviewing rules compliance program data relevant to an 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.
- Compare the agency program with FRA regulations and APTA Standard Red Flags.
- Compliance check results that may be "too good," i.e., there are never any exceptions.
- Compliance checks that are not spread over days and times; from an employee perspective, compliance checks should be unexpected.
- Compliance checks that are not spread over all locations—for example, a preponderance of checks done at reporting locations.
- Compliance checks limited to PPE, tardiness, and "easy" checks.

Interviews

Interviewees who meet the objectives of filling in the blanks or clarifying events should be selected, including eyewitnesses, employees, and passengers. 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 vehicle operators, controllers and maintenance technicians.

At the scene, investigators are the least informed about the specifics of the accident. After a few days, they have more information that can help them ask better questions and better assess the information provided by interviewees. Additionally, information developed after the on-scene phase may identify new individuals who can shed light on the event.

NTSB Approach to Interviews

The interview approach used by NTSB has been proven effective. Interviews are not interrogations; they are structured conversations, and interviewees are an equal partner. They should be made to feel at ease and encouraged to relate observations without interruption. Interviewees can have one representative with them (union representative, attorney, co-worker); their supervisor or manager cannot be a representative. Individual agency's policies may differ.

Effective Investigation Practice: NTSB Approach to Interviews

- Interview, not an interrogation; an interrogation approach is counterproductive
- Cooperative and informal, yet structured conversation
- Interviewee is an equal partner
- Interviewee encouraged to cooperate
- Interviewee allowed to relate observations without interruption or intimidation
- Interviewee can have one representative present
- Usually conducted informally and voluntarily
- Recorded and transcribed
- No “off-the-record” interviews
- Appeal to interviewee about need for transportation safety and prevention
- Most are in favor of these goals and want to help and share their observations

Establishing rapport and cooperation is vital because people are under no obligation to help. Although some may be able to be compelled to be interviewed (employees, for example), they cannot be compelled to cooperate and provide their best effort.

NTSB investigators typically record interviews, have them transcribed, and share them with the interviewee, allowing an accuracy check.

Experience has shown that an interrogation approach is not productive. An appeal should be made to the interviewee noting the social benefit (to fellow employees, passengers, society) of prevention of future events. The purpose of the interview is to get a complete picture of the facts to prevent future occurrences, rather than to attempt to identify blame or solicit a confession. An interrogation implies that questioning is done on a formal or authoritative level, such as a lawyer/witness situation or a police officer/suspect session. This type of questioning may be devious, shrewd, or clever with the objective of tricking, trapping, or antagonizing the witness to get the information. An interview, rather than an interrogation, is desirable in the questioning of witnesses by accident investigators. Witnesses are encouraged with the need for safety and prevention. Most people are in favor of these goals and willingly recount their observations.

- **Identify interviewees.** Who will be interviewed should be determined, as well as when and why? If possible, a time and place for the interview should be selected that will put the interviewee most at ease. Goals for the interview should be set, and critical areas should be identified.
- **Acknowledge interviewee concerns.**Concerns the interviewee may have should be noted, and investigators should be ready to discuss and address as much as possible. Eyewitnesses may fear of seeing their name in media, be reluctant to get involved, fear “getting it wrong,” etc. Interviewees who are familiar with direct participants may be concerned about the effect on potential participants, damage to the company/organization, or their personal responsibility. Potential participants may have concerns about

loss of livelihood, damage to reputations, lawsuits, responsibility for the injury/death of innocent people, etc.

- **Be prepared.** Investigators should know the operating rules and method of operation involved as much as possible. Circumstances of the accident should be understood, as should the rules and procedures involved, witness statements, timeline, video, event recorder, and other recorded data.
- **Identify the information to be obtained.** Interviews should include the order in which information is to be obtained, determination of the general questions that will elicit the information to be obtained for each topic, establishment of ground rules for conducting the interview, and assurance that the interviewee is as comfortable as possible.
- **Establish ground rules.** Transit agency personnel should have an understanding of the ground rules in advance of an interview and should know how to manage requests for representation. Interviews should not be conducted alone, particularly those with someone who may have been involved in the event. Interviewees should understand that notes will be taken during the interview. Only one person at a time should be interviewed; no interviewees should be permitted to observe other interviews, interruptions to either questions or answers should not be allowed, but follow-up questions should be. 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 interviewee representatives.** In some cases, interviewees may want a representative. NTSB protocol allows an interviewee to have no more than one representative of the interviewee's choosing. 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 of record the interview.** Interviewees should be informed if the interview will be recorded. Some agencies (including NTSB) 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 may be nuances that a recorder will not capture. An interviewee may object to recording. Our 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.** A rapport should be developed with the interviewee, even if it takes an extended amount of time. This must be done before beginning the interview, as it will set the stage for the rest of the interview.

Key points and recommended processes for conducting interviews are included in Appendix C.

Reenactments and Sight Distance Evaluations

Reenactments and sight distance observations are often 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.

Tests

Agencies typically have existing test criteria that are used on a routine basis in preventive maintenance or when subsystems or components are replaced. Post-incident testing can use the same tests to verify the operating condition of signal systems, ventilation fans, track switch operation, vehicle braking, and any other subsystem or component that may be relevant to the event under investigation. For example, if signal system performance needs to be validated, it may require a simple series of shunt tests or, in more complex events, the functional verification of an entire interlocking.

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 using the same equipment or the same type of equipment. 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 all were focused on identifying the item (train, auto, worker), creating an artificiality from normal operations.

Most investigators will usually need to rely on technical staff to perform many of the tests, but investigators 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. Investigators will need engineering support from within agency or specialized consultants to help organize and select appropriate labs and testing protocols. The agency engineering group may already have some contracts in place.

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

Drug/Alcohol Testing

FTA drug-alcohol testing requirements are found at 49 CFR Part 655. Additional DOT-wide requirements are found at 49 CFR Part 40. In addition to alcohol, FTA requires drug testing 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 Human Factors). If accident conditions triggered employee post-accident or probable cause drug- 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.

Survival Factors[55]

The survival factors element of an investigation seeks to understand why some people were killed and injured while 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 like automotive seat belts, airbags and emergency lighting that are now commonplace.

Survival factors investigations involve an examination of:

- Evacuation
- Control compartment and passenger car interior configurations
- Control compartment and passenger car interior damage
- Fatal and nonfatal crash injuries
- Emergency response
- Disaster preparedness planning and training

The output of the survival factors investigation will be a separate survival factors report or a survival factors section in the final report. (See Appendix D.)

Emergency Response Documents and Debrief

On-scene investigators should have attended a "hot wash" with responders where what went right and what challenges were encountered were discussed. For transit agencies, control center records, recorded transmissions, SCADA data, and any other records of the event should be obtained and reviewed.

[55] *NTSB Investigator's Manual*, Volume III – Regional Investigations.

Debriefs with responders are required on FRA regulated properties and are recommended on transit by NTSB and by APTA standards. FTA Safety Advisory SA-15-1 requires SSOA to audit agencies with subway tunnel environments for compliance with NFPA Standard 130 that, in turn, requires critiques "after exercises, drills, and actual emergencies."

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

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. 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, in turn, notified/dispatched
- Fire department/EMS dispatch logs showing when the notification was received, when units were dispatched, and when they arrived on-scene
- In a mass casualty event, EMS responder triage logs that show how many people were triaged, color-coded tag counts, lists of names, and disposition of injured
- IC log and notes that can be obtained
- Photographs and videos from response agencies and other parties
- Challenges or problems identified in the hot wash and debrief that should result in a review of agency SOPs and emergency plan with modifications where needed.

An evaluation of medical response also should be provided and should include 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 responders, police, and medical staff as possible to determine what problems were encountered while responding to the event.

Survival Examination – Interviews and Key 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 passengers were 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, other agency employees, responders, and witnesses.

Effective Investigation Practice

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

Key information to obtain 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
- Firefighting/rescue activity pertaining to all vehicles
- Condition of windshields, wipers, lights
- Did seats 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
- Condition of debris, signage, emergency lighting, exits, carry-on bags, and mobility devices
- Seat belt and shoulder harness condition before and after impact (if applicable)
- Difficulty releasing restraints (if applicable)
- Injuries resulting from passenger ejection or penetration by outside objects
- Door functioning as intended for emergency access or passenger evacuation
- Emergency lighting function
- Involvement of fire, performance of interior furnishings
- Required emergency equipment in place (e.g., fire extinguishers) and use
- Instructions provided over vehicle intercom

Key information to obtain regarding vehicle exterior:

- External factors relative to the accident site. Supplement with photographs, videos, sketches, drawings

- Description of site, 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, heading path to and from main wreckage site
- Description of obstacles/structures struck: (height, construction)
- Description of terrain: (elevation, slope/grade, soil)
- Use of issues related to emergency egress windows/door releases
- Responders encountering difficulty accessing equipment—have keys or know how to trigger door release mechanisms
- If applicable, fuel tank leaks, involvement of fire involved
- Survivable space maintained in passenger areas and control cab
- Vehicle equipped with crash protective features such as corner posts, accident posts, or crumple zones and their function

Several standards, regulations, and guidelines have been developed to improve the crashworthiness features of rail cars. Investigators can use these standards as benchmarks in comparison to performance in the event under investigation:

- FRA passenger equipment safety standards at 49 CFR Part 238
- APTA passenger rail equipment safety standards
- Moving Ahead for Progress in the 21st Century Act (MAP-21) requirements for minimum safety performance standards for rolling stock
- American Society of Mechanical Engineers (ASME) RT 1 (light rail)
- ASME RT 2 (heavy rail)
- APTA RT-VIM-S-026-12 Rail Transit Vehicle Passenger Emergency Systems
- NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

The investigatory element can be broken down into several areas, including first creating an injury table to identify by individual and type of injury those individuals involved in the event. A detailed list of crew member injuries should be generated, and the same type of interview process should be conducted with the operating crew as was done with the injured passengers. Particular attention should be taken to extract information that can shed light on crew actions just before and just after the event.

Injuries/Fatalities

In a mass casualty event on a public transit system, cataloging injuries can be challenging, as uninjured passengers and those with minor injuries may walk away to continue their journey. Even determining the number of passengers involved can be difficult, as transit agencies do not maintain a passenger manifest like some other modes of transportation. Additionally, the Health Insurance Portability and Accountability Act (HIPAA) provides patient privacy protections and restricts medical providers from providing patient information.

Sources that investigators can use to catalog injuries and fatalities include:

- Vehicle interior video recorders
- Claims
- Interviews
- Statements
- Triage logs
- Other emergency responder records

Based on these sources, investigators may want to prepare a grid cataloging the numbers and types of injuries as shown below:

	Employees	Responders	Passengers	Total
Fatal				
Serious				
Non-serious Injury				
Total				

A detailed list of all fatal injuries should also be provided that includes where the individual was sitting during the event and all pathological information relating to the individual's injuries. A detailed list and interviews related to injuries received by emergency responders are also of great value to the survival factors investigation. Answers about how and why these injuries were received may help other emergency responders avoid the same risks.

A critical element of the survival factors investigation is documenting the response and actions of the emergency response and emergency responders. Several key facts need to be documented, with information from emergency responder records, interviews with responders, and attendance at post-event debriefs; some medical information may not be readily available due to HIPAA restrictions. Information to be documented includes:

- 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 in the past to understand how well agencies have prepared. An assessment of disaster preparedness should be performed to include a review of any training provided to operating employees, fire, police, EMS, hospitals, and City, County, or State Offices of Emergency Management (OEM). It is also suggested that a review of the City, County, and transportation authority emergency management plan be reviewed and assessed for its efficacy.

FRA regulations have been developed to improve emergency response to passenger rail events. Although these regulations do not apply to most rail transit systems, they provide useful guidance to emergency planners and investigators. For rail transportation systems governed by FRA rules and procedures, 49 CFR § 239.105 requires emergency preparedness training to be performed with all potential emergency responders in the event of an event. The rule states that railroad officials conduct a debriefing with emergency responders to determine the effectiveness of emergency plans and to critically review the roles, responsibilities, and performance of the agencies involved in responding to the event to improve emergency planning and response to any other events.

Resources for evaluating the agency's emergency preparedness and response include the following:

- APTA Standard for Rail Transit System Emergency Management (RT- S-OP-007-03)
- FTA Recommended Emergency Guidelines for Rail Transit Systems (March 1985), FTA Public Transportation System Security and Emergency Preparedness Planning Guide (January 2003)
- NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems

Change Management/Configuration Management

Configuration Management (CM) is a process for establishing and maintaining consistency of a product's performance, functional and physical attributes with its requirements, design, and operational information throughout its life. From a historical perspective, CM practices were first formalized in the defense and aerospace industries, bringing related industry best practices together under a common framework.

When accidents are investigated, it is essential to understand what has changed or may have changed as it relates 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. CM is applied over the life cycle of a product and provides:

- Visibility and control of its performance, functional and physical attributes
- Verification that the product performs as intended
- Documentation to sufficient detail of its projected life cycle, fabrication or production, operation, maintenance, repair, replacement, and disposal

CM applies to both hardware and software[56] components, including operating rules, procedures, and drawings. Changes to hardware and software should be evaluated and approved by affected agency departments, documented, and evaluated to make sure 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

Climatic change includes:

- Changes in temperatures (heat vs. cold)
- Seasonal variations (snow, rain, hurricanes)
- Acts of God (cyclonic storms, flooding, earthquakes)

Heat can affect the system as a result of extremely high temperatures occurring during the summer months. The local electric utility company may not be capable of meeting the peak energy demand placed upon it by customers using air conditioners and other appliances, which can result in sporadic “brownouts” or ‘blackouts” that can disrupt the signal system and other electronics. Operations using OCS may experience sags in hot weather, particularly if one of the weight tensioners binds. Track buckles (sun kinks) in continuously welded rail are a serious heat-related concern. Investigators should be familiar with any special procedures triggered by temperature fluctuations. There may be

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

“heat watch” inspection requirements or speed restrictions put in place when temperatures reach a certain point. In cold weather, there are risks of cracked rails, rail pull apart, as well as ice buildup on special trackwork, third rail, and on flanges.

Operational change includes:

- Increased service (closer headways) to meet growing ridership demands
- Competition between maintenance forces and transportation personnel for track access due to new regulatory requirements
- Increased length of trains
- Offset with skip-stop or express service in addition to the local operation initially provided

Increased headways can result in less time to perform maintenance and inspections. Increased train length, coupled with closer headways, may put stress on the power system beyond design maximums resulting in fires or stranded trains.

Change from external factors includes:

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

Examples of external changes that may impact system operation are station egress issues with increased patronage, increased trespassing, and local regulations on noise at crossings or from maintenance. For example, track drainage and fouled ballast may be exacerbated by raised paved areas adjacent to the track. Competition for track access can be the result of a mandated change by regulatory agencies, thereby increasing the amount of time needed to perform routine work activities. For example, a new Roadway Worker Protection (RWP) regulation may result in additional time consumed establishing a work zone. This creates a demand for extra track time to complete the normal daily maintenance and inspection activities.

Personnel changes include:

- High rate of attrition/retirement resulting in a significant loss of institutional knowledge, i.e., “brain drain”
- Lack of adequate succession planning strategies

- Recent hires inexperience
- Changes in senior management and 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.

Change from maintenance activities includes:

- Alignment and surfacing of the track, i.e., create changes in super-elevation, cross-level, or gauge
- Introduction of a new product that changes the track modulus
- Replacement of components, resulting in disarraying of wiring, leading to potential incorrect rewiring of circuitry.
- Revised procedures not fully distributed to all departments
- Maintenance work on OCS (re-tensioning, replacement of parts) that changes the interface with train, pantograph, and wire to impact issues that may contribute to incidents

Many agencies have implemented resiliency and recovery strategies following events such as Super-Storm Sandy; the use of outside contractors to support this work has dramatically increased at some rail agencies. The use of outside contractors for maintenance work can lead to changes in equipment loadings, equipment not compatible with tunnel clearances due to contractor unfamiliarity with system constraints. Additionally, the agency must ensure that these individuals are trained and qualified on RWP.

Other changes may be associated with the update of existing technologies or the testing and/or integration of new technologies. Investigators should evaluate the potential unintended consequences of technology changes. Agencies may adopt new technology for a variety of reasons:

- Improve performance
- Meet increased ridership demands
- Reduce accident claims
- Address retiring legacy systems that have exceeded their useful life
- Current system inefficiency, i.e., difficult to track and control train meets, overtakes, and alternative service needs
- Equipment exceeding its life expectancy and needs to be replaced, reconditioned, or retrofitted with a newer version
- Manufacturer no longer supports equipment, or it has become too expensive to repair and maintain

- Equipment change out at end of life cycle
- Mandated by legislation, i.e., PTC technology
- Design modifications & retrofits
- Upgrades as part of SGR initiatives

System changes include:

- Rail line extensions
- New rail lines
- Added stations
- New signal systems to increase throughput
- Rail service improvements (adding new crossovers, new sidings, double tracking)
- Yard improvements
- New rail cars

Acquisition of additional railcars from other manufacturers may create compatibility problems concerning crash energy management between different fleets as well 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 train service or rail equipment on any one line. Any change to the wheel profile on new cars will affect the track structure. The acquisition of new car equipment or the mixing of different fleets needs to be thoroughly evaluated.

