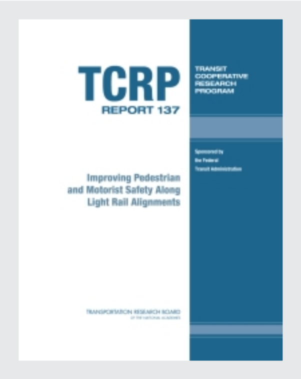

Improving Pedestrian and Motorist Safety Along Light Rail Alignments

DETAILS

147 pages | | PAPERBACK
ISBN 978-0-309-11808-8 | DOI 10.17226/14327

AUTHORS

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 137

Improving Pedestrian and Motorist Safety Along Light Rail Alignments

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Public Transit

Research sponsored by the Federal Transit Administration in cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2009
www.TRB.org

TRANSIT COOPERATIVE RESEARCH PROGRAM

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TCRP REPORT 137

Project A-30
ISSN 1073-4872
ISBN 978-0-309-11808-8
Library of Congress Control Number 2009939561

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TRANSIT COOPERATIVE RESEARCH PROGRAM

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Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

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Printed in the United States of America

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FOREWORD

By Gwen Chisholm Smith
Staff Officer
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TCRP Report 137: Improving Pedestrian and Motorist Safety Along Light Rail Transit Alignments addresses pedestrian and motorist behaviors contributing to light rail transit (LRT) safety and describes mitigating measures available to improve safety along LRT alignments. The report also includes recommendations to facilitate the compilation of accident data in a coordinated and homogeneous manner across LRT systems. Finally, the report provides a catalog of existing and innovative safety devices, safety treatments, and practices to use along LRT alignments.

The results of this research may be useful to transit operators, consultants, and state safety oversight agencies.

Previous light rail safety related research, including *TCRP Report 17: Integration of Light Rail Transit into City Streets, TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*, and *TCRP Research Results Digest 5: Second Train Coming Warning Sign Demonstration Projects*, looked at a number of safety systems, identified safety measures, and proposed safety enhancements—but they did not provide a systematic approach for the evaluation of current measures. New safety issues, or at least the potential for new safety issues, have arisen and need to be evaluated. Additionally, a review of the actual effectiveness of the proposed measures identified in the previous research based on actual experience provides before-and-after examples that could affirm or disprove their safety benefits.

In addition, it is currently difficult to compile meaningful safety data in a time-efficient manner. Individual transit agencies have conducted localized safety studies on an ad-hoc basis; however, these studies have not been coordinated or conducted following consistent procedures. A system of compiling safety data is needed to enable transit agencies across the country to report comparable safety data.

Under TCRP Project A-30, iTRANS Consulting Inc. was asked to develop a framework or template for collecting data to be used to improve pedestrian and motorist safety along light rail transit alignments. To fulfill this project objective, the research team did the following: (1) collected, reviewed, and summarized published and unpublished information from U.S. and foreign LRT systems relevant to safety measures, devices, and practices on LRT alignments, including at-grade crossings and stations with enhanced safety for pedestrians, motor vehicles, and LRT passengers; (2) conducted a survey of U.S. LRT agencies to gather information on the type of data that are collected after an LRT accident (This information includes a description of the type of accident data provided to the state safety oversight agency, as well as the accident information provided to FTA and other regulatory agencies.); (3) conducted a survey of LRT systems in North America to identify innovative control devices, applications, and unique operating environments and practices related to light rail safety that have been implemented, including enforcement and educational practices; (4) developed a methodology to perform risk analysis for safety measures at LRT alignments; and (5) using the information gathered from the data collected, identified successful elements and new technologies used to improve light rail safety, described possible factors (including pedestrian and motorist behavior) contributing to LRT safety, and recommended ways to facilitate the compilation of accident data in a coordinated and consistent manner across LRT systems.

CONTENTS

SUMMARY

Improving Pedestrian and Motorist Safety Along Light Rail Alignments

Introduction

TCRP Project A-30's goal was to provide guidelines for improving pedestrian and motorist safety along light rail transit (LRT) alignments. The project had three central objectives:

- To develop a framework or template for collecting data for assessing pedestrian and motorist safety along LRT alignments,
- To identify and summarize pedestrian and motorist behavior, and
- To document best practices for improving pedestrian and motorist safety along LRT alignments.

To accomplish these objectives, a wide range of tasks was undertaken, and the project was divided into two phases. In Phase I, the project team undertook the following tasks:

- Literature review of LRT safety issues, safety measures, devices, practices, and new technologies relevant to LRT alignments.
- Survey of North American LRT agencies.
- Preliminary round of assembly and analysis of basic LRT crash data obtained from federal, state, and local transit agencies. Suitable data were difficult to obtain.
- Summary of all information gathered, and preparation of Phase 2 work plan.

In Phase II, the team undertook the following tasks:

- Consultation with representatives of the Federal Transit Administration (FTA), State Safety Oversight (SSO) agencies, and local LRT operating agencies. Follow-up requests for data at the agency, state, and national levels.
- Site visits to selected LRT agencies. Five agencies were visited: Utah Transit Authority, Salt Lake City, Utah; Metro Transit, Minneapolis, Minnesota; Hudson-Bergen Light Rail Line, Hudson County, New Jersey; San Francisco Municipal Railroad, San Francisco, California; and Santa Clara Valley Transportation Authority, Santa Clara County, California. The five site visits included system observation, safety workshops, and stakeholder consultation. The visits allowed for the collection of further information about data collection, collision records, the use of the *Manual on Uniform Traffic Control Devices* (MUTCD), and LRT safety issues. The visits provided valuable opportunities for detailed discussion of the effectiveness of treatments, risk assessment, data gathering, and data processing.
- Further review of LRT safety data, including: compilation and analysis of newly available data, review of data collection and storage procedures, and development of recommendations concerning data collection and processing.

- Creation of detailed catalog of LRT-related safety treatments (characteristics, examples of installation, safety effectiveness)
- Development of a risk assessment methodology.

The second phase focused on successfully meeting project objective requirements that remained after Phase I and producing this final report, which documents all the project's activities, findings, and recommendations.

The first objective listed above (developing a framework for collecting LRT safety data) was the most straightforward. The second objective (pedestrian and motorist behavior) and the third objective (best practices for improving pedestrian and motorist safety along LRT alignments) presented major challenges. In particular, the detailed research statement called for a review of the effectiveness of treatments based on experience to date. The project team examined the collision data gathered as part of the project and conducted an extensive literature review, but found very little statistically significant information. The problem was amplified by the quantity and quality problems identified in the National Transit Database (NTD) and by the paucity of data available directly from local transit agencies. In response to these limitations, the project team took a dual approach: assessing treatments quantitatively where quantitative data were available, and collecting and summarizing qualitative and anecdotal information where quantitative data were not available.

This summary is divided into the following sections:

- State of the practice methodology and summary,
- LRT safety data available from local transit agencies, SSOs, and the NTD,
- Safety issues and their treatment,
- Catalog of LRT safety treatments,
- Risk analysis methodology for LRT, and
- Review of the accident data collection process.

State of the Practice Methodology and Summary

The number of LRT systems in North America is growing, and existing systems are expanding. There is great interest in further guidance on addressing safety issues. Agencies have developed their own strategies for improving safety on the light rail alignment, but there is no clearinghouse to share this information. The literature review, survey of agencies, telephone consultation with agencies and SSOs, and observations and additional information obtained during the site visits enabled the project team to identify and summarize the most important safety issues cited by agencies.

A long list of important safety-related problems emerged: pedestrian jaywalking and trespassing, safe station access, illegal turns, traffic control violations, gate violations, conflicting signals and signs, poor signal clearance, best ways to provide traffic signal pre-emption, pinch points on platforms, sideswipes, lack of information for the light rail vehicle (LRV) operator, and the public's lack of respect for LRVs. The top concerns share common causes. Collisions occur when people cross into the alignment because of inattention, confusion, or purposeful noncompliance, or when operators fail to follow procedure and behave in unexpected ways. These points may seem obvious, but agencies must make a distinction between preventing risky behavior due to inattention and confusion, and preventing risky behavior due to purposeful noncompliance. Understanding the underlying reasons for collisions on LRT alignments is essential to designing appropriate treatments.

Agencies address safety concerns in two ways: physical measures, and education and enforcement programs. Physical improvements are designed to keep motorists, pedestrians, and cyclists out of the alignment, or to give them information about the LRT alignment. Physical measures may be active or passive. Active measures respond to an approaching LRV. Passive measures are fixed. Education and enforcement programs may focus on operators or the public. Public programs are typically used to increase awareness about safety near LRT alignments.

LRT Safety Data Available from Local Transit Agencies, SSOs, and the NTD

In the United States, LRT collision data are collected and stored at three levels of transit administration. As part of the data collection portion of the project, the project team identified the purpose of storing collision data at each level, identified the data collected, assessed the quality of the data collected, identified any potential issues or deficiencies, and, where possible, analyzed the data to determine root causes and contributing factors for LRT collisions.

