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A Pilot Examination of a Joint Railroad Management-Labor Approach to Root Cause Analysis of Accidents, Incidents, and Close Calls in a Diesel and Car Repair Shop Environment

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6. AUTHOR(S)
Alex Viale and Stephen Reinach

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02451-1196

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13. ABSTRACT
This report presents findings from a 1-year pilot study investigating the feasibility and practicality of a joint railroad management-labor approach to root cause analysis (RCA) of accidents, incidents, and close calls in a diesel and car repair shop environment. The primary objective of the study was to evaluate the value and utility of a joint railroad management-labor RCA process. Participating labor and management representatives identified seven RCA opportunities during the study period; however, only one was investigated. Participants identified a number of barriers that made it difficult for the project to succeed in its current form. Key barriers included a lack of study leadership; poor interaction and communication between labor and management participants and between participants and the employees involved in the accidents, incidents, and close calls; challenges with employee participation; perceived minimal opportunity to conduct RCA; and complexity of the RCA tools and process. Suggestions for future implementation addressed these barriers. The report discusses additional lessons learned and recommendations for any future implementation of a joint labor-management RCA process. The joint management-labor RCA process and tools should experience greater success once these barriers are addressed.

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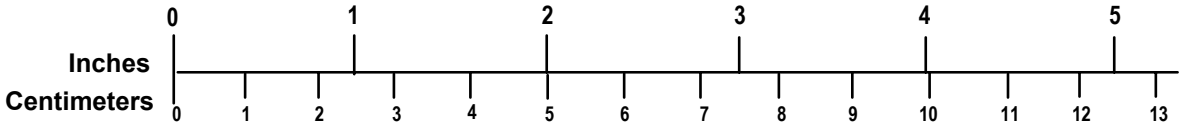

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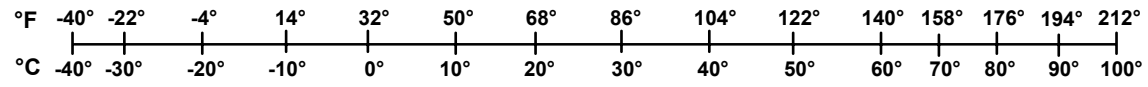

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Preface

This report presents the results of a 1-year pilot study aimed at outfitting railroad labor and management personnel with the training and materials necessary to enable them to conduct their own root cause analyses (RCA) of accidents, incidents, and close calls in a diesel and car repair shop setting. The goal of this exploratory research was to determine the feasibility of railroad labor and management jointly conducting their own RCA of accidents, incidents, and close calls using a set of data collection and analysis tools developed for this project. The study focused on determining the utility and value of the RCA approach and tools.

This research was sponsored by the Federal Railroad Administration (FRA) Office of Research and Development Contract DTFR53-01-D-00029. The authors express thanks to Dr. Thomas Raslear, FRA Office of Research and Development Human Factors Program, for supporting this work. The authors also give special thanks to the representatives from the participating railroad and labor unions for their time and energy experimenting with a novel, joint approach to accident/incident investigation. Thanks, too, for their candid opinions regarding why this study was not successful in its current form and how to successfully implement any future joint labor-management RCA initiatives. Lastly, the authors thank Ms. Judith Gertler and Ms. Susan McDonough for reviewing drafts of this manuscript and providing valuable feedback on its readability.

Executive Summary

Safety in the railroad industry has improved markedly over the last decade. According to recent Federal Railroad Administration (FRA) data, the total accident/incident rate in the railroad industry has fallen from 26.37 per million train miles (mtm) in 1996 to 17.39 in 2005.[1] In addition, employee injuries (including fatal) have declined. FRA data indicate 9,199 railroad employees were injured while on duty and an additional 33 killed in 1996.[2,3] By 2005, the number of employee-on-duty injuries had declined to 5,557, and fatalities totaled 25. Further analysis indicates, however, that while the total accident/incident rate and employee injuries have decreased, the number and rate of train accidents alone has increased over this time period. In 1996, 2,443 train accidents (3.64 train accidents per mtm) occurred. In 2005, this number rose to 3,152 (3.99 train accidents per mtm).

One of the most effective means of reducing accidents/incidents and increasing safety is to understand the diverse set of contributing factors that allow an accident/incident to occur. This report describes the results of a 1-year (yr) pilot examination of a joint railroad management-labor approach to root cause analysis (RCA) of accidents, incidents, and close calls in a railroad diesel and car repair shop environment. RCA is a systematic approach to accident, incident, and close call investigation that enables one or more individuals to identify individual, organizational, technological, and situational factors that contributed to each accident, incident, or close call. A guiding principle behind RCA is that a single event is not responsible for an accident, incident, or close call. Rather, multiple factors play a role in every accident, incident, and close call, and each factor is important to identify and understand as a means to mitigate future occurrences.

The research team chose the Human Factors Analysis and Classification System (HFACS) to provide the theoretical backbone to the RCA. HFACS has its basis in James Reason's (1) generic error modeling system (GEMS) and (2) Swiss cheese model of accident causation (Reason, 1990). The Swiss cheese model depicts accidents as arising from holes in an organization's defenses at various levels of the organization, beginning with the operator and working all the way up to organizational decisions and conditions. Active failures by the operator combine with latent conditions or factors upstream in the organization to lead to an accident (or incident or close call). Accidents (and incidents and close calls) occur, therefore, when all of the active and latent factors (i.e., holes) line up to allow accident energy (characterized as a straight line) to penetrate these various organizational levels. Accidents (and incidents and close calls) are prevented when an organization's defenses and barriers prohibit the alignment of active and latent factors and conditions.

HFACS has a logical structure and is a scientifically valid approach to human error. Furthermore, HFACS, as a classification system, is diagnostic, reliable, and comprehensive,

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[1] SOURCE: FRA Office of Safety data retrieved from http://safetydata.fra.dot.gov/OfficeofSafety/Query/Default.asp?page=statsSas.asp June 9, 2006.

[2] Ibid.

[3] SOURCE: FRA Office of Safety data retrieved from http://safetydata.fra.dot.gov/OfficeofSafety/Query/Default.asp?page=castab.asp June 9, 2006.

according to its authors. This is critical since the taxonomy must accommodate a wide range of railroad operational situations and circumstances that can lead to accidents, incidents, and close calls. Wiegmann and Shappell initially developed HFACS for the aviation domain (2003). As a result, the research team made some minor changes to HFACS to optimize its relevancy to the railroad industry. The modified HFACS taxonomy has the label HFACS-RR (railroad).

The primary objective of this research was to gain an understanding of the potential for railroads and labor to jointly conduct human factors-based RCA investigations of accidents, incidents, and close calls to uncover contributing factors at various levels of the railroad system. The focus of the project was on participant feedback on (1) implementation of the RCA method and tools and (2) the utility of the approach for the railroad industry in general.

The specific objectives of this research project were to:

- Assist the railroad industry in identifying contributing factors to accidents, incidents, and close calls beyond the employee.
- Obtain industry and labor feedback on the value and utility of the RCA methods and tools.
- Examine the usefulness of a modified version of HFACS in the railroad industry to support accident, incident, and close call investigations.

Implementing a joint management-labor RCA process required a location where labor and management were co-located. The diesel and car repair shop operating environment was a candidate study environment because management and labor are co-located, and this environment hosts a variety of skilled craft workers, providing access to a variety of job types and numerous and varied work experiences throughout each day.

The researchers invited representatives from several railroads and labor unions, as well as FRA, to participate in a stakeholder meeting in April 2004. Researchers shared and discussed project goals and methods at this informational meeting. One railroad and four labor unions subsequently agreed to participate in the pilot study. Each labor union identified one local member to participate in the study, while the railroad identified several candidates to support the project.

Researchers developed a set of paper-based tools based on HFACS-RR to guide management and labor investigators through the data collection and analysis process. Foster-Miller conducted a 2-day (d) training session at the host railroad with management and labor representatives in November 2004. The training served to educate and familiarize participants (some of whom had not attended the stakeholder meeting) on the principles of RCA, the HFACS-RR taxonomy of human error, and the specific RCA tools and methodology for data collection and analysis.

Candidate occurrences for RCA included all accidents, incidents, and close calls that took place in the diesel and car repair shop environment regardless of whether the event met FRA reporting criteria. The accident, incident, or close call had to occur in the diesel or car repair shop environment and involve a member of a participating union. Events where the Federal Employer's Liability Act (FELA) might be involved were not candidates for study.

The original methodology required one management and one labor representative to jointly conduct each RCA. The labor representative that participated in a particular RCA depended on who was involved in the accident, incident, or close call. For example, if a carman was involved

in an accident, then a carman representative participated. If a sheet metal worker was involved, then a sheet metal worker representative participated. During the initial training, labor and management agreed to allow labor representatives to conduct each RCA on their own while management representatives would be available to assist as needed.

The initial data collection period lasted 6 months (mo), from November 10, 2004, to May 10, 2005. Because participants were able to conduct only one RCA in this time period, the data collection period was extended an additional 6 mo, to the end of November 2005. In the end, participants identified a total of 7 RCA opportunities during the 1-yr study period, but investigated only 1 incident using the RCA tools and method. One labor and one management representative jointly performed the single RCA. They identified five contributing factors associated with three of the five HFACS-RR levels.

Midway through the study, it became clear a number of barriers were preventing successful implementation of the RCA process and tools. To identify these barriers, researchers conducted telephone interviews with participating management and labor representatives to obtain their feedback. The debriefing survey, a set of questions originally designed to obtain feedback at the end of the study on the utility and value of the RCA tools and process, helped tap into study barriers and solicit suggestions for future implementation.

Key themes among barriers identified include the following:

- *Lack of leadership.* Participants felt that labor and management lacked strong leadership to ensure the study's success.
- *Poor interaction and communications*. Participants noted that it was awkward to interview a co-worker as part of the RCA process. Participants also noted inadequate communication from some study participants to other diesel and car repair shop employees about the study, as well as from management to labor participants about the existence of accidents, incidents, or close calls.
- *Challenges associated with participation*. Participants observed several barriers related to their own participation and that of employees involved in an accident, incident, or close call. Participants identified a lack of participant availability for one RCA and difficulty coordinating multiple participant and employee schedules to conduct RCAs. In addition, concern over management retribution was a factor for one labor representative participant who chose not to support the project after the training. The same concern was noted as a possible factor for why those involved in an accident, incident, or close call chose not to cooperate. Some felt that FELA may have contributed to low cooperation by employees involved in accidents, incidents, or close calls.
- *Perceived minimal opportunity to conduct RCA*. Some perceived few opportunities to investigate accidents, incidents, or close calls due to the relatively safe diesel and car repair shop work environment.
- *Complex RCA tools and process*. At least one participant felt that the RCA tools and method may be too complicated and the training insufficient, and that these may have hindered participation.

Based on study participant feedback and pilot study experience, the researchers make the following recommendations to increase the likelihood of success of any future attempt at implementing a joint management-labor RCA process:

- *Expand study to all yard crafts*. Any future study should be opened up to include the entire yard environment, including train and engine employees. This strategy will increase the number and types of opportunities to conduct RCA. This will require initial stakeholder buy-in from additional labor unions, such as the United Transportation Union and Brotherhood of Locomotive Engineers and Trainmen.
- *Draw on the railroad's safety committee(s) to provide study participants, and use the safety committee venue to discuss, raise awareness of, and select RCAs to pursue*. Incorporate the study as a task for the participating railroad's safety committee(s) to take on. Safety committee members could serve as representative labor and management participants, and accidents, incidents, and close calls that are brought to the attention of the safety committee could serve as possible candidates for RCA.
- *Communicate information about the study to, and solicit cooperation from, all railroad employees*. The participating railroad should increase communication to all yard employees about the study. The participating railroad might consider posting a general notice to all employees to: inform them about the project; ask employees to notify participating labor or management representatives about any accident, incident, or close call they were involved in; ask employees to cooperate in any RCA process; and encourage employees to cooperate and make it clear that their participation is sanctioned by both labor and management. Participating labor unions may also consider posting a similar notice to their members. Enhancing the process of communicating the existence of accidents, incidents, and close calls to study participants will help ensure that few opportunities are missed due to omissions or delays.
- *Train participating labor and management representatives to better recognize RCA opportunities*. The combination of expanding the study to all crafts and increasing the ability of participants to recognize RCA opportunities will improve the overall likelihood of successfully completing a number of RCAs.
- *Identify one labor representative and one management representative to be study champions*. Select one labor representative and one management representative as the overall study co-chairs whose jobs are to act as a conduit of information and serve as study administrators. These two chairs could have specific roles, such as identifying RCA opportunities, assigning participants to conduct the RCA, communicating information to their relative constituents (labor and management), and performing general problem solving. These chairs could also act as liaisons among the participating railroad, labor organizations, and researchers, in case assistance is needed or questions arise.
- *Indemnify participating labor and management involved in RCA (both participants and involved employees) so that neither labor nor management can use information collected in the RCA against the other party*. Indemnification should reduce concerns over retribution and FELA. This, in turn, should increase the number of those who participate as labor and management participants and employees who have been involved in an

accident, incident, or close call. Indemnification may require some type of written agreement.

A number of obstacles impeded implementing the joint approach to RCA in the pilot study. These obstacles, however, do not necessarily indicate a complete failure of the process. Instead, the obstacles and pilot study experience highlight the challenges that must be addressed before future attempts are made at implementing a joint railroad management-labor approach to RCA of accidents, incidents, and close calls.

1. Introduction

This report describes the results of a 1-yr pilot examination of a joint railroad management-labor approach to RCA of accidents, incidents, and close calls in a railroad diesel and car repair shop environment. Accidents and incidents include collisions, derailments, employee-on-duty injuries, and other incidents that result in some type of harm to railroad property, infrastructure, or personnel. Close calls are events that narrowly avoid resulting in an accident or incident. Close calls share similar contributing factors with events that result in some type of harm; the primary difference is that some type of defense, or barrier, helped to avoid a negative outcome.

RCA is a methodical approach to accident, incident, and close call investigation that enables one or more individuals to systematically identify individual, organizational, technological, and situational factors that contributed to an accident, incident, or close call. A guiding principle behind RCA is that accidents, incidents, and close calls are not caused by one event. Rather, multiple factors play a role in every accident, incident, and close call, and each is important in mitigating future occurrences.

The primary goal of this pilot effort focused on obtaining feedback on the utility and value of this approach for the railroad industry.

1.1 Background

Safety in the railroad industry has improved markedly over the last decade. The total accident/incident rate in the railroad industry has fallen from 26.37 per mtm in 1996 to 17.39 in 2005.[4] In addition, employee injuries (including fatal) have declined. According to FRA data,[5,6] in 1996, 9,199 railroad employees were injured while on duty and an additional 33 killed. By 2005, the number of employee-on-duty injuries declined to 5,557, and fatalities totaled 25. Additional analysis shows, however, that while the total accident/incident rate, as well as employee injuries, has decreased, the number and rate of strictly train accidents has increased over this time period. In 1996, 2,443 train accidents (3.64 train accidents per mtm) occurred, and in 2005, this number rose to 3,152 (3.99 train accidents per mtm).

Furthermore, accidents/incidents are costly. For example, job-related injuries cost American railroads over $1 billion annually (Transportation Research Board, 1994). American railroads do not operate under workman's compensation statutes. When a railroad employee is injured, depending on the circumstances, he or she may submit an injury claim to the railroad, which, in turn, chooses either to pay the injured employee or to litigate the case. Though only a small number of claims reach the courtroom, the litigation costs to the railroads are high, and the legal process often delays settlements to injured employees.

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[4] SOURCE: FRA Office of Safety data retrieved from http://safetydata.fra.dot.gov/OfficeofSafety/Query/Default.asp?page=statsSas.asp June 9, 2006.

[5] Ibid.

[6] SOURCE: FRA Office of Safety data retrieved from http://safetydata.fra.dot.gov/OfficeofSafety/Query/Default.asp?page=castab.asp June 9, 2006.

To reduce the number and severity of accidents/incidents and thereby increase railroad safety and reduce costs associated with accidents/incidents, it is imperative to understand the diverse set of circumstances and characteristics (i.e., the contributing factors) that allow accidents/incidents to occur. One of the most effective means of understanding the circumstances and characteristics of accidents/incidents is through the appropriate design and use of RCA.

This report describes the results of a 1-yr pilot examination of a joint management-labor approach to RCA of accidents, incidents, and close calls in a railroad diesel and car repair shop environment.

1.2 Objectives

The primary objective of this research was to gain an understanding of the potential for railroads and labor to jointly conduct human factors-based RCA investigations of accidents, incidents, and close calls to uncover contributing factors at various levels of the railroad system. Neither the volume of cases investigated nor the raw data were of primary interest in this project. Rather, the focus of the project was on participant feedback on implementing the RCA methods and tools, as well as the utility of the approach for the railroad industry in general. Ideally, human factors RCA would eventually become a standard and acceptable practice in the railroad industry.