Budget changes include:

- Procurement Department ordering a part at a significant cost savings to the agency, not realizing it is inadequate and could cause a malfunction or an incident leading to a major rail incident
- Budget constraints that can adversely impact maintenance and inspections and training
- Low bid requirements that may result in parts and materials that do not meet agency needs
- Specifications that may be rewritten to reduce costs at the risk of reducing safety
- Labor costs that impacting the budget, driving 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 may have been too low due to the difficulty of the project. (*Note*: This emphasizes the importance of including safety in the procurement process. If there is an intention to change a specification or allow a procurement 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.)

Human Factors

The objective of the human factors 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, specific operator background and performance, various psychological and physiological sub-disciplines that can offer analytic explanations for an operator's performance (human and organizational) and the ergonomic and environmental issues affecting operator behavior.[57]

Investigators are responsible for documenting and analyzing various human factors within the disciplines of engineering, physiology, and psychology. They determine how these factors interrelate and interact and how they influenced the perceptions, decision making, and actions of individuals involved in an accident. Examples of human factors and their related disciplines include:

Human Factor	Discipline
Training, education	Education
Control/Equipment design	Engineering
Perception, sensation, kinesthetic	Experimental Psychology
Operator/crew communication and interactions	Social Psychology
Medical conditions, toxicology	Physiology, Pharmacology
Mood, mental state, habits, and life events	Clinical Psychology

The following human factor-related elements may contribute to an event and should be examined:

- Experience/familiarity/background
- Distraction, including external stressors
- Task–time Relationships
- Environmental

[57] The term "operator" may also include but not be limited to dispatchers, MOW personnel, and others whose actions or inactions are of interest to the investigator.

- Noise/vibration/motion
- Training
- Health factors, including fatigue
- Operator assaults

Experience/Familiarity/Background

The investigator can determine an operator's experience and familiarity with both the equipment and the territory. Areas of inquiry 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 particular 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 operator's attention to something other than the operating task. As research has shown, distraction has been determined to be a factor in several accidents. The investigator can work to determine if the operator was distracted at or near the time of the event. Areas of inquiry 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?
- Did you have any particular concerns about your cargo (if applicable) just before 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?
- Does your vehicle have a CB radio, television, or any other communication device? Were you using or manipulating any device before the accident?
- 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, texting)? If yes, obtain complete details. (*Note*: The investigator should determine and evaluate the agency's electronic device policy.)

Task–Time Relationships

Not only is it essential to determine what the operator was doing at the time of the crash, but it is also important to decide on what time pressure, if any, they may have been under and how their activities relate in time to other activities or events. Areas of inquiry 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., taking a siding, a stop? How far in distance and time were you from that change when the accident occurred?

Along with a description of the task is the operator’s perception of their workload. When assessing workload, attention should be given to typical and event-specific workload. Areas of inquiry include the following:

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

External Conditions

Questioning in this area focuses on the environmental conditions external to the rail vehicle. The investigator can obtain weather condition reports as an independent verification of the operator's statement. Questions to ask include:

- What was the weather like at the time of the accident (Cloudy, sunny, raining, windy, snowing, clear)?
- Had the weather changed recently?
- What were the surface conditions at the time (icy, wet, dry)?
- Had the track surface/road conditions changed recently?
- Had there been any changes in the type or configuration of the track?

Internal Conditions

Questioning can focus on the conditions inside the vehicle at the time of the accident, beginning with the following questions and follow-up as necessary:

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

Illumination

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

- Were you operating outdoors, elevated, open cut, or in a tunnel environment?

- 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?
- Did the accident occur in the daytime or the nighttime?
- Where was the sun/moon (if you know?) Did the sun/moon cause you any problems?
- Did the headlights of other trains, 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?

Noise/Vibration/Motion

This section helps 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 include:

- What did you hear just before the accident?
- Any new or unusual noises, either from the track or from the train?
- Did you notice any unusual motion or vibration in the vehicle?
- Describe the vehicle's motion during the accident

Training

Training of operators in the wake of an accident is of interest to the investigator. The following questions can initially be asked of an operator, tailored as needed and based upon their level of experience and education and their familiarity with equipment, procedures, policies, and systems.

- What operator education classes or training have you had? Please list when and where they 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.

- What is your recurring training requirement and was this made available to you?
- 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?

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
- Supervisor interview

Health Factors

Health factors include several subtopics:

- General health
- Physical limitations
- Mental distractions
- Sensory acuity
- Drug/alcohol ingestion
- Fatigue

General Health

NTSB has subpoena authority to obtain medical records; however, an RTA investigator is constricted 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 is advised to discuss this issue with their internal legal and medical personnel to ensure that they are aligned regarding the proper protocols to follow during an event to ensure HIPAA regulations are not violated. In many instances, the agency's medical staff will be relied upon to review the employee's medical work history to determine if preexisting medical conditions were known and adequately controlled.

The investigator may evaluate the RTA's medical screening process for medically-based conditions such as sleep disorders. Some RTAs attempt to elicit this information from questionnaires, which are not always 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). Areas of inquiry include:

- How is your overall health?
- When was your last physical examination? What were the results? Any problems or issues noted?
- Do you have any physical limitations?

Sensory Acuity

An operator's sensory acuity may play a vital role in an accident. Information on both vision and hearing may also be protected by HIPAA regulations; however, this information may be available for the internal medical department to assess. This information may not be available to the RTA investigator unless the individual volunteers it. Questions to ask the operator or their family include:

- 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?
- 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? (Get make/model/date of 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 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 by this section is not administered within eight hours following the accident, the employer must cease attempts to administer an alcohol test and maintain the record. Regulations also require that a drug test be administered within 32 hours of the accident.

Unfortunately, many over-the-counter (OTC) drugs are not currently part of standardized testing. The investigator should determine and document the applicable RTA policy, or lack thereof, on self-reporting the use of all medications by covered employees and 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:

- 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?[58]
- Did you take all of 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 OTC drugs 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 this document, the focus is on mental fatigue. Mental fatigue is 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 on other factors such as sleep deprivation and overall health, which can reduce mental and physical functioning. Although the level of fatigue varies, causes of fatigue in a work context may include:

- Long work hours
- Long hours of physical or mental activity
- Insufficient break time between shifts

[59] 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.

- Changes to jobs or shift rotations
- Inadequate rest
- Excessive stress
- Having multiple jobs
- Combination of these factors.
- Changes to home environments, such as a new baby, change in patterns and routines, new or changing caregiver roles
- Changes in home relationship status such as divorce or separation

The effects of fatigue include:

- Reduced decision-making ability
- Reduced ability to do complex planning
- Reduced communication skills
- Reduced productivity or performance
- Reduced attention and vigilance
- Reduced ability to manage stress on the job
- Reduced reaction time - both in speed and thought
- Loss of memory or the ability to recall details
- Failure to respond to changes in surroundings or information provided
- Inability to stay awake (e.g., falling asleep while operating machinery or driving a vehicle)
- Increased tendency for risk-taking
- Increased forgetfulness
- Increased errors in judgment
- Increased sick time, absenteeism, rate of turnover
- Increased medical costs
- Increased incident rates
- Impaired judgment and concentration
- Lowered motivation
- Slow reaction time
- Increased risk-taking behavior

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

- 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 normal ones—anything missing, new, odd
- People they saw or talked to and times
- Time, duration, and location of naps
- Medications 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 by a surviving operator, the most effective way to obtain this information may be to have the operator begin at waking three days before the accident and move step-by-step through the days. The more detail that can be obtained, the better to determine if fatigue did or did not play a role in the accident. If an operator declines to be interviewed or does not survive, the investigator can 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 before the accident. Information from this history will touch on every area of the human factors 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, to the time the operator awoke. (See Appendix G.) Questions include:

- When do you usually go to sleep and get up on your days off? How much sleep do you usually get?
- When do you usually go to sleep and get up on days you have to work? How much sleep do you typically get on those days?
- Do you usually take naps? When, for how long, and why?
- How would you describe the overall quality of your sleep?
- Can you estimate how long it usually 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 the three days before the accident?
- Do you take any medicines to help you fall asleep or stay asleep? What medications (prescribing doctor)? Did you take them three days before the accident?
- Do you take any medicines that make it difficult to fall asleep? Did you take them in the three days before the accident?

Biomathematical models of fatigue attempt to predict the effects of various work patterns on job performance and also consider scientific input about the relationship among working hours, sleep, and employee performance.

- **Fatigue Audit InterDyne (FAID)** – Using formulae developed and validated by Dr. Adam Fletcher and Professor Drew Dawson at the Centre for Sleep Research at the University of South Australia, FAID can assist in identifying fatigue exposure and tracking the effects of associated risk improvements to hours of work. The statistical models in FAID estimate work-related fatigue based on four factors:
  - Time of day of work and breaks
  - Duration of work and breaks
  - Work history in the preceding seven days
  - Biological limits on recovery sleep

  A FAID score indicates the sleep opportunity that a work pattern allows. As the relative sleep opportunity associated with a work pattern decreases, the FAID score increases. Scores between 80 and 100 are equivalent to the predicted level of work-related fatigue achieved after 23 to 24 hours of continuous sleep deprivation. Performance impairment at the same levels of sleep deprivation has been associated with a blood alcohol concentration of over 0.05%.[59]

- **Fatigue Avoidance Scheduling Tool (FAST)** – FAST was developed by the U.S. Air Force in 2000–2001 to address the problem of aircrew fatigue in aircrew flight scheduling. Fatigue predictions in FAST are derived from the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE). It is a Windows program that allows scientists, planners, and schedulers to quantify the effects of various work-rest schedules on human performance. It provides work and sleep data entry in graphic, symbolic (grid) and text formats. The graphic input-output display shows cognitive performance effectiveness as a function of time. The goal of the planner or scheduler is to keep

[59] Dawson, D., and Reid, K., 1997, "Fatigue, Alcohol and Performance Impairment," *Nature*, 388, p. 235.

performance effectiveness at or above 90% by manipulating the timing and lengths of work and rest periods. A work schedule is entered as red bands on the timeline. Sleep periods are entered as blue bands across the timeline, below the red bands.

Each rail transit system should consider evaluating the use of a commercially-available computerized system to analyze data on fatigue levels and identify fatigue risk factors. These approaches often incorporate a computer-based system that can track the changes in these metrics and evaluate the effectiveness of policies used to address them.

APTA report RT-OP-S-023-17, "Fatigue Management Program Requirements," provides standard requirements for rail transit systems in establishing and implementing a fatigue management program and related systems. Specifically, it provides rail transit systems with the baseline requirements for Fatigue Management Programs (FMPs) to mitigate the impacts of fatigue on their operations and thereby improve the quality and safety of rail service. The document addresses three primary areas with accompanying elements:

- Purpose of FMP:
  - Assemble FMP steering committee
  - Conduct FMP pre-implementation study
  - Develop FMP policy
  - Develop FMP roles and responsibilities
  - Develop FMP implementation timeline
  - Ongoing FMP communications
  - Monitor and evaluate FMP
- Core FMP components:
  - Fatigue considerations in incident investigation
  - Personnel work schedules
  - Fatigue management education
  - Fatigue-related absences and reports
  - Rest areas
  - Sleep disorder screening and treatment
  - Data assessment metrics

The 2019-2020 NTSB Most Wanted List of Transportation Safety Improvements focuses on several human performance areas. These include the following with a focus on rail and transit recommendations:[60]

[61] For additional information about all NTSB Most Wanted List recommendations, see www.ntsb.gov/mostwanted.

- **Distraction** – Distraction is an increasing and life-threatening problem in all modes of transportation. There are currently four open recommendations pertaining to the elimination of distractions in the railroad industry. One is to the FRA requiring railroads to use technology-based solutions that detect the presence of signal-emitting portable electronic devices that inform the railroad management about the detected devices in real-time. A second is to a Class One railroad recommending that they incorporate the use of handheld signal detection devices into their operational efficien¬cy program on the use of portable electronic devices, and finally two to Amtrak recommending that they revise their train dispatcher rules so that potentially distracting activi¬ties are not permitted while dispatchers are on duty, and to incorporate strategies into their initial and recurrent train¬ing for operating crewmembers to allow them to recognize and effectively man¬age multiple concurrent tasks in prolonged, atypical situations to sustain their attention on train operations.
- **Alcohol and other drug impairment** – Impairment is a contributing factor in many transportation accidents across all modes. Impairment in transportation is not limited to just alcohol; it also includes impairment by other drugs, legal or illicit. There are currently six open recommendations to the commuter rail (FRA) and one to the transit industry, (FTA) pertaining to ending alcohol and other drug impairment. The recommendations to FRA request that they:
  - Develop sources of information for train crewmembers on the hazards of using specific medications when performing their duties, as well establishing an educational program about those sources.
  - Establish comprehensive testing requirements of fatal railroad and, in concert with FTA, transit accidents, to ensure identification of the role played by common prescription and over-the-counter medications.
  - Modify regulations found at Title 49 CFR Part 219 to include any railroad signal, maintenance, and other employees whose actions at or near a grade crossing involved in an accident may have contributed to the occurrence or severity of the accident.
  - Revise the definition of covered employee to include employees performing safety-sensitive functions found at 49 CFR Part 209, and 5) to strengthen medical certification regulations for employees in safety-sensitive positions. NTSB recommended FTA seek authority similar to FRA regulations (Title 49 CFR § 219.207) to require that transit agencies obtain toxicolog¬ical specimens from covered transit employees and contractors who are fatally injured as a result of an accident.
- **Fully implement PTC** – PTC systems can stop a train before an accident occurs. Although Congress mandated that PTC be installed and operating by December 31, 2018, only 25% of passenger route miles and 60% of

passenger locomotives have to date met that criteria. There are currently 16 open recommendations to the FRA, FTA, various freight, and commuter railroads and one each to a manufacturer of railroad signal systems and APTA related to PTC. These recommendations pertain to either fully implementing PTC, or the application of PTC to specific issues including training, improperly aligned switches, after-arrival track authority, maintenance of way vehicles, and protection for roadway workers, either from the regulatory perspective (i.e., FRA and FTA), individual railroads, APTA and a manufacturer of railroad signal systems.

- **Reduce fatigue-related incidents** – Fatigue is a pervasive problem in transportation that degrades a person's ability to stay awake, alert, and attentive to the demands of safely controlling a train. There are currently 23 open recommendations to the FRA, FTA, APTA, Association of American Railroads (AAR), American Short-Line and Regional Railroad Association (ASLRRA), various freight and commuter railroads and labor organizations. These recommendations address a variety of fatigue-related issues, including establishment of programs that continuously improve fatigue management systems, conducting research on methods that identify and mitigate the risks associated with fatigue, validating biomathematical models of fatigue, revising medical protocols that screen and provide treatment for sleep disorders, and implementation of predictable work and rest schedules.
- **Require medical fitness-screen for and treat OSA** – Undiagnosed and untreated OSA continues to be deadly in all modes of transportation, including railroads and transit. There are currently twelve open recommendations to the FRA, AAR, APTA, ASLRRA, and rail transit agencies. These recommendations address a variety of related issues, including establishing programs to identify op¬erators who are at high risk for OSA or other sleep disorders and require that such operators be appropriately evaluated and treated, developing and implementing protocols to routinely screen and fully evaluate safety-sensitive employees for sleep disorders and ensure that such disorders are adequately ad¬dressed if diagnosed, and ensuring that operator impairment due to medical condi¬tions, including OSA, is part of the hazard manage¬ment portion of a system safety program plan.
- **Employee Assistance Program** – An Employee Assistance Program (EAP) is a voluntary, confidential program that helps employees (including management) work through various life challenges that may adversely affect job performance, health, and personal well-being to optimize an organization's success. EAP services include assessments, counseling, and referrals for additional services to employees with personal and work-related concerns, such as stress, financial issues, legal issues, family problems, office conflicts, and alcohol and substance use disorders. EAPs also often work with management and supervisors, providing

advanced planning for situations, such as organizational changes, legal considerations, emergency planning, and response to unique traumatic events. The investigator should evaluate the agency's EAP programs to ensure that employees who are exposed to traumatic events receive the assistance that they need.

Operator Assaults

The TRACS report "Preventing and Mitigating Transit Worker Assaults in the Bus and Rail Transit Industry" was published on July 6, 2015. In October 2014, the FTA Administrator tasked representatives from state and local transportation agencies, labor unions, research organizations, and national transportation associations to work together to create recommendations (see below) for FTA to prevent assaults against transit workers. Specifically, the Administrator tasked TRACS to:

- Develop recommendations for FTA on the key elements that should comprise an SMS approach to preventing and mitigating transit worker assaults
- Identify risks and impediments to a safe workplace and a process to reduce the hazards that enable these assaults.