The three levels of transit administration that collect and store incident reports are the FTA (for the NTD), the SSO agencies, and local transit agencies. The primary source of all data is onsite investigations using some type of collision report form. Normally, the local agency conducts the incident investigation, but the SSO is mandated either to conduct an investigation or to ensure that the local agency is doing so. The SSO reviews the findings of the local agency's incident report, and accepts or dissents. If the SSO dissents, the SSO may conduct its own review, or may ask the agency to revise the agency's review. The local transit agency must also submit monthly reports on incidents meeting set criteria to the NTD. SSOs make an annual submission to the NTD.

Figure 1 shows the transfer of incident data from the scene of the incident across the three levels of transit administration.

The project team received and analyzed data from a number of sources:

- The National Transit Databases from the FTA for each year from 2002 to 2007, including all reported safety and security incidents, both "reportable" (formerly "major") incidents, and "non-reportable" (formerly "non-major") incidents;
- One SSO database, provided by the California Public Utilities Commission (CPUC); and
- Extractions of varying levels of detail from the databases of eight local LRT agencies.

Safety Issues and Their Treatment

Safety analysts use tools such as before-and-after studies to determine the most appropriate treatments to address safety issues. One method of addressing safety concerns is root cause analysis (RCA). RCA is a formal process that distinguishes contributing factors from root

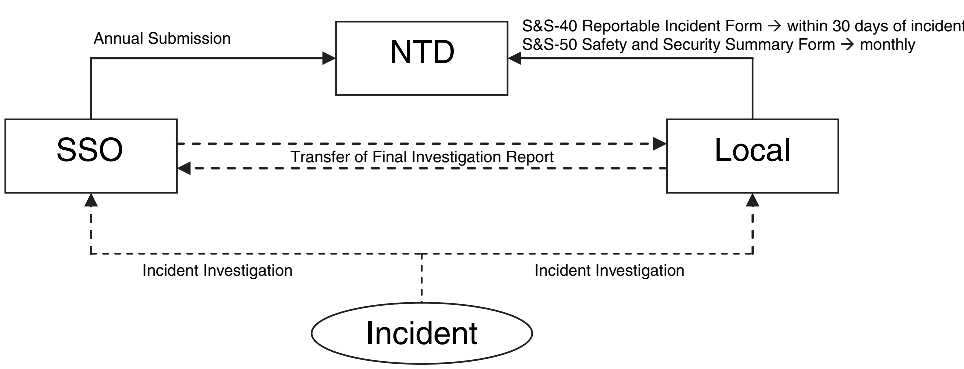

Figure 1. Transit incident data transfer across levels of transit administration.

causes. Contributing factors influence the occurrence or severity of the collision, but their elimination would not have prevented a collision from occurring. RCA goes beyond contributing factors to stress the importance of identifying root causes: the underlying flaws or problems that lead to an undesirable outcome. Safety treatments should attempt to identify and mitigate the fundamental weaknesses of the system to prevent incidents from recurring.

It is difficult to determine the root causes of LRT collisions statistically. It is also difficult to determine the effectiveness of LRT safety treatments statistically. Statistical problems arise because collisions (and especially specific types of collisions) are both rare and random events. Practical problems arise because of the inadequacies of much of the LRT data available. *Data collection practices need to be expanded and standardized to create a central, national database that will be useful for research studies.*

Because LRT collisions are rare and random, some types of statistical studies may never be meaningful, even with improved data collection. Proxy measures can, however, provide a useful substitute for collisions and can be used to make a quantitative assessment of the effectiveness of safety measures. Proxy measures could also be used in RCA. Proxy measures can have the advantage that they allow agencies to identify and treat safety hazards before there is an incident.

Suggested proxy measures include:

- Operator reports,
- Risky behavior,
- Emergency braking records,
- Insurance and non-recoverable cost records, and
- Customer complaints.

The project team analyzed the data available and considered the information obtained from agencies during the site visits. Four strategies are recommended to address safety issues:

- Give responsibility to the operators;
- Increase motorist, pedestrian, and cyclist awareness by providing active, appropriate information for them to act upon at each LRT location;
- Educate the public and increase awareness of risks in the LRT alignment; and
- Separate LRT space from the space occupied by other modes, using physical barriers, environmental cues, or traffic control.

Catalog of LRT Safety Treatments

A wide range of specific safety treatments is available and used along LRT alignments. Although little quantitative information is available, agencies have accumulated significant anecdotal information about the implementation and effectiveness of many treatments. The project team assembled this information, and any available quantitative information, into an easy-to-use, highly accessible catalog of LRT safety treatments. The catalog includes details of 31 LRT treatments. Where possible, photos of actual examples of the treatments are included. The catalog is designed to be used as a stand-alone resource. It is presented as Appendix A of this report.

The 31 treatments are divided into 7 categories. The treatments and categories are:

1. Signals and active warnings
   a) Signal priority
   b) Transit signal pre-emption

   c) Audible crossing warning devices
   d) Constant warning time systems
   e) Pre-signals
   f) Flashing light signals
   g) Limits on downtime of gates
   h) On-vehicle audible warning devices—automatic and LRV–operator-activated
   i) Illuminated, active, in-pavement marking systems
   j) Blank out signs
   k) Pedestrian signals
2. Signs
   a) Stop and yield signs
   b) Retroreflective advance warning signs
   c) Flashing train-approaching warning signs
   d) Gate crossing status indication signals
3. Second train approaching treatments
   a) Second train signals and active signs
   b) Second train warning signs
4. Gates
   a) Pedestrian automatic gates
   b) Four-quadrant gates
5. Pedestrians
   a) Pedestrian fencing/landscaping
   b) Offset (or Z) pedestrian crossings
   c) Pedestrian swing gates
6. Channelization/markings
   a) Pavement marking, texturing, and striping
   b) Quick curbs
   c) Rumble strips
   d) Channelizations
   e) Illumination of crossings
7. Education and enforcement
   a) Photo enforcement
   b) Enforcement
   c) Education outreach programs
   d) CCTV/video recording

Risk Analysis Methodology for LRT

The project team approached the task of developing a risk analysis methodology for LRT alignments by:

- Reviewing the established concept and principles of road safety audits,
- Consulting the FTA's "Hazard Analysis Guidelines for Transit Projects" standard, and
- Examining the process of safety issue identification in a number of recent sources from North America and the United Kingdom.

A safety issue checklist for LRT agencies was then developed.

The FHWA *Road Safety Audit Guidelines* document explains safety audit principles and shows how road safety audits are adapted to take into account the stage in the life-cycle of the road (from preliminary design to detail design and in-use stages). The document is a good example of a road safety audit publication and is widely used in the road design and management field.

The basic principles of road safety audits emphasize the importance of considering safety from the perspective of all possible users of the roadway. Users include pedestrians, cyclists, private motorists, and commercial operators. Their trip purposes vary (commuting, tourism, commercial vehicle operation, etc.) and their level of safety awareness and knowledge varies. During the audit, an independent multi-disciplinary team also examines all aspects of the road design, identifies potential risks, and suggests mitigation measures. The audit team's findings are then discussed with the road design team, and the most appropriate course of action is developed. The mitigation options available will vary greatly depending on the problems and circumstances identified, the cost, and the stage of design and/or operation of the facility.

The FHWA guidelines and two other widely used North American safety audit guideline documents were used to summarize the steps involved in conducting a safety audit:

- Select the safety audit team,
- Provide background information to the safety audit team,
- Conduct a pre-audit meeting to review project information,
- Assess/analyze background information,
- Perform site inspections under various conditions,
- Prepare and submit safety audit report,
- Conduct safety audit completion meeting,
- Prepare formal response (completed by project owner/design team), and
- Incorporate safety audit findings into project (where appropriate).

The FTA's *Hazard Analysis Guidelines for Transit Projects* recommends conducting hazard identification, assessment, and resolution using Military Standard 882D (MIL-STD-882D), the U.S. Department of Defense (DoD) Standard Practice for System Safety. This standard describes the process of examining and resolving safety issues and describes the requirements for developing and implementing a system safety program. During the site visits, a number of local LRT staff mentioned that the FTA Guidelines are a commonly used reference for safety management and a commonly used basis for safety problem resolution.

The principles and approach adopted in road safety audits and by the FTA and others were used to develop a draft LRT Alignment Risk Assessment Checklist. The emphasis was on usability rather than including every detail of every possible issue because it was important to keep the checklist to a reasonable length. The draft checklist was presented and discussed at the safety workshops conducted during the site visits. It was then revised, and the final version is presented in this report.

Review of the Accident Data Collection Process

A key task was the development of recommendations for improving the collision data collection process at the local and national levels. LRT agencies, SSOs, and the FTA and its NTD are all involved in data collection, dissemination, and analysis. Improving the quantity and quality of the data available is an important part of facilitating the statistical analysis of LRT safety data at the national level.

Collision data collection forms and methods were requested from LRT agencies. It proved difficult to obtain material from many agencies, but 11 agencies provided material. The project team conducted a detailed review of the forms provided. The review considered data quality, data consistency, gaps and redundancies in the data, and problems that arose when incidents were selected and transferred from one agency to another. The analysis provided the basis for a set of collision data collection process recommendations.