The specific objectives of this research project were to:

- Assist the railroad industry in identifying contributing factors to accidents, incidents, and close calls beyond the employee.
- Obtain industry and labor feedback on the value and utility of the RCA methods and tools.
- Examine the usefulness of a modified version of HFACS in the railroad industry to support accident, incident, and close call investigations.

1.3 Overall Approach

To implement a joint management-labor RCA process, researchers first identified a location where labor and management were co-located, since the project involved both. Researchers identified the diesel and car repair shop operating environment as a candidate study environment because management and labor are co-located and this environment hosts a variety of skilled craft workers, providing access to a variety of job types and numerous and varied work experiences throughout each day.

Researchers invited representatives from several railroads and labor unions, as well as FRA, to participate in a stakeholder meeting in April 2004. Discussions of the project goals and methods were a part of this informational meeting. One railroad and four labor unions subsequently agreed to participate in the pilot study. Each labor union identified one local member to participate in the study, while the railroad identified several candidates to support the project.

A set of paper-based tools, based on HFACS-RR, guided management and labor investigators through the data collection and analysis process. A 2-d training session, conducted at the host railroad with management and labor representatives in November 2004, introduced the study participants to the RCA methods and tools. The training served to educate and familiarize

participants, some of whom had not attended the stakeholder meeting, on the principles of RCA, HFACS-RR taxonomy of human error, and specific RCA tools and methodology for data collection and analysis.

The initial data collection period lasted 6 mo, from November 10, 2004, to May 10, 2005. Due to the lack of RCA conducted in the first 6 mo, researchers extended the data collection period an additional 6 mo, to the end of November 2005. Researchers developed a debriefing questionnaire for use at the conclusion of the study to elicit, from study participants, the merits of the joint RCA process and tools, as well as possible next steps.

1.4 Scope

Candidate RCA opportunities included all accidents, incidents, and close calls that occurred in the diesel and car repair shop environment, regardless of whether the event met FRA reporting criteria. The accident, incident, or close call had to occur in the diesel or car repair shop environment and involve a member of a participating union. Researchers excluded events where FELA might be involved. Otherwise, study participants chose which events to investigate using the RCA process and tools.

1.5 Organization of the Report

This report has several sections. Section 2 discusses the methods used in the pilot study. Section 3 contains the results. Section 4 presents key findings and lessons learned from the pilot, and it also includes some recommendations for future research. Section 5 contains a list of references used in the conduct of this study. The report includes a number of appendices. The first six appendices contain the RCA data collection and analysis tools (job aids) developed for use in the pilot study. Specifically, Appendix A presents a copy of the data collection checklist. Appendix B presents the interview questions: one each for operators, frontline supervisors, and senior level managers. Appendix C presents the five HFACS-RR flowcharts (one for each of the five HFACS-RR levels) that were aids to data collection and analysis. Appendix D presents an HFACS-RR analysis worksheet that was designed to aid participants. Appendix E presents a set of corrective actions mapped to specific HFACS-RR categories. Appendix F presents an incident report form. Appendix G presents a set of post-study questions that were designed to obtain participant feedback regarding the RCA process and tools. A list of abbreviations and acronyms used in the report follows the last appendix.

2. Methods

This section presents the methods used in the study. First, Section 2.1 provides a description of RCA—the overall philosophy behind the study. Next, Section 2.2 describes HFACS, an accepted taxonomy of human error. Section 2.3 describes a slightly modified version of HFACS (HFACS-RR); HFACS-RR provides the backbone and structure to the data collection and analysis. Section 2.4 then describes a number of RCA tools developed for this project for collecting and analyzing accident, incident, and close call data. Researchers hosted an initial stakeholder meeting to share the study's objectives and methods; Section 2.5 contains details of the stakeholder meeting. Section 2.6 describes a 2-d training period provided to participants. Finally, Section 2.7 details the data collection procedures for the accidents, incidents, and close calls investigated.

2.1 RCA

RCA is a method of accident, incident, and close call investigation (data collection) and analysis that enables investigators or researchers to identify individual, organizational, technological, and situational factors that contributed to an accident, incident, or close call. RCA is a qualitative approach to understanding accidents, incidents, and close calls that complements quantitative analysis of large descriptive accident, incident, and close call databases. A guiding principle behind RCA is that a single event does not solely cause accidents, incidents, and close calls. Rather, multiple factors play a role in every accident, incident, or close call. RCA is a process used to methodically and objectively shed light on these contributing factors; many of which are otherwise difficult to find or are not readily identifiable in larger accident, incident, and close call databases.

RCA examines active and latent factors. Active factors are those decisions, conditions, or other aspects that are closest in time and physical space to the accident, incident, or close call. Traditionally, active factors are most often cited as the cause of an accident, incident, or close call (for example, an operator's errant press of the wrong button on a remote control device). On the other hand, latent factors (decisions or conditions) often exist for years and may never be identified as a safety issue unless they are subject to examination. An example might be a poor interface design for a piece of equipment or an unsafe operating practice.

The basis of RCA is the tenet that the immediate act that precedes an accident, incident, or close call is simply the last step in a series of events that led to the occurrence. RCA focuses on unwinding the tape to explore all of the systemic factors that led to the accident, incident, or close call. To do this, one examines individual, organizational, technological, and situational factors. Each of these factors can be, and often is, at least partly responsible for providing a situation conducive to the accident, incident, or close call's occurrence. RCA yields complex and rich information regarding the likely contributors to an accident, incident, or close call, possibly leading to a more complete understanding of organizational safety.

An important element of RCA is its nonpunitive nature. An operator often bears the blame for an accident, incident, or close call because the operator is associated most recently in time and most closely in space with the last event that goes wrong. This punitive approach to accident, incident, and close call investigation, referred to as the bad apple theory by Dekker (2002), seeks

to fix the problem by blaming the employee. Taken to its extreme, management removes the employee from service or fires him/her. Thus, the problem appears to be fixed. Given that this approach does not remedy any real systemic problems, however, other employees are likely to repeat the same unsafe act for which their coworker received discipline.

Human error is much more complex. In fact, as Petersen (2003, p. 28) notes in a discussion of human error, "Human errors at lower levels of the organization are symptoms of things that are wrong in the organization at higher levels." Furthermore, James Reason, a leading expert in the field of human error theory, notes,

> …human error is a consequence not a cause. Errors…are shaped and provoked by upstream workplace and organizational factors. Identifying an error is merely the beginning of the search for causes, not the end. The error, just as much as the disaster that may follow it, is something that requires an explanation. Only by understanding the context that provoked the error can we hope to limit its recurrence (Reason, 1997, p. 126).

Since errors "are shaped and provoked by upstream workplace and organizational factors," a basic tenet of RCA is that it seeks to identify a broad range of factors that may have contributed to an accident, incident, or close call, from an individual operator's action or inaction to a senior-level executive decision that may have occurred several years before the event.

2.2 HFACS

To support the RCA, researchers necessarily identified an appropriate human error taxonomy to provide the framework for data collection and analysis. One particularly successful human error classification system is HFACS (Wiegmann and Shappell, 2003). HFACS has its basis in Reason's (1) GEMS and (2) Swiss cheese model of accident causation (Reason, 1990). The Swiss cheese model depicts accidents as arising from holes in an organization's defenses at various levels of the organization, beginning with the operator and working all the way up to organizational decisions and conditions. Active failures by the operator combine with latent conditions or factors upstream in the organization to lead to an accident (or incident or close call). Accidents (and incidents and close calls) occur, therefore, when all of the active and latent factors (i.e., holes) line up to allow accident energy (depicted as a straight line) to penetrate these various organizational levels. An organization's defenses and barriers can, however, prohibit the alignment of active and latent factors and conditions thereby preventing accidents (and incidents and close calls).

Wiegmann and Shappell (2003) originally developed HFACS as a classification system to help analyze U.S. naval aviation mishaps. HFACS was subsequently broadened to include commercial and general aviation domains as well. HFACS models error at four different levels, beginning with the operator and moving upward in the organization. The four levels mirror Reason's Swiss cheese model of error. The four levels of HFACS are unsafe acts (Reason's active failures—the operator activity that occurs closest in time and space to an accident, incident, and close calls), preconditions for unsafe acts, unsafe supervision, and organizational influences. These latter three levels relate to Reason's latent factors or conditions, and they often exist for years before they contribute to an accident, incident, and close call. For each level, Wiegmann and Shappell (2003) identified a number of second-level categories. Some second-level categories divide further into third-level categories. A total of 19 unique categories of

contributing factors exist. Figure 1 provides an overview of HFACS and conveys the structure of HFACS and the unique categories of contributing factors. HFACS applies Reason's Swiss cheese model of human error to an accident, incident, and close call classification system and provides a theory-driven structure to accident, incident, and close call investigation (i.e., RCA) findings. For a discussion of each unique category's definitions, see Wiegmann and Shappell (2003).

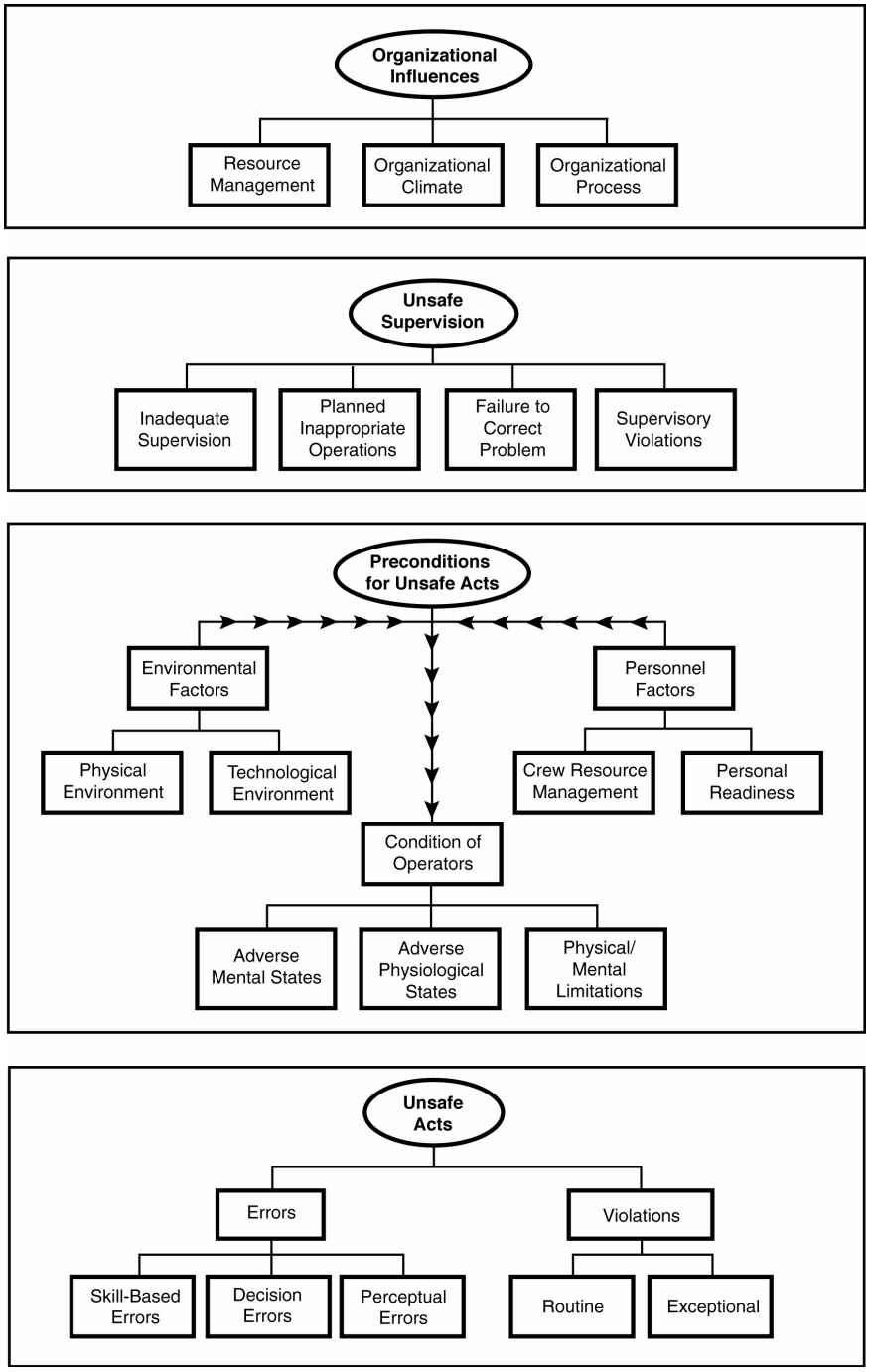

Figure 1. Original HFACS Taxonomy (Wiegmann and Shappell, 2003)

The use of a theoretically-driven RCA approach ensures that the accident, incident, and close call contributing factors identified during an investigation go beyond what happened to why an error occurred. Furthermore, such an approach allows for identifying the relationship between contributing factors more readily (for example, some types of errors may be linked to other types of contributing factors). Classifying errors based on their underlying theoretical nature enables identifying global trends across error forms, which on the surface may appear totally different. Consequently, and perhaps most importantly, one can identify corrective actions more readily to prevent errors and accidents, incidents, and close calls from recurring, since the data collected during the investigation highlight the underlying systemic problems that contributed to the events in the first place.

Historically, HFACS provided the means primarily to analyze data available from existing accident, incident, and close call investigations. However, HFACS was also a methodology that could guide accident, incident, and close call investigations and support collection of human factors-related information. Some Federal agencies, such as the U.S. Coast Guard and the U.S. Department of Defense, are now experimenting, using HFACS to support accident, incident, and close call investigations, as well as analysis (Wiegmann and Shappell, 2003; A. Carvalhais, personal communication, October 11, 2005).

Researchers selected HFACS to provide the theoretical backbone to RCA, given its logical structure and scientifically valid approach to human error. Furthermore, HFACS, as a classification system, is diagnostic, reliable, and comprehensive (Wiegmann and Shappell, 2003). This is critical since the taxonomy must accommodate a wide range of railroad operational situations and circumstances that can lead to accidents, incidents, and close calls. The initial use of HFACS was in the aviation domain. As a result, researchers made some minor changes to HFACS to optimize its relevancy to the railroad industry. The following section discusses these changes.

2.3 HFACS-RR

To ensure the best fit between HFACS and the railroad industry and to increase its acceptance within the railroad industry, researchers made several minor changes to HFACS. The overall tree structure of HFACS remained. The modified HFACS taxonomy has the label HFACS-RR. An advantage of the original HFACS is that it uses generic terms and descriptors that are applicable to a range of industries and activities. Although others have made minor alterations to HFACS to suit their particular application, for example, to address air traffic control (HFACS-ATC; Scarborough and Pounds, 2001) and military activities (Canadian Armed Forces or CF-HFACS; see Wiegmann and Shappell, 2003), most of the original HFACS taxonomy remains in HFACS-RR to preserve the original structure, thus facilitating future comparisons between data collected in this study and HFACS-based accident, incident, and close call analyses in other industries.

To begin, researchers softened the names of the top HFACS level to become more neutral. For example, unsafe acts of operators is now operator acts. Table 1 presents the original and modified terms.

Table 1. Original HFACS and New HFACS-RR Top-Level Categories

Original HFACS Top-Level Category	Modified HFACS-RR Top-Level Category
Unsafe acts of operators	Operator acts
Preconditions for unsafe acts	Preconditions for operator acts
Unsafe supervision	Supervisory factors
Organizational influences	Organizational factors

Researchers also added a new fifth level named outside factors to the HFACS-RR taxonomy. Outside factors include the regulatory environment and the economic/political/social/legal[7] environment in which railroads operate. Outside factors cover those influences outside the railroad or organization that affect how the organization operates and its decisions.

Other changes to the original HFACS taxonomy (and contained in the new HFACS-RR taxonomy) include the following:

- Replaced the term violations with the term contraventions throughout the HFACS-RR taxonomy to avoid stigma and biases associated with violations. Violations in the railroad industry are often associated strictly with (operating, safety) rules. Contraventions are more general short-cutting and rule-bending, and they may not necessarily be tied to violating a specific rule.
- Added a new subcategory under operator acts/contraventions called acts of sabotage. Acts of sabotage are related to the investigation only when the act is in response to a problematic organizational factor that is identified.
- Added fourth subcategory under the organizational factors category called organizational contraventions. This subcategory addresses upper level management and executive contraventions and short-cutting of existing organizational (i.e., internal) procedures or processes. This subcategory further addresses externally imposed municipal, State regulations, and Federal regulations. This category parallels supervisory contraventions and contraventions of the operators themselves.

Figure 2 presents the new HFACS-RR taxonomy with these modifications incorporated. The new HFACS-RR taxonomy contains a total of 23 unique categories of accident, incident, and close call contributing factors. Several of the 23 unique categories can be further classified (see Wiegmann and Shappell, 2003), if sufficient information exists to support the subcategorization:

- Skill-based errors can be subcategorized into attention failures, memory failures, and technique errors.
- Decision errors can be subcategorized into procedural errors, poor choices, and problem-solving errors.
- Resource management can be subcategorized into human resources, equipment and facility resources, and monetary/budget resources.