Although there is considerable focus on addressing bus transit operator assaults, the scope of this tasking is intended to include addressing assaults for all types of transit employee categories and all modes of transit. Based on a review of available literature, TRACS developed the following summary of risk factors for assaults against transit workers:

- Direct interaction with the public, especially with passengers who may be intoxicated, have a mental illness, or be experiencing frustration due to fare increases, service reductions, or delays. Bus operators usually interact directly with passengers, while rail operators experience assault most often during rules disputes and when waking sleeping passengers.
- Working alone, in isolated or high- crime areas, during late night or early morning hours raises the risk of assault against transit operators.
- Handling and enforcing fares. Most assaults against bus operators occur during fare disputes.
- Having inadequate escape routes. Transit operators often lack a way to escape from passengers who threaten or begin to assault them.

These recommendations included:

- Installing protective barriers, video surveillance, Automatic Vehicle Locator (AVL) systems, and overt or covert alarms on bus and rail transit vehicles

- Training safety-sensitive employees about how to de-escalate potentially violent situations, the importance of reporting assaults, and the standard agency response to reports of assault
- Educating the public about reporting assaults by conducting public awareness campaigns, providing resources and incentives for passengers to report assaults, and meeting with passengers to discuss strategies for preventing assaults
- Providing support for transit workers by offering psychological support and post-incident counseling, responding to every report of assault or other serious incident, and involving transit workers in safety committees
- Enforcing transit agency policy by posting passenger codes of conduct, suspending service for assailants, posting police officers on transit vehicles and property in high-risk areas, providing legal support for transit workers who file complaints, and collaborating with other agencies and organizations to develop social safety plans and advocate for changes in state and local legislation to better address assaults against transit employees
- Collecting data regarding the number, location, times, and types of assaults as well as the number, type, and implementation times of each risk control strategy to enable the evaluation of the effectiveness of each strategy and the overall SMS in preventing transit worker assaults

On May 24, 2019, FTA published a notice entitled “Protecting Public Transportation Operators from the Risk of Assault” in the *Federal Register*.[61] This notice alerted transit agencies to the need to address the risk of transit operator assaults when identified through the processes required under the PTASP regulation. The PTASP regulation requires transit agencies to develop and implement SMS processes, which include identifying safety hazards, assessing the related safety risks, and then establishing methods of risk mitigation.

Analysis

There is no bright line that separates the fact-gathering phase from the analysis phase of the investigation. In the on-scene and early stages of the investigation, investigators are cautioned about reaching conclusions. This is important because investigators 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 a rear-end collision between two trains will concentrate more on signals, braking, operational performance, and human performance than on track conditions.

[61] *Federal Register*, Vol. 84, No. 101, May 24, 2019, Notices.

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:

- Ishikawa (Fishbone) chart
- Fault Tree Analysis
- Software Hardware Environment Liveware (SHEL) model
- Root cause analysis
- 5 Whys

Each of these methods is further described in Appendix E.

Part 4: Report Development and Corrective Action Plans

Report Timing

Agencies have internal requirements to produce a preliminary summary report on the incident along with any recommended immediate actions within 24–36 hours. SSO program standards 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

The agency's report format will likely be driven by SSO program standard requirements. The report format in this manual uses an NTSB report format for convenience and is not intended to supplant what may be required by the individual SSOs or agency policy. Report headings may vary slightly based on the circumstances of the individual accident and the standard prescribed by a SSOA. Appendix F provides recommendations for report organization and headings/content.

For stylistic formatting (punctuation, numbering, references), unless otherwise directed by the SSO program standard or an agency style manual, the *Chicago Manual of Style* is a useful standard. 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 lead the reader to specific findings and recommendations that should drive the development and content of CAPs.

Corrective Action Plans

Corrective actions need to be linked to recommendations and developed in a way that is achievable and measurable. As with any action plan, a CAP must explain the action being taken (what), the reason (why), the person responsible for making it happen (who), and a realistic schedule (When). Without these key elements, any action plan is likely to fail.

Key CAP elements include the following:

- What – What are the specific action and measurable result?
- Why – Links back to the accident investigation and recommendation
- Who – Who (job title) is responsible for shepherding the action to completion?
- When – Identify a realistic time frame and set a date

Developer of the CAP may be the department that owns (is responsible for implementation of) the CAP item in conjunction with the investigators (usually the Safety Department). The SSOA will approve the CAP and approve and verify the closure and may also be involved in CAP development.

Most agencies use a CAP database or spreadsheet as a tracking tool and to provide periodic reports on CAP status. Effective systems are easy to use and allow generating reports on current status. Additionally, the CAPs can be monitored through regular status meetings, where problems can be identified and resolved. This also allows for the identification and resolution of unintended consequences. Often SSOA personnel participate in CAP status meetings.

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

The CAP puts the action verb 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.

Effective Investigation Practice

Example of Washington Metrorail Safety Commission (WMSC) 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 responsible manager will report that the CAP item has been completed. Before closure, the CAP item's satisfactory completion must be verified, and appropriate signoffs documented, including that of the SSOA.

Part 5: Role of FTA and SSOA

FTA specifies requirements for transit accident investigations in 49 CFR Part 674. These regulations require SSOAs to "investigate or require an investigation" of accidents. The regulation also states that the FTA ("The Administrator") may conduct an independent investigation or an independent review of the SSO and agency investigation. Section 674.35 – Investigations establishes the requirements for these investigations, as follows:

- An SSOA must investigate or require an investigation of an accident and is responsible for the sufficiency and thoroughness of all investigations, whether conducted by the SSOA or RTA. If an SSOA requires an RTA to investigate an accident, the SSOA must conduct an independent review of the RTA's findings of causation. In any instance in which an RTA is conducting its internal investigation of the accident or incident, the SSOA and the RTA must coordinate their investigations in accordance with the SSO program standard and any agreements in effect.
- Within a reasonable time, an SSOA must issue a written report on its investigation of an accident or review of an RTA's accident investigation in accordance with the reporting requirements established by the SSOA. The report must describe the investigation activities; identify the factors that caused or contributed to the accident; and set forth a corrective action plan, as necessary or appropriate. The SSOA must formally adopt the report of an accident and transmit that report to the RTA for review and concurrence. If the RTA does not concur with an SSOA's report, the SSOA may allow the RTA to submit a written dissent from the report, which may be included in the report, at the discretion of the SSOA.
- All personnel and contractors that conduct investigations on behalf of an SSOA must be trained to perform their functions in accordance with the Public Transportation Safety Certification Training Program.
- The Administrator may conduct an independent investigation of any accident or an independent review of an SSOA's or an RTA's findings of causation of an accident.

The SSOA lays out its method of complying with the 49 CFR Part 674 regulations in its program standard. Typically, these require the agency to prepare and submit an accident investigation plan for the SSOA to review and approve. In most cases, the SSOA requires the agency to conduct accident investigations on behalf of the SSOA. The SSOA then independently reviews accident reports submitted to them and either approves or requires additional investigative activities. The SSOA may, at its discretion, perform an independent investigation.

Working with SSOA or FTA on Investigations

With delegated investigations, SSOA and FTA personnel may monitor investigative activities and witness testing, inspections, or re-creations. Agencies should plan to honor such requests and have appropriate procedures written into their accident investigation procedures.

Both SSOA and the FTA have the authority to conduct independent investigations. With independent SSOA or FTA investigations, agencies can plan to coordinate their activities to minimize confusion or miscommunication. Federal and state oversight personnel are expected to comply with agency procedures for roadway access, RWP rules, and PPE.

Agencies benefit from a teamwork approach. The NTSB management model for investigations has worked very well, and participants often note the value of the approach and the sense of teamwork that develops. Technical workgroups are convened to develop factual material on specific technical areas such as track, signals. This model is a good benchmark for FTA and SSOA investigations.

In the initial stages, the focus of the investigation is fact-based. Agencies benefit from having the right technical staff to support working groups to develop the facts thoroughly. As the investigation proceeds, keep in mind the logic chains discussed elsewhere in this manual—the facts underpin the analysis.

Continuous Improvement

A transit agency may ask the following questions when examining its overall safety performance and how well its SMS is working: “Are we getting the safety performance that is outlined in our safety objectives?” “Is our SMS process adequate and being followed?” The answers to these questions support SMS continuous improvement,[62] a process by which a transit agency examines safety performance to identify safety deficiencies and conducts a plan, under the direction of the Accountable Executive, to address identified safety deficiencies. Evaluating the established SMS is necessary to ensure that it effectively and efficiently allows the agency to meet safety objectives and performance targets. Continuous improvement activities may include annual reviews of overall safety performance and assist transit agencies in identifying weaknesses in SMS organizational structures, processes, and resources to promptly address.

[63] FTA, *SMS Safety Assurance Participant Guide*, v12_09282018.

Continuous improvement occurs from:

- Timely safety information that enables executives to make informed decisions about allocating resources
- Accountability being placed at the appropriate levels of authority
- Ability to actively identify hazards and mitigate safety risks based on the prioritized allocation of resources
- Support for systemwide communication about safety issues up, down, and across the agency
- Improved safety culture that empowers employees and solicits information from them on safety hazards and concerns

Continuous improvement is an auditing function that allows the agency to:

- Assess the effectiveness of the SMS to determine if it was performing as intended
- Assess adherence to the agency's written and intended SMS policy, procedures, and processes
- Identify the causes of sub-standard performance
- Develop CAPs to address sub-standard performance

CAPs are instituted when the SMS, or any part of it, is not being performed correctly. Hazards are not being identified, or no one is doing anything once the hazard is identified, or agencies are not following through on implementation activities or even data collection. These are signs that something in the SMS is not working correctly.

Continuous improvement tools and activities include conducting self-assessments, audits, gap analysis, and external reviews. The results of continuous improvement activities may include identification of breakdowns and disconnects, such as practical drift, and correct the process at the level where it is deficient (front-line, department level, or at the broader organizational level).

Even when fully implemented, the continuous improvement sub-component of SMS is always relevant, year after year, and always improving to meet the needs of the agency. The transit industry is never static; personnel, equipment, technology, routes, tracks, and the operating environment change constantly. Therefore, SMS will continuously change, adapt, and be refined, evolving as necessary to meet organizational changes and objectives.

This evolution of the SMS is a primary goal of continuous improvement—ensuring that formal activities and tools are in place to regularly verify efficiency, effectiveness, and ongoing improvements in the management of safety. RTAs can benefit from scrutiny by external parties, such as an APTA peer review team. Performing these activities proactively identifies vulnerabilities in the agency's defenses. As such, the RTA will want to thoroughly evaluate the recommendations provided by these entities and, if adopted, monitor as a CAP and track to closure. A case study APTA Peer Review is provided below.

Case Study: Best Practice for Continuous Improvement – APTA Peer Review

The following case study demonstrates how RTAs can use contracted resources to develop a fuller understanding of technical issues that may play a role in an accident and help to identify root cause(s) and other contributing factors that result in incidents, as well as develop proactive measures to reduce risk.

APTA provides peer review services to its members through its owned subsidiary, North American Transit Services Association (NATSA). At the request of the agency, NATSA brings a team of industry experts to the property to review a selected area, i.e., operations, security, or safety conditions and provides the property with a written report containing observations, conclusions, and recommendations.

It should be noted that an agency can have a fully regulatory compliant track maintenance program, as one example, and still experience incidents. Therefore, as a best practice, agency leadership should consider having external expertise evaluate areas where concerns are identified and where the agency is having difficulties reversing a negative trend.

This case study focuses on rail breaks. The integrity of running rail is critical to safe train operation. A broken rail that occurs while active train traffic is occurring creates a risk of derailment; therefore, RTAs perform a variety of maintenance activities such as rail destressing, elimination of bolted joints, rail grinding to remove surface defects, to reduce the probability of broken rails occurring. Also, RTAs conduct both visual and automated inspections to reduce the likelihood of rail defects going undetected. Visual inspections typically do identify a portion of broken rails at an agency; however, at the point that a rail break is readily visible to the naked eye, there is a significant potential for an accident.

In many cases, broken rails are identified due to a disruption to the signal system's normal operations, i.e., a failed track circuit. Upon response to the signal failure, signals personnel will typically diagnosis the rail break. Also, periodic Ultrasonic (UT) testing is performed to identify and schedule repairs on track segments with internal defects that may not be detected by a visual inspection or are currently present.

Case Study – APTA Peer Review of WMATA

The WMATA General Manager requested that APTA perform a peer review to examine rail breaks on the system. The agency had previously experienced a mainline derailment in January 2018 due to a broken rail. Also, during data analysis activities, the agency identified an uptick in the total number of broken rails occurring at the agency and specifically, those related to thermite weld breaks. Therefore, WMATA leadership sought external expertise via APTA to help improve the agency's performance in this area. These actions are demonstrative of a learning organization.

The APTA Peer Review Team comprised individuals with extensive experience in track maintenance and engineering:

- General Manager of Power and Way Maintenance, Chicago Transit Authority
- Principal Engineer, Rolling Contact Fatigue, National Response Center (NRC) – Automotive and Surface Transportation Research Centre
- Assistant Chief Officer, Track Engineering, New York City Transit
- Manager, Coupling System and Truck Castings Committee, Transportation Technology Center
- Director of Track Engineering and Utility, Southeastern Pennsylvania Transit Authority
- Lead Engineer, APTA

The peer review team's activities were not intended to be an investigation into the specifics of any one event, but rather it was an overview of the adequacy and effectiveness of the agency's strategies to prevent broken rails and to better identify and correct broken rails that do occur before they result in an incident. In addition, the following information details some key activities performed by the agency and observations and recommendations of the peer review team. This discussion is not intended to be an exhaustive description of all aspects of the peer review.

APTA's peer review team report "Findings of the NATSA Peer Review Panel on Rail Breaks, Washington Metropolitan Area Transit Authority, April 1-5, 2019," was issued in late 2019. The scope of the report includes reviewing running rail breaks with an emphasis on welds, current programs for rail installation, maintenance, inspection, training, and the identification, documentation, and correction of defects.

General Observations

The peer review team identified that WMATA could improve configuration management and record-keeping activities pertaining to Continuous Welded Rail (CWR) installation and destressing. The peer review team also identified that WMATA's rail grinding program is corrective rather than preventive and not tonnage based; therefore, the peer review team recommended that WMATA:

- Establish a tonnage based preventive grinding program

- Evaluate profiles being used based on current wheel profiles and vehicle design
- Use faster, fewer passes while rail grinding
- Minimize wastage and improve quality assurance

WMATA uses visual inspections and its Track Geometry Vehicle (TGV) data collection for track inspections, which is typical in the transit industry. The peer review team identified that during track inspections, rail corrugation is assessed visually with no recorded measurements. Based on these findings, the peer review team recommended:

- Agency should evaluate the use of a corrugation measurement system
- Use a lower action threshold for addressing corrugation defects
- Explicitly include water leaking on the rail as a reportable “red” defect
- Use TGV thermal imaging with location determination
- Continue to explore the use of track component imaging to identify surface and special trackwork defects
- Increase supervisor and superintendent track walks and have them enter data on the same forms as inspectors
- Continue to remediate stray current corrosion issues

The team identified welding processes as an area of improvement. Cold weather procedures were not documented, current welding procedures likely produced defective welds, and there was no requirement for a Level III Non-Destructive Testing (NDT) inspector on staff to develop training and certification for UT inspectors and there were no written procedures or training material related to UT inspection and certification. The review team recommended that thermite welding and inspections include:

- Further refinement and testing of welds previously installed
- Use of wrap-around bars as a secondary layer of safety until all suspect welds can be replaced
- Continue build-out of the welding program with qualified and certified welders including a Level III NDT qualified individual
- Use written and practical testing to qualify thermite welders
- Create a flash butt welding program
- Replace suspect welds with flash butt welds
- Use manufacturers to train the trainer
- Establish UT inspection procedures using American Railway Engineering and Maintenance-of-Way Association (AREMA) Chapter 4 as a starting point

The peer review team suggested that WMATA improve document configuration management so "everyone (is) working towards the common goal … from the same set of documents."

State of Good Repair and Transit Asset Management

SGR and Transit Asset Management (TAM) are both integral to SMS and are mandated through Federal transit law.

The text of the Public Transportation Safety Act of 2010 was incorporated into both the transit asset management and safety provisions of MAP–21 (see §3638, 111th Congress (2010)). In the report accompanying that Act, Congress stated that ''state of good repair directly relates to the safety of a public transportation system, as the likelihood of accidents increases as the condition of equipment and infrastructure worsens'' §112–232 at 10 (2010). The requirements proposed under the Act were intended to establish a ''monitoring system for the safety and condition of the nation's public transportation assets.''