For data to be available for analysis at the national level, it will be necessary to retain SSO agencies and the FTA and its NTD. Redundancies in the way data move from organization to organization should, however, be avoided in a restructured national reporting system.

The project makes three recommendations for the development of a national LRT collision data reporting system:

1. A standardized electronic reporting form should be developed and made available to all local LRT agencies.
2. All collision reports should include relevant traffic exposure measures. Exposure measures are required to put each collision in its local context and to allow for meaningful aggregation and comparison at the national level.
3. Details of location geometry and all safety and traffic control devices should be collected. These details are required to support a high quality and meaningful national analysis of the safety effects of LRT safety treatments.

Summary of Recommendations

Following is a summary of the nine major recommendations put forward in this report. Details about each recommendation are provided in the chapter cited in brackets.

1. Use proxies to assess the effectiveness of specific safety treatments without needing to wait for a significant number of collisions [Chapter 4].
2. Follow four general treatment strategies [Chapter 4]:
   a) Give responsibility to the operators,
   b) Increase motorist, pedestrian, and cyclist awareness through active, appropriate information,
   c) Education, and
   d) Separate LRT space from the space occupied by other modes.
3. Continue to add to the LRT Catalog of Safety Treatments provided in Appendix A [Chapter 5].
4. Use a standard LRT risk analysis methodology that addresses all of the elements listed in the LRT Alignment Risk Assessment Checklist provided in Chapter 6 [Chapter 6].
5. Develop and implement a standardized, comprehensive, electronic LRT incident reporting form [Chapter 7].
6. Provide a reporting form structure that can be easily transferred into a searchable electronic database [Chapter 7].
7. Ensure that LRT collision reports include fields for storing geometric details and traffic exposure measures that apply to the specific incident site [Chapter 7].
8. To support national-level analysis of LRT safety, an LRT crossing database should be created. This database should include for each alignment location (crossing or segment): details of geometry, control devices, and traffic exposure [Chapter 7].
9. In the standardized electronic LRT incident reporting form, consider using fields that provide the most valuable information for researchers, designers, and operators, as listed in Chapter 7 [Chapter 7].

CHAPTER 1

Introduction

Research Problem Statement

Many major metropolitan regions in North America are currently planning, constructing, or already have LRT systems. Although these systems have excellent overall safety records, collisions do occur, and public perception often runs counter to the statistics. TCRP has produced several reports dealing with pedestrian and motorist safety along LRT alignments. The reports include *TCRP Report 17: Integration of Light Rail Transit into City Streets; TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety;* and *TCRP Research Results Digest 51: Second Train Coming Warning Sign: Demonstration Projects.*

In addition, TCRP has a number of ongoing safety related studies. These include TCRP Projects D-9, "Transit Vehicles and Facilities on Streets and Highways," and D-10, "Audible Signals for Pedestrian Safety in Light Rail Transit Environments." TCRP Reports 17 and 69 led to the development of Chapter 10 of the MUTCD. Chapter 10 is intended as a reference for LRT designers and operators.

These research efforts, and others, looked at a number of systems, identified safety measures, and proposed safety enhancements, but they did not include a systematic approach for evaluating existing safety improvement measures. New safety issues have emerged, or are likely to emerge, and these issues also need to be evaluated. A review of the effectiveness of the safety measures identified in the previous research based on actual experience could provide before-and-after examples that affirm or disprove the safety benefits of the recommendations made. However, the complete data required to conduct definitive studies of the effectiveness of LRT safety measures are not readily available.

In addition, it is currently very difficult to assemble complete and meaningful safety data in a time-efficient manner. Safety studies conducted by individual transit agencies have usually been local and ad-hoc, and often not coordinated or conducted according to consistent procedures. The results are not available to researchers in a centralized repository. To facilitate the compilation of safety data, guidelines are needed to enable transit agencies to report comparable safety data in a consistent and comprehensive fashion that will support research and help to improve LRT safety.

Research Objectives

The TCRP established three objectives in the Research Project Statement. These objectives are addressed in this report in the chapters identified in brackets. The objectives are:

- To develop a framework or template for collecting data to be used to improve pedestrian and motorist safety along LRT alignments [Chapter 7],
- To identify and summarize pedestrian and motorist behaviors [Chapter 2, Chapter 3], and
- To document best practices for improving pedestrian and motorist safety along light rail transit alignments [Chapter 2, Chapter 4, Chapter 5, Chapter 6].

The activities of this project were organized in two Phases, and framed by 12 Tasks defined by the TCRP. The original Phases and Tasks are reproduced below. The chapters that address the tasks are included in brackets. Some tasks are addressed briefly in the text followed by more in-depth analysis or results in the appendices.

Phase I

Task 1

Collect, review, and summarize published and unpublished information from U.S. and foreign LRT systems relevant to safety measures, devices, and practices on LRT alignments including at-grade crossings and stations that will enhance safety for pedestrians, motor vehicles, and LRT passengers [Chapter 2].

Task 2

Conduct a survey of U.S. LRT agencies to gather information on the type of data that is collected after an LRT collision. This effort should include, but not be limited to, a description of the type of collision data provided to the state safety oversight agency, as well as the collision information provided to FTA and other regulatory agencies [Chapter 2, Chapter 3].

Task 3

Collect and review collision data for the past 10 years from North American LRT systems, including root cause and contributing factors. Information should be gathered from published and unpublished data reports as available from transit agencies and industry professionals [Chapter 3].

Task 4

Conduct a survey of LRT systems in North America to identify innovative control devices, applications, and unique operating environments and practices related to light rail safety that have been implemented, including enforcement and educational practices. Collect information on the effectiveness of each application and operational practice including before-and-after studies or other analyses that may have been conducted. In addition, identify applications or practices that have been discontinued after their initial application, and the reasons for their discontinuation [Chapter 2, Chapter 5].

Task 5

Based on the survey conducted in Task 4, identify elements from Chapter 10 of the MUTCD that have been adopted by the LRT systems. Of those elements that have been adopted, describe the LRT system results of their implementation. Of those elements of the MUTCD that have not been adopted, explain why not [Chapter 5].

Task 6

Identify new technologies (e.g., variable message signs, GPS, audible devices, train control systems, and in-pavement lighting) that may have an effect on light rail safety applications [Chapter 2, Chapter 5].

Task 7

Using information gathered in Tasks 1 through 6, produce a detailed Phase II work plan to assess the effectiveness of existing and innovative devices and practices of LRT systems, including at-grade crossings and stations. The work plan should:

- Identify the devices or practices to be evaluated;
- Describe the methodology to be used;
- List possible factors contributing to LRT safety, such as alignment type, engineering design, light rail vehicles characteristics, type of control devices, and operating environment; and
- Include focus groups or other means of testing to identify pedestrian and driver attitudes as they approach an LRT alignment.

Task 8

Submit an interim report that summarizes the findings of Tasks 1 through 7.

Phase II

Task 9

Assess the effectiveness of existing and innovative devices and practices of LRT systems, including at-grade crossings and stations, using the approved Phase II work plan [Chapter 5].

Task 10

Develop a methodology to perform risk analysis for safety measures at LRT alignments [Chapter 6].

Task 11

Using the information gathered in Task 3 and the results of Task 9, develop recommendations to facilitate the compilation of collision data in a coordinated and consistent manner across LRT systems in the United States. The data should allow for a meaningful comparison of collision rates across transportation modes as well as for a more rigorous assessment of the effectiveness of safety measures, devices, and practices that could be implemented on LRT alignments. The recommendations should indicate the type of collision data that should be collected by the LRT agency and describe the best format for delivery to regulatory agencies [Chapter 7].

Task 12

Submit a final report that documents the entire research effort. Develop guidelines that:

- Identify successful elements and new technologies used to improve light rail safety [Chapter 5],
- Assess the effectiveness of existing and innovative devices and practices used to improve LRT safety [Chapter 5],
- Describe possible factors (including pedestrian and motorist behavior) contributing to LRT safety [Chapter 3, Chapter 4],

- Describe a methodology to perform a risk analysis for safety measures at LRT alignments [Chapter 6], and
- Recommend ways to facilitate the compilation of collision data in a coordinated and consistent manner across LRT systems [Chapter 7].

Research Issues

LRT is becoming an increasingly important mode of transportation for residents of major metropolitan regions of the United States and Canada. While streetcars have been in use in a number of cities for many decades, the concept and operation of the modern LRT is quite new in many locations. The operating characteristics of the LRV and the common practice of keeping LRT operations in close proximity to conventional street activities of motor vehicles and pedestrians introduces a new set of safety issues to the urban environment. As more urban areas choose to invest in LRT, it is increasingly important to understand the resulting safety challenges and the mitigation measures available to maintain and improve safety along LRT alignments.

There are several key issues. These include identifying the safety problems that may be present in a certain setting, selecting corrective measure(s) that should be implemented to improve safety in specific settings, and assessing their likely safety benefits in a meaningful way. Improved collision data that are assembled in a consistent format and linked directly to the physical and operating circumstances of the LRT are essential for conducting valid LRT safety studies.