[7] The legal environment includes other-than-regulatory laws that affect railroad operations.

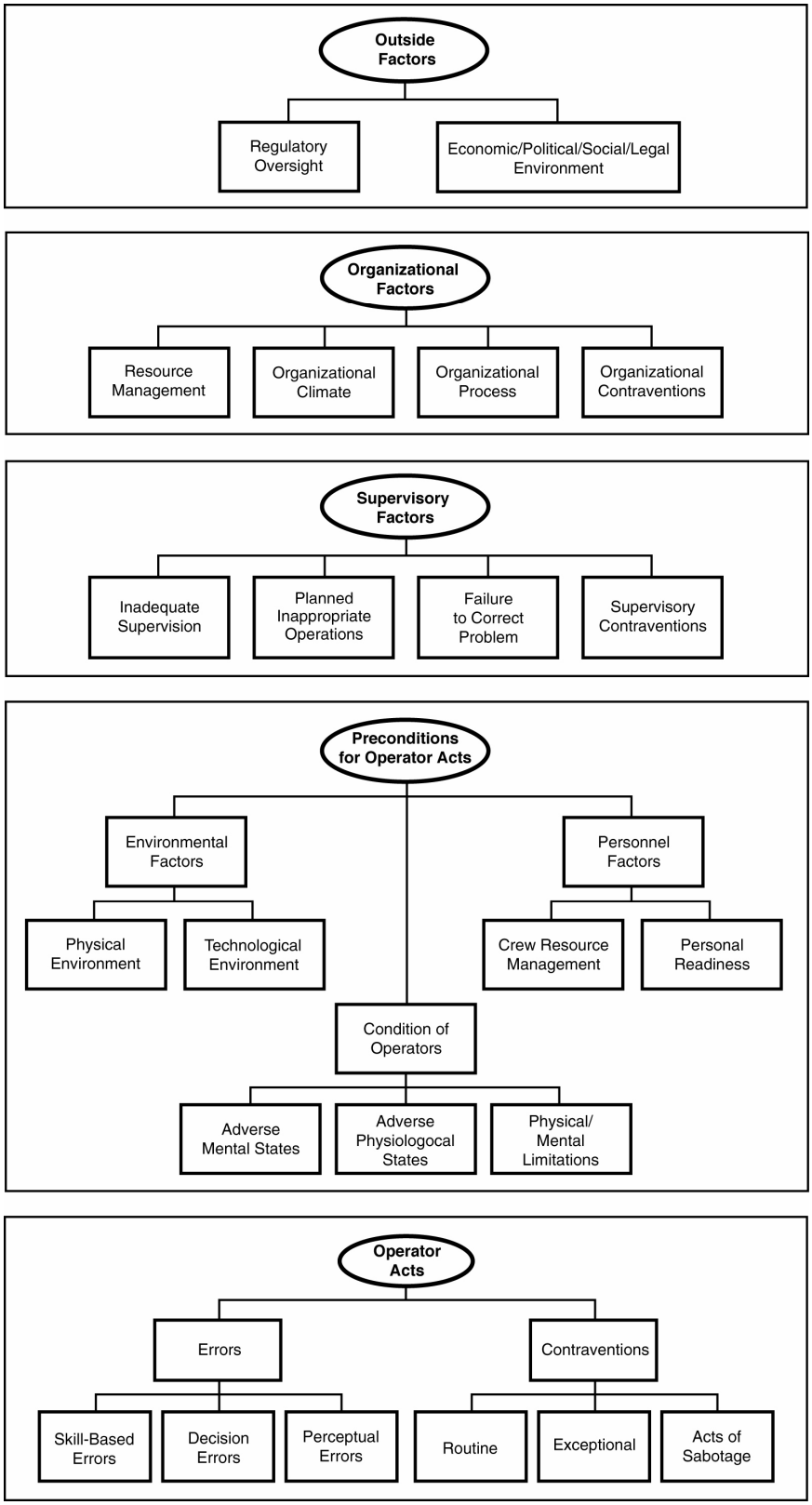

Figure 2. HFACS-RR

- Organizational climate can be subcategorized into organizational structure, organizational policies, and organizational culture.
- Organizational process can be subcategorized into organizational operations, organizational practices and procedures,[8] and organizational oversight.

Figure 3 reconfigures the five HFACS-RR levels according to their flow of influence. Influence flows from the outer levels toward the inner levels. That is, outside factors can influence all other HFACS-RR levels (organizational factors, supervisory factors, preconditions, and operator acts); organizational factors can influence supervisory factors, preconditions, and operator acts; supervisory factors can influence preconditions and operator acts; and preconditions can influence operator acts. This diagram pictorially shows how a number of contexts—preconditions, supervisory factors, organizational factors, and outside factors—can influence operator acts.

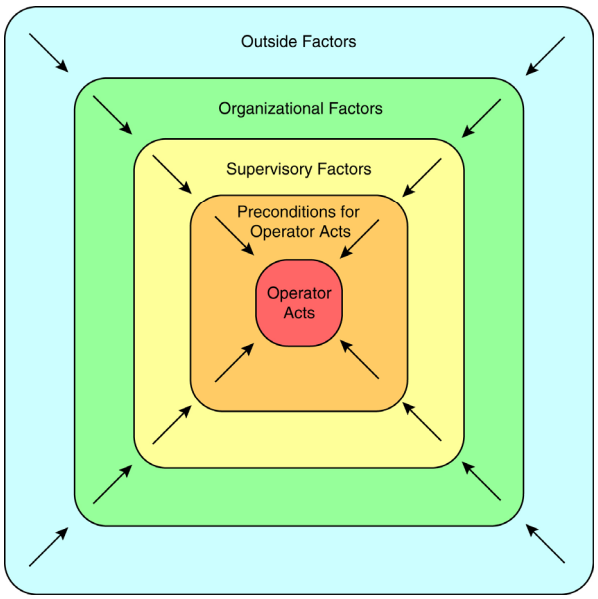

Figure 3. HFACS-RR Flow of Influence

Researchers used the RCA philosophy combined with the HFACS-RR structure to develop paper-based tools to guide management and labor investigators through the data collection and analysis process. The following section describes each of these tools.

2.4 Development of RCA Tools

Researchers developed a number of paper-based tools based on the HFACS-RR taxonomy and Reason's Swiss cheese model of human error. They designed tools to systematically guide

[8] Wiegmann and Shappell (2003) originally discuss procedures under the organizational influences/organizational process subcategory. The authors changed procedures to practices and procedures in the HFACS-RR taxonomy since many of the activities undertaken in a railroad switching yard environment involve practices (more broad methods of operation), rather than procedures, which are more specifically prescribed methods.

management and labor users through the RCA process, primarily focusing on data collection and analysis. Descriptions of each individual tool appear below.

2.4.1 RCA Primer

The RCA primer provides study participants with a theoretical background and overview of the pilot study. The primer briefly discusses the objectives of the study, RCA methodology, HFACS-RR taxonomy of human error, study methodology, and paper-based tools.

2.4.2 RCA Pilot Study Flowchart

The flowchart illustrated in Figure 4 conveys the overall process of conducting an RCA and served as a job aid to study participants. It presents the general flow of activities that were to take place when an accident, incident, or close call occurred during the pilot study.

2.4.3 HFACS-RR Diagram

The HFACS-RR diagram provides an overview of the human error taxonomy and aids investigators in systematically focusing on the five distinct error contribution categories: (1) operator acts (often referred to as active factors since they are the conditions, decisions, or other aspects that are closest in time and physical space to the accident, incident, or close call), (2) preconditions for these operator acts, (3) supervisory factors, (4) organizational factors, and (5) outside factors. Figure 2 presents the HFACS-RR taxonomy.

2.4.4 HFACS-RR Flow of Influence Diagram

Figure 3, which conveys the flow of influence among the five HFACS-RR levels, is part of the HFACS-RR worksheet described in Section 2.4.8. It serves as a job aid to support the theoretical understanding of how contributing factors at different levels of the organization influence each other.

2.4.5 Data Collection Checklist

This checklist (see Appendix A) contains a list of employee and railroad records and information that investigators may want to consider or otherwise examine as part of an RCA. It is a broad-based list designed to address a variety of possible accidents, incidents, or close calls. The list, however, is not exhaustive. The types of data of interest will depend on the circumstances of the particular accident, incident, or close call investigated. Investigators may pick and choose items from this checklist to help identify, prioritize, and eventually examine relevant information as part of the RCA.

2.4.6 Interview Questions

A series of three questionnaires (Appendix B) contain interview questions investigators may consider asking as part of the RCA. Much like the data collection checklist, each set of questions is broad-based to address a variety of possible accidents, incidents, or close calls. No set of questions is exhaustive. Rather, the questions serve to help investigators begin to consider factors at each of the five different HFACS-RR levels that may have contributed to the accident,

incident, or close call. The types of questions of interest will depend on the circumstances of the accident, incident, or close call being investigated. As with the data collection checklist, investigators can pick and choose questions from these questionnaires to guide interviews with employees, supervisors, and management. Investigators may also find that they have many other questions once they know the specifics of the accident, incident, or close call they are investigating. Researchers developed separate questionnaires for operators, frontline supervisors, and upper management.

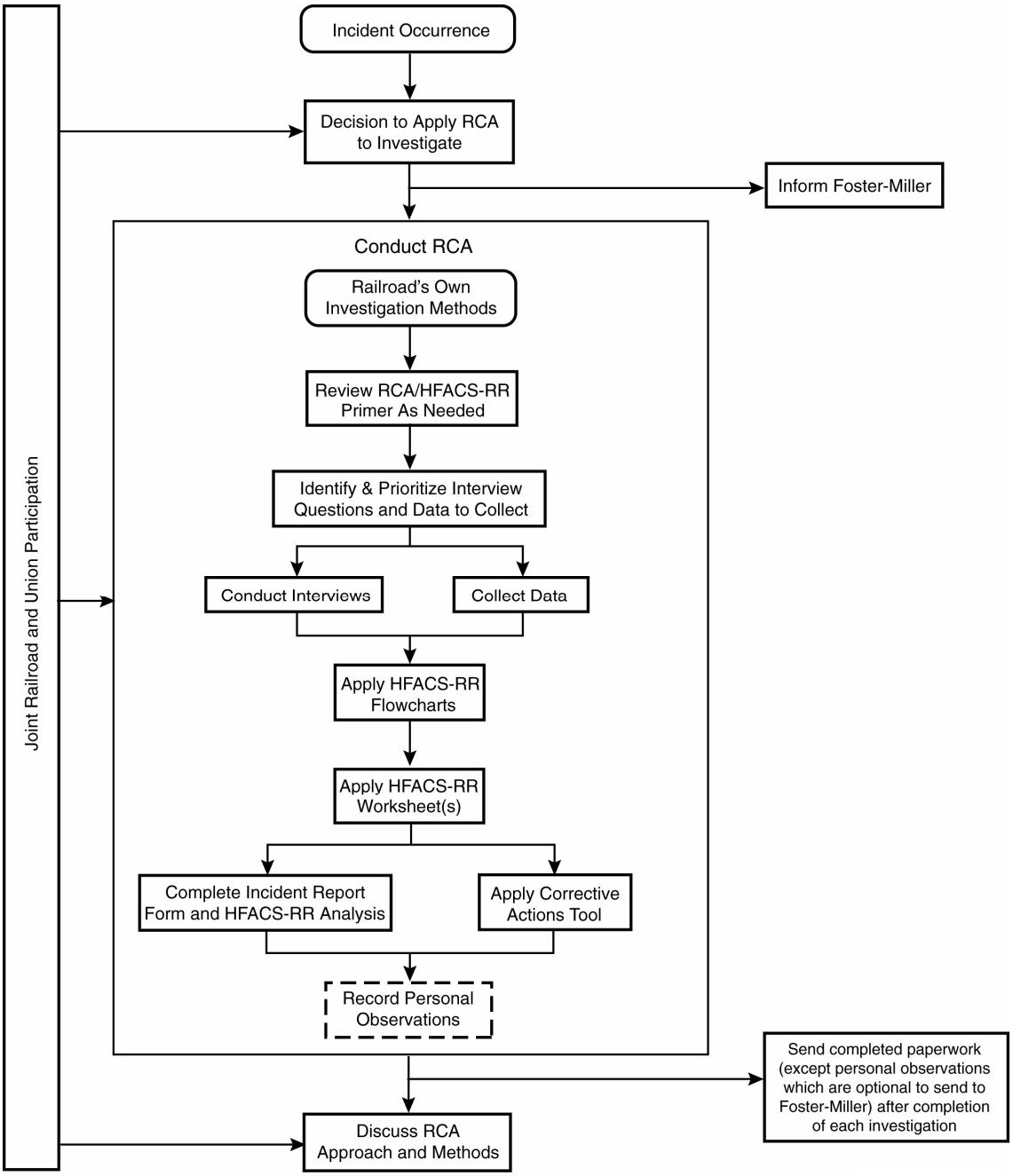

Figure 4. Pilot Study Flowchart

2.4.7 HFACS-RR Flowcharts

Researchers designed five flowcharts (see Appendix C) to help investigators look for and consider particular factors in each of the five HFACS-RR levels, as they relate to the accident, incident, or close call under investigation. The five flowcharts serve to guide both initial collection of information and analysis of the information. Use of these flowcharts enables investigators to think through potential contributing factors at each level of the organizational system during the data collection phase and the actual analysis. The flowcharts are helpful in ensuring that active and latent failures are at least considered, if not identified, as contributing to a particular accident, incident, or close call.

2.4.8 HFACS-RR Worksheet

The HFACS-RR worksheet (see Appendix D) helps investigators be as thorough as possible in the investigation and analysis. This worksheet requires the investigator to affirm whether or not each category contributed to the accident, incident, or close call. The worksheet first prompts an investigator to record all operator acts that have been identified as contributing to the accident, incident, or close call, and to include a brief explanation. Next, the worksheet prompts the investigator to consider preconditions for operator acts and determine whether factors at that level influenced the operator acts. The investigator then considers supervisory factors, organizational factors, and finally outside factors. For each level, the investigator must note whether or not any factors contributed to the accident, incident, or close call. Finally, for each contributing factor, he/she then must identify the corresponding HFACS-RR category.

2.4.9 Corrective Actions Guide

Five corrective action charts (see Appendix E) help to identify which, of 11, potential corrective actions may be used to mitigate contributing factors that are identified. One corrective action chart exists for each of the five HFACS-RR levels, and corrective actions map to specific HFACS-RR categories. The corrective action charts, which mirror the HFACS-RR flowcharts, and the mapping of corrective actions to HFACS-RR categories facilitate the identification of one or more appropriate corrective actions for each contributing factor that is identified.

2.4.10 Accident, Incident, and Close Call Report Form

The accident, incident, and close call report form (see Appendix F) is a top-level, two-page form that calls for basic descriptive information about the accident, incident, or close call that was investigated; this provides a matrix where the investigators can record their HFACS-RR analysis of the accident, incident, or close call. Investigators complete this form at the conclusion of each RCA investigation.

2.4.11 Post-Study Feedback Questionnaire

The researchers developed a set of post-study feedback questions (see Appendix G) to elicit feedback on the usefulness and value of the RCA methods and paper-based tools to support joint labor-management accident, incident, and close call investigations in the railroad industry.

2.5 Stakeholder Meeting

Researchers invited FRA, five railroads, and six labor unions that represent diesel and car repair shop employees to participate in an initial stakeholder meeting in April 2004. The purpose of this meeting was to share the study's objectives and methods with potential participants. Researchers explained the benefits of participation, which included a more thorough understanding of factors that contribute to diesel and car repair shop accidents, incidents, and close calls; and an improved ability to identify these factors, improved safety, and potentially improved labor-management relations. Participants discussed challenges and concerns of conducting this type of study in an operational setting, and the researchers encouraged attendees to express their ideas for how to successfully implement this project. Ultimately, one railroad and four labor unions agreed to participate in the pilot study.

2.6 Study Participant Training

The authors conducted a 2-d training session at the host railroad with management and labor representatives in November 2004. The training served to educate and familiarize participants—some of whom had not attended the stakeholder meeting—on the principles of RCA, the HFACS-RR taxonomy of human error, and the specific RCA tools and methodology for data collection and analysis. The training also included the opportunity to review public National Transportation Safety Board (NTSB) investigations as examples and practice mapping NTSB-identified contributing factors to HFACS-RR categories using the flowcharts and other RCA tools.

2.7 Data Collection Procedures

Candidates for RCA included all accidents, incidents, and close calls that occurred in the diesel and car repair shop environment. These include both FRA-reportable and non-reportable accidents and injuries. The accident, incident, or close call had to occur in the diesel or car shop environment and must have involved a member of a participating union. Occurrences where FELA might be involved were not candidates for study.