Several transit rail accidents have been attributed to inadequate SGR of assets.[63] SGR is defined as the condition in which a capital asset[64] can operate at a full level of performance. When transit assets are not in an SGR, the consequences include increased safety risks, decreased system reliability, higher maintenance costs, and lower system performance.

On July 26, 2016, FTA published a final rule, codified at 49 Code of Federal Regulations 625, Transit Asset Management, which required public transportation providers to develop and implement TAM plans and establish minimum Federal requirements for TAM. A TAM plan must include an asset inventory, condition assessments of inventoried assets, and a prioritized list of investments to improve the SGR of their capital assets. Furthermore, the final rule also established SGR standards and four SGR performance measures, further discussed below.

Specifically, TAM denotes the strategic and systematic practice of procuring, operating, inspecting, maintaining, rehabilitating, and replacing transit capital assets to manage performance, risks, and costs over their life cycles to provide safe, cost-effective, and reliable public transportation. TAM is a business model that prioritizes funding based on the condition of transit assets to achieve and maintain an SGR for the nation's public transportation assets. It establishes a

[63] For example, WMATA, L'Enfant Plaza Station Electrical Arcing and Smoke Accident Washington, D.C. January 12, 2015, NTSB Accident Report NTSB/RAR-16/01 PB2016-103217; Railroad Accident Brief: Angels Flight Railway Derailment, Los Angeles, California, September 5, 2013, NTSB Accident Number DCA13FR011; Railroad Accident Brief: Collision of Two Chicago Transit Authority Trains, Forest Park, Illinois, September 30, 2013, NTSB Accident Number DCA13FR014.

[64] Capital assets principally include equipment, rolling stock, infrastructure, and facilities.

framework for transit agencies to monitor and manage public transportation assets, improve safety, increase reliability and performance, and establish performance measures in order to help agencies keep their systems operating smoothly and efficiently.

Key Components of a TAM

The following comprise the performance measures of a TAM. A TAM plan is a plan that includes an inventory of capital assets, a condition assessment of inventoried assets, a decision support tool,[65] and a prioritization of investments. Specifically, a TAM plan is a tool that can aide transit providers in:

- Assessing the current condition of its capital assets
- Determining what the condition and performance of its assets should be (if they are not already in an SGR)
- Identifying the unacceptable risks, including safety risks, in continuing to use an asset that is not in an SGR
- Deciding how to best balance and prioritize anticipated funds (revenues from all sources) towards improving asset conditions and achieving a sufficient level of performance within those means

A TAM policy is a transit provider's documented commitment to achieving and maintaining an SGR for all of its capital assets. The TAM policy defines the transit provider's TAM objectives and defines and assigns roles and responsibilities for meeting those objectives. A TAM strategy is the approach a transit provider takes to conduct its policy for TAM, including its objectives and performance targets. A TAM system is a strategic and systematic process of operating, maintaining, and improving public transportation capital assets effectively throughout the life cycles of those assets.

[65] A decision support tool is an analytic process or methodology to help prioritize projects to improve and maintain the SGR of capital assets within a public transportation system, based on available condition data and objective criteria or to assess financial needs for asset investments over time.

Section 4

Safety Promotion

A transit agency must establish a comprehensive safety training program for all agency employees and contractors directly responsible for the management of safety in the agency's public transportation system. The training program should include refresher training, as necessary.

Competencies and Training

A transit agency must establish a comprehensive safety training program for all agency employees and contractors directly responsible for the management of safety in the agency's public transportation system. The training program must include refresher training, as necessary. The RTA may consider training for Board Members or others involved in approving or overseeing the PTASP.

In addition to specifying training requirements, RTAs may choose to define necessary competencies, including knowledge, skills, and abilities required to perform various positions. A training needs assessment can help assist transit agencies on what employees need to succeed.

RTAs may find that SMS training is most effective when focused on the specific activities an individual must perform to manage safety. For example, focus frontline employee SMS training on how to report safety conditions, rather than just general SMS concepts. A competency:

- Groups together the knowledge, skills, and abilities required to fulfill job roles effectively
- May cross various job roles and functions
- May be useful as an employee training topic
- Can be developed from a variety of sources

Safety Communication

A transit agency must communicate safety and safety performance information throughout the agency's organization that, at a minimum, conveys information on hazards and safety risks relevant to employees' roles and responsibilities and informs employees of safety actions taken in response to reports submitted through an employee safety reporting program.

RTAs may choose to consider what and how to communicate safety information. Relevant questions include, but are not limited to:

- What information does this individual need to do their job?
- How can we ensure they understand what is communicated?

- How can we ensure they understand what action they must take as a result of the information?
- How can we ensure the information is accurate and kept up to date?
- Are there any privacy or security concerns to consider when sharing information? If so, what should we do to address these concerns?

There are numerous mediums for safety communication:

- Providing contact information for facility safety committee members
- Creating and communicating a “Safety Topic of the Month”
- Establishing employee recognition programs
- Posting SMS material on safety bulletin boards
- Posting information regarding employee reporting systems
- Posting “Safety Campaign” information
- Posting safety performance objectives, safety performance targets, and safety performance indicators

Appendix A Hazard Analysis Forms

OHA Form[66]

System:	OPERATING HAZARD ANALYSIS (OHA)	Sheet Of
Subsystem:		Prepared by: Date:
Drawing No:		Reviewed by: Date:
OHA No: Rev. No:		Approved by: Date:

General Description			Hazard Cause/Effect		Hazard Risk Index (Initial)	Corrective Action		Hazard Risk Index (Final)
Task Description	Hazard Description	Probability of Occurrence	Potential Cause	Effect on Personnel/Subsystem/System		Possible Controlling Measures and Remarks	Resolution	

Figure A-1 *Sample OHA Form*

OHA Form Instructions

- In the "Task Description" column, describe the task being performed.
- In the "Hazard Description" column, describe a human act of commission or omission, error, or fault condition that could lead to an accident involving potential injury, death, or equipment damage.
- In the "Probability of Occurrence" column, enter the probability of occurrence of the error or fault condition, measured in events per million hours of operations. Give data sources, such as experience and statistics in similar applications, human factor studies.
- In the "Potential Cause" column, enter the most likely primary and secondary causes of a hazard, including those induced by hardware,

[66] USDOT, Federal Transit Administration, *Hazard Analysis Guidelines for Transit Projects*, Washington, DC, January 2000.

software, procedures, and the environment, which can potentially contribute to the presence of the hazard.

- In the "Effect on Personnel/Subsystem/System" column, describe the effect that the human error or fault condition may have on personnel, patrons, the public, equipment, facilities, and the entire system, in terms of system safety and operational impact (e.g., delay, inconvenience, injury, damage, fatality)
- In the "Hazard Risk Index (RI)" column, enter a combination of the qualitative measures of the worst potential consequence resulting from the hazard, and its probability of occurrence (e.g., IA, IIB).
- In the "Possible Controlling Measures and Remarks" column, describe actions that can be taken or procedural changes that can be made to prevent the anticipated hazardous event from occurring. Enter the name(s) of related analysis and reference number(s) and which approach is being proposed: Design Change, Procedures, Special Training.
- In the "Resolution" column, describe changes made or steps taken relative to design and procedures, training, to eliminate or control the hazard.

System:	TRAIN SIGNAL SYSTEM	**OPERATING HAZARD ANALYSIS (OHA)**	**Sheet**	**Of**
Subsystem:	PREVENTIVE MAINTENANCE PROCEDURE Wayside Signal Equipment		**Prepared by:**	**Date:**
Drawing No:			**Reviewed by:**	**Date:**
OHA No:	**Rev. No:**		**Approved by:**	**Date:**

General Description			**Hazard Cause/Effect**		**Hazard Risk Index (Initial)**	**Corrective Action**		**Hazard Risk Index (Final)**
Task Description	**Hazard Description**	**Probability of Occurrence**	**Potential Cause**	**Effect on Personnel/Subsystem/System**		**Possible Controlling Measures and Remarks**	**Resolution**	
NOTIFY OPERATIONS CONTROL CENTER (OCC) OF THE ACTIVITY TO BE PERFORMED	FAILURE TO NOTIFY MAY RESULT IN WORKER BEING STRUCK BY TRAIN	1×10^{-6}	HUMAN ERROR	POSSIBLE INJURY TO MAINTENANCE WORKER	IIIC	INSURE THAT THE MAINTENANCE PROCEDURE REQUIRES NOTIFICATION TO OCC PRIOR TO STARTING WORK ACTIVITY	PROCEDURE CORRECTED ON (10/15/2015)	IIID
INSPECT SIGNAL EQUIPMENT FOR DAMAGE, RUSTED, LOOSE, BROKEN OR MISSING COMPONENTS	SIGNAL EQUIPMENT MAY FAIL OR THE MAINTENANCE WORKER MAY BE ELECTROCUTED	1×10^{-6}	IMPROPER MAINTENANCE VANDALISM	ELECTROCUTION OF MAINTENANCE WORK FAILURE OF THE SIGNAL SYSTEM	IIIC	MODIFY PROCEDURE TO INSURE MAINTENANCE PERSONNEL UTILIZE APPROPRIATE PPE	PROCEDURE CORRECTED ON (10/15/2015)	IIID
INSPECT TWC COMMUNICATION EQUIPMENT AND HARDWARE FOR DEFECTIVE INSULATION, RUST OR DAMAGE	SIGNAL EQUIPMENT MAY FAIL OR THE MAINTENANCE WORKER MAY BE ELECTROCUTED	1×10^{-6}	IMPROPER MAINTENANCE VANDALISM	ELECTROCUTION OF MAINTENANCE WORK FAILURE OF THE SIGNAL SYSTEM	IID	MODIFY PROCEDURE TO INSURE MAINTENANCE PERSONNEL UTILIZE APPROPRIATE PPE	PROCEDURE CORRECTED ON (10/15/2015)	IIID

Figure A-2 *Sample Completed OHA Form*

FMEA Form

System: Subsystem: Drawing No. FMEA No. Rev. No.			Failure Modes and Effects Analysis (FMEA)			Sheet 1 of 1 Date: Prepared by: Reviewed by: Approved by:	
General Description			**Hazard Cause/Effect**			**Corrective Action**	
LRU No. & Description	***Failure Mode***	***Cause of Failure***	***Effect of Failure on Subsystem System***	***Probability of Occurrence***	***Severity of Occurrence***	***Possible Controlling Measures and Remarks***	***Resolution***

Figure A-3 *Sample FMEA Form*

FMEA Form Instructions[67]

- In the "Line Replaceable Units" column, enter assemblies, parts, and components addressed within each subsystem and system "No. & Description" assign a number to each Line Replaceable Unit (LRU) and briefly describe the characteristics of the LRUs.
- In the "Failure Mode" column, describe an immediate failure mode or fault condition, which could lead to an accident involving potential injury, death, or equipment damage.
- In the "Cause of Failure" column, enter the primary and secondary causes that can potentially contribute to the presence of the hazard.
- In the "Effect of Failure on Subsystem/System" column, describe the effect that the failure mode of fault condition may have on the item and the next higher level, i.e., subsystem or system element in terms of inputs and outputs, and terms of system safety and operational impact (e.g., delay, inconvenience, injury, damage, fatality).
- In the "Probability of Occurrence" column, enter the probability of occurrence of the failure mode or fault condition, measured in events per million hours of operation. Give data sources, such as experience in similar applications.
- In the "Severity of Occurrence" column, enter the potential impact of a fault condition or failure mode on system operation (catastrophic, critical to insignificant).

[67] *Ibid*.

- In the “Possible Controlling Measures and Remarks” column, describe actions that can be taken or procedural changes that can be made to prevent the anticipated hazardous event from occurring. Enter the name(s) of related analysis and reference number(s) and which approach is being proposed: design change, procedures, specialized training.
- In the “Resolution” column, describe changes made or steps taken relative to design and procedures, training, to eliminate, mitigate or control the hazard.

Qualitative Safety Risk Evaluation Worksheets and Exercise

The worksheets on the following pages were developed by the ASSP Risk Assessment Certification Program Committee.[68] Tables 2-1 and 2-2 (provided earlier in the document), and Table 2-9 and the worksheets on the following pages are presented as a guide for those who may want to use the qualitative safety risk evaluation process.

Table A-1 *Hierarchy of Controls*

Protective Measure (Control)	Examples	Mitigation Reduction Factors: Reduction and Risk Factor	Mitigation Reduction Factors: Example
Avoidance / Elimination	Design a task, step, equipment, material, or tool to be eliminated before it is put into production or use	Severity and Exposure Reduction	
	Eliminate human interaction Replace/eliminate a reaction step Eliminate pinch points (increase clearance)	100%	Elimination (e.g., human interaction) may also eliminate Exposure. In this case, re-do the Risk Assessment based on the new task
Substitution (Severity)	Automated materials handling (robots, conveyors) to reduce significantly human interaction	Severity Reduction Only	
	Replace with a less toxic compound. Significantly reduce speed, noise, weight (energy)	90% Substitution with little or no hazard	Replace oil with water, replace lifting 75 lbs with 5 lbs
		80% Substitution with something that still has some hazards	Replacing flammable with no-combustible, replace lifting 75 lbs with 20 lbs Automation: e.g., automated material handling where humans have been removed except for upset conditions

[68] See www.assp.org.

Protective Measure (Control)	Examples	Mitigation Reduction Factors	
		Reduction and Risk Factor	Example
Engineering (Severity Only)	Barriers	Likelihood Reduction only	
	Interlocks Presence sensing devices (light curtains, safety mats)	70% Isolation and or guards with interlocks.	Engineering controls like guards, that also have interlocks
	Fixed machine guards, Emergency stops Pressure relief valves, Energy isolation valves	60% Engineering control redundancy or multiple engineering controls	Two-hand controls plus light curtains
	Non-skid floor coatings Local exhaust ventilation, containerization	50% Single engineering control	Two-hand control, light curtain, physical barrier
	Two-hand controls	40% Engineering controls that require admin intervention to initiate	LOTO, where a physical device like a lock requires human intervention to initiate
Administrative (Training, Procedures, Warnings and Awareness Means) Likelihood only	Safe work procedures	Likelihood reduction only	
	Safety inspections Training Lights, beacons, and strobes	30% Training, plus warnings, signs, plus inspections/observations	Training, plus inspection to verify that controls are being practiced, plus at least one other
	Computer warnings Worker rotation Alarms (gas meter, fire) Barrier tape, tags, floor markings Signs and Labels Beepers, horns, and sirens Buddy systems, attendants, observers, supervision, schedule limits.	20% Training, plus warnings, signs	If there is a warning light, operators need to be trained to be aware of what it means
Personal Protective Equipment (PPE)	Earplugs, gloves, respirators.	Likelihood Reduction Only	
	Safety glasses, face shields	10% Multiple PPE	Multiple PPE must be for the same hazard. e.g., gloves and arm guards
		5% Single PPE	Must be specific to the hazard

From ANSI B11.0 2010

The Semi-Quantitative Safety Risk Evaluation method assigns a percent reduction of safety risk based on the Order of Precedence of Risk Reduction. These percent reductions were developed by the American Society of Safety Professionals (ASSP) Risk Assessment Certification Program Committee.

Subject: Overhead Catenary System Traction Power Lineman

From the information on the worksheet: Operation, Job/Task Assessed, and Job/Task Description, three hazards from the Job/Task Description were selected as an example. The worksheets have been previously completed to guide the reader.

Figure A-4 *Job/Task Assessment Worksheet*

PERFORMED BY:		**DATE:**	
SITE:	OCS poles in rail yard	**OPERATION:**	Maintaining Overhead Contact System that provides electrical power for light rail, heavy rail, and streetcar systems.
JOB/TASK ASSESSED:	Climbing steel utility poles that support the Overhead Contact System (OCS) that provides traction power.		
JOB/TASK DESCRIPTION: (include basis for severity, occurrence, exposure and existing controls)	Power line crews are required to climb steel utility poles that support the Overhead Contact System (OCS) that provides traction power, to maintain the wires, adjust the tension in the electrical wires, suspension (messenger wire) wires, and guy wires, replace insulators, and repair or replace damaged electrical wires. The OCS provides 750 volts of direct current (DC) to the pantograph on the top of the rail vehicles that operate on the track. The track serves as the return for the current to the traction power substation. The OCS remains energized in most cases during employee work activities. The height of the poles is 35-40 feet. Maintenance is performed year-round, so there is exposure to freezing temperatures and excessively hot temperatures (90^{0} F.+). In emergencies, linemen might have to climb poles in high winds, rain, sleet, ice, and snow. A significant amount of work on the mainline rail system is performed at night, so there is less impact to rail service. Existing Controls: Work positioning system, hard hat, leather gloves, eye protection. Lineman training.		