Research Approach

The work was undertaken by iTRANS Consulting with support from Herbert Levinson and TRA Inc. under the guidance of a TCRP panel. Various activities were required to fulfill the project and task objectives, and some of the original project tasks overlapped.

In Phase I, the team undertook the following activities:

- Literature review of LRT safety issues, safety measures, devices, practices, and new technologies relevant to LRT alignments [Tasks 1, 6].
- Survey of North American LRT agencies [Tasks 2, 4, 5, 6].
- Initial assembly and analysis of basic LRT crash data from federal, state, and local transit agencies. Note that, for a number of reasons, data were difficult to obtain at this stage. The reasons will be described later in the report [Task 3]. It should be noted that the words "accident," "collision," and "crash" are often used interchangeably in the literature and elsewhere to refer to a traffic incident that involves at least one vehicle impacting with another road user or object, usually resulting in injury or property damage. In recent years, the trend in the traffic safety field has been to favor "crash" and avoid "accident" as "accident" implies an event that cannot be prevented. It remains a common practice, however, to use the term "accident" in much of the literature and also in the industry, so the term "accident" sometimes appears in this report.
- Summary of all information gathered, and preparation of the Phase 2 work plan [Tasks 7, 8].

Using the results of Phase I and the guidance of the panel, the project team designed a revised approach to Phase II. The second phase focused on preparing a final report that would successfully meet the project objectives.

Phase II included the following activities:

- Consultation with representatives of the Federal Transit Administration (FTA), State Safety Oversight (SSO) agencies, and local LRT operating agencies. Follow-up requests for data at the agency, state, and national levels [Tasks 3, 9, 11].
- Site visits to selected LRT agencies. The site visits included system observation and stakeholder consultation. The visits allowed for the collection of further information about data collection, collision records, the use of the MUTCD, and LRT safety issues. The visits provided valuable opportunities for detailed discussion of the effectiveness of treatments, risk assessment, data gathering, and data processing [Tasks 3, 4, 5, 9, 10, 11].
- Further review of LRT safety data, including compilation and analysis of newly available data; review of data collection and storage procedures; and development of recommendations concerning data collection and processing [Tasks 3, 9, 11].
- Assembly of profiles for various LRT-related safety treatments [Tasks 9, 12].
- Development of a risk assessment methodology [Tasks 10, 12].

Structure of Final Report

The final report is organized into seven chapters. The chapters summarize the findings of the activities described above, and provide recommendations for transit agencies, SSOs, the FTA, the NTD, and other groups involved in LRT safety. A large amount of supporting technical and detailed information is included in the appendices.

The seven chapters are:

- This chapter, the Introduction.
- Chapter 2, State of the Practice Methodology and Summary, which provides an overview of the present state of the practice concerning LRT safety, focusing on the system as a

whole. The content is based largely on information gathered during the literature review, agency survey, and site visits. The complete literature review, which describes the state of knowledge and current practice as published in the available literature, is included in Appendix B. The complete summary of the survey results is included in Appendix C. A series of technical memoranda that provide summaries of the activities and findings of the site visits carried out for this project are assembled in Appendix D.

- Chapter 3, LRT Safety Data Available from Local Transit Agencies, SSOs, and the NTD: A major component of the initial tasks and project objectives was to gather and analyze existing LRT collision data. Chapter 3 discusses transit safety data from three sources: the transit agencies, the SSOs, and the NTD. The chapter outlines some of the inconsistencies in the data and some of the challenges that arise when using transit data for statistical analysis. Chapter 3 also presents the main system-wide findings obtained from an analysis of the available data.
- Chapter 4, Safety Issues and their Treatment, which provides an introduction to the concepts of root causes and contributing factors, and discusses how these concepts are applied to LRT safety. The chapter continues with an overview of the types of safety issues that are reported in the literature and by LRT agencies. This overview is followed by a summary of four strategies that are key to organizing and implementing LRT safety measures. The strategies were developed from the work undertaken for this project and the observations made by the project team.
- Chapter 5, LRT Catalog of Safety Treatments, which introduces the broad set of LRT safety treatments that are addressed in detail in Appendix A in catalog format. The catalog includes pictures and information about the treatment, impacts of the safety treatment, and examples from agencies that have installed the treatment. The catalog also comments on the use of the MUTCD for LRT applications.
- Chapter 6, LRT Risk Analysis Methodology, which reviews the concept of risk assessment, and presents a checklist for assessing risk through safety audits on LRT alignments.
- Chapter 7, Improving the Crash Data Collection Process, which provides an overview of how LRT crash data are currently collected, and recommends a standardized process for gathering, storing, and sharing LRT crash data. The recommended approach is intended to better support the analysis of safety trends and the analysis of effects of safety treatments in the future.

CHAPTER 2

State of the Practice Methodology and Summary

As discussed in the introduction, LRT is increasing in popularity, and new systems are being introduced in many parts of North America. Although LRT collisions are rare, the safety issues associated with LRT collisions may be severe. LRT agencies are currently subject to the safety methods and standards mandated by the FTA. Chapter 8 of the *Manual of Uniform Traffic Control Devices* provides guidance for traffic control and signage issues, but the standards and guidance available do not address all the needs of LRT agencies in addressing safety issues. To fill the gaps, agencies have developed their own strategies for improving safety on light rail alignments.

The existing body of knowledge concerning LRT safety experience is based on both practical experience and formal research. Local agencies, the police, and other experts who work directly with existing systems have a wide variety of knowledge. Some of this knowledge is based on the available data. Some of it may be anecdotal, based on direct experience of "what works and what doesn't." In this project, local expertise has been recorded through stakeholder consultations and through site visits and workshops with LRT agencies, police, and related organizations. Where possible, the local expertise is supported and complemented by the available data. In addition to the practical knowledge base rooted in local expertise, various institutions have conducted research into LRT safety related subjects. The research includes reviews and formal, statistical studies.

This chapter presents a summary of the current research and state of the practice based on four main sources:

1. The extensive literature review completed in Phase I. The review assembled the documentation available on LRT safety issues and practices.
2. The survey of agencies completed in Phase I. A complete summary of the survey results can be found in Appendix C.
3. Telephone consultation with agencies and SSOs carried out as follow-up to the survey, and repeated in Phase II
4. Observations and additional information from consultations during the site visits. Complete summaries of each site visit can be found in Appendix D.

This chapter documents the literature review, and is divided into two sections. The Methodology section summarizes the methodology used to gather the literature and other source material. The State of the Practice section summarizes the findings of the literature review, and provides an overview of the current state of the practice. The complete results of the literature review are available in Appendix B.

Methodology

Literature Review

The literature review was designed to collect, review, and summarize published and unpublished information relevant to safety measures, devices, and practices on LRT alignments. The information was gathered from United States and foreign LRT systems. The safety issues considered included at-grade crossings, stations, and safety practices that enhance safety for pedestrians, motor vehicles, and LRT passengers.

The full literature review (Appendix B) describes the application of the treatment, the measures taken to improve safety, the quantified safety impacts in terms of changes in the number and/or type of collisions (where available), and any potential caveats that could affect the transferability of the results to any other system. As quantified information was limited, anecdotal evidence of safety improvements and resulting changes to surrogate measures is also described in detail.

To obtain the information required for the literature review, the project team searched the following databases:

- Institute of Transportation Engineers (ITE) digital library,
- Transportation Research Information Services (TRIS),

- International Road Research Database (IRRD),
- Organization of Economic Cooperation and Development Library (OECD),
- FTA publications,
- NTD Safety and Security Reports,
- Historical NTD information,
- American Public Transportation Association publications (APTA),
- Transportation Association of Canada (TAC) library catalogue,
- The European Commission's Transport website (http://ec.europa.eu/transport/index_en.html), and
- Personal and organization libraries of research team members.

In addition to searching these sources, the research team attempted to obtain unpublished documents through contacts at various North American LRT systems, the FTA, the Transportation Research Board Committee on Light Rail Transit (AP075) and the APTA Rail Transit Standards Operating Practices Committee. Although some contacts provided reports, the reports they provided had already been reviewed during the initial literature review. As a result, no unpublished documents were added to the material.

The state of the practice summary documents the most significant information gathered during the literature review.

Survey of Agencies

The Survey of LRT Agencies was a single online survey that combined the requirements of Task 2 (LRT Collision Data Collection) with Task 4 (LRT Innovative Control Devices and Applications), Task 5 (Assessment of MUTCD Elements along LRT Alignments), and Task 6 (LRT and New Technologies). The survey was implemented online to provide easy access to the target agencies dispersed across the United States and Canada. The survey content and structure were designed to minimize the burden on participants.

The survey included questions related to collision data, and questions designed to determine the availability of data. Topics included:

- LRT and roadway characteristics,
- Vehicular and pedestrian traffic volume data,
- Details of 35 LRT treatments,
- Observations of risky behavior or near misses between LRV and motorists and pedestrians (e.g., videotapes from CCTV cameras),
- Inventory of treatments with dates of implementation,
- Use of traffic control elements identified in Chapter 10 of the MUTCD, and
- Use of new technologies.