A particular union's participation in the RCA was dependent on which employee was involved in the occurrence. If an accident, incident, or close call involved an electrical worker, for example, then a labor representative from that craft worked with one local management representative to investigate the occurrence. If an occurrence involved a member of another union (for example, a sheet metal worker), then the labor representative for that craft participated in the investigation alongside railroad management.

Participating labor and management also agreed that if the railroad would routinely conduct an investigative hearing following the particular accident, incident, or close call, this hearing would be waived unless criminal activity was involved. If criminal activity were a factor, then railroads and labor could elect a traditional approach to investigating. The goal of bypassing the routine investigation was to facilitate an open rapport between the railroad and employees involved in the accident, incident, or close call under investigation.

Researchers encouraged participants to limit the duration of each investigation to 8-12 hours (h) per investigator. This was considered a reasonable amount of time to spend on each RCA given that study participants still needed to tend to their regular job responsibilities. Once labor and

management made a decision to investigate an accident, incident, or close call, the study participants-turned-investigators used the RCA tools to guide data collection and analysis.

The original methodology required one management representative and one labor representative to jointly conduct each RCA. The representative that participated in a particular RCA depended on who was involved in the accident, incident, or close call. If a carman was involved in an accident, then the carman representative participated. If a sheet metal worker was involved, then the sheet metal worker representative participated, and so on. During the initial training, however, both labor and management agreed in empowering labor to conduct each RCA while management representatives would be available to assist as needed.

Researchers planned to conduct a feedback meeting at the end of the data collection period. The purpose of this meeting was to discuss the advantages and disadvantages of the RCA process/tools used in the pilot study, parts of the process/tools that were liked and disliked, and suggested changes to facilitate employing this approach in the railroad industry on a larger scale. To prepare for this meeting, researchers asked participants to record personal observations of the process and tools throughout the pilot study. This end-of-study debriefing meeting never occurred due to a number of barriers that were encountered during data collection. The next section discusses the results of the study along with these barriers.

3. Results

This section presents the results of the RCA study. Participants identified a total of seven RCA opportunities. One RCA was performed among these seven opportunities. Section 3.1 presents the seven opportunities that study participants identified. More specifically, Section 3.1.1 presents a brief description of the six RCA opportunities that were not investigated, while Section 3.1.2 presents the details and the results of the single RCA.

A number of barriers prevented more successful implementation of the RCA process, including failure to identify additional RCA opportunities. Section 3.2 describes a number of participant-identified barriers to more successful RCA implementation and presents their suggestions for future implementation. The section concludes with some additional participant observations on the utility and application of the RCA tools and method to the railroad industry.

3.1 Accidents, Incidents, and Close Calls

Study participants identified 7 RCA opportunities during the 1-yr study period. Opportunities consisted of six employee injuries and one close call. Participants conducted a single RCA for one of the injuries. Section 3.1.1 describes the six opportunities that were not investigated. Section 3.1.2 presents the single event that was investigated using RCA.

3.1.1 Accidents, Incidents, and Close Calls Not Investigated

Participants identified 6 RCA opportunities that they did not investigate during the 1-yr study period. Brief descriptions of each of the six opportunities include the following:

1. An employee was replacing a brake shoe when the truck moved. This was a close call, but no injuries occurred. This event occurred just before the start of the study, so participants used this case as their first RCA. In the RCA interview the employee was unable to recall details or information pertaining to the occurrence.
2. An employee injured his back replacing brake shoes. The employee was using a pry bar to free the brake rigging from the wheel when he slipped and complained of back pain. The employee refused medical treatment, and no railroad incident report was filed. It was not clear whether or not this individual was actually injured at work. Due to the lack of clarity regarding the injury, labor participants did not pursue this incident. The incident subsequently became a reportable work-related injury when the individual took time off for the injury.
3. A carman was injured while crossing on-track equipment. The employee relates that he crossed over on a walkway of a covered hopper; he swung around to the side ladder and stepped down to the ground. As he did so, he said he lost his balance putting his foot on an obstruction in the walkway, probably a brake shoe, which caused him to twist around to the left, hitting his head on the side of the car. The labor representative who was going to participate was out of town and thus not immediately available. In addition, a temporary fall-out between management and labor occurred around the same time.

4. A carman pinched his finger using a hand tool. A railroad management representative attempted to conduct an RCA alone several months later, but the injured employee became uncomfortable so the RCA was terminated.
5. A carman struck his head on a grab iron while dismounting a car.
6. A diesel shop machinist ground off part of his right index finger proximal to distal phalanx and lacerated a tendon. The machinist was holding a washer in his hand against the side of the pedestal grinding wheel. While exerting force with his hand to push the washer against the wheel, his work kicked off the grinder.

3.1.2 Slip/Trip/Fall RCA

The one incident that was investigated jointly by one management and one labor representative involved a slip/trip/fall injury to a carman described in the following paragraph.

> The employee was walking from a vehicle across the 42/43 switch, carrying an end-of-train (EOT) device toward a main on track 39. The employee was carrying the 25-pound (lb) EOT device on his right shoulder. He stepped with his left foot over the south end of the rail switch at heel of point. The employee stated he was not aware that the ground was lower than the ties, and his left foot went about 4 inches (in) down farther than he anticipated. He caught himself and touched the south rail with the toe of his right foot. The employee felt the south main track in his left side lower back. He continued work after the incident and reportedly felt fine. He later reported the incident to the company around 2 p.m. after he felt pain at rest while eating lunch. He declined medical attention.

The investigation took the labor and management representatives approximately 2 h to complete. Labor and management jointly identified five contributing factors associated with three of the five HFACS-RR levels. Table 2 summarizes the HFACS-RR analysis.

Following the RCA, the participating labor and management representatives recorded their feedback regarding the RCA tools and approach. They found the HFACS-RR flow of influence diagram helpful in explaining the purpose of the study to the injured employee. Feedback suggests that the HFACS-RR flowcharts were also helpful. The participating labor and management representatives read the flowchart questions aloud to the employee or otherwise reviewed them as the interview proceeded. They noted that the flowcharts were valuable in assuring that everything was covered.

3.2 Barriers to Implementation and Suggestions for Future Implementation

By the end of the first 6 mo of the study period, it was apparent that significant barriers existed to successful implementation of the RCA process and tools, even on a pilot basis. To learn more, researchers contacted participating labor and management representatives via telephone to obtain their feedback and opinions to better understand barriers to implementation and solicit suggestions for how to improve the process and chances of success in the future. The researchers used several questions from the end-of-study debriefing survey to help identify study barriers and suggestions for future implementation.

Table 2. Results of HFACS-RR Analysis

General HFACS-RR Category	Occurrence	Specific HFACS-RR Category
Operator Acts	Slip, trip, fall. Lack of attention to condition of footing in switch.	Skill-based error/attention failure
Preconditions	Carrying EOT device (25 lb) on shoulder creates additional balance issue if footing is not 100 percent. Ballast between ties lower than ties. Not looking ahead despite clear view understanding footing/ [loss of] situational awareness.	Environmental factors/technological environment Environmental factors/physical environment Condition of operators/adverse mental state
Supervisory Factors	None.	
Organizational Factors	Employee spent the first part of the shift retrieving EOT devices in yard before he could work outbound trains. Employee says he was not hurried.	Resource management/equipment/facility resources
Outside Factors	None.	

3.2.1 Barriers to Implementation

This section presents labor and management-identified barriers related to participation in the study. A majority of the barriers relate to the RCA process. Identified barriers included the following:

- *Awkwardness interviewing a co-worker*. Participants noted that it was awkward approaching and interviewing a co-worker involved in an accident, incident, or close call.
- *Minimal opportunity to investigate accidents, incidents, or close calls*. The diesel and car repair shop environment is one of the safer railroad work environments. Consequently, few opportunities (accidents, incidents, or close calls) existed to conduct RCA.
- *Lack of a study champion*. Several participants noted that, although labor and management officials supported the study at higher levels of their respective organizations, no single champion was onsite to ensure that RCAs were conducted and that the study succeeded. In one example, participants initiated the RCA process, but one of the participants was subsequently pulled in other directions and did not return to followup. Consequently, participants did not perform the RCA. Separately, some participants observed that a change in upper management (not the management participant) part-way through the study appeared to change the tone of the organizational culture and may have led to a shifting of the railroad's priorities.
- *Lack of study participant (i.e., labor representative) availability.* The absence of one study participant who was going to conduct a particular RCA resulted in a delay in implementation and eventually a lost opportunity to conduct the RCA.

- *Need for coordination of multiple schedules.* The need to coordinate multiple schedules made it difficult to bring specific study participants and the involved employee together to conduct RCAs.
- *Inadequate communication.* Two separate communication issues existed. First, a lack of communication existed about the study in general to diesel and car repair shop employees not participating in the project, regarding their roles of notifying study participants of any accidents, incidents, or close calls. For example, some employees who were involved in, or knew of any incidents, were not aware of the study, and they therefore did not know to contact a study participant. Second, inadequate communication also existed between participating management and labor. Some labor participants did not hear about particular accidents, incidents, or close calls, or they heard about an event only through the grape vine.
- *Concern over management retribution.* Several participants noted that fear of retribution or embarrassment may have caused involved employees to not want to participate and share information. Separately, one study participant explained that he was never interested in the project because he felt that retribution for participating would occur. Consequently, this participant did not involve himself in the study subsequent to the November 2004 training.
- *FELA*. FELA may have impacted the willingness of labor representatives and employees involved in an accident, incident, or close call to participate.
- *Overly complex RCA tools and method*. Some participants noted that a reluctance or hesitation may have existed to participate by some because the RCA tools and method may have been too complicated, or some study participants may have lacked a full understanding of the principles of RCA and human factors. At least one participant also suggested that the one-time skills training session at the beginning of the study may not have been adequate to fully prepare participants.
- *Unclear nature of one particular accident, incident, or close call*. In one case, participants were unclear at the time of the event whether or not the incident occurred on the job. The injured employee refused medical treatment, and, as a result, study participants did not pursue the incident. Subsequently, management treated the injury as a reportable work injury. Although the nature of the injury is not specifically related to the RCA process or tools, it did create a barrier to carrying out RCA in this particular instance.

3.2.2 Suggestions for Future Implementation

Labor and management offered a number of suggestions to make future RCA implementation successful. All suggestions are process-oriented improvements.

- *The study needs a champion.* Some study participants suggested that railroad management take a more active role in leading the project and make it clear that management encourages participation by labor representatives and involved employees. Another suggestion was for union officers to demonstrate a clear leadership role because otherwise analysis of one employee's actions by another union employee may not be

feasible. Participants felt that participating management and labor representatives must take the study and process seriously.

- *Whoever is first available among labor representatives should investigate.* Because the railroad is small and the work environment is common, most people know one another across craft lines; consequently, craft distinction is not a significant issue. Therefore, no need exists to match the labor representative with the craft of the individual involved in the accident, incident, or close call. This will avoid problems due to delays in identifying the right people to conduct a particular accident, incident, or close call RCA investigation.
- *Identify safety committee members who can participate in the study as labor representatives since safety committee members are clearly interested in determining causes of accidents, incidents, and close calls and finding solutions.* This is in contrast to the pilot study, where participating labor union officers chose a member of their organization to participate as a labor representative in the study.
- *Use accident, incident, and close call data posted on bulletin boards each week as candidate opportunities to conduct RCA.* Safety data posted on bulletin boards have recently become a source of regular communication from management to employees about yard safety each week. This information could be a starting point for identifying candidate cases for RCA.
- *Use previously investigated accidents, incidents, and close calls as a source of candidate RCA opportunities*. Include one of the participating labor representatives during an official investigation of an accident, incident, or close call, or enable labor representatives to conduct the RCA immediately after railroad management collects their own data for their own accident/incident investigation. If labor representatives are not available, then brief them immediately after the investigation or as soon as possible.
- *Improve communication about the accident, incident, or close call to participating labor representatives.*
- *Gain the trust of those employees involved in the accident, incident, or close call, and ensure that information provided by these employees will not be used against them.* Participants suggested that this may require more than a verbal agreement.

3.2.3 Observations on the Utility and Application of the RCA Tools and Method to the Railroad Industry

Lastly, several participants offered observations on the RCA tools and process that did not clearly fall into the categories of barriers or suggestions for future implementation. These observations related to the utility and application of the RCA methodology to the railroad industry. Participant observations included the following:

- *One participant felt that the RCA tools and method focus too much on blaming individuals rather than on identifying contributing causes*. This participant explained that the host railroad's current process of accident, incident, and close call analysis does not delve into sources of operator error (e.g., technique error) as much as identifying contributing causes (e.g., training issue). According to this participant, the current

railroad approach identifies significant human factor causes, and more complicated or systemic human factor issues are handled as retraining or process adjustments with minimum reference to a particular individual, thus getting away from fixing too much blame. This participant also felt that the railroad's current approach helps to reach consensus in the field so that leadership can move away from blaming someone and implement improvements and prevention strategies as quickly as possible.

- *This process may be better suited to other, more complex operating environments where a higher degree of human input exists.* Examples include dispatching and signal work, where the process could be used to identify sources of error in these environments.
- *The value of the RCA process is in proportion to the value of the severity of the accident, incident, or close call*. As one participant observes,

> At an abstract level, experienced accident investigators know that the difference between a bumped head getting off a car and a fall, and a much more serious injury can be infinitely small in time or space. The 'accident pyramid' is an accepted concept. But application of the RCA for smaller accidents, incidents, or close calls does not seem to yield the insights per hour invested that a quick but thorough interview can yield.

4. Key Findings, Lessons Learned, and Recommendations for Future Research

Section 4 is organized into three sections. Section 4.1 presents key findings from the study, including participant-identified barriers and suggested improvements for future implementation. Next, Section 4.2 discusses some additional lessons learned. These include barriers to the current study and suggestions for future implementation beyond those identified by labor and management participants. Finally, Section 4.3 discusses recommendations for future implementation. Recommendations are based on what has been learned in this study in order to increase the likelihood of success in the future.

4.1 Key Findings

Participating labor and management representatives helped identify a number of barriers that made it difficult for the project to succeed in its current form. Participant-identified barriers focused on the study's process for identifying candidate RCA opportunities and collecting data. Many of these process issues were related to the interaction between participants or between participants and involved employees. A positive consequence of participants' abilities to identify specific barriers is that they were also able to identify specific suggestions for overcoming these barriers in future implementations of the RCA process.

Key themes among barriers identified include the following:

- *Lack of leadership.* Participants felt that labor and management lacked strong leadership to ensure the study's success.
- *Poor interaction and communications*. Participants noted that it was awkward to interview a co-worker as part of the RCA process. Participants also noted inadequate communication from some study participants to other diesel and car repair shop employees about the study, as well as from management to labor participants about the existence of accidents, incidents, or close calls.
- *Challenges associated with participation*. Participants observed several barriers related to their own participation and that of employees involved in an accident, incident, or close call. Participants identified a lack of participant availability for one RCA and difficulty coordinating multiple participant and employee schedules to conduct RCAs. In addition, concern over management retribution was a factor for one participating labor representative who chose not to support the project after the training. The same concern was noted as a possible factor for why those involved in an accident, incident, or close call chose not to cooperate. Some felt that FELA may have contributed to low cooperation by employees involved in accidents, incidents, or close calls.
- *Perceived minimal opportunity to conduct RCA*. Some perceived few opportunities to investigate accidents, incidents, or close calls due to the relatively safe diesel and car repair shop work environment.
- *Complex RCA tools and process*. At least one participant felt that the RCA tools and method may be too complicated and the training insufficient, which may have hindered participation.

Participant suggestions for future RCA implementation specifically addressed barriers that were identified. Key themes among these suggestions include the following:

- *A need for effective leadership and communication exists*. Participants suggested the study needs champions, and suggestions included both labor and management leadership. Other related suggestions include improving communications about the incidence of accidents, incidents, and close calls to participating labor representatives; gaining the trust of those employees involved in the accident, incident, or close call; and ensuring that information provided by these employees will not be used against them.
- *Improve the process for identifying who participates in the study*. Participants suggested several improvements to the selection process, including selecting labor participants from within the safety committee and allowing whoever is first available among labor representatives to conduct the RCA; the process used in the pilot study was to match the craft of the labor representative to the craft of the involved employee (e.g., if a carman were injured, then the carmen labor representative was responsible for conducting the RCA).
- *Increase awareness of opportunities to conduct RCA*. Participants identified several ways to increase awareness of opportunities to conduct RCA, including using accident, incident, and close call data posted on bulletin boards each week as opportunities to conduct RCA and using officially investigated accidents/incidents as a source of RCA opportunities.

4.2 Additional Lessons Learned

Additional lessons learned included:

- *Researchers not being co-located with the study limited their effectiveness to provide oversight to the RCA process*. The distance between the researchers' location and the study site precluded close oversight of the study, possibly influencing participation by study participants and those employees involved in an accident, incident, or close call. A local researcher's presence could have assisted some RCA by facilitating interviews or making employees more comfortable and, in general, could have served as a more effective study champion. Researchers' offers to make telephone calls or sit in meetings were generally ineffective.
- *Empowering labor to be solely responsible for identifying RCA opportunities and conducting RCA was not effective.* At the start of the study, rail management empowered participants to be solely responsible for identifying the accidents, incidents, or close calls and conducting the RCA. However, a variety of barriers prevented this from being an effective strategy. In fact, labor and management jointly performed the single RCA that occurred. Because management is in the best position to first learn about accidents, incidents, or close calls, and because they are in the best position to influence people and make critical decisions about resources used in the study, researchers recommend that future attempts to implement RCA employ management and labor jointly from the start.