Table A-2 *Hazard Identification Worksheet*
(Refer to other worksheets for hazards and consequences)

Hazard Category	Hazard Aspect	Energy Source	Trigger Event(s)	Consequence Severity	
				Actual*	Worst Case
Unwanted Energy	Electric shock Arc Flash	750 volts DC	Lineman contacts energized wire		
Gravity	Changing levels	Body	Lineman loses footing while climbing		4
Environmental	Temperature extremes, Visibility, weather	Body	Severe cold makes it difficult to maintain a firm grip. Extreme heat can cause heat stress; working at night affects depth perception, leading to misjudgment of the proximity of energized wires		4

** If 3–5 years of reliable data available pertaining to severity of consequence, actual severity could be used rather than worst-case severity.*

Note: The completed worksheets (Figures A-2 through A-4) are based on the hazards listed in the Hazard Identification Worksheet: 1) For the Likelihood (b) calculation, on the Risk Analysis Worksheet (beginning on the next page), Occurrence (y): As Agency data are collected and accumulated, the Occurrence element of the Likelihood will play an increasingly more significant role in the determination of Likelihood. Although there may be an exposure pathway, the data might indicate that a specific consequence is not occurring at the Agency. 2) Use the table Hierarchy of Controls to complete sections (2) and (4) "controls" of the Hazard Analysis worksheets.

Figure A-5 *Risk Analysis Worksheet #1*

RISK ANALYSIS WORKSHEET # 1
**Tip: use the information from Page 1 and the Hierarchy of Control, Risk Matrix, and the Risk Reduction Calculation Worksheets to complete this page.*

HAZARD #1: Electric Shock, Arc Flash

CONSEQUENCE (a) *(severity)*	**LIKELIHOOD (b)** Likelihood = Average of Exposure (x) and Occurrence (y) For FSI, Likelihood = Highest of either x or y		**INITIAL RISK (c)** *(product of consequence (a) and Likelihood (b))*
	Exposure (x)	**Occurrence (y)**	
☒ Catastrophic (Cat) 4 ☐ Critical 3 ☐ Marginal 2 ☐ Negligible 1	☒ Frequent 5 ☐ Probable 4 ☐ Occasional 3 ☐ Remote 2 ☐ Improbable 1	☐ Frequent 5 ☒ Probable 4 ☐ Occasional 3 ☐ Remote 2 ☐ improbable 1	☒ High (>11) Unacceptable ☐ Serious (7-11) Undesirable ☐ Medium (>3 and <7) Acceptable w/review ☐ Low (<=3) Acceptable
	Likelihood Average = 5 – Fatality/Serious Injury (FSI)		Risk Number = 20

EXISTING CONTROL(S)	**DESCRIBE EXISTING CONTROL(S)**
☐ Substitution	
☐ Engineering	
☒ Administrative / Training	Hazard Communication Training, Lineman training
☒ PPE	Work positioning system, hard hat, leather gloves, eye protection.

(1) INITIAL RISK *(from above)*	**(2) CONTROLS**				**(3) EXISTING RISK** *(from Risk Reduction Calculation Worksheet)*
	(I) Substitution	**(II) Engineering**	**(III) Admin**	**(IV) PPE**	
(a) Consequence = 4 (b) Likelihood = 5 (c) Risk = 20	☐ 90% ☐ 80%	☐ 70% ☐ 60% ☐ 50% ☐ 40%	☐ 30% ☒ 20%	☐ 10% ☒ 5%	(a) Consequence = 4 (b) Likelihood = 3.8 (c) Risk = 15
Is the risk acceptable?	☐ Yes ☒ No				

ADDITIONAL MITIGATING CONTROL(S) *(include any existing controls remaining)*	**DESCRIBE MITIGATION STRATEGY** *(include any existing controls remaining)*
☐ Avoidance/elimination	
☐ Substitution	
☒ Engineering	Install insulated wire covers for OCS adjacent to the work area. De-energize OCS when possible – night shift. Install ground wire on OCS to prevent inadvertent re-energization. Emergency work during revenue service hours usually is performed with OCS energized to avoid interrupting service on all line segments.

Risk Analysis Worksheet #1 (Cont'd.)

☒ Administrative / Training	Hazard Communication Training, Lineman training, including the use of insulated wire covers and PPE listed below. Post "Danger, High Voltage" signs. Conduct field inspections. Discuss hazards and safety risks in job briefing. Provide training on proper methods of grounding of OCS wire.
☒ PPE	Use rubber insulated gloves with leather protectors and insulated sleeves, arc flash clothing arc flash rated face-shields and eye protection, electrical rated wide brim hardhats.
☐ None	

<table>
<tr><th rowspan="2">(1) INITIAL RISK
(from above)</th><th colspan="4">(4) CONTROLS</th><th rowspan="2">(5) RESIDUAL RISK
(from Risk Reduction Calculation Worksheet)</th></tr>
<tr><th>(I) Substitution</th><th>(II) Engineering</th><th>(III) Admin</th><th>(IV) PPE</th></tr>
<tr><td>(a) Consequence = 4
(b) Likelihood = 5
(c) Risk = 20</td><td>☐ 90%
☐ 80%</td><td>☒ 70%
☐ 60%
☐ 50%
☐ 40%</td><td>☒ 30%
☐ 20%</td><td>☒ 10%
☐ 5%</td><td>(a) Consequence =4
(b) Likelihood = 0.945
(c) Risk = 3.78</td></tr>
<tr><td>**Critical to safety?**</td><td colspan="5">☒ Yes* ☐ No **If Yes, ensure layered controls & continuous monitoring processes are in place*</td></tr>
<tr><td>**Is the risk acceptable?**</td><td colspan="5">☐ Yes ☒ No** *** If No, decide on treatment priority* *__FSI: Therefore, the risk remains unacceptable. Strictly monitor implementation and effectiveness of mitigation.__</td></tr>
</table>

**If the consequence is either a fatality/serious injury (FSI) and the consequence cannot be eliminated by design or substitution, then the safety risk remains unacceptable because there is a human factor in each of the applied mitigations. Strictly monitor implementation and effectiveness of mitigation.*

Figure A-6 *Risk Analysis Worksheet #2*

RISK ANALYSIS WORKSHEET # 2

**Tip: use the information from Page 1 and the Hierarchy of Control, Risk Matrix, and the Risk Reduction Calculation Worksheets to complete this page.*

HAZARD #2: Gravity – Fall from Height – OCS Pole

CONSEQUENCE (a) *(severity)*	LIKELIHOOD (b) Likelihood = Average of Exposure (x) and Occurrence (y) For FSI, Likelihood = Highest of either x or y		INITIAL RISK (c) *(product of consequence (a) and Likelihood (b))*
	Exposure (x)	**Occurrence (y)**	
☒ Catastrophic (Cat) 4 ☐ Critical 3 ☐ Marginal 2 ☐ Negligible 1	☒ Frequent 5 ☐ Probable 4 ☐ Occasional 3 ☐ Remote 2 ☐ Improbable 1	☐ Frequent 5 ☐ Probable 4 ☒ Occasional 3 ☐ Remote 2 ☐ Improbable 1	☒ High (>11) Unacceptable ☐ Serious (7-11) Undesirable ☐ Medium (>3 and <7) Acceptable w/review ☐ Low (<=3) Acceptable
	Likelihood Average = 5 (FSI)		Risk Number(a) X (b) = 20

EXISTING CONTROL(S)	DESCRIBE EXISTING CONTROL(S)
☐ Substitution	
☐ Engineering	
☒ Administrative / Training	Hazard Communication Training, Lineman training
☒ PPE	Work positioning belt

(1) INITIAL RISK *(from above)*	(2) CONTROLS				(3) EXISTING RISK *(from Risk Reduction Calculation Worksheet)*
	(I) Substitution	(II) Engineering	(III) Admin	(IV) PPE	
(a) Consequence = 4 (b) Likelihood = 5 (c) Risk = 20	☐ 90% ☐ 80%	☐ 70% ☐ 60% ☐ 50% ☐ 40%	☐ 30% ☒ 20%	☐ 10% ☒ 5%	(a) Consequence = 4 (b) Likelihood = 3.8 (c) Risk = 15.2
Is the risk acceptable?	☐ Yes ☒ No				

ADDITIONAL MITIGATING CONTROL(S) *(include any existing controls remaining)*	DESCRIBE MITIGATION STRATEGY *(include any existing controls remaining)*
☐ Avoidance/elimination	
☐ Substitution	
☒ Engineering	Use aerial lift or bucket truck to access OCS poles rather than climbing poles.
☒ Administrative / Training	Hazard Communication training, lineman training, aerial lift, or bucket truck training, PPE training, posted warning signs. Conduct field inspections to ensure conformance to the use of mitigation controls and to ensure that mitigation is effective. Discuss hazards and safety risks in job briefing.
☒ PPE	Personal fall protection system attached to aerial lift or boom of bucket truck, rubber insulated gloves with leather protectors and insulated sleeves, arc flash clothing, arc flash rated face-shields, and eye protection, and electrical rated wide brim hardhats.
☐ None	

Risk Analysis Worksheet #2 (Cont'd.)

<table>
<tr><th rowspan="2">(1) INITIAL RISK
(from above)</th><th colspan="4">(4) CONTROLS</th><th rowspan="2">(5) RESIDUAL RISK
(from Risk Reduction Calculation Worksheet)</th></tr>
<tr><th>(I)
Substitution</th><th>(II)
Engineering</th><th>(III)
Admin</th><th>(IV)
PPE</th></tr>
<tr><td>(a) Consequence = 4
(b) Likelihood = 5
(c) Risk = 20</td><td>☐ 90%
☐ 80%</td><td>☒ 70%
☐ 60%
☐ 50%
☐ 40%</td><td>☒ 30%
☐ 20%</td><td>☒ 10%
☐ 5%</td><td>(a) Consequence = 4
(b) Likelihood = 0.945
(c) Risk = 3.78</td></tr>
<tr><td>**Critical to safety?**</td><td colspan="5">☒ Yes* ☐ No **If Yes, ensure layered controls & continuous monitoring processes are in place*</td></tr>
<tr><td>**Is the risk acceptable?**</td><td colspan="5">☐ Yes ☒ No** *** If No, decide on treatment priority* *FSI: Therefore, the risk remains unacceptable. Strictly monitor implementation and effectiveness of mitigation.

**** <u>NOTE</u>: If the consequence is either a serious injury or a fatality and the consequence cannot be eliminated by design or substitution, then the safety risk remains unacceptable because there is a human factor in each of the applied mitigations. Strictly monitor implementation and effectiveness of mitigation.***</td></tr>
</table>

Figure A-7 *Risk Analysis Worksheet #3*

RISK ANALYSIS WORKSHEET # 3
**Tip: use the information from Page 1 and the Hierarchy of Control, Risk Matrix, and the Risk Reduction Calculation Worksheets to complete this page.*

HAZARD #3: Environmental

CONSEQUENCE (a) *(severity)*	LIKELIHOOD (b) Likelihood = Average of Exposure (x) and Occurrence (y) For FSI, Likelihood = Highest of either x or y		INITIAL RISK (c) *(product of consequence (a) and Likelihood (b))*
	Exposure (x)	**Occurrence (y)**	
☒ Catastrophic (Cat) 4 ☐ Critical 3 ☐ Marginal 2 ☐ Negligible 1	☐ Frequent 5 ☒ Probable 4 ☐ Occasional 3 ☐ Remote 2 ☐ Improbable 1	☐ Frequent 5 ☐ Probable 4 ☒ Occasional 3 ☐ Remote 2 ☐ Improbable 1	☒ High (>11) Unacceptable ☐ Serious (7-11) Undesirable ☐ Medium (>3 and <7) Acceptable w/review ☐ Low (<=3) Acceptable
	Likelihood Average = 4 (FSI) (Ignore Occurrence [Y]		Risk Number(a)X(b) = 16

EXISTING CONTROL(S)	DESCRIBE EXISTING CONTROL(S)
☐ Substitution	
☐ Engineering	
☒ Administrative / Training	Hazard Communication training, lineman training, training in the health effects of extreme temperatures.
☒ PPE	Leather gloves, hard hat

(1) INITIAL RISK *(from above)*	(2) CONTROLS				(3) EXISTING RISK *(from Risk Reduction Calculation Worksheet)*
	(I) Substitution	(II) Engineering	(III) Admin	(IV) PPE	
(a) Consequence = 4 (b) Likelihood = 4 (c) Risk = 16	☐ 90% ☐ 80%	☐ 70% ☐ 60% ☐ 50% ☐ 40%	☐ 30% ☒ 20%	☐ 10% ☒ 5%	(a) Consequence = 4 (b) Likelihood = 4 (c) Risk = 16
Is the risk acceptable?	☐ Yes ☒ No				

ADDITIONAL MITIGATING CONTROL(S) *(include any existing controls remaining)*	DESCRIBE MITIGATION STRATEGY *(include any current controls remaining)*
☐ Avoidance/elimination	
☐ Substitution	
☒ Engineering	Use aerial lift or bucket truck to access OCS poles. Erect enclosure around aerial lift or bucket and work area to isolate lineman from weather effects. Provide adequate lighting for night work.

Risk Analysis Worksheet #3 (Cont'd.)

☒ Administrative / Training	Hazard Communication training, lineman training, training in the health effects of extreme temperatures. Conduct field inspections. Discuss hazards and safety risks in job briefing. Suspend work per OSHA Standard, Title 29 C.F.R. 1910.269, Electric Power Generation, Transmission, and Distribution. High wind: A wind of such velocity that the following hazards would be present: • An employee would be exposed to being blown from elevated locations, or an employee or material handling equipment could lose control of material being managed, or an employee would be exposed to other hazards not controlled by the standard involved. Note: Winds exceeding 40 miles per hour (64.4 kilometers per hour), or 30 miles per hour (48.3 kilometers per hour) if material handling is involved, are not generally considered as meeting these criteria unless precautions are taken to protect employees from the hazardous effects of the wind. Postpone work.
☒ PPE	Personal fall protection system attached to aerial lift or boom of bucket truck, rubber insulated gloves with leather protectors and insulated sleeves, arc flash clothing, arc flash rated face-shields, and eye protection, cooling vests, electrical rated wide brim hardhats.
☐ None	

(1) INITIAL RISK *(from above)*	**(4) CONTROLS**				**(5) RESIDUAL RISK** *(from Risk Reduction Calculation Worksheet)*
	(I) Substitution	**(II) Engineering**	**(III) Admin**	**(IV) PPE**	
(a) Consequence = (b) Likelihood = (c) Risk =	☐ 90% ☐ 80%	☐ 70% ☒ 60% ☐ 50% ☐ 40%	☒ 30% ☐ 20%	☒ 10% ☐ 5%	(a) Consequence = 4 (b) Likelihood = 1.008 (c) Risk = 4.032

Critical to safety?	☒ Yes* ☐ No **If Yes, ensure layered controls & continuous monitoring processes are in place*
Is the risk acceptable?	☐ Yes ☒ No** *** If No, decide on treatment priority ** **FSI: Therefore, the risk remains unacceptable. Strictly monitor implementation and effectiveness of mitigation.** **** NOTE: If the consequence is either a serious injury or a fatality and the consequence cannot be eliminated by design or substitution, then the safety risk remains unacceptable because there is a human factor in each of the applied mitigations. Strictly monitor implementation and effectiveness of mitigation.***

The following three risk hazard calculation examples are provided to demonstrate the process that an agency may use to calculate initial, existing, and residual risk hazards. When utilizing these examples, you will want to follow these tips/guidelines:

1. Work through the steps in order, 1 through 3.
2. If the consequence (1a) is Catastrophic, i.e., fatal, or serious injury, only apply the highest of either exposure (x) or occurrence (y) to the likelihood (1b). This is an FSI potential.
3. Always apply the more effective control first.
4. Carry over the new existing likelihoods from the last box in the row above, to the first box in the row below.
5. If there are no existing controls, use the initial risk (1c) to calculate the existing risk (3c).
6. Fill in Risk Analysis form using the final calculations; use the corresponding labels (e.g., 1a, 2IV,) as a guide.