The survey questions were pilot tested for usability and clarity by having a remote participant (a staff member from the Utah Transit Authority) complete the survey using a talking out loud protocol while on the phone with the research team. The purpose of the pilot test was to provide sufficient insight to validate the usability of the survey and to determine the approximate time required for completion. Following the user testing session, the survey was revised to improve the survey's ease of use and clarity. The revised survey was submitted to the Panel for review on October 20, 2006. The final survey incorporating the Panel's comments was launched on November 6, 2006.

In addition to developing the survey, the project team identified a survey contact at agencies across North America. At the request of the TCRP Panel, representatives from new LRT systems that were about to become operational were also contacted. In total, 37 transit agencies were asked to participate in the survey. The location of the agencies contacted is shown in Figure 2, and the names of the systems are listed in Table 1.

A list of stakeholders was developed. The list contained 86 contacts, and included at least two representatives from each of the 37 transit agencies shown in Table 1. It was important for every agency to have more than one contact in order to facilitate the collection of various types of sample data (e.g., collisions, volumes, geometric design, etc.). Before the representatives from the various transit agencies were invited to participate in the survey, the survey team made introductory phone calls to initiate contact.

Every individual contact received an initial e-mail invitation and a supporting phone call at the start of the survey. The survey was scheduled to run from the beginning of November until the end of December 2006, but due to a lack of response from the transit agencies during the early stages, the time period was extended until mid-January 2007. To maximize the survey response rate, the research team made follow-up phone calls to encourage participation from agencies that had not completed or responded to the survey by the end of December. The phone calls to LRT agencies continued through early January with the last survey response received on January 6, 2007.

In total, survey responses were received from 24 different LRT agencies (Table 2).

Telephone Consultations

In Phase II of the project, the project team began making consultation calls with representatives from local agencies and SSO offices. A list of 22 SSO representatives and 32 local agency representatives was provided by FTA. The 54 representatives were contacted between February and May 2008, and were asked about the following topics:

- Data collection practices;
- Relationship between the SSO and the local agencies overseen by the SSO;

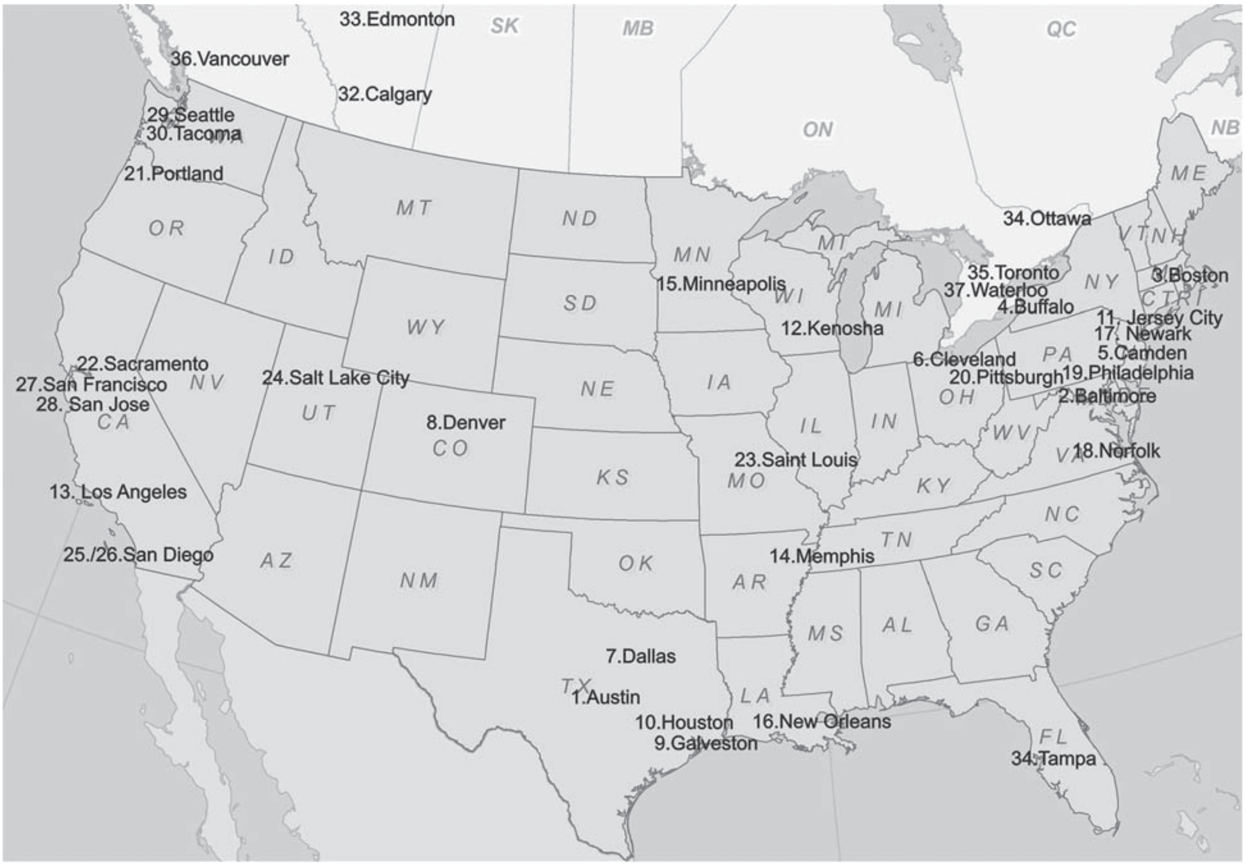

Figure 2. Location of LRT systems in the United States and Canada included in the survey.

- Data transfer activities (between local agency, NTD, and SSO);
- Availability of data for research purposes; and
- Interest in participating in the upcoming site visits, where appropriate.

In total, 14 consultations were completed with representatives from SSOs and local agencies. Consultations with SSOs focused on the SSO role and data transfer, while calls to agencies focused on procuring additional data, the form of their relationship with the SSO, and their willingness to participate in site visits.

Site Visits

From May to July of 2008, the project team conducted five site visits to LRT agencies across the United States. The site visits usually had two components:

1. A tour of the LRT system, accompanied by a knowledgeable agency representative where possible; and
2. A meeting with LRT agency staff and other stakeholders as available. The meetings ranged from informal one-on-one meetings to more formal stakeholder workshops, depending on the agency's preference and availability.

The site visits gave the project team the opportunity to observe different safety treatments and problematic locations (as identified by the respective agencies) in situ. They also allowed the project team access to the knowledge and experience of the experts who run these systems every day.

The agencies chosen for the visits were selected from the 24 agencies that responded to the survey. An initial screening identified locations that had implemented a number of different safety treatments. Different alignment types, histories of operation, and geographic locations were also targeted. Seven agencies were contacted directly to request site visits.

The five agencies who responded and who were visited were:

1. Utah Transit Authority, Salt Lake City, Utah;
2. Metro Transit, Minneapolis, Minnesota;
3. Hudson-Bergen Light Rail Line, Hudson County, New Jersey;
4. San Francisco Municipal Railroad, San Francisco, California; and
5. Santa Clara Valley Transportation Authority, Santa Clara County, California.

A complete summary of the findings of the five site visits is included in Appendix D.

Table 1. List of LRT systems surveyed.

Map No.	Locations	System
1.	Austin, TX	ASG (Capital Metropolitan Transportation Authority All Systems Go!) (Proposed system with construction scheduled to start in summer 2006. The system was tested in Spring 2009 and was not yet in service at the time of publication.)
2.	Baltimore, MD	MTA-MD (Maryland Transit Administration)
3.	Boston, MA	MBTA (Massachusetts Bay Transportation Authority)
4.	Buffalo, NY	NFTA (Niagara Frontier Transit Authority)
5.	Camden, NJ	NJT (New Jersey Transit – River LINE)
6.	Cleveland, OH	GCRTA (Greater Cleveland Regional Transit Authority)
7.	Dallas, TX	DART (Dallas Area Rapid Transit)
8.	Denver, CO	RTD (Regional Transit District)
9.	Galveston, TX	GIT(Galveston Island Transit)
10.	Houston, TX	Metro (Metropolitan Transit Authority of Harris County)
11.	Jersey City, NJ	NJT-HBLR (New Jersey Transit – Hudson-Bergen Light Rail)
12.	Kenosha, WI	KT (Kenosha Transit)
13.	Los Angeles, CA	LACMTA (Los Angeles County Metropolitan Transportation Authority)
14.	Memphis, TN	MATA (Memphis Area Transit Authority)
15.	Minneapolis, MN	MT (Metro Transit)
16.	New Orleans, LA	NORTA (New Orleans Regional Transit Authority)
17.	Newark, NJ	NJT-NCS (New Jersey Transit – Newark City Subway)
18.	Norfolk, VA	HRT (Hampton Roads Transit) (Currently under construction. Expected completion date is in early 2009)
19.	Philadelphia, PA	SEPTA (Southeastern Pennsylvania Transportation Authority)
20.	Pittsburgh, PA	PAAC (Port Authority of Allegheny County)
21.	Portland, OR	TriMet (Portland TriMet)
22.	Sacramento, CA	SRTD (Sacramento Regional Transit District)
23.	Saint Louis, MO/IL	BSDA (Bi-State Development Agency)
24.	Salt Lake City, UT	UTA (Utah Transit Authority)
25.	San Diego, CA	SDTI (San Diego Trolley Inc.)
26.	San Diego, CA	NCTD (North County Transit District)
27.	San Francisco, CA	SF Muni (San Francisco Municipal Railway)
28.	San Jose, CA	SCVTA (Santa Clara Valley Transportation Authority)
29.	Seattle, WA	WFSC (King County Metro)
30.	Tacoma, WA	ST (Sound Transit, Link)
31.	Tampa, FL	HART (Hillsborough Area Regional Transit)
32.	Calgary, Alberta	C-Train
33.	Edmonton, Alberta	Edmonton Transit System
34.	Ottawa, Ontario	O-Train (diesel-powered pilot project)
35.	Toronto, Ontario	TTC (Toronto Transit Commission) Streetcars
36.	Vancouver, British Columbia	CLCO (Canada Line Rapid Transit Link – RAV Line)
37.	Waterloo, Ontario	Region of Waterloo (Waterloo LRT) (In the environmental assessment stage)