4.3 Recommendations for Future Implementation of a Joint Labor-Management RCA Process

Based on study participant feedback and pilot study experience, researchers make the following recommendations to increase the likelihood of success of any future attempt at implementing a joint management-labor RCA process:

- *Expand study to all yard crafts*. Any future study should include the entire yard environment, including train and engine employees. This strategy will increase the number and types of opportunities to conduct RCA. This will require initial stakeholder buy-in from additional labor unions, such as the United Transportation Union and Brotherhood of Locomotive Engineers and Trainmen.
- *Draw on the railroad's safety committee(s) to provide study participants, and use the safety committee venue to discuss, raise awareness of, and select RCAs to pursue*. Incorporate the study as a task for the participating railroad's safety committee(s) to take on. Safety committee members could serve as representative labor and management participants; accidents, incidents, and close calls that are brought to the attention of the safety committee could serve as possible candidates for RCA.
- *Communicate information about the study to, and solicit cooperation from, all railroad employees*. The participating railroad should increase communication to all yard employees about the study. The participating railroad might consider posting a general notice to all employees to inform them about the project; ask employees to notify participating labor or management representatives about any accident, incident, or close call they were involved in; ask employees to cooperate in any RCA process; and encourage employees to cooperate and make it clear that their participation is sanctioned by both labor and management. Participating labor unions may also consider posting a similar notice to their members. Enhancing the process of communicating the existence of accidents, incidents, and close calls to study participants will help ensure that few opportunities are missed due to omissions or delays.
- *Train participating labor and management representatives to better recognize RCA opportunities*. The combination of expanding the study to all crafts and increasing the ability of participants to recognize RCA opportunities will improve the overall likelihood of successfully completing a number of RCAs.
- *Identify one labor and one management representative to be study champions.* Select one labor representative and one management representative as the overall study co-chairs whose jobs are to act as a conduit of information and serve as study administrators. These two chairs could have specific roles, such as identifying RCA opportunities, assigning participants to conduct the RCA, communicating information to their relative constituents (labor and management), and performing general problem solving. These chairs could also act as liaisons among the participating railroad, labor organizations, and researchers, in case assistance is needed or questions arise.
- *Indemnify participating labor and management involved in RCA (both participants and involved employees) so that neither labor nor management can use information collected in the RCA against the other party.* Indemnification should reduce concerns over retribution and FELA, thereby increasing the number of those who participate as labor

and management participants and employees who have been involved in an accident, incident, or close call. Indemnification may require some type of written agreement.

4.4 Conclusions

The goal of this pilot study was to evaluate the feasibility of railroad labor and management jointly conducting their own RCA of accidents, incidents, and close calls using a set of data collection and analysis tools that were developed for this project. The focus of the study was on determining the utility and value of the joint approach to RCA, including the RCA process and tools. Clearly a number of obstacles impeded successful implementation of the RCA methodology. These obstacles, however, do not necessarily indicate a failure of the process, but rather, highlight challenges that must be addressed before future attempts are made to implement a joint railroad management-labor approach to RCA of accidents, incidents, and close calls. There was limited evaluation of the RCA tools due to the lack of opportunity to apply them. The limited feedback on the utility and value of the RCA tool was both positive and negative. While some participants suggested that the tools may have been complex, at least one participant noted that the tools were helpful in explaining the purpose of the study to an individual interviewed in an incident and in ensuring complete application of the RCA methodology. The one complete RCA demonstrated further utility in the tools. Labor and management participants were able to identify 5 contributing factors associated with 3 of the 5 HFACS-RR levels, while requiring only 2 h to complete the investigation. Although a number of barriers to successful implementation of RCA existed in this pilot study, there are indications that this methodology could be successful once these barriers are removed.

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Appendix A.
Data Collection Checklist

The data collection checklist contains a list of employee and railroad information that investigators may want to consider or otherwise examine as part of RCA. It is a broad-based list designed to address a variety of possible accidents, incidents, and close calls, but it is not exhaustive. Investigators can pick and choose items from this checklist to help identify, prioritize, and eventually examine relevant information as part of the RCA.

Researchers attempted to categorize each checklist item into one of the five different HFACS categories, but often an item could be categorized into two or more HFACS categories depending on the information collected. For example, work schedule and rest information could be related to a precondition (personal readiness, say, if an employee did not get enough sleep the night before because he was out late with friends) or a supervisory factor (if, for example, work scheduling is the issue). Consequently, the following checklist items are simply listed based on whether the information pertains to (1) the employee or (2) the carrier and the accident, incident, or close call.

- Employee information
    - Time employee(s) went on-duty before accident, incident, or close call.
    - Number of hours on duty at time of accident, incident, or close call.
    - Hours of service/work schedule records for previous 30 days for employees involved in accident, incident, or close call. For each of the last 30 days, collect information on:
        - Date and time on-duty
        - Date and time off-duty
    - Qualification dates for employee(s) involved in accident, incident, or close call.
    - Dates and performance data related to employee training and his/her most recent rules test.
    - Number of efficiency tests performed in last 12 months, and of these how many were related to the circumstances involved in the accident, incident, or close call. How many of the tests over the last 12 months did the employee pass and fail?
        - Date and outcome of most recent efficiency test? Related to the accident, incident, and close call?
    - Information on any prior infractions, discipline, and commendations.
- Carrier and accident, incident, and close call information
    - All relevant operating and safety rules that were in effect at the time of the accident, incident, or close call.
    - Copies of any Special Instructions, General Notices, General Orders, General Bulletins, Superintendent Instructions, and/or Division special orders and instructions that supersede or augment timetable and rulebook authority, that were

in effect at the time of the accident, incident, or close call and that were relevant to the accident, incident, or close call in any way.

- Copy of any work orders used at time of accident, incident, or close call.
- Overview of the training program(s) received by employee(s) involved in the accident, incident, or close call.
- Copy of employee statements and initial carrier report.
- Copy of photographs of accident, incident, or close call.
- PPE worn and condition of PPE.
- Work equipment inspection and maintenance logs and record books.
- Rolling equipment (cars, locomotives, and other rail vehicle) inspection and maintenance logs and record books.
- Work equipment operating instruction manuals/guides.
- Rolling equipment operating instruction manuals/guides.
- Maintenance/inspection procedure checklists, guides, aids, manuals, and directions.

Appendix B.
Interview Questions

Researchers developed three questionnaires to aid investigators in probing accidents, incidents, and close calls. Each questionnaire focuses on a different level of the organization; within each questionnaire, researchers organized questions by HFACS-RR level. The first interview questionnaire addresses issues related to the operating employees. The second questionnaire addresses front-line supervisors. The third questionnaire focuses on senior-level managers within the organization. Much like the data collection checklist, each questionnaire is broad-based and addresses a variety of possible accidents, incidents, and close calls, but it is not exhaustive. Rather, questionnaires should help investigators to begin to consider factors at each of the five different HFACS-RR levels that may have contributed to the accident, incident, or close call. Questionnaires begin on the following page.

Operator Interview Questionnaire

Starter questions

1. Imagine yourself back at the incident. Think about where you were, what you saw, what you heard, what you smelled, what you felt. Please tell us about what happened, starting at the beginning. Try to be as specific as possible regarding times and locations and landmarks when describing the events for us. We would like to hear all of the details, regardless of how important you think they are. Start whenever you are ready and take as much time as you would like.
2. Who else was nearby or involved? Where were they located? What were they doing?
3. Describe the workday leading up to the incident. Did you have any rest breaks the day of the incident?

Operator Acts

1. Was your task during the time of the incident routine to you? Did you have prior experience with this task?
2. Is there more than one way you could have completed the task? What are they?
3. Were there any distractions at the time of the incident?
4. Were there any explicit operating and safety rules that governed your activity leading up to the incident? What were they? How helpful are they? Did you take any short-cuts? Is this common?
5. What PPE were you wearing? Who provides your PPE—you or the railroad?

Preconditions

1. Prior to the incident when did you last work?
2. What was your work schedule during the previous 3 d? What were your other activities during this 3-d period?
3. When did you go to sleep each of the previous 3 nights? When did you wake up? Did you feel well rested?
4. Is your work schedule regular or irregular?
5. Is your work schedule predictable (i.e., known ahead of time) or are you on-call?
6. Were you working an unusual schedule the day the incident occurred?
7. How many consecutive days, including the day of the incident, had you worked?
8. Approximately how many days in the last month did you work?
9. When are your days off? When was your last vacation and how many days was it?

10. How was your workload on the day of the incident? Were there any time pressures or incentives to work faster?
11. What was the condition of the equipment when you began your shift? Did you have any problems with any of the equipment? Did you or other employees ever complain about the condition of the equipment to supervisors?
12. What was the condition of the PPE? Was the PPE adequate?
13. Describe the operating environment the day of the incident—what was the weather like, temperature, noise, visibility, etc.
14. What was the mood of the other employees before the incident?
15. Did you hold a job briefing at the beginning of the shift? What did it address? Do you hold a job briefing every day?
16. More generally, how would you describe the communication among employees the day of the incident? What about communication specifically among your own team, as well as between you and the supervisor on duty at the time of the incident?
17. In the past year:
    a. Have you had major changes in your health (good or bad)?
    b. Have there been major changes in your financial situation (good or bad)?
    c. Have there been major changes in your personal life (e.g., separation, divorce, birth, death, changes in the health of immediate family/close friends)?

Supervisory Factors

1. What was your training like? Please be as specific as you can. Was it sufficient? Who trained you? How much work experience did they have?
2. Do you feel you were adequately prepared to do your job at the end of your training? If not, why not?
3. Does any of your work involve coordination with other employees (i.e., do you work as part of a team)? If so, did you receive any training in crew resource management or any other type of communication and coordination among team members?
4. Has this sort of incident or problem happened before to anyone that you are aware of? Was it reported? Was something done to correct it?
5. How would you describe your supervision?
6. Have you ever been encouraged by a supervisor to cut corners or bend rules?
    a. Have you heard of others being encouraged to cut corners or bend rules?
    b. If rule bending occurs, is your supervisor aware of it?
7. Are you aware of your supervisor ever cutting corners, or disregarding a rule, procedure, or policy, to get something done on time, or for any other reason?

Organizational Factors

1. Do you feel that staffing in the shop is adequate?
2. Has workload level recently increased in the shop? To what do you attribute this?
3. How is safety communicated to you?
4. How would you describe the safety culture at your railroad?
5. How do you report safety-related problems or recommendations? Are your comments received well? Is there a way for you to bring up safety-related issues without fear of retribution, such as through a safety hotline? Do you find this effective?
6. Are there any barriers to you communicating with the people above you who influence your job?
7. What contact is there between top management and yourself or other employees?
8. How would you describe labor/management relations in the shop and at the railroad more generally?

Frontline Supervisor Questionnaire

Operator Acts

1. What should the operator(s) have done? Typically what would have happened?
2. What operating/safety/other rules, notices, special instructions, etc., govern the operator's activities just prior to the incident?
3. Did the operator violate a practice, rule or procedure? Which ones? Could you describe?
4. Is there more than one way the operator could have completed the task? What are they?

Preconditions

1. What was the condition of the equipment used to do the job? Describe how this equipment is maintained. Are there any problems with any of the equipment or parts known to you or others?
2. What PPE should the operator have been wearing at the time of the incident? What was the condition of the PPE at the time of the incident?
3. (If working in a team) Had the operators worked together before?
4. (If working in a team) Did the operators get along personally?
5. How did the operator get along with other operators working at the time?
6. Did anyone ever complain about working with this operator?

Supervisory Factors

1. Are supervisors (foremen, assistant supervisor, and superintendent) required to be current on all operating rules and procedures?
2. Have you ever been trained to use the equipment used in the incident? How many supervisors are qualified or otherwise familiar with the equipment in use at the time of the incident?
3. Please describe the training for the operator involved in the incident. Who trains the operators? What is the instructor's prior background and experience? What is the classroom portion of training like? What is on-the-job training (OJT) like? Is there any structure to OJT? How does the railroad determine when an individual is qualified? Are any formal checklists or other aids used?
4. Do you provide crew resource management or any type of communications training to operators who work in teams? What does it entail?
5. How do you track operator performance?
6. What is the performance record of the operator(s) involved in the incident? Has the operator been involved in any previous incidents?

7. Who investigates incidents, and what is involved (i.e., what is the process)? What does the investigation result in?
8. How many similar incidents have happened at this location? What has been done to correct the situation?

Organizational Factors

1. How does the railroad communicate safety information to operators (e.g., newsletters, videos)?
2. How would you describe the safety culture at this shop?
3. How much overtime is there at this shop? How does overtime work?
4. How would you describe labor/management relations at this shop?
5. How would you describe communication between you and your management?
6. Have you ever received pressure or encouragement from your supervisor or superior to bend rules or cut corners?
7. Has there been a large increase or decrease in staffing or workload recently? Can you describe it? To what do you attribute this increase or decrease?

Outside Factors

1. How much communication do you have with the FRA? What is the nature of this communication? How often are FRA inspectors onsite? What types of things do they look at/for?

Middle and Upper Management Questionnaire

Organizational Factors

1. In the past several years, has the railroad undergone a significant expansion or reduction of its operations? To what do you attribute this? Was this increase/decrease in staff or workload anticipated?
2. How would you describe labor-management relations?
3. What contact is there between your railroad's headquarters and your location?
4. Do you have a corporate safety office? What are its activities? Who does it report to?
5. How does your railroad communicate safety information to its employees (e.g., newsletters, videos)?
6. How are incidents investigated? Is there incident reporting and investigation? How and to whom are incidents reported?
7. Describe the railroad's safety program and management methods.
8. How does the company examine safety trends (good and bad) in the diesel and car repair shops?
9. Are you aware of similar incidents in other parts of your system?

Outside Factors

1. How much interaction does your railroad have with the FRA? How would you describe the relationship between your railroad and the FRA?
2. Are there any regulations or other outside influences such as the economy that you feel contributed, perhaps indirectly, to the incident? Please describe.

Appendix C.
HFACS-RR Flowcharts

Figures C-1 through C-5 depict five flowcharts designed to help investigators look for and consider particular factors in each of the five HFACS-RR levels as they relate to the accident, incident, or close call under investigation. These flowcharts enable investigators to think through potential contributing factors at each level of the organizational system during the data collection phase and the actual analysis. The flowcharts are helpful in ensuring that active and latent failures are at least considered, if not identified, as contributing to a particular accident, incident, or close call.