STEP 1: Calculate Initial Risk Hazard # 1

(Exposure + Occurrence)/2 = Likelihood
Likelihood x Consequence = Initial Risk

5 (FSI)	(3-Ignore-FSI)		5	5	4	20
(Exposure (x) +	*Occurrence (y) /2*	=	*Likelihood (1b)*	*Likelihood (1b)* x	*Consequence (1a)* =	*Initial risk (1c)*

STEP 2: Calculate Existing Risk Hazard # 1

(2-I) Substitution Initial *Consequence – (Initial Consequence x Control Reduction) = New (existing) Consequence*

Initial Consequence (1a) x	*Control Reduction (2I)* =	*Reduction (e)*	*Initial Consequence (1a)* –	*Reduction (e)* =	*New existing consequence (3a)*

(2-II) Engineering Initial *Likelihood – (Initial Likelihood x Control Reduction) = New Likelihood*

Initial Likelihood (1b) x	*Control Reduction (2II)* =	*Reduction (f)*	*Initial Likelihood (1b)* –	*Reduction (f)* =	*New existing likelihood (3b)*

(2-III) Admin *New Likelihood [unless there were no entries for (2a) and (2b) then use Initial Likelihood] – (Initial Likelihood x Control Reduction) = New Likelihood*

5	20% (0.20)	1	5	1	4
New Likelihood (3b) x	*Control Reduction (2III)* =	*Reduction (g)*	*New Likelihood (3b)* –	*Reduction (g)* =	*New existing likelihood (3b)*

(2-IV) PPE *New Likelihood [unless there were no entries for (2a), (2b), and (2c) then use Initial Likelihood] – (Initial Likelihood x Control Reduction) = New Likelihood*

4	5% (0.05)	0.2	4	0.2	3.8
New Likelihood (3b) x	*Control Reduction (2IV)* =	*Reduction (h)*	*New Likelihood (3b)* –	*Reduction (h)* =	*New existing likelihood (3b)*

Existing Risk: New *existing likelihood x New existing consequence = Existing risk*

3.8	4	15.2
New Existing Likelihood (3b) x	*Consequence (3a)* =	*Existing risk (3c)*

STEP 3: Calculate Residual Risk Hazard # 1

*Tips

- Apply from Initial risks
- Calculate Reduction from the entire set of new and existing controls remaining.

(3-I) Substitution *Initial Consequence – (Initial Consequence x Control Reduction) = New (Residual) Consequence*

Existing Consequence (3a) x	*Control Reduction (4I)* =	*Reduction (i)*	*Existing Consequence (3a)* –	*Reduction (i)* =	*New residual consequence (5a)*

(3-II) Engineering *Initial Likelihood – (Initial Likelihood x Control Reduction) = New (Residual) Likelihood*

5	70% (0.70)	3.5	5		3.5	1.5
Existing Likelihood ×	*Control Reduction (2II)* =	*Reduction (j)*	*Existing Likelihood*	−	*Reduction (j)* =	*New residual likelihood*

(3-III) Admin *New residual Likelihood [unless there were no entries for (3a) and (3b) then use Existing Likelihood] – (Initial Likelihood x Control Reduction) = New (Residual) Likelihood*

1.5	30% (0.30)	0.45	1.5	0.45	1.05
New residual Likelihood ×	*Control Reduction (2III)* =	*Reduction (k)*	*New residual Likelihood* −	*Reduction (k)* =	*New residual likelihood*

(3-IV) PPE *New residual Likelihood [unless there were no entries for (3a), (3b), and (3c), then use Existing Likelihood] – (Initial Likelihood x Control Reduction) = New (Residual) Likelihood*

1.05	10% (0.10)	0.105	1.05	0.105	0.945
New Likelihood (3b) ×	*Control Reduction (2IV)* =	*Reduction (l)*	*New Likelihood (3b)* −	*Reduction (l)* =	*New residual likelihood (5b)*

Residual Risk- *New residual likelihood x New existing consequence = Residual risk*

0.945	4	3.78
Likelihood (3b) ×	*Consequence (5a)* =	*Residual risk (5c)*

STEP 1: Calculate Initial Risk Hazard # 2 Gravity – Fall from Height – OCS Pole

(Exposure + Occurrence)/2 = Likelihood
Likelihood x Consequence = Initial Risk

5 (FSI)	Ignore because of FSI		5	5	4	20
(Exposure (x) +	*Occurrence (y))*	=	*Likelihood (1b)*	*Likelihood (1b)* ×	*Consequence (1a)* =	*Initial risk (1c)*

STEP 2: Calculate Existing Risk Hazard # 2

(2-I) Substitution Initial *Consequence – (Initial Consequence x Control Reduction) = New (existing) Consequence*

Initial Consequence (1a) ×	*Control Reduction (2I)* =	*Reduction (e)*	*Initial Consequence (1a)* −	*Reduction (e)* =	*New existing consequence (3a)*

(2-II) Engineering *Initial likelihood – (Initial likelihood x Control Reduction) = New likelihood*

Initial Likelihood (1b) ×	*Control Reduction (2II)* =	*Reduction (f)*	*Initial likelihood (1b)* −	*Reduction (f)* =	*New existing likelihood (3b)*

(2-III) Admin *New existing likelihood [unless there were no entries for (2a) and (2b) then use Initial likelihood] – (New Likelihood x Control Reduction) = New existing likelihood*

5	20% (0.20)	1	5	1	4
New Likelihood (3b) ×	*Control Reduction (2III)* =	*Reduction (g)*	*New likelihood (3b)* −	*Reduction (g)* =	*New existing likelihood (3b)*

(2-IV) PPE *New existing likelihood – [unless there were no entries for (2a), (2b), and (2c), then use initial likelihood] (New likelihood x Control Reduction) = New likelihood*

4	5% (0.05)	0.2	4	0.2	3.8
New existing likelihood (3b) ×	*Control Reduction (2IV)* =	*Reduction (h)*	*New likelihood (3b)* −	*Reduction (h)* =	*New existing likelihood (3b)*

Existing Risk *New existing likelihood x New existing consequence = Existing risk*

3.8	4	15.2
Likelihood (3b) ×	*Consequence (3a)* =	*Existing risk (3c)*

<u>STEP 3: Calculate Residual Risk Hazard # 2</u>

*Tips

- Apply from <u>Initial</u> risks
- Calculate Reduction from the entire set of new <u>and</u> existing controls remaining.

(3-I) Substitution Initial *Consequence – (Initial Consequence x Control Reduction) = New (Residual) Consequence*

Existing Consequence (3a) ×	*Control Reduction (4I)* =	*Reduction (i)*	*Existing Consequence (3a)* −	*Reduction (i)* =	*New residual consequence (5a)*

(3-II) Engineering Initial *Likelihood – (Initial Likelihood x Control Reduction) = New (Residual) Likelihood*

5	70% (0.70)	3.5	5	3.5	1.5
Existing Likelihood ×	*Control Reduction (2II)* =	*Reduction (j)*	*Existing Likelihood* −	*Reduction (j)* =	*New residual likelihood*

(3-III) Admin New residual *likelihood [unless there were no entries for (3a), and (3b), then use initial likelihood] – (Initial likelihood x Control Reduction) = New (residual) likelihood*

1.5	30% (0.30)	0.45	1.5	0.45	1.05
New residual Likelihood ×	*Control Reduction (2III)* =	*Reduction (k)*	*New residual Likelihood* −	*Reduction (k)* =	*New residual likelihood*

(3-IV) PPE New residual *likelihood [unless there were no entries for (3a), (3b), and (3c), then use initial likelihood] – (Initial likelihood x Control Reduction) = New residual likelihood*

1.05	10% (0.10)	0.105	1.05	0.105	0.945
New Likelihood (3b) ×	*Control Reduction (2IV)* =	*Reduction (l)*	*New Likelihood (3b)* −	*Reduction (l)* =	*New residual likelihood (5b)*

Residual Risk New *residual likelihood x New existing consequence = Residual risk*

0.945	4	3.78
Residual likelihood (3b) ×	*Consequence (5a)* =	*Residual risk (5c)*

Appendix B

Investigator Go-Bag Contents

Investigators typically "customize" their go-bags to include items they anticipate using or have found useful in the past. The following list provides items that investigators should consider as they develop a resource kit to have available 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

Investigative Tools

- Video recorder
- Tape recorder
- Camera, charged batteries
- Flashlights/extra batteries
- Note pads/pens/graph paper pad/memory sticks
- Templets for sketches
- Chalk/paint pens/spray paint
- Measuring wheel, non-metallic tape measure
- Spare film/memory cards
- Evidence control kit (containers/forms/tags/markers)
- Calibrated gauges[69]
- Track: Track gauge, top & side wear gauges
- Signals: Track shunts, switch fouling gauge
- Mechanical: Wheel flange and "back-to-back" gauges
- Other gauges and meters specific to agency equipment
- Pre-identified and up to date agency manuals/documents
- Signal system drawings
- Schematics
- Track charts
- Rule books
- Other specialized documents and plans specific to agency operations

[69] Specialized tools must 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 C

Key Points for Conducting Interviews

One-on-one interviews may be necessary, particularly when obtaining witness statements after an event since witnesses may be anxious to leave. An interview team of two is preferred—one to conduct the interview, the other to take notes or operate a recorder. 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:

- Have one person designated as the lead interviewer.
- Keep 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 must 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 obtained and to understand different perspectives of the same event. People involved have information that we do not have, information is needed to develop a factual record, interviewee's cooperation is needed, and they do not need us. Some people can be compelled to be interviewed but cannot be compelled to be helpful. Establishing rapport is a key to success.

- **Potential participants:**
  - Operating & maintenance personnel
  - Supervisors/managers
  - Victims
  - Bystanders
  - Residents
- **Those familiar with potential participants:**
  - Friends
  - Coworkers
  - Managers
  - Emergency crews – fire, EMS, hospital staff, law enforcement, news media, walk-ins

Key interview points before the interview starts:

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

Key points on question sequence:

- With 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:

- Show attention to the interviewee at all times.
- Be aware of and avoid nonverbal 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 interviewees appear uncomfortable or begin 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. You should 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 turns 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 the questions if there is a reason to believe that an 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 they have any questions that should have been asked.
- Ask if they have 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

Survival and Witness Statements and Questionnaire

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
- Other agency employees
- Responders
- Witnesses

Be sensitive to interviewee injuries. Request permission to tape record the interviews. If a recorder is used, the interviewer and interviewee will 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 his/her observations without interruption. The person designated as note-taker only jots down 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 copies of seating diagrams of the vehicle type the interviewee was occupying available. 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?

Appendix E Analytical Tools to Aid Investigation Process

Fishbone Charts

Ishikawa or fishbone charts aim to help you list out all the 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.

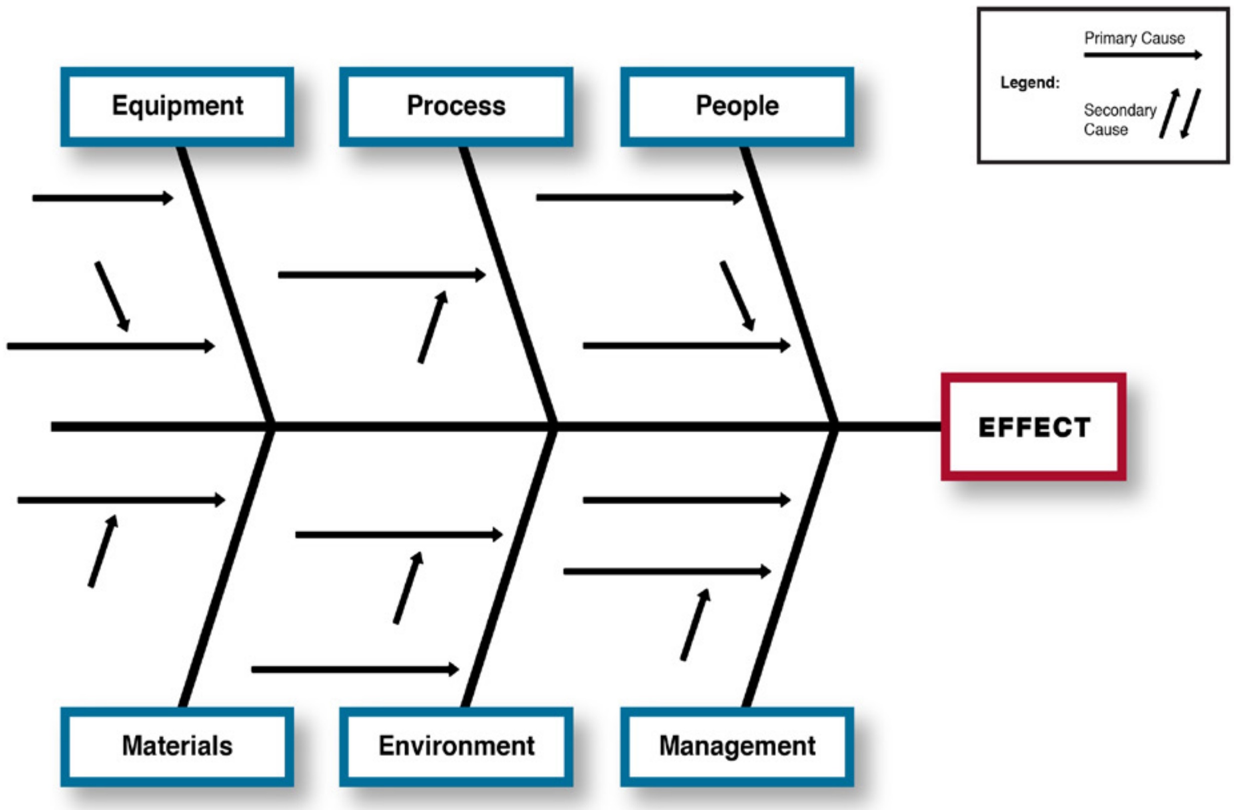

Figure E-1 *Fishbone Chart*

Source: TSI

Fault Tree Analysis

Fault tree analysis 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. Fault tree analysis imposes a logic flow that can help to support the probable cause of an event. A simplified example is shown below.

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. These conditions are linked to the event box by an "and" gate – meaning both conditions must exist together. Possible causes are in circles at the bottom of the graphic. These are connected to the logical explanations by "or" gates, meaning that any one of these causes would be sufficient to result in the event.

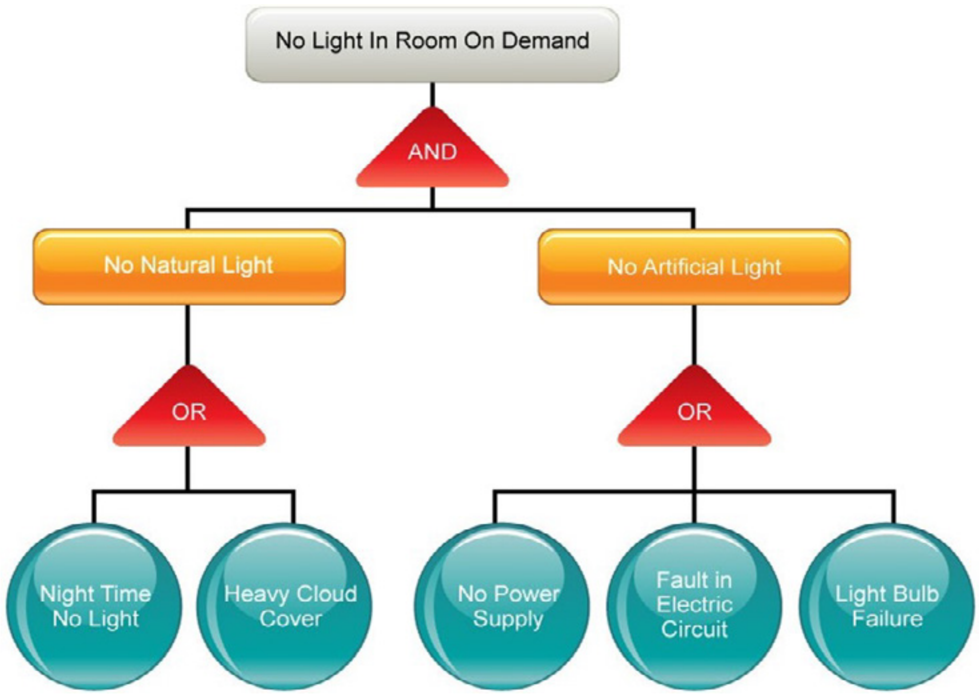

Figure E-2 *Fault Tree Analysis*
Source: TSI

Further analysis of factual information developed in an investigation will help to rule in or rule out the bottom level causes. For example, if the light bulb tests OK, we can rule out light bulb failure from the equation. When you get to the bottom level of a fault tree, you are at the root cause. In the above example, you can envision going deeper (see "5 Whys" below). For instance, if a fault in the electric circuit is verified, we would then ask why? Was there a maintenance issue, an overload issue, a training issue, a parts issue?

Several commercial vendors produce proprietary root cause analysis tools and also provide training classes. A free root cause analysis tool can be obtained from NASA at the following link: http://nsc.nasa.gov/RCAT/Software/NewRequest.

SHEL Model

The International Civil Aviation Organization (ICAO) SHEL model 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. According to the SHEL Model, a mismatch between the Liveware and the four other components contributes to human error. It groups factual material into the five groups:

Software	Hardware	Environment	Liveware (Central)	Liveware (Peripheral)
• Documentation • Procedures • Symbols	• Machinery • Equipment	• Internal • External	• Human Element	• Other Humans Involved

Source: CUTR

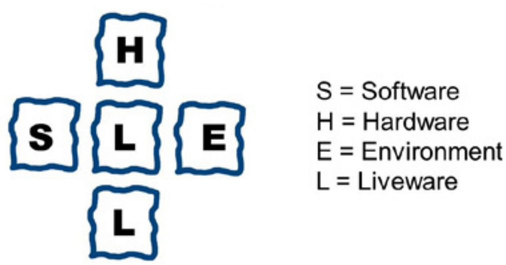

Figure E-3 *SHEL Model*

Source: ICAO 9859, Safety Management Manual

"5 Whys"

A similar method of getting to the root cause is often referred to as the "5 Whys." This system involves asking "why" until you reach the root cause of an event. A simplified example:

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

If you stop at number 1 or 2, you will fix only the immediate problem on the accident vehicle. The out-of-calibration torque wrench remains in service awaiting the next accident. Even stopping at #5 will fix only the individual torque wrench and does not entirely solve the problem.