State of the Practice Summary

TCRP Report 69 indicated that LRT systems in North America are generally safe. A crash at any given crossing is a rare event, but when a collision occurs at an LRT crossing, the outcome is often severe (*1*). The following sections provide information about current safety practices along the LRT alignment. LRT Exposure to Pedestrians and Motor Vehicles describes the influence of LRT exposure. The next section identifies the top safety issues, and LRT Safety Treatments provides basic information about the types of treatments available to LRT agencies.

LRT Exposure to Pedestrians and Motor Vehicles

A number of TCRP research projects have discussed safety in the LRT alignment. *TCRP Report 17* (TCRP Project A-05)

Table 2. List of LRT agencies responding to the online survey.

Map No.	Locations	System
2.	Baltimore, MD	MTA-MD (Maryland Transit Administration)
5.	Camden, NJ	NJT (New Jersey Transit – River LINE)
8.	Denver, CO	RTD (Regional Transit District)
10.	Houston, TX	Metro (Metropolitan Transit Authority of Harris County)
11.	Jersey City, NJ	NJT-HBLR (New Jersey Transit – Hudson-Bergen Light Rail)
12.	Kenosha, WI	KT (Kenosha Transit)
13.	Los Angeles, CA	LACMTA (Los Angeles County Metropolitan Transportation Authority)
14.	Memphis, TN	MATA (Memphis Area Transit Authority)
15.	Minneapolis, MN	MT (Metro Transit)
19.	Philadelphia, PA	SEPTA (Southeastern Pennsylvania Transportation Authority)
20.	Pittsburgh, PA	PAAC (Port Authority of Allegheny County)
21.	Portland, OR	TriMet (Portland TriMet)
22.	Sacramento, CA	SRTD (Sacramento Regional Transit District)
23.	Saint Louis, MO/IL	BSDA (Bi-State Development Agency)
24.	Salt Lake City, UT	UTA (Utah Transit Authority)
25.	San Diego, CA	SDTI (San Diego Trolley Inc.)
26.	San Diego, CA	NCTD (North County Transit District)
27.	San Francisco, CA	SF Muni (San Francisco Municipal Railway)
28.	San Jose, CA	SCVTA (Santa Clara Valley Transportation Authority)
29.	Seattle, WA	WFSC (King County Metro)
30.	Tacoma, WA	ST (Sound Transit, Link)
32.	Calgary, Alberta	C-Train
33.	Edmonton, Alberta	Edmonton Transit System
35.	Toronto, Ontario	TTC (Toronto Transit Commission) Streetcars

focused on light rail operating on-street at low to moderate speeds, while *TCRP Report 69* (TCRP Project A-13) investigated light rail safety for operations in semi-exclusive rights-of-way at speeds greater than 55 km/h (35 mph). TCRP Project D-09 provided more general information about the design of transit vehicles and facilities, both bus and light rail. Several other studies of specific safety problems and treatments have been published by TCRP and other organizations.

LRT alignments are typically categorized into three right-of-way types for planning purposes. These classifications are also used for operations and safety. TCRP Reports 17 and 69 and TCRP Project D-09 used this classification system to distinguish between different types of light rail alignments. The classification system is useful because the type of alignment and the resulting level of exposure to vehicles and/or pedestrians have significant safety implications.

TCRP Report 17 provides this information about the three basic alignment classes (*2*):

1. Type a. Exclusive alignments use full grade separation of both motor vehicle and pedestrian crossing facilities. Exclusive alignments eliminate grade crossings and operating conflicts, and maximize safety and operating speeds.
2. Type b. Semi-exclusive alignments keep the LRT apart from road vehicles and pedestrians, except where road vehicles and pedestrians intersect at an at-grade crossing. Operating speeds on segments that do not have automatic crossing gates are governed by vehicle speed limits on the streets or highways. On Type b segments where the right-of-way is fenced, operating speeds are maximized (based on geometric limits), but these higher speeds are typically maintained only for short distances, often on segments between grade crossings.
3. Type c. Non-exclusive alignments allow for mixed flow operation with motor vehicles or pedestrians, resulting in higher levels of operating conflicts and lower-speed operations. Non-exclusive alignments are often found in downtown areas where there is a willingness to forgo operating speeds in order to access areas with high population density and many potential riders.

Table 3 summarizes the alignment classification set out in *TCRP Report 69* (*1*). That report provides more detailed descriptions of each subcategory.

TCRP Report 17 considered the safety issues and implications associated with the different types of light rail alignment,

Table 3. LRT alignment classification.

Class	Category	Description of Access Control
Exclusive	Type a	Fully grade separated or at-grade without crossings
Semi-exclusive	Type b.1	Separate right-of-way
	Type b.2	Shared right-of-way, protected by barrier curbs and fences (or other substantial barriers)
	Type b.3	Shared right-of-way, protected by barrier curbs
	Type b.4	Shared right-of-way, protected by mountable curbs, striping and/or lane designation
	Type b.5	LRT/pedestrian mall adjacent to parallel roadway
Non-exclusive	Type c.1	Mixed traffic operation
	Type c.2	Transit-only mall
	Type c.3	LRT/pedestrian mall

Source: *TCRP Report 69* (*1*)

and suggested the following sequence for route alignment choices in order of desirability (*2*):

- Exclusive alignment (Type a),
- Separate right-of-way (Type b.1),
- Median alignment protected by barrier curbs and/or fences (Types b.2 and b.3),
- Median alignment protected by mountable curbs and striping (Type b.4),
- Operation in reserved transit malls or pedestrian areas (Types b.5, c.2, and c.3), and
- Operation in mixed traffic (Type c.1).

After considering safety, some additional issues can also be addressed. For example, Type a alignments, where the LRT is completely separated from the road and pedestrian network, allow LRVs to reach high speeds, but may be difficult for riders to access from surrounding areas. These types of alignment are most often served by park-and-ride lots or other transit modes. Type b and Type c alignments create more exposure to safety issues, but they offer the advantage of providing more direct access to a variety of land uses (*3*).

This report is concerned with the interactions of pedestrians and motor vehicles with LRT alignments, and addresses both Type b and Type c alignments. It does not address Type a alignments as Type a alignments are designed to eliminate pedestrians and motor vehicle interactions, except in unusual or extraordinary circumstances (e.g., trespassing).

In all the various systems visited, the LRT staff noted considerably different operating behaviors between the downtown street-running sections and the more suburban restricted right-of-way (ROW) sections. In at least one case, LRT staff commented that transit operators felt that they noticeably relaxed when entering a restricted ROW section after navigating a much more complex mixed traffic median-running environment. Many agencies reported that left-hand turn collisions are a significant issue. These collisions are avoided in areas where left hand turns are physically restricted. Physical separation of general traffic from the LRT remains the best way to prevent collisions, but it is not always the most efficient or desirable from a cost or ridership perspective. This is because the needs of other modes and the need for access must be considered when designing a light rail system. Physical separation, where feasible, can include a combination of separate alignments, grade separation at intersections, and fencing/barrier systems.

Top LRT Safety Issues

The objective of the literature review and the consultations with LRT operators was to identify the most significant safety issues along LRT alignments. Identification of safety issues is a useful step in the selection of safety treatments, as it permits the selection of specific treatment(s) for a problem rather than general or default measures.

The first three lists of safety issues presented in this section summarize the main LRT safety issues according to *TCRP Report 17, TCRP Report 69,* and the site visits conducted for this project. The lists are extensive because of the need to recognize a wide variety of different alignments and local considerations, and because much of the information is anecdotal rather than quantitative in origin. The lists have no statistical significance, but provide a broad view of the types of issues that LRT agencies and SSOs are facing and trying to mitigate.

The fourth list condenses the three lists into the top five safety areas facing LRT agencies.

TCRP Report 17 (*2*) investigated 10 transit agencies with operating speeds of less than 35 mph (55 km/h). The authors identified some common safety-related problems faced by

LRT agencies through agency interviews, collision analysis, and field surveys.