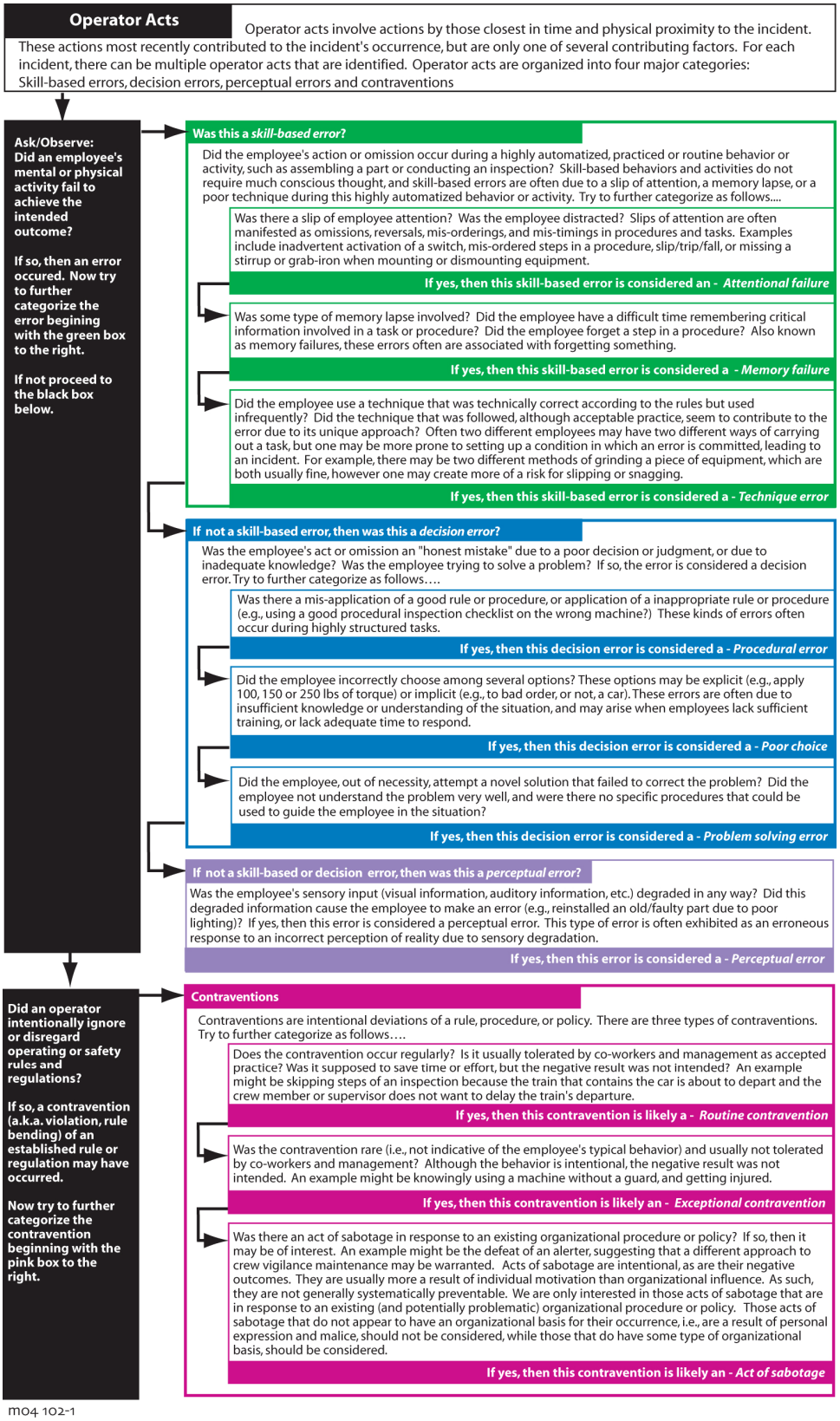

Figure C-1. Operator Acts Flowchart

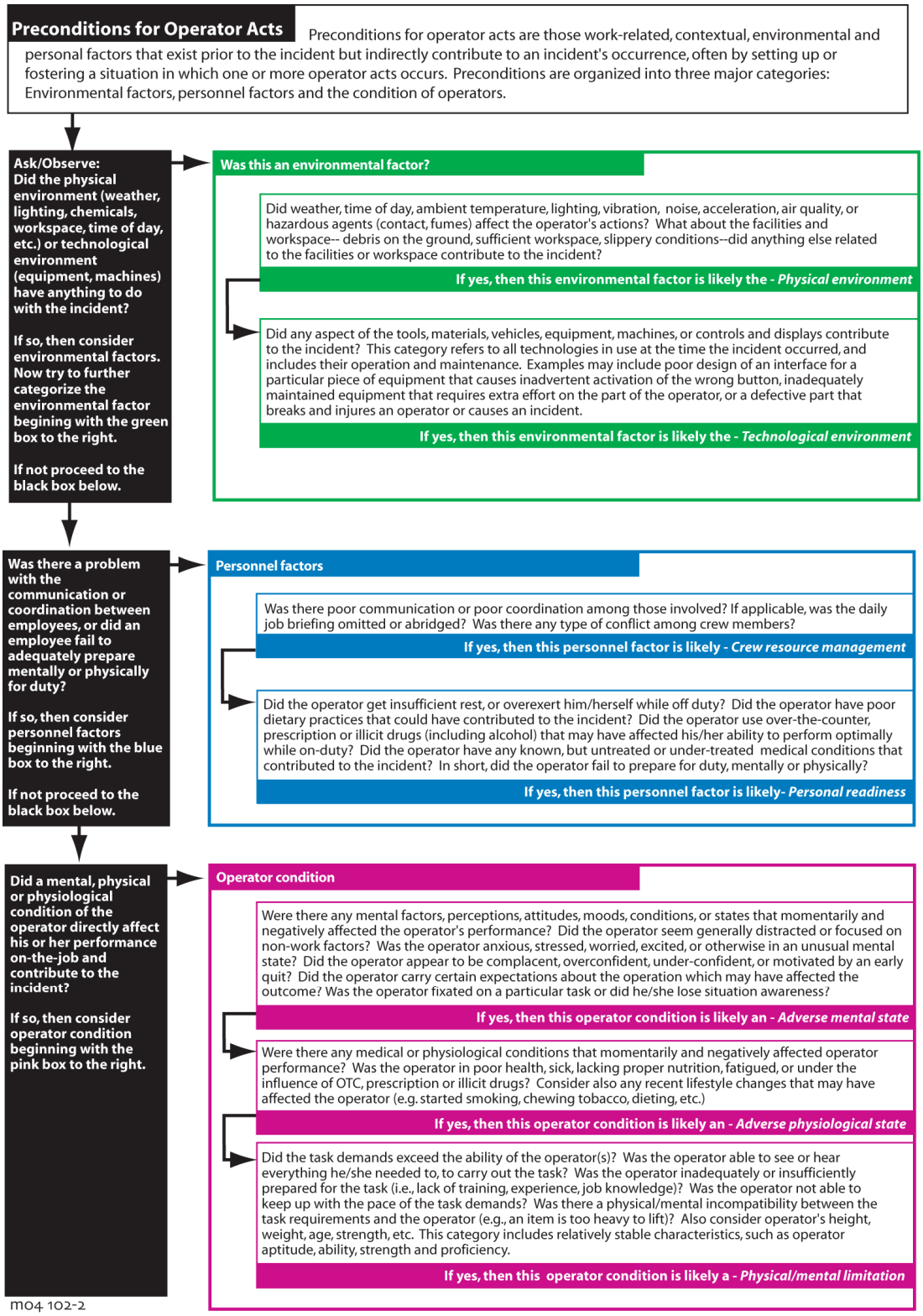

Figure C-2. Preconditions for Operator Acts Flowchart

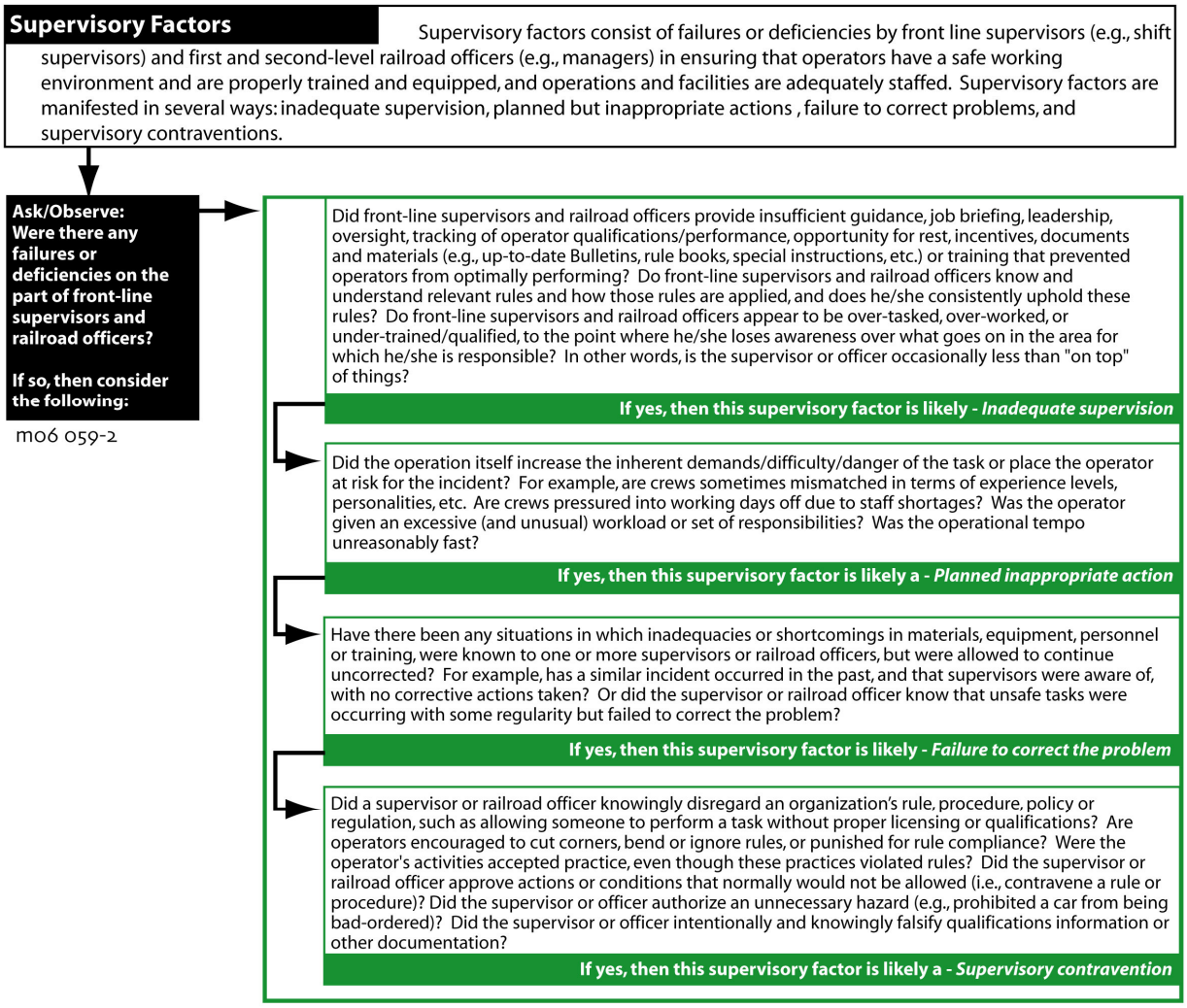

Figure C-3. Supervisory Factors Flowchart

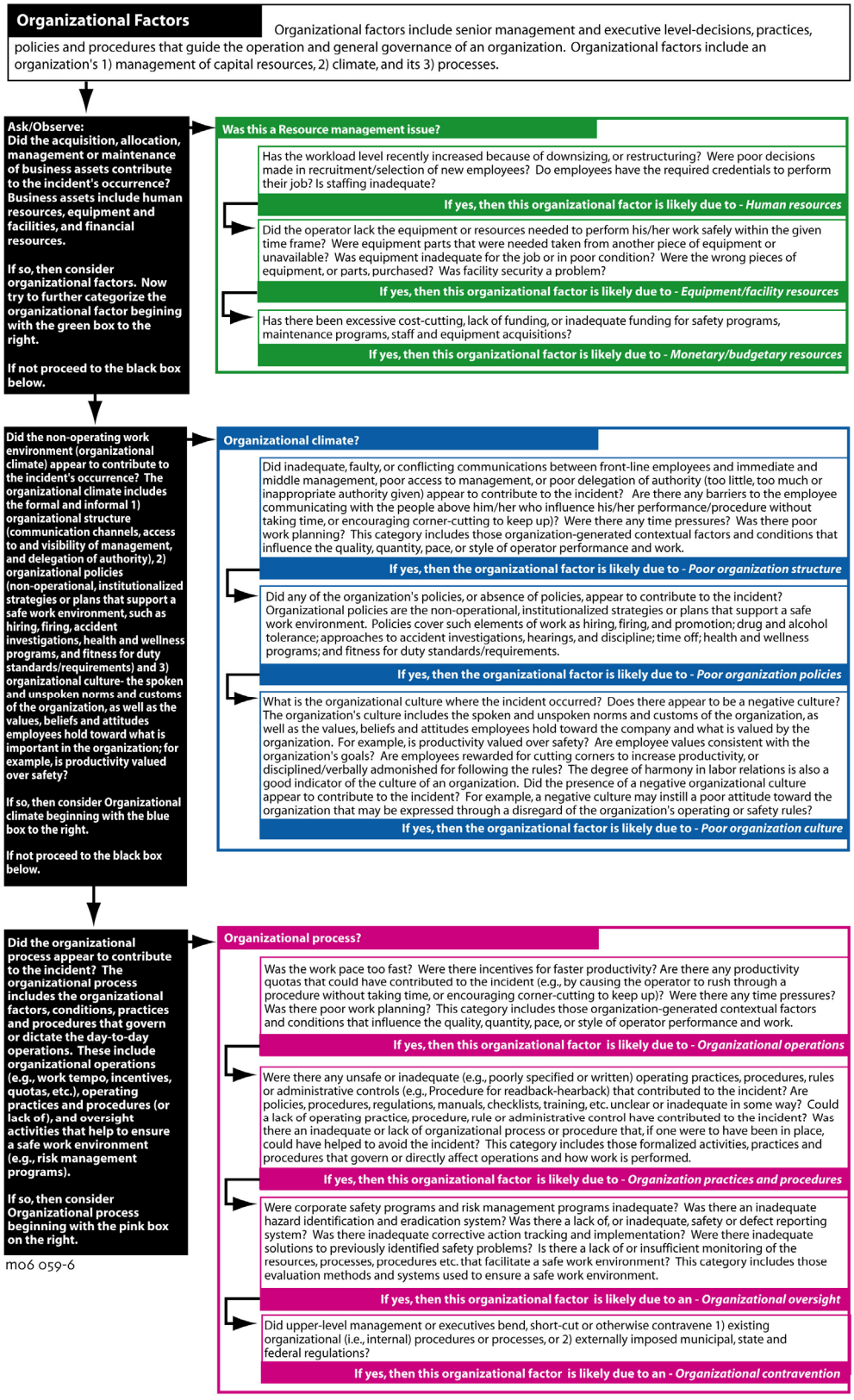

Figure C-4. Organizational Factors Flowchart

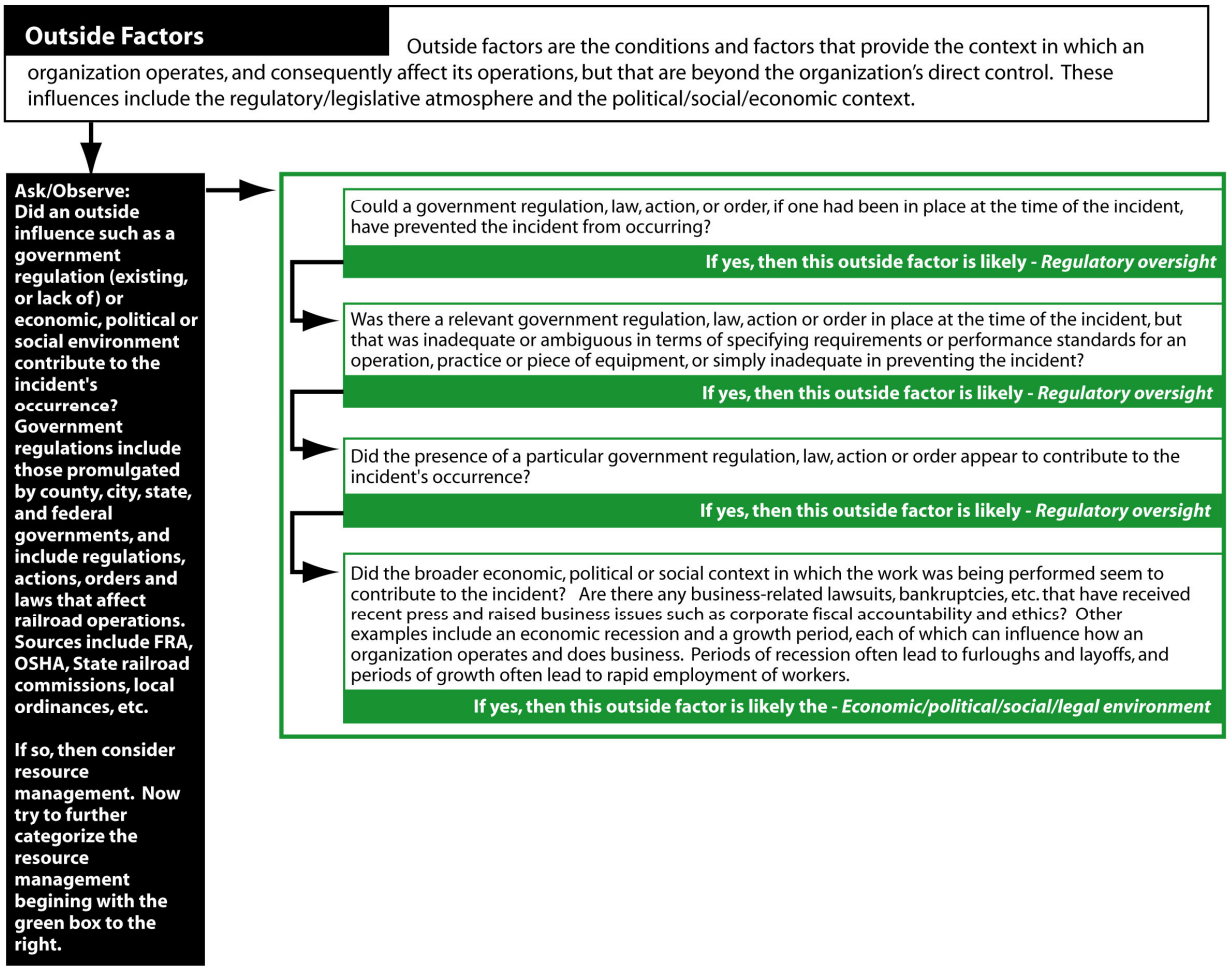

Figure C-5. Outside Factors Flowchart

Appendix D.
HFACS-RR Worksheet

The HFACS-RR worksheet helps investigators to be as thorough as possible in the investigation and analysis. The worksheet allows space for the investigator to note whether or not each unique HFACS-RR category contributed to the accident, incident, or close call. The worksheet also prompts investigators to list all contributing factors and map each contributing factor to the appropriate HFACS-RR category.