In this case, you could go on for a couple more “why” levels to get at a root cause related to organizational policy, procedures, management oversight, quality control, training. There is nothing magic about the number five. If you get to the root cause after three whys, great. If it takes 10, that is OK, too. The idea is not to stop short so that the underlying problem can be identified and dealt with.

The analysis logically links to the cause and lays the foundation for the recommendations to address the deficiencies, and which lead to corrective action plans.

These four tools can help the investigator organize their thinking and assist in determining the critical factors in the accident scenario.

Appendix F

Investigation Report Organization/ Content

A recent NTSB major accident report was organized as follows and may be used to guide the investigation report.

- Figures and Tables
- Acronyms and Abbreviations
- Executive Summary
- Factual Information
- Accident
- Accident Narrative
- Agency(s) background
- Operations
- Oversight
- Personnel Information
- Damages
- Equipment Information
- Survival Factors
- Injuries
- Emergency Response
- Track and Structures
- Signal and Train Control
- Other infrastructure
- Analysis
- Introduction
- Specific Issues Identified in the particular accident
- Human Performance
- Equipment Crashworthiness
- Survival Factors
- Conclusions
- Findings
- Probable Cause and Contributing Factors
- Recommendations

Less complicated and more minor accidents may use a more abbreviated format depending on the circumstances and SSO program standard requirements. NTSB uses a “brief” report format for less complicated accidents. Most NTSB brief reports include the following headings:

- The Accident
- Background
- The Investigation
- Safety Issues
- Post-Accident Actions
- Probable Cause (and contributing factors)
- Recommendations

Absent other direction from the SSO program standard or FTA, the NTSB accident report organizational model is considered an industry best practice for accident reports. The format and report organization used by the agency may be spelled out in the SSO program standard. In some cases, the program standard will require the agency to submit an accident investigation procedure for review and approval. The development of such a procedure is a good opportunity to come to agreement with the SSOA on process details, including acceptable formats.

Figures and Tables

This section is for the convenience of the reader to find figures and tables within the report.

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, use the acronym or abbreviation. Only the acronyms and abbreviations used in the report need to be included in this section.

Executive Summary

The Executive Summary is a condensed version of the full report intended to allow readers to get acquainted with a large body of material without them having to read the entire document. It is one of the essential sections 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 will typically 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.

Factual Information

General

This section is the start of 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 those areas that are relevant to the cause of the accident and lead to the recommendations. The facts support the analysis that, in turn, supports the cause and recommendations. Think of the factual portion of the report as the foundation and the analysis, conclusion, and cause as the house. Without a good foundation underpinning it, the house will be prone to problems.

The factual section does not need to address every single fact that has been developed over the course of the investigation; however, there needs to be a clear logic chain between facts, analysis, conclusions, and cause.

The Accident

The accident description provides the basic facts of the accident. It tells the reader the "Who," "What," "Where," and "When." The "Why" is reserved for the analysis section. A map or aerial image of the scene is helpful here.

Accident Narrative

This section tells the factual story of the accident. The timeline is a significant help here. Usually, the "story" begins at the start of the trip or shift and leads up to and includes the accident sequence.

Agency(s) Background

This section explains the organizational relationships and how the agency's safety plan ties it all together. With a single owner/operator it is relatively straight forward. Some agencies have more complicated arrangements with multiple contractors operating trains and maintaining rolling stock and infrastructure.

Effective Investigation Practice

Typical information in the accident description section of a report includes:

- Type of accident, i.e., derailment, collision
- Accident date and time
- Accident location
- Name of the rail line
- Track number & milepost (stationing marker, column number) or cross street(s)
- Train/equipment/staff involved
- Train type, the direction of travel, consist (train makeup)
- Operator's view on approach
- Other vehicles/equipment/persons involved
- Other vehicle types, direction, makeup (if applicable)
- Injury summary
- Total damage
- Weather conditions

Operations

This section lays out the operating scheme (single track, double track, signaled, non-signaled), train control system, governing operating documents, operating rule book, and any other operations manuals or guidance. Lay out factually any discrepancies between requirements and what happened during the accident sequence. For example, the train order in effect listed a 10-mph speed restriction between MP 14.5 and MP 15.0. Event recorder data indicated that the accident train traveled at 25 mph between these two points. Save a discussion of the significance of these facts for the analysis section.

Oversight

This is the location to explain the SSOA relationship, when and how the event was reported, and the involvement of the SSOA 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 FRA has a role in shared use or OSHA is engaged in an employee injury.

Personnel Information

This section covers the relevant key players in the accident, which might include train operators, maintenance technicians, controllers, or supervisors. Personnel information might consist of fitness for duty checks, training and experience, disciplinary record, and promotion history. Remember not to include any personally identifiable information like social security numbers, phone numbers or addresses.

Damages

Dollar damages are broken down by category (track, signals, electrification, vehicles). A simple table format can capture this information and present it.

Equipment Information

This section lays out the necessary information on the train consist and other equipment involved. Describe the pre-departure inspection of the equipment and any anomalies discovered. Include factual information that is relevant to the accident, for example, weight, crashworthiness design features, rehabilitation history, or age. Describe the post-accident positions of equipment and a factual description of damage. Photos and diagrams can be helpful with this.

Survival Factors

This section of the report focuses on the issues related to the survivability of the passengers and the train crew, and the ability of the passengers and crew to safely evacuate. Factual information on survivable space, emergency exits, and 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 the simple injury table noted in the post-on-scene section. 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.

Transit agencies should consult their legal department on any health-related data to avoid sharing medical information in violation of HIPAA.[70]

Emergency Response

Explain which response agencies were involved. List the factual information regarding time notified, time of arrival, and any delays or problems with evacuation, triage, or transport of injured. A response timeline table is helpful here. Include any factual information from the debrief.

Track and Structures

In an accident with no track connection, this section can be omitted or include a concise description of the track structure. If track and structures were factors in the accident, a detailed factual 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 with facts.

Signal and Train Control

In an accident with no signal connection to the cause, this section can be omitted or include a concise description of the signal system. If the signal system was a factor in the accident, a detailed factual 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 with facts.

Other Infrastructure

This is the section to discuss any other infrastructure or system that may have been a factor in the accident, for example, power, communications, ventilation,

[70] For specific details on HIPAA requirements, see www.hhs.gov.

SCADA. Any discrepancies between requirements and performance should be laid out factually. The goal is to logically tie in the factual discussion to support the conclusions in the analysis.

Analysis

General

This is the area of the report where the meaning of the facts is explained—when a discrepancy is found between what policy, procedures, specifications, or regulation requires and what is found in the accident. How is this discrepancy relevant? The analysis section is where the significance of the facts developed is explained. Some discrepancies may not pass the “so what” test; for example, a train traveling 3 mph over the speed limit is not likely a factor in a derailment event, whereas a train at 30 mph over the speed limit likely is. Keep in mind the logic chain that must be present.

Effective Investigation Practice

The logic chain to strive for:

- Facts are based on observable, verified and accurate information.
- Analysis is based on those facts.
- Conclusions are based on the analysis.
- Causes and contributing factors are the output of that logic chain.
- Recommendations address the cause and contributing factors.

Introduction

The introduction provides the opportunity to discuss the exclusions. Exclusions are the potential causal areas that were examined and found not to be factors in the accident. For example, in a hypothetical grade crossing collision, the report might note that investigators inspected the track, examined maintenance records, and found no anomalies. At the end of the introduction, provide a summary noting that the agency concludes that none of the following was determined to be a factor in this accident: the condition of the track. That statement is then repeated in the conclusions section.

Specific Issues Identified in the Particular Accident

In this section, the report discusses and analyzes the factors that were judged to be factors in the accident. For example, in the hypothetical grade crossing collision, if it was found that the crossing gates did not lower because a circuit had been bypassed with a “jumper wire” during maintenance, 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 maintenance and the control center, and between the control center and the train. At the end of each analysis discussion, specify and explain the conclusion reached. There needs to be a clear logic chain between the facts, analysis, and conclusion.

Human Performance

Any human performance issues such as work environment, fatigue, experience, training, impairment, distraction, or medical conditions[71] are discussed here.

Survival Factors

Equipment Crashworthiness

If no crashworthiness issues were developed, this section might 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, would be discussed here.

Emergency Response

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

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

If any responders were injured during the response, a discussion is needed in this section on the nature of the injuries and the circumstances. This may lead to recommendations on training, equipment, or procedures under agency control. Any problems discussed in this section must be supported by factual information.

Conclusions – Findings

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

[71] Ensure compliance with HIPAA requirements.

Probable Cause and Contributing Factors

This section is in two parts—the primary cause, as determined by the facts and the analysis conducted by the rail investigative team and contributing factors that were discovered during the analysis of the facts that without these factors, the accident may not have occurred.

Probable cause and contributing factors can sometimes be terms of art as the difference between the probable cause, and a contributing factor may be grey rather than black and white. In NTSB reports, sometimes the probable cause 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.

Since the deeper objective of the investigation is to identify preventive measures, the report writers should consider which elements of the causal picture best logically support the preventive recommendations. The primary causal and contributing factors of the accident should be clearly stated in the conclusion section.

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

Effective Investigation Practice

Example of logic flow:*

- Fact: Eight ineffective ties were observed at the point of derailment (POD).
- Fact: Track gauge and tie conditions exceeded the tolerance allowed by the standards.
- Fact: POD was at the point of wide gauge.
- Analysis: Wide gauge resulted from ineffective ties.
- Analysis: Conclusion—the derailment resulted from a wide gauge in the track.
- Probable Cause: the probable cause of this derailment was a wide track gauge condition, resulting from the use of deteriorating wooden crossties.

**The contributing factors in this hypothetical example would layout relevant issues like training, inspection schedules, and capital replacement programs that were explained in the analysis.*

Recommendations

The report should provide either immediate recommendations or discuss corrective actions that were implemented as the report was being prepared, i.e., a chafing wire was identified during the post-accident investigation of a train fire, which triggers a fleet-wide inspection.

Once the cause and contributing factors have been determined, the investigators, together with the associated agency departments, develop a realistic and practical remedy to prevent a similar accident from happening again. This may take time and money or may involve immediate changes to rules and procedures, but it must be fully understood what needs to be done immediately, within the short term, and what long-term solution is required to prevent future events of this nature.

The recommendations section of a rail report must provide a set of actions that should be taken to prevent reoccurrences of this accident. These recommended improvements should be organized by time so that those requiring immediate action can be implemented, while others requiring more time and funding can be scheduled for a permanent fix for 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 signal systems and upgrading them with PTC systems.

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, 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 response electrification safety training” would not meet this test. A more focused approach is needed, such as “revise the emergency response training program to cover the use of agency supplied third rail probes.” Recommendations should logically link to the corrective action plans.

Appendix G

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 before the accident. Information from this history will touch on every area of the human factors 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, to the time the operator awoke.

Initial questions to ask include but may 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 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/get up the three days before the accident?
- Did you nap any of the three days before the accident? If so, when/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(s))?
- 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, cell phone records, logbooks, alarm clock settings, and hotel wake-up calls. Try to establish a baseline for on and off-duty days, as well as specifics for the 72 hours (see above) before the accident and compare the two. Specific information to obtain includes:

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

Acronyms and Abbreviations

AAR	Association of American Railroads
ALARP	As Low as Reasonably Practicable
APTA	American Public Transportation Association
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASLRRA	American Short-Line and Regional Railroad Association
ASME	American Society of Mechanical Engineers
ASRS	Aviation Safety Reporting System
ASSP	American Society of Safety Professionals
AVL	Automatic Vehicle Locator
BP	British Petroleum
BRP	Blue Ribbon Panel
BTS	Bureau of Transportation Statistics
C3RS	Confidential Close Call Reporting System
CAP	Corrective Action Plan
CBTC	Communications Based Train Control
CCTV	Closed Circuit Television
CSB	Chemical Safety and Hazard Investigation Board
CEO	Chief Executive Officer
CFR	Code of Federal Regulations
CM	Configuration Management
CSO	Chief Safety Officer
CUTR	Center for Urban Transportation Research
CWR	Continuous Welded Rail
EAP	Employee Assistance Program
EMS	Emergency Management System
FAID	Fatigue Audit InterDyne
FAST	Fatigue Avoidance Scheduling Tool
FAMES	Fatality Analysis of Maintenance-of-way Employees and Signalmen
FEMA	Federal Emergency Management Agency
FIRS	Fire Incident Reporting System
FMEA	Failure Modes and Effects Analysis
FMP	Fatigue Management Program
FRA	Federal Railroad Administration
FRSA	Federal Railroad Safety Act
FSI	Fatality/Serious Injury
FTA	Federal Transit Administration
HAZWOPER	Hazardous Waste Operations and Emergency Response
HBV/HIV	Hepatitis B Virus/Human Immunodeficiency Virus
HIPAA	Health Insurance Portability and Accountability Act

HF	Human Factor
IC	Incident Commander
ICAO	International Civil Aviation Organization
ICS/NIMS	Incident Command System/National Incident Management System
IIC	Investigator in Charge
LIRR	Long Island Railroad
LRU	Line Replaceable Unit
LTA	Lost Time Accident
MAP-21	Moving Ahead for Progress in the 21st Century Act
MIL-STD	Military Standard
MNR	Metro-North Railroad
MOU	Memorandum of Understanding
MTA	New York Metropolitan Transportation Authority
NASA	National Aeronautics and Space Administration
NATSA	North American Transit Services Association
NDT	Non-Destructive Testing
NFPA	National Fire Protection Association
NRC	National Response Center
NTSB	National Transportation Safety Board
NTSSA	National Transit Systems Security Act
NYCT	New York City Transit
OCS	Overhead Contact Systems
OEM	Office of Emergency Management
OHA	Operating Hazard Analysis
OTP	On-Time Performance
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
PMI	Preventive Maintenance and Inspections
POD	Point of Derailment
PPE	Personal Protective Equipment
PRT	Peer Review Team
PTASP	Public Transportation Agency Safety Plan
PTC	Positive Train Control
RAC	Risk Assessment Code
RI	Risk Index
ROCC	Rail Operations Control Center
RTA	Rail Transit Agency
RWP	Roadway Worker Protection
SA	Safety Assurance

SAFTE	Sleep, Activity, Fatigue and Task Effectiveness
SCADA	Supervisory Control and Data Acquisition
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 Program
SSOA	State Safety Oversight Agency
TAM	Transit Asset Management
TCRP	Transit Cooperative Research Program
TGV	Track Geometry Vehicle
TRACS	Transit Advisory Committee for Safety
TSI	Transportation Safety Institute
TSS	Transit System Security
TSSP	Transit Safety and Security Program
TWU	Transport Workers Union
UT	Ultrasonic Testing
WMATA	Washington Area Metropolitan Transit Authority
WMSC	Washington Metrorail Safety Commission
ZBB	Zero-based budget

References

American National Standards Institute (ANSI)/American Society of Safety Professionals (ASSP), 2011. Risk Assessment Techniques. ANSI/ASSP Z690.3-2011. Des Plaines, IL: ANSI/ASSP approved January 11.

American Public Transportation Association (APTA). 2018. Rail Transit Accident/Incident Notification and Investigation Requirements. APTA RT-OP-S-002-02, Rev. 3. Washington, DC: APTA approved July 26. https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-RT-OP-S-002-02-Rev-3.pdf.

APTA. Security and Emergency Management Standards. Washington, DC. https://www.apta.com/research-technical-resources/standards/security/.

APTA. On-Board Recording Equipment, Periodic Inspection, and Maintenance. APTA RT-VIM-RP-015-03, Rev. 2. Washington, DC: APTA approved June 8, 2003. https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-RT-VIM-RP-015-03-Rev-2.pdf.

APTA. Rule-Compliance Program Requirements. 2017. APTA-RT-OP-S-11-10. Washington, DC: APTA approved April 7. https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-RT-OP-S-011-10-Rev-2.pdf.

APTA. Rulebook Development and Review. 2018. APTA-RT-OP-S-001-02, Rev. 3. July 6. https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-RT-OP-S-001-02-Rev-3.pdf.

APTA. Fatigue Management Program Requirements. APTA RT-OP-S-023-17. Washington, DC: APTA approved April 7, 2017. https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-RT-OP-S-023-17.pdf.