These were:

- Pedestrian safety:
  - Trespassing on tracks
  - Jaywalking
  - Station and/or cross-street access
- Side-running alignment
- Vehicles operating parallel to LRT's ROW turning left across tracks:
  - Illegal left turns
  - LRV pre-emption violating motorists' expectation of protected left-turn signal phases
- Traffic control:
  - Passive turn restriction sign violations
  - Active turn restriction sign violations
  - Confusing traffic signal displays
  - Poor delineation of dynamic envelope
- Motor vehicles on tracks
- Crossing safety (right-angle crashes)
- Poor intersection geometry

TCRP Report 69 (*1*) investigated 11 LRT lines with operating speeds greater than 35 mph (55 km/h). The common safety-related problems identified were:

- System division:
  - Vehicles drive around closed automatic gates
  - LRV operator cannot visually confirm whether gates are working
  - Slow trains share tracks/crossings with faster LRVs and near-side LRT station stops
  - Motorists disregard regulatory signs at LRT crossings and grade crossing warning devices
  - Motor vehicles queue back across LRT tracks from a nearby intersection controlled by STOP signs (MUTCD R1-1)
  - Sight distances are limited at LRT crossings
  - Motor vehicles queue across LRT tracks from downstream obstruction
  - Automatic gate and traffic signal interconnect malfunctions
- System operations:
  - Freight line is shared with LRT
  - Freight line was converted to LRT line
  - Collisions occur when second LRV approaches pedestrian crossing
  - Motorists disregard grade crossing warning devices
- Traffic signal placement and operation:
  - Motorists confused about apparently conflicting flashing light signal and traffic signal indications
  - Track clearance phasing
  - Excessive queuing near LRT crossings
  - Turning vehicles hesitate during track clearance interval
  - Vehicles queue back from closed gates into intersection
  - LRT crosses two approaches to a signalized intersection (diagonal crossing)
  - Motorist confused about gates starting to go up and then lowering for a second time, when a second LRV arrives from the opposite direction
  - LRT versus emergency vehicle pre-emption
  - Turning motorists violate red protected left-turn indication due to excessive delay
  - With leading left-turn phasing, motorists violate red protected left-turn arrow moving on the green phase when trains also turn
- Automatic gate placement:
  - At angled crossings or for turning traffic, gates descend on top of or behind motor vehicles
- Pedestrian control:
  - Limited sight distance at pedestrian crossing
  - Pedestrians dart across LRT tracks without looking

The five agencies consulted during the site visits for this project noted a variety of safety issues. The issues cited by these agencies as being the most important safety concerns are:

- Jaywalking between marked crossing locations (i.e., mid-block, at stations, etc.);
- Trespassing at stadium stations after events;
- Pedestrians crossing against signals and/or against warning devices;
- Pedestrian collisions due to a "second train";
- Pedestrian inattention and/or distraction;
- Increased severity of pedestrian collisions;
- Pinch points on platforms;
- Risky behavior by cyclists;
- Vehicles trapped inside gates;
- Vehicles crossing tracks despite gates, signals, and/or warnings;
- Vehicles stopped on tracks due to queuing in peak traffic periods;
- Collisions in left turn lanes shared with LRT tracks;
- Left turn collisions, especially where the LRT operates in the center alignment;
- Right turn collisions, including collisions that occur on unusual alignments or where right turn on red is prohibited;
- Sideswipes on Type b.4 and c.1 alignments;
- Motorist confusion such as driving on restricted ROW;
- The public's level of respect for LRV is less than that for heavy rail;
- System inconsistencies that impact motorist and pedestrian expectations; and
- LRV operator error.

Every LRT system operates in its own unique context. In general, however, different categories of rail transit alignment have different types of safety issues. For example, LRT alignments with lower operating speeds (less than 35 mph (55 km/h)) generally have a higher level of interaction between LRVs and pedestrians, cyclists, and motorists. Warning systems and traffic control devices for LRT crossings vary between lower and higher operating speeds, and on different sections of the same system. These differences are likely to be reflected in the safety issues experienced.

The project team summarized the above issues into five top areas of safety concern that must be addressed along LRT alignments:

1. Motorist, cyclist, and pedestrian inattention;
2. Motorist, cyclist, and pedestrian confusion;
3. Lack of appropriate physical separation between motorists, cyclists, pedestrians, and the LRV;
4. Risky behavior by motorists and pedestrians; and
5. Operator error or lack of information.

The five top areas of safety concern were common themes noted in almost all communications with LRT agency staff, and should serve as a basic checklist for addressing safety problems. As sufficient data are not available to determine the relative importance of the safety concerns, it is not possible to indicate which are the most important. It is also worth noting that the concerns are not necessarily independent. For example, during the site visits, pedestrians were observed to use marked and controlled crossings far more often where there was some physical barrier to direct them.

It is clear that motorist- and pedestrian-related behaviors are challenges in LRT safety. LRT agencies can deal directly with operator error or lack of information, but they do not have direct influence over motorists and pedestrians. At the macro level, it may be impossible or impractical to provide complete physical separation between LRT and other modes for many LRT systems. LRT agencies and the broader transportation planning authorities must balance the risk of collisions with other needs and considerations for the greatest overall value. At the micro level, there must be a distinction between preventing risky behavior due to inattention and confusion, and preventing risky behavior due to purposeful noncompliance. The agencies visited were clear that purposeful noncompliance can be difficult, if not impossible, to prevent.

LRT Safety Treatments

LRT safety treatments can be divided into two major categories: physical improvements (including traffic controls) to the immediate environment surrounding the LRT, and education and enforcement programs for LRT staff and the community that live or work in the LRT area. LRT safety treatments can be applied system-wide or to specific locations. In many cases, individual treatments are not applied in isolation, but are applied as part of an integrated treatment package. A package of treatments can be effective, as some safety issues cannot be addressed by a single treatment alone, but when a package of treatments is applied, it may be difficult to discern which element of a package has the most effect on safety.

This section provides an overview of *physical improvements* and *programs within the community*. Additional information about safety treatments is presented in Chapter 4. Detailed information about specific treatments is presented in Chapter 5 and Appendix A, the Catalog of Safety Treatments.

Physical Improvements

Physical improvements, including traffic control improvements, can be divided into two overall types: active and passive measures. Passive measures do not change with the approach of the LRV, whereas active measures react when an LRV approaches. A passive physical treatment might be a warning for pedestrians or motorists about the presence of an LRV. An active physical treatment might be a device that physically prevents pedestrians and vehicles from entering the ROW. While passive measures have the advantage of simplicity (for example, they cannot fail electrically or mechanically), the change that occurs in an active device has the effect of generating attention from the intended audience of motorists, pedestrians, and cyclists. This may add considerably to the safety benefit of the basic message. During the site visits, the project team observed that well-designed active measures appeared more effective than passive measures, and this was also noted in the feedback from agency staff.

Active treatments that were not well tuned to their environment lost impact. For example, in one location the site visit team observed a pedestrian crossing with flashing lights and bells that rang for many seconds longer than necessary and consequently seemed to be ignored by virtually all pedestrians in the vicinity who crossed the tracks regardless of the warning. The message was certainly clear but the information was treated as incorrect by the pedestrians. However if the bell would start ringing much closer to the arrival time of the LRV, people might take it more seriously. In another location observed, an active second train warning sign had poor contrast and was essentially unreadable in daylight conditions, so the message was not effectively delivered.

Education and Enforcement Programs

The second major category of treatments comprises programs within the agency and community. These programs include education and enforcement activities. It is common for agencies to provide safety training programs for LRV operators. Other programs focus on educating motorists, pedestrians, and cyclists about safety near LRT alignments through signage on platforms, educational brochures, and web pages on safety.

Community programs have been implemented across the country, many in cooperation with Operation Lifesaver's Light Rail branch (Operation Lifesaver, www.oli.org). The programs target children and/or adults through different styles and modes of message delivery and different key safety messages. Some jurisdictions have promoted the inclusion of light rail safety information in their state driver's handbooks. Local enforcement agencies may be involved by means of issuing citations for infringement of the LRT's ROW and other unsafe behavior. Some agencies are also using speakers at their stations and in the LRV to broadcast public safety messages.

Summary

The existing body of knowledge regarding LRT safety experience includes both formal research and practical experience. Following an extensive literature review, a survey of local transit agencies, follow-up consultations with local transit agencies, and information gathered during site visits, the project team was able to identify the five most critical areas of safety concern that must be addressed along LRT alignments. These safety concerns are inattention of those approaching the LRT alignment; confusion of those approaching the LRT alignment; lack of appropriate separation between motorists, cyclists, pedestrians, and the LRV; risky behavior by those approaching the LRT alignment; and LRV operator error or lack of information. The statistical information available is insufficient to determine the relative importance of these safety concerns, or the nature of any interrelationships between them.

LRT safety treatments can be divided into two major categories: physical improvements to the immediate environment surrounding the LRT, and education and enforcement programs. Appendix A provides a detailed catalog of LRT safety treatments.