HFACS-RR Worksheet

Introduction: This worksheet has been prepared to aid you in exploring the deeper contributing factors related to the operator acts that have been identified. Using the operator acts as a starting point, this worksheet will help you consider each HFACS-RR category, and note whether or not each HFACS-RR category influenced or otherwise played a role in contributing to the incident. Although rare, it is possible that some operator acts do not have any higher level contributing factors associated with them. The majority of operator acts, though, will have several higher-level contributing factors.

To recap, the HFACS-RR is a model of human error that looks at incidents at five different, hierarchical categories. These five categories are operator acts, preconditions for the operator acts, supervisory factors, organizational factors, and lastly factors outside the organization (see Figure D-1). You will notice the flow of influence such that the outer boxes influence the inner boxes. For example, supervisory factors influence preconditions for operator acts and operator acts. As a second example, outside factors may influence all other categories, starting with organizational factors.

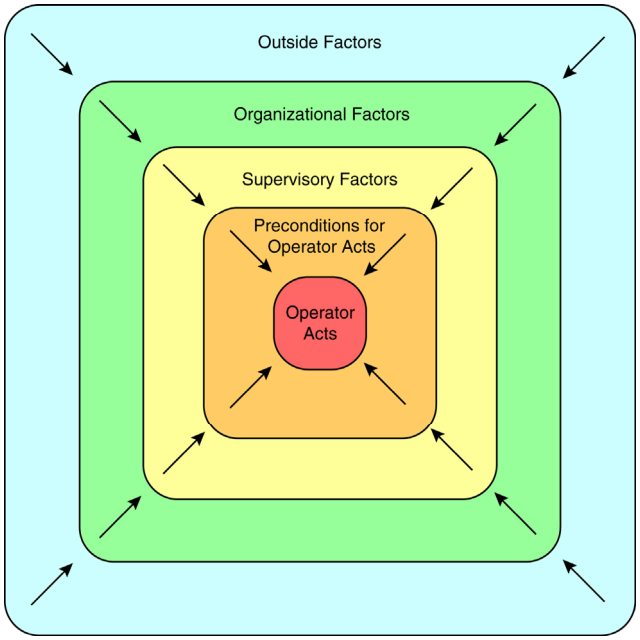

Figure D-1. HFACS-RR Flow of Influence

Instructions: Begin by recording all operator acts (the center of the diagram) that you have identified as contributing to the incident, and a brief explanation. For example, if a train crew passes an absolute stop signal, the operator act category might be *attentional failure* (a type of HFACS-RR operator act). Use the information you have collected to assign the most specific category of operator act that is possible. For example, if it is known that the train crew was responding to a call from a cell phone, then *attentional failure* might be identified as the HFACS-RR operator act. If the crew did not see the signal due to glare from the sun, on the other hand, this might be categorized as a *perceptual error*. You may choose to select a broader HFACS-RR category without further specification if you lack sufficient information to support your analysis. For example, if you are not sure the error was due to a memory failure or attentional failure, you might simply categorize the operator act as a skill-based error.

Next, review the HFACS-RR *preconditions for operator acts* (the next outer square), and think about whether any of the operator acts you have identified were influenced by any HFACS-RR preconditions. After you are done, consider supervisory factors, and whether any supervisory factors affected any preconditions or operator acts. Next, consider organizational factors, and whether any organizational factors affected or influenced any supervisory factors, preconditions or operator acts. Lastly, consider outside factors and whether any of these may have played a role in influencing any organizational factors, supervisory factors, preconditions or operator acts.

Please be sure to complete the entire worksheet.

Operator Acts

Operator acts involve actions or inactions by those closest in time and space to the incident—a train crewmember or shop employee, for example. These actions most recently contributed to the incident's occurrence, but they are only one of several factors that contributed to the incident. In fact, for each incident, there may be multiple operator acts that are identified.

Please list below all operator acts that you have identified as contributing to the incident. Use the HFACS-RR flow charts to assist you in categorizing each operator act.

HFACS-RR operator act 1: _____

HFACS-RR operator act 2: _____

HFACS-RR operator act 3: _____

HFACS-RR operator act 4: _____

Preconditions for Operator Acts

Preconditions for operator acts are those work-related, contextual, environmental and personal factors that exist prior to the incident but that indirectly contribute to an incident's occurrence, often by setting up a situation in which one or more operator acts occur. Preconditions are organized into three major categories: Environmental factors, personnel factors and the condition of operators.

Please confirm whether or not one or more preconditions contributed to any of the operator acts listed above. Note that more than one precondition can influence each operator act. For each precondition you have identified, please provide a brief explanation.

Environmental factors:

Physical environment: _____Yes _____ No

Technological environment: _____Yes _____ No

Personnel factors:

Crew resource management: _____Yes _____ No

Personal readiness: _____Yes _____ No

Operator Condition

Adverse mental state: _____Yes _____ No

Adverse physiological state: _____Yes _____ No

Physical/mental limitation: _____Yes _____ No

Explanation(s): _____

_____

_____

_____

_____

Supervisory Factors

Supervisory factors consist of failures or deficiencies by front line supervisors (e.g., shift supervisors, gang leaders) and first and second-level railroad officers (e.g., managers, foremen) in ensuring that operators have a safe working environment, are properly trained and equipped, and operations and facilities are adequately staffed. Supervisory factors are manifested in several ways: inadequate supervision, planned but inappropriate actions, failure to correct problems, and supervisory contraventions.

Please confirm whether or not one or more supervisory factors contributed to any of the preconditions or operator acts that you have identified. Note that more than one supervisory factor could have contributed to any precondition or operator act. For each supervisory factor that you have identified, please provide a brief explanation.

Inadequate supervision: _____Yes _____ No

Planned inappropriate operations: _____Yes _____ No

Failed to correct problem: _____Yes _____ No

Supervisory contraventions: _____Yes _____ No

Explanation(s): _____

_____

_____

_____

Organizational Factors

Organizational factors are senior management and executive level-decisions, practices, policies, and procedures that guide the operation and general governance of an organization. Organizational influences include an organization's 1) management of capital resources, 2) climate, and its 3) processes.

Please confirm whether or not one or more organizational factors contributed to any of the supervisory factors, preconditions or operator acts that you have identified. For each organizational factor that you have identified, please provide a brief explanation.

Resource management

Human resources: _____Yes _____ No

Equipment and facility resources: _____Yes _____ No

Monetary/budget resources: _____Yes _____ No

Organizational Climate

Poor organizational structure: _____Yes _____ No

Poor organizational policies: _____Yes _____ No

Poor organizational culture: _____Yes _____ No

Organizational Process

Organizational operations: _____Yes _____ No

Organizational practices and procedures: _____Yes _____ No

Organizational oversight: _____Yes _____ No

Organizational Contraventions: _____Yes _____ No

Explanation(s): _____

_____

_____

_____

_____

Outside Factors

Outside factors are the conditions and influences that provide the context in which an organization operates, and consequently affect its operations, but that are beyond the organization's direct control. These factors include the regulatory/legislative environment and the political/social/economic atmosphere.

Please confirm whether or not one or more outside factors contributed to any of the organizational factors, supervisory factors, preconditions, or operator acts that you have identified. For each outside factor that you have identified, please provide a brief explanation.

Regulatory oversight: _____Yes _____ No

Economical/Political/Social environment : _____Yes _____ No

Explanation(s): _____

_____

_____

_____

_____

Appendix E.
Corrective Actions Guide

Appendix E presents 5 corrective action guides and a set of definitions of 11 generic corrective actions. Corrective actions map to specific HFACS-RR categories. Researchers formatted the guides similar to the HFACS-RR flowcharts to increase their usability. Figure E-1 presents corrective actions relevant to operator acts. Figure E-2 presents corrective actions relevant to preconditions for operator acts. Figure E-3 presents corrective actions relevant to supervisory factors. Figure E-4 presents corrective actions relevant to organizational factors. Figure E-5 presents corrective actions relevant to outside factors. Lastly, Table E-1 presents definitions and examples of the 11 generic corrective actions.