APTA. Crash and Fire Protected Inward and Outward Facing Audio and Image Recorders in Rail Transit Operating Compartments. Recommended Practice, RT-OP-RP-024-19. 2019. Washington, DC: APTA approved April 12, 2019. https://www.apta.com/research-technical-resources/standards/rail/apta-rt-op-rp-024-19/.

APTA. Findings of the NATSA Peer Review Panel on Rail Breaks, Washington Metropolitan Area Transit Authority. Washington, DC: APTA approved April 1-5, 2019.

American Railway Engineering and Maintenance-of-Way Association. *AREMA Manual*, Chapter 4. Rail. Lanham, MD: AREMA, approved in 2019. https://www.arema.org/files/pubs/mre/2019/AREMA_MRE_Chapter_4_2019.pdf.

American Society of Mechanical Engineers. Safety Standard for Structural Requirements for Light Rail Vehicles. ASME RT 1-2015. Washington, DC: ASME approved 2015. https://www.techstreet.com/searches/25131496?msclkid=6782dadb2f8f1be0d8b5875e6df024cf&searchText=ASME+RT-1&sid=msn&utm_medium=cpc&utm_source=bing.

American Society of Mechanical Engineers. Safety Standard for Structural Requirements for Heavy Rail Transit Vehicles. ASME RT-2-2014. Washington, DC: ASME approved 2014. https://www.techstreet.com/searches/25131537?msclkid=f8afa41e81ab1cd55c37f99bc5863795&searchText=ASME+RT-2&sid=msn&utm_medium=cpc&utm_source=bing.

Burlington Northern & Santa Fe Railway Co v. White, 548 U.S. 53 (2006). https://supreme.justia.com/cases/federal/us/548/53/.

Dawson, D., and Reid, K. 1997. Fatigue, Alcohol, and Performance Impairment. *Nature*, 388: 235. https://www.nature.com/articles/40775.

French, S., and Steel, T. 2017. Investigation of Safety Management Systems and Safety Culture. Presented at International Transport Forum. Discussion Paper 2017-20, prepared for Roundtable on Safety Management Systems (23-24 March 2017, Paris). United Kingdom, August. https://www.itf-oecd.org/sites/default/files/docs/investigation-sms-safety-culture.pdf.

Hopkins, A., 2008. Failure to Learn: the BP Texas Refinery Disaster. CCH Australia. https://books.google.com/books/about/Failure_to_Learn.html?id=47nKUYQGDAsC

Institute of Electrical and Electronics Engineers. IEEE Standard for Rail Transit Vehicle Event Recorder. IEEE 1482.1-1999. New York, NY: IEEE approved September 1, 1999. Reaffirmed June 9, 2005. Superseded by IEEE 1482.1-2013. https://standards.ieee.org/standard/1482_1-1999.html.

International Civil Aviation Organization. 2018. ICAO 9859, *Safety Management Manual*. 4th ed. https://store.icao.int/safety-management-manual-doc-9859.html.

Long Island News and Print. 2014. Blue Ribbon Panel Recommends Steps to Improve MTA Rail Safety. LongIsland.com. August 27. https://www.longisland.com/news/08-27-14/blue-ribbon-panel-recommends-steps-to-improve-mta-rail-safety.html.

Lyon, B., and Popov, G. 2018. Risk Management Tools for Safety Professionals – Part I, Section 3. American Society of Safety Professionals. Des Plaines, IL. https://www.amazon.com/Risk-Management-Tools-Safety-Professionals/dp/093987413X/ref=tmm_hrd_swatch_0?_encoding=UTF8&qid=&sr=.

National Academies of Sciences, Engineering, and Medicine, Transportation Research Board. Transit Cooperative Research Program. 2011. Report 149: Improving Safety-Related Rules Compliance in the Public Transportation Industry. Washington, DC. http://www.trb.org/Publications/Blurbs/166125.aspx.

National Aeronautics and Space Administration (NASA). NASA Root Cause Analysis Tool (RCAT). https://software.nasa.gov/software/LEW-19737-1.

NASA. NASA Root Cause Analysis Tool (RCAT). https://software.nasa.gov/software/LEW-19737-1.

National Fire Protection Association. Standard for Fixed Guideway Transit and Passenger Rail Systems. NFPA 130, 2017 ed. Quincy, MA: ANSI approved June 2, 2016. https:// catalog.nfpa.org/NFPA-130-Standard-for-Fixed-Guideway-Transit-and-Passenger-Rail-Systems-P1229.aspx?icid=D729.

National Transportation Safety Board (NTSB). NTSB FY 2018-2022 Strategic Plan. Washington, DC. https://www.ntsb.gov/about/Pages/strategic-plan-engagement.aspx.

NTSB. NTSB, FY 2018-2022 Strategic Plan. Washington, DC. https://www.ntsb.gov/about/Pages/strategic-plan-engagement.aspx.

NTSB. 2001. Railroad Special Investigation Report—Two Rear-End Collisions Involving Chicago Transit Authority Rapid Transit Trains at Chicago, Illinois, June 17, and August 3, 2001 (NTSB/SIR-02/01). https://www.ntsb.gov/safety/safety-studies/Documents/SIR0201.pdf.

NTSB. Recommendations R-02-18 (FTA); R-02-22(CTA); and R-08-02 (WMATA). https://www.ntsb.gov/safety/safety-recs/RecLetters/R02_18_19.pdf, https://www.ntsb.gov/safety/safety-recs/_layouts/ntsb.recsearch/Recommendation.aspx?Rec=R-02-022, https://www.ntsb.gov/_layouts/ntsb.recsearch/Recommendation.aspx?Rec=R-08-002.

NTSB, October 25, 2013. NTSB Investigative Hearing Transcript RE: Two Metro-North Railroad Accidents in May 2013. Docket No. DCA 13MR003. 78 FR 64026. https://www.federalregister.gov/documents/2013/10/25/2013-25157/investigative-hearing.

NTSB. NTSB Railroad Accident Brief: Angels Flight Railway Derailment. Los Angeles, California, September 5, 2013, NTSB Accident Number DCA13FR011. Washington, DC: NTSB adopted June 23, 2014. https://www.ntsb.gov/investigations/AccidentReports/Reports/RAB1402.pdf.

NTSB. NTSB Railroad Accident Brief: Collision of Two Chicago Transit Authority Trains. Forest Park, Illinois, September 30, 2013, NTSB Accident Number DCA13FR014. Washington, DC: NTSB adopted April 13, 2015. https://www.ntsb.gov/investigations/AccidentReports/Reports/RAB1502.pdf.

NTSB. Special Investigation Report on Railroad and Rail Transit Roadway Worker Protection. NTSB/SIR 14-03. Washington, DC: NTSB adopted September 24, 2014. https://www.ntsb.gov/safety/safety-studies/Documents/SIR1403.pdf.

NTSB. NTSB Special Investigation Report. Organizational Factors in MNR Railroad Accidents. NTSB/SIR-14-04. Washington, DC: NTSB adopted November 19, 2014. https://www.ntsb.gov/safety/safety-studies/Documents/SIR1404.pdf.

NTSB. NTSB Accident Report, Washington Metropolitan Area Transit Authority, L'Enfant Plaza Station Electrical Arcing, and Smoke Accident. Washington, D.C. January 12, 2015, NTSB/RAR-16/01 PB2016-103217. Washington, DC: NTSB adopted May 3, 2016. https://www.ntsb.gov/investigations/AccidentReports/Reports/RAR1601.pdf.

NTSB. 49 CFR Part 840, Rules Pertaining to Notification of Railroad Accidents. https://ecfr.federalregister.gov/current/title-49/subtitle-B/chapter-VIII/part-840.

NTSB. 49 CFR Part 831, Investigation Procedures. https://ecfr.federalregister.gov/current/title-49/subtitle-B/chapter-VIII/part-831.

NTSB. NTSB Most Wanted List of Transportation Safety Improvements 2019-2020. https://www.ntsb.gov/safety/mwl/Pages/default.aspx.

New York City Transit. Joint Track Safety Task Force Final Report. November 20, 2007. http://www.twulocal100.org/sites/twulocal100.org/files/track_safety_task_force_final_0.pdf.

Reason, J. 1997. *Managing the Risks of Organizational Accidents*. Ashgate Publishing Co., Burlington, VT. https://www.amazon.com/Managing-Risks-Organizational-Accidents-Reason/dp/1840141050.

Snook, S. A., 2000. *Friendly Fire: The Accidental Shootdown of U. S. Blackhawks over Northern Iraq*. Princeton University Press. Princeton, N.J. (Digital Location 5234) https://press.princeton.edu/titles/6847.html.

United States Chemical Safety Board. 2007. BP America Refinery Explosion. Report number 2005-04-I-TX. https://www.ecfr.gov/cgi-bin/ECFR?page=browse/.

US Congress. Moving Ahead for Progress in the 21st Century Act of 2012, Pub. L. 112-141, 126 Stat. 405. https://www.congress.gov/112/plaws/publ141/PLAW-112publ141.pdf.

US Congress. Public Transportation Safety Act of 2010. S. 3638 (111th). https://www.govtrack.us/congress/bills/111/s3638/text.

United States Department of Health & Human Services. Health Insurance Portability and Accountability Act of 1996 (HIPAA). https://www.hhs.gov/hipaa/index.html.

United States Department of Labor, Occupational Safety and Health Administration (USDOL/OSHA). Memorandum, March 12, 2012, Subject: Employer Safety Incentive and Discrimination Policies and Practices. https://www.osha.gov/as/opa/whistleblowermemo.html.

USDOL/OSHA, 29 CFR § 1910.120, Hazardous Waste Operations, and Emergency Response. https://ecfr.federalregister.gov/on/2020-08-03/title-29/subtitle-B/chapter-XVII/part-1910/subpart-H?section=1910.120.

USDOL/OSHA. 29 CFR § 1910.1030, Bloodborne Pathogens. https://ecfr.federalregister.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-Z/section-1910.1030.

United States Department of Transportation. 49 CFR Part 40, Procedures for Transportation Workplace Drug and Alcohol Testing Programs. https://ecfr.federalregister.gov/current/title-49/subtitle-A/part-40.

United States Department of Transportation (USDOT), Federal Aviation Administration. 2000. FAA System Safety Handbook, Chapter 9: Analysis Techniques. Washington, DC: December 30, 2000. https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/risk_management/ss_handbook/.

USDOT, Federal Railroad Administration. 2014. Federal Railroad Administration Report to Congress: Operation Deep Dive MNR Commuter Railroad Safety Assessment. Washington, DC: March 2014. www.fra.dot.gov/Elib/Document/3586.

USDOT, Federal Railroad Administration. 2015. Confidential Close Call Reporting System (C3RS): Lessons Learned Evaluation – Baseline Phase Report No. DOT/FRA/ORD-19/01. Washington, DC. https://www.fra.dot.gov/Elib/Document/14515.

USDOT, Federal Railroad Administration. 2019. Confidential Close Call Reporting System (C3RS): Lessons Learned Evaluation – Final Report. Report No. DOT/FRA/ORD-19/01. Washington, DC. https://www.fra.dot.gov/eLib/Details/L19804.

USDOT, Federal Railroad Administration. 49 CFR Part 207, Railroad Police Officers. https://eCFR.io/Title-49/CFR207_main.

USDOT, Federal Railroad Administration. 49 CFR Part 209, Railroad Safety Enforcement. https://eCFR.io/Title-49/CFR209_main.

USDOT, Federal Railroad Administration. 49 CFR Part 217, Railroad Operating Rules. https://eCFR.io/Title-49/pt49.4.217.

USDOT, Federal Railroad Administration. 49 CFR Part 219, Control of Alcohol and Drug Abuse. https://eCFR.io/Title-49/pt49.4.219.

USDOT, Federal Railroad Administration. 49 CFR Part 225, Railroad Accidents/Incidents: Reports of Classification, and Investigations. https://eCFR.io/Title-49/pt49.4.225.

USDOT, Federal Railroad Administration. 49 CFR Part 238, Passenger Equipment Safety Standards. https://eCFR.io/Title-49/CFR238_main.

USDOT, Federal Railroad Administration. 49 CFR Part 239, Passenger Train Emergency Preparedness. https://eCFR.io/Title-49/CFR239_main.

USDOT, Federal Transit Administration. FTA guidance document: Recommended Emergency Guidelines for Rail Transit Systems. Washington, DC: March 1985. https://www.transit.dot.gov/regulations-and-guidance/safety/recommended-emergency-preparedness-guidelines-rail-transit-systems.

USDOT, Federal Transit Administration. Hazard Analysis Guidelines for Transit Projects. Washington, DC: January 2000. https://www.transit.dot.gov/oversight-policy-areas/hazard-analysis-guidelines-transit-projects-final-report-january-2000.

USDOT, Federal Transit Administration. Public Transportation System Security and Emergency Preparedness Planning Guide. Washington, DC: January 2003. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/PlanningGuide.pdf.

USDOT, Federal Transit Administration, Transit Advisory Committee for Safety. TRACS Working Group 11-01 Report, Establishing a Confidential, Non-Punitive, Close Call Safety Reporting System for the Rail Transit Industry. Washington, DC: July 16, 2012. https://www.transit.dot.gov/regulations-and-guidance/safety/close-call-safety-reporting-11-01.

USDOT, Federal Transit Administration. SMS Gap Analysis Report, Washington Metropolitan Area Transit Authority. Washington, DC: June 17, 2015. https://www.transit.dot.gov/.../files/docs/WMATA_SMS_Gap_Analysis_Final_Report.pdf.

USDOT, Federal Transit Administration. Compendium of Transit Safety Standards. Washington, DC: 2015. https://www.transit.dot.gov/regulations-and-guidance/safety/compendium-transit-safety-standards.

USDOT, Federal Transit Administration, Transit Advisory Committee for Safety (TRACS). Building Toward a Strong Safety Culture Within the Bus and Rail Transit Industry. 16-01, Final Report. Washington, DC: February 27, 2017. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/safety/64011/building-toward-strong-safety-culture-tracs-16-01-final-report.pdf.

USDOT, Federal Transit Administration, 49 CFR Part 625, Transit Asset Management. https://eCFR.io/Title-49/pt49.7.625.

USDOT, Federal Transit Administration, 49 CFR Part 655, Prevention of Alcohol Misuse, and Prohibited Drug Use in Transit Operations. https://eCFR.io/Title-49/pt49.7.655.

USDOT, Federal Transit Administration, 49 CFR Part 670, Public Transportation Safety Program. https://eCFR.io/Title-49/pt49.7.670.

USDOT, Federal Transit Administration, 49 CFR Part 672, Public Transportation Safety Certification Training Program. https://eCFR.io/Title-49/pt49.7.672.

USDOT, Federal Transit Administration, 49 CFR Part 673, Public Transportation Agency Safety Plan. https://eCFR.io/Title-49/pt49.7.673.

USDOT, Federal Transit Administration, 49 CFR Part 674, State Safety Oversight. https://eCFR.io/Title-49/pt49.7.674.

USDOT, Federal Transit Administration. Audit All Rail Fixed Guideway Public Transportation Systems (RFGPTS) with Subway Tunnel Environments. FTA Safety Advisory SA-15. Washington, DC: June 17, 2015. https://www.transit.dot.gov/regulations-and-guidance/safety/safety-advisory-15-1-audit-all-rail-fixed-guideway-public.

USDOT, Federal Transit Administration. Protecting Public Transportation Operators from the Risk of Assault. 84 FR 24196. Washington, DC: May 24, 2019. https://www.federalregister.gov/documents/2019/05/24/2019-10281/protecting-public-transportation-operators-from-the-risk-of-assault.

USDOT, Federal Transit Administration, Transit Advisory Committee for Safety. Membership List. Washington, DC: March 2019. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/safety/118676/tracs-membership-list-march-2019.pdf.

USDOT, Federal Transit Administration, Transit Advisory Committee for Safety. TRACS List of 25 Safety Focus Areas. Washington, DC: March 2019. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/safety/131961/tracs-list-25-safety-focus-areas-march-2019.pdf.

USDOT, Transportation Safety Institute. Federal Transit Administration Safety Management System: Safety Assurance Participant Guide, v. 12-09282018. Oklahoma City, OK. [Note: The Safety Assurance Participant Guide is not online; however, equivalent information is available in a Safety Assurance Webinar:] https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/safety/133191/ptasp-sa-july-11-2019.pdf.

USDOT, Transportation Safety Institute. Federal Transit Administration Course No. FT00543, Transit Rail System Safety, Instructor Guide. V. 11_022219. Oklahoma City, OK: February 22, 2019.

USDOT, Transportation Safety Institute. Federal Transit Administration Course No. FT00543, Transit Rail System Safety, Participant Guide. V. 11_022219. Oklahoma City, OK: February 22, 2019.

The University of Chicago. *Chicago Manual of Style*, 17th ed. (2017). The University of Chicago Press. Chicago.

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https://www.transit.dot.gov/about/research-innovation