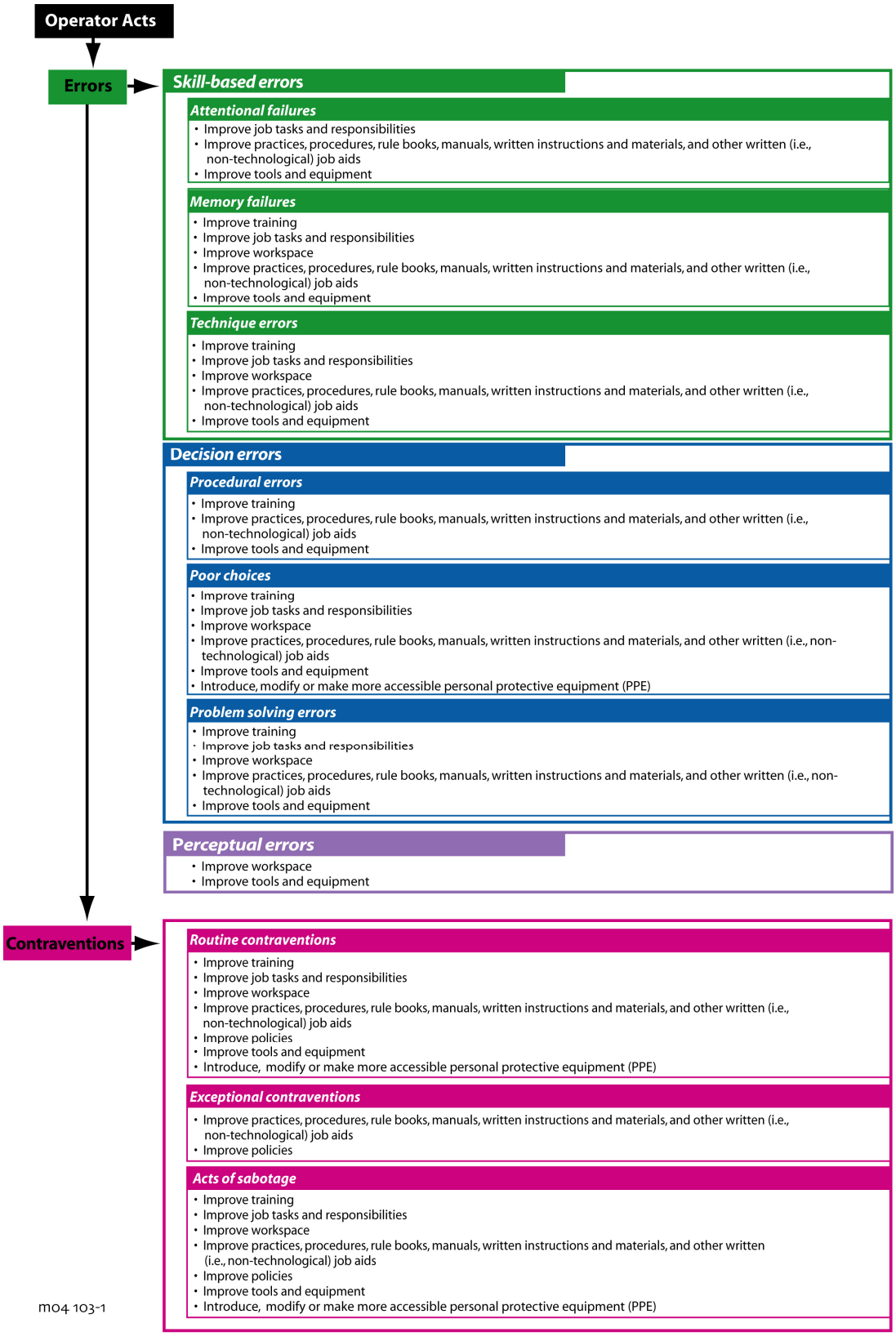

Figure E-1. Operator Acts Corrective Action Guide

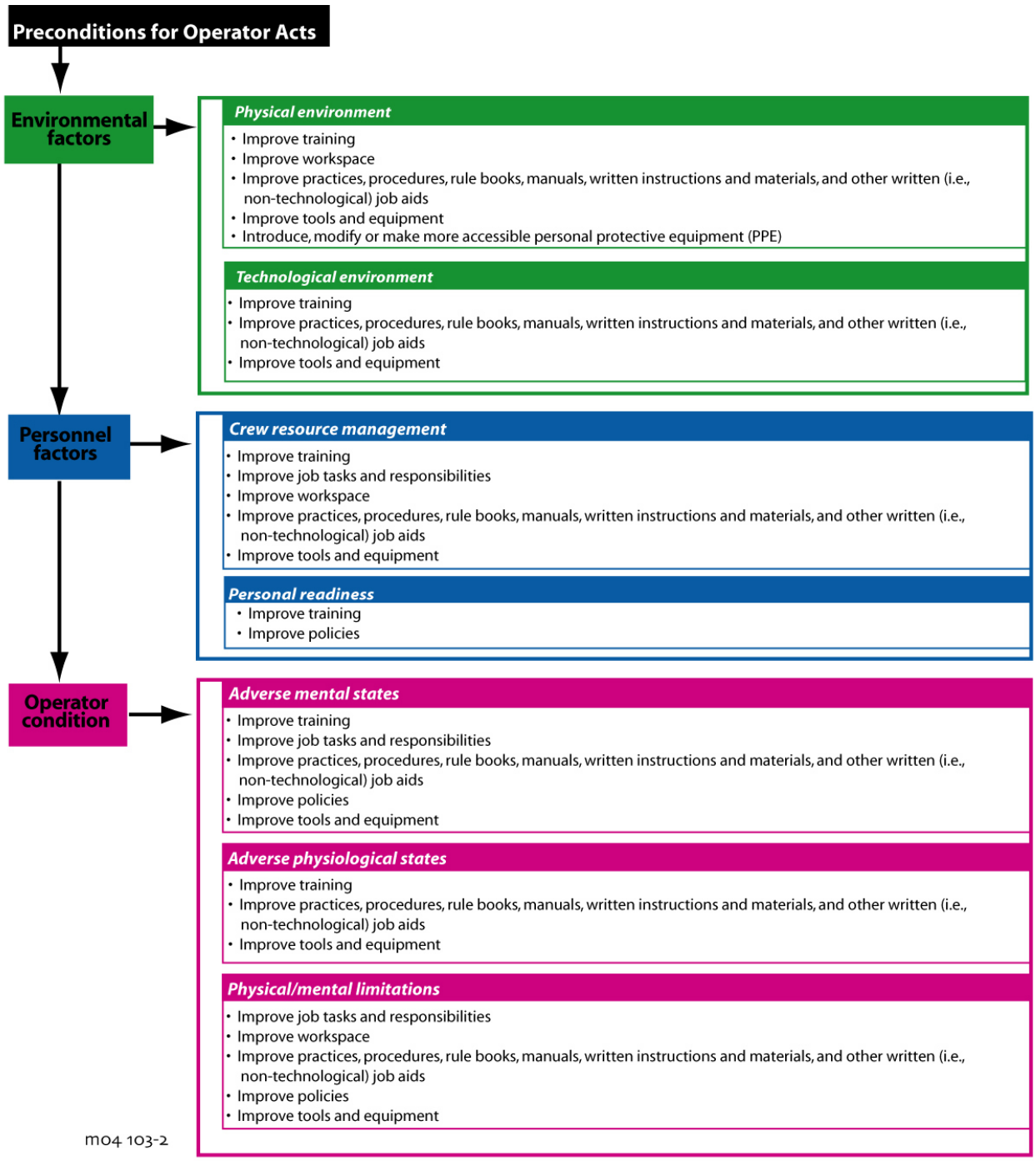

Figure E-2. Preconditions for Operator Acts Corrective Action Guide

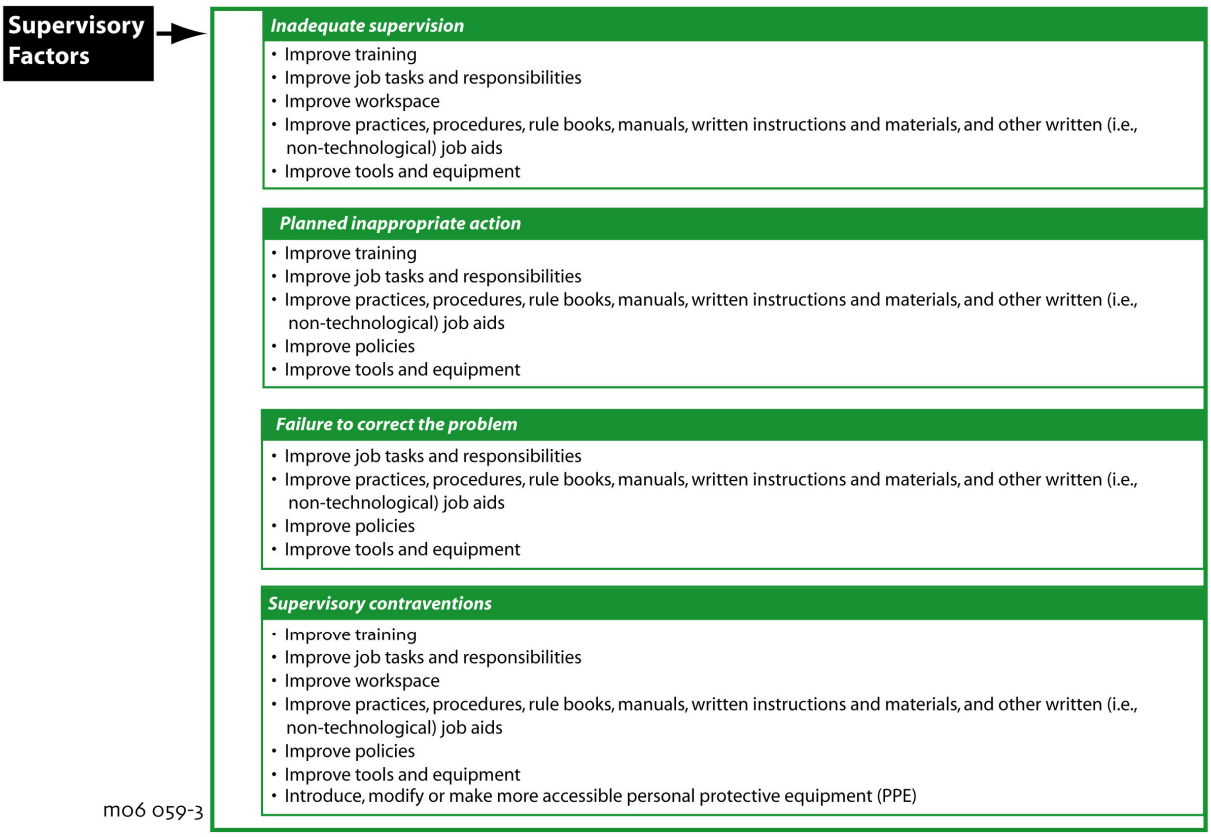

Figure E-3. Supervisory Factors Corrective Action Guide

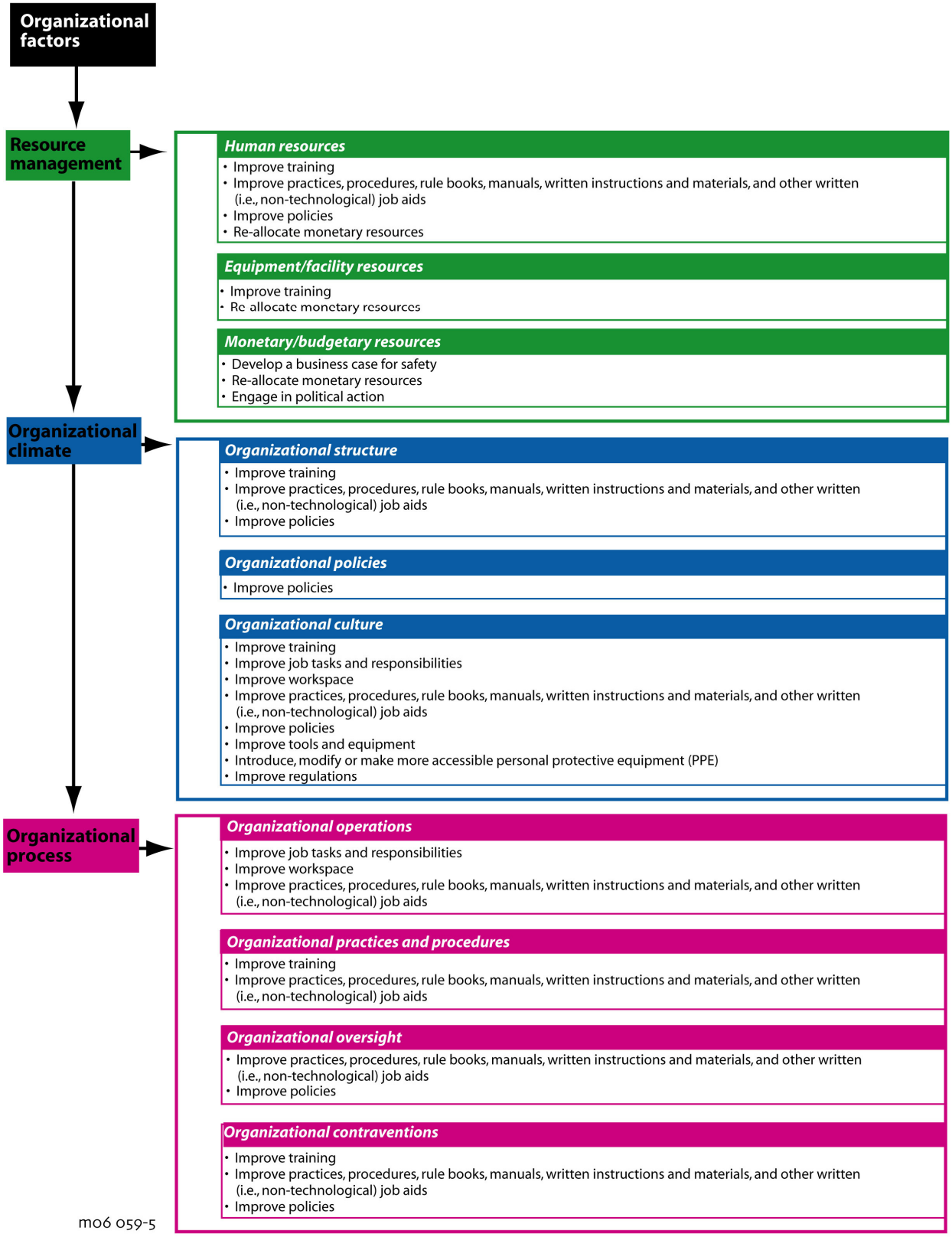

Figure E-4. Organizational Factors Corrective Action Guide

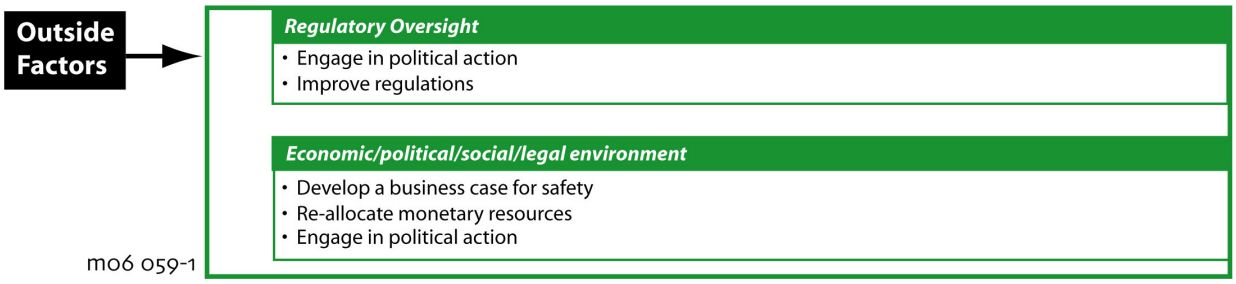

Figure E-5. Outside Factors Corrective Action Guide

Table E-1. Corrective Action Definitions and Examples

	Corrective Action[9]	Definition	Corrective Action (E)ngineering (A)dministrative (P)PE (G)overnment action	Example(s)
1.	Improve training	This action includes introducing new training or improving existing (new hire, new procedure, refresher) training. Corrective actions can address training content/materials and methods, and can include classroom, OJT, and simulation-based approaches, among others.	A	• Introduce refresher training on infrequently used procedure or tool • Improve existing training procedure • Increase frequency of refresher training • Introduce *job preview* into new hire training • Implement crew resource management training
2.	Improve job tasks and responsibilities	Improvements to job tasks and responsibilities include both complete overhaul of job tasks/responsibilities and changes to one task/responsibility. Improvements can be to existing tasks or the introduction of new tasks/responsibilities.	E, A	• Reduce job responsibilities or tasks
3.	Improve workspace	Improvements to the workspace focus on the physical layout of the area or facility in which a particular job is carried out. This space can include a diesel or car repair shop, for example, or an entire yard or even a stretch of main track on which a train-and-engine crew makes runs. Improvements can be partial, where one or more	E	• Rearrange work stations to improve work flow • Add warning signs in yards indicating presence of remote control locomotive operations • Conduct an ergonomic assessment of, and eliminate or otherwise mitigate, physical hazards

[9] While some corrective actions will involve unilateral implementation by the railroad, many will require cooperation and partnerships with labor unions and/or FRA and any other governmental body responsible for railroad safety in the affected area(s).

	Corrective Action[9]	Definition	Corrective Action (E)ngineering (A)dministrative (P)PE (G)overnment action	Example(s)
		components of the physical space are modified, or whole, where the physical space is completely overhauled.		• Re-locate a supervisor to work physically closer to employees for which he/she is responsible
4.	Improve practices, procedures, rule books, manuals, written instructions and materials, and other written (i.e., non-technological) job aids	Improvements to practices, procedures, etc., cover all methods and materials that govern or aid employees in carrying out their work safely. Improvements can include the introduction of a new practice or procedure, or the modification of an existing one.	A	• Re-write a rule to increase understanding, clarity • Create a new work procedure • Implement rest breaks • Introduce calisthenics to warm up employees in physically active jobs • Improve job briefing procedure • Develop a new checklist or memory aid • Create 24-hr hotline to report hazards • Create a new procedure for disseminating updates to the rule book • Implement more frequent equipment or facility inspections • Make proficiency testing peer-based, and focus on safe behaviors rather than on rule violations
5.	Improve policies	This category includes those non-operational strategies that dictate and govern all other aspects of work. These include policies regarding employee hiring, promotion, accident investigations, and hearings.	A	• Improve accountability for actions • Introduce a new hire screening tool
6.	Improve tools and equipment	Improvements to tools and equipment can include acquisition of new tools/equipment and modifications to existing tools/equipment. This	E	• Introduce a guard to a machine with exposed moving parts • Conduct a human factors assessment of

	Corrective Action[9]	Definition	Corrective Action (E)ngineering (A)dministrative (P)PE (G)overnment action	Example(s)
		category also includes new or improved instructions, and assessments of tools and equipment to determine their adequacy.		tool/equipment interface and functionality • Re-design a tool to avoid inadvertent activation of a control • Add well-designed (i.e., clearly communicated) warning labels to equipment • Improve instructions
7.	Personal protective equipment (PPE)	This category includes introducing, modifying, or making more accessible PPE, such as eyewear, ear protection, vests, clothing (e.g., rain gear), and boots.	P	• Introduce mandatory ear protection • Add eyeglass dispensers in more locations to increase PPE accessibility
8.	Develop a business case for safety	This corrective action involves written and oral communications to superiors to convince superiors of the need and merit for additional resources.	A	• Produce cost/benefit analysis advocating preventive spending/improvements (e.g., $250,000 spent now will save $2 million later)
9.	Re-allocate monetary resources	This corrective action covers the re-direction of financial assets to a safety-related program to explicitly address one of the safety deficiencies identified in the investigation.	A	• Increase spending on yard maintenance
10.	Political action	This action involves official, organizational communications with, voting, and legal contributions to, political representatives, such as congressmen and senators, as well as local municipalities, in order to affect a change to a Federal, State, local, or other governmental regulation, or order. This action also includes	G	• Write letter to, or visit with, legislative representative

	Corrective Action[9]	Definition	Corrective Action (E)ngineering (A)dministrative (P)PE (G)overnment action	Example(s)
		obtaining grants or other financial support from FRA and others outside the railroad to defray costs of implementing corrective actions.		
11.	Improve regulations	This corrective action involves working with FRA to improve safety and explicitly address one of the safety deficiencies identified in the investigation. The target deficiency must be governed by, or potentially governed by, a Federal, State, or other regulation.	G	• Work with FRA to change a regulation

Appendix F.
Incident Report Form

Appendix F contains a copy of the incident report form used in this study. Researchers asked study participants to complete the two-page form after each RCA investigation and return it to the research team.

Railroad Incident Report Form

Instructions: Please complete the following information after completing your investigation to help us understand the circumstances under which the incident occurred and the context for your application of the root cause analysis methodology.

Railroad: _____

Investigators _____

Railroad representative: _____

Labor representative: _____

Date of incident (mm/dd/yyyy): ____/____/____

Time of day of incident (include a.m. or p.m.): _____

Where did the incident occur (shop/facility name/location, etc.): _____

Weather at the time of the incident: _____

Temperature at the time of the incident: _____

Date(s) incident was investigated: _____

Approximate number of hours, per investigator, it took to complete the investigation:

_____ for railroad representative _____ for labor representative

---

Describe the incident (the task being performed, equipment involved, personnel involved, the sequence of events leading up to the incident, the hazard(s) and/or unexpected event, the nature of the incident, the severity of the incident, etc.). Use a second page if necessary:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

HFACS-RR Analysis

Instructions: Based on your use of the HFACS-RR flow charts and worksheets, please record your findings here, beginning with unsafe acts. For each general HFACS-RR category, include a brief description of the activity, event, or occurrence in the middle column, and record the specific HFACS-RR category in the far right column.

General HFACS-RR Category	Occurrence	Specific HFACS-RR Category
Operator Acts		
E.g., →	*Employee forgot a step in a maintenance procedure*	*Memory failure*
Preconditions		
Supervisory Factors		
Organizational Factors		
Outside Factors		

Appendix G.
Post-Study Feedback Questions

Post-study feedback questions elicit feedback at the conclusion of the study on the usefulness of the RCA methods and paper-based tools, as well as the overall value of the RCA process. Due to various barriers encountered in this study, participants did not gain sufficient experience to provide complete answers to many of these questions. A subset of these questions, however, guided telephone interviews with labor and management part way through the study to obtain their feedback on barriers and suggestions to successful implementation in the future.

The questions are organized around two primary themes—the RCA process and the RCA tools.

RCA process questions

1. Did Foster-Miller provide sufficient training in the use and application of the RCA process and tools?
2. Did you find the RCA process easy to use?
3. Did you find the RCA process easy to incorporate into your own investigation approach? How did you incorporate the RCA process into your own investigation approach?
4. What did you think of the labor-management collaborative process for investigating incidents?
5. Did the RCA process provide new insights regarding contributing factors that you may not have otherwise identified using your traditional investigation approach?
6. How easy was it to examine operating rules, supervisory procedures and overall railroad policies (i.e., the supervisory and organizational factors)?
7. During the investigation and analysis, was it difficult to completely avoid culpability (blaming someone) for the incident? If so, why?
8. How would you describe the interview process with those involved in the incident? Were interviewees cooperative? If so, to what do you attribute this? If not, why not? Did the RCA tools/process provide you with enough guidance on what questions to ask during the interviews?
9. Was it clear when to conclude your investigation? What rules of thumb or guidance did you use to help you conclude your investigation?
10. Were you able to complete the investigation in the 8-12 hour time period estimated for each incident investigation and analysis? How long did it take you to complete each investigation and analysis? Is this a reasonable amount of time to expect? If not, how much time is reasonable for each investigation and analysis?
11. Do you feel that you or your railroad would benefit from incorporating this approach into the railroad's existing investigation process?
12. What are some barriers to incorporating this approach?

13. What would you do differently if you were to formally incorporate this process into your railroad's existing accident investigation process? If you were designing the RCA process for the entire railroad industry to use, what changes would you make?

RCA tool questions

1. Did you find the tools we gave you helpful or burdensome in investigating incidents and identifying contributing factors? Which tools were helpful and which were burdensome?
2. Did the HFACS-RR flow charts help you to identify contributing factors, or did it make the investigation more cumbersome?
3. Was it easy to classify contributing factors using the HFACS-RR categories?
4. Was the tool that mapped the HFACS-RR categories to corrective action categories helpful? Were the corrective action categories explicit enough or too broad to be of use? Were you able to identify some specific corrective actions based on the corrective action categories? Would more explicit corrective action suggestions have been more helpful?
5. Were you able to identify any operator acts that contributed to an incident?
6. Were you able to identify any preconditions that contributed to an incident?
7. Were you able to identify any supervisory factors that contributed to an incident?
8. Were you able to identify any organizational factors that contributed to an incident?
9. Were you able to identify any outside factors that contributed to an incident?

Abbreviations and Acronyms

d	day(s)
EOT device	end-of-train device
FELA	Federal Employers' Liability Act
FRA	Federal Railroad Administration
GEMS	generic error modeling system
h	hour(s)
HFACS	Human Factors Analysis and Classification System
in	inch(es)
lb	pound(s)
mo	month(s)
mtm	million train miles
NTSB	National Transportation Safety Board
OJT	on-the-job training
RCA	root cause analysis
yr	year(s)