Physical improvements can be further categorized into passive measures and active measures. In general, well-designed active measures (including traffic controls) that suited their environment were more effective in increasing LRT safety than were passive measures. A wide variety of education and enforcement programs are available, but the effectiveness of these programs is difficult to quantify. While it is possible to implement measures to prevent risky behavior resulting from inattention or confusion, it is virtually impossible to mitigate the impact of deliberate noncompliance.

CHAPTER 3

LRT Safety Data Available from Local Transit Agencies, SSOs, and the NTD

This chapter presents a review of LRT collision data obtained from transit agencies across the United States. The purpose of this chapter is to identify the purpose of collecting and storing collision data at each level of government, identify the actual data collected at each level, assess the quality of the data collected and identify any potential issues or deficiencies, and, where possible, analyze the data to determine root causes and factors contributing to LRT collisions.

The Data Collection and Transfer between FTA/NTD, SSO, and Local Transit Agencies section outlines the relationship between the three hierarchical levels of transit administration, and identifies the datasets requested and received by the project team from various transit agencies. The National Transit Database, SSO Agencies, and Local Transit Agencies sections examine the collision data available at the federal, state, and local transit agency levels, respectively. The Comparison of Databases section concludes with a comparison of the data available across the three levels of transit administration.

Data Collection and Transfer between FTA/NTD, SSO, and Local Transit Agencies

Incident report data are collected and stored at three distinct hierarchical levels of transit administration in the United States: the federal level, state level, and local level. This section briefly outlines how transit incident data are stored and transferred between the three levels of transit administration. The purpose and method of incident data collection at each level of transit administration are presented in Chapter 7 and Appendix E.

The primary source of incident data is the information collected at the scene of the incident using collision report forms. According to Rule 49 CFR Part 659 of the Federal Transit Administration Act, it is the responsibility of the SSO agency to "investigate, or cause to be investigated . . . any incident involving a rail transit vehicle or taking place on rail transit-controlled property" meeting certain notification requirements (see the Data Collected by NTD section) (*4*). Based on discussions with SSO and local transit agencies, it is usually the local transit agency that conducts the incident investigation at the scene. When this is the case, the local transit agency is required to incorporate practices specified and approved by the oversight agency into the investigation procedure used by the local transit agency.

In addition, the local transit agency is required to transmit a final investigation report that identifies any contributing or casual factors and outlines a corrective action plan. The SSO agency is required to review the findings of the investigation report, and either adopt it or formally transmit its dissent to the report findings.

When the SSO agency disagrees with the findings of the investigation report, the SSO agency may conduct its own independent investigation of the incident. In the case where the SSO agency does not authorize the local transit agency to conduct incident investigations on its behalf, but instead chooses to investigate the incident directly, the SSO agency is responsible for compiling the final investigation report and transmitting it to the local transit agency. The exact methodology employed to meet the above requirements is left largely to the discretion of the SSO and local transit agencies, and may differ between jurisdictions. The SSO agency is responsible to compile and submit to the FTA an annual report summarizing its oversight activities, including a description of the contributing/casual factors of investigated collisions, and the status of any corrective actions.

In addition to meeting its obligation to the SSO agency, the local transit agency is also required to investigate all incidents meeting the NTD criteria of a reportable incident outlined in the Data Collected by NTD section. The local transit agency is responsible for completing and submitting the S&S-40 Reportable Incident Report form (S&S-40 form) for each reportable incident within 30 days of incident occurrence. In addition to this, local transit agencies are required to submit the S&S-50 Safety and Security Monthly Summary

Report form (S&S-50) on a monthly basis. This form reports a summary of the non-reportable safety and security incidents that occurred within the previous month. Figure 3 illustrates the transfer of incident data from the scene of the incident across the three levels of transit administration.

As indicated in Figure 3, the incident investigation can be performed by the SSO agency, the local transit agency, or both. However, in practice, it is the local transit agency that conducts the incident investigation and transfers the final investigation report to the SSO agency.

Collision Data Available, Requested, and Received

In an effort to conduct a comprehensive review and accurate analysis of LRT safety data, the project team requested collision databases from a variety of transit agencies at each of the three levels of transit administration.

The NTD provided two complete databases in Microsoft Excel format, which contained all reported safety and security incidents that occurred between the years 2002 and 2007. The first database contained all of the "non-reportable" (formerly "non-major") incidents reported to the NTD through the S&S-50 form. The second database contained all the "reportable" (formerly "major") incidents reported to the NTD through the S&S-40 form. Since the non-major incident database did not contain sufficient detail to either identify individual incidents or be used in safety analysis, only the major incident database (henceforth referred to as the "NTD database") was examined.

The project team also requested databases from a number of SSO agencies. However, only the CPUC provided a database for analysis. The CPUC database was provided in MS Excel format, and included a total of 22 data fields. Based on discussions with SSO agencies, it appears that many SSO agencies do not store electronic collision data suitable for conducting safety analysis on multiple incidents. The data collected by SSO agencies is primarily intended for the investigation of individual incidents with the goal of developing a suitable corrective action plan. However, some SSO agencies are moving toward electronic database systems that would be suitable for conducting large-scale safety analysis.

The project team conducted a survey of local transit agencies to determine the availability and quality of collision data at the local transit agency level. In total, 24 local transit agencies responded to the survey. Of these 24 agencies, 21 had collision data in either hardcopy or electronic format. The project team followed up by requesting collision data from most of the transit agencies who had indicated that they had collision data, but many transit agencies either did not respond to these requests or declined to provide collision data. In total, collision data was obtained for eight local transit agencies. However, the transit agencies that did decide to provide collision data were either unable or unwilling to provide it in database format. In addition, the time period covered by the data varied from agency to agency.

National Transit Database

The United States Congress created the NTD to be "the Nation's primary source for information and statistics on the transit systems of the United States" (*5*).

The mandate of the NTD is set forth in Title 49 U.S.C. 5335(a), which states:

> To help meet the needs of individual public transportation systems, the United States Government, State and local governments, and the public for information on which to base public transportation service planning, the Secretary of Transportation shall maintain a reporting system, using uniform categories to accumulate public transportation financial and operating information and using a uniform system of accounts. The reporting and uniform systems shall contain appropriate information to help any level of government make a public sector investment decision. The Secretary may request and receive appropriate information from any source.

Any recipient or beneficiary of the "Urbanized Area Formula Program" and "Other Than Urbanized Area (Rural)

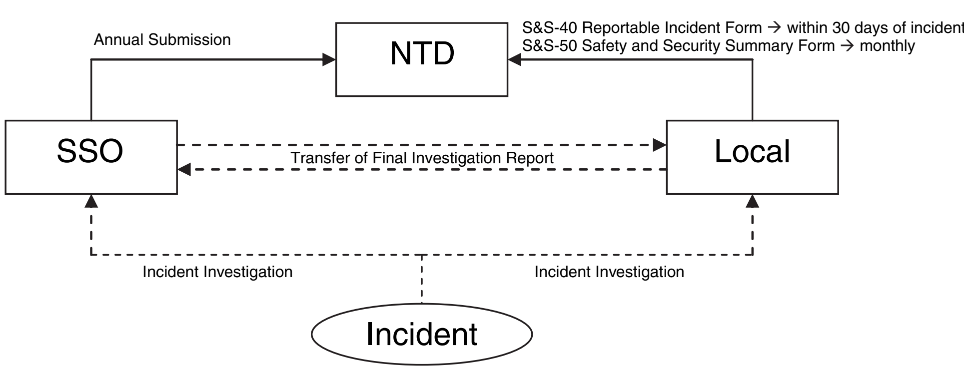

Figure 3. Transit incident data transfer across levels of transit administration.

Formula Program" is required to submit data to the NTD; there are currently over 650 transit agencies that send reports to the NTD (*5*).

Purpose of NTD Safety Data Collection

The FTA receives and compiles data in the NTD from each agency with an LRT system in the United States through a standard electronic reporting form. The data collected by the NTD is used by a variety of organizations for diverse purposes, including formulation of National Transit Policy, state and regional planning and investment, academic/industry research, special analyses, and applications relating to the private sector/general public (*5*). In order to meet the diverse demands of its users and provide summary level information to the public, the NTD produces publications such as *Transit Profiles, Data Tables,* and *National Transit Summaries and Trends.* These publications summarize important service, financial, operational, and modal data for both individual agencies and the nation as a whole. The NTD provides these publications for download free of charge on the NTD website (http://www.ntdprogram.gov/ntdprogram).

The NTD is not directly involved in efforts to improve transit safety at the local level: transit safety is the responsibility of the SSO and local transit agencies. In fact, the NTD was not primarily designed for the purpose of reporting of safety and security data. It is only "in recent years (that) the NTD has grown to include safety, security, and rural transportation data" (*5*). According to the NTD website, the stated objective of the collection of safety and security data by the NTD is the development of performance benchmarks based on the statistics obtained from transit systems nationwide (*6*). The data collected by the NTD from the SSO and local transit agencies are used to produce publications summarizing national transit service and safety data.

Data Collected by NTD

The data collected by the NTD can be divided into four general categories: operational characteristics, service characteristics, capital revenue and assets, and financial operating statistics. Data pertinent to safety analysis primarily falls into the categories of service and operational characteristics.

The actual reporting of the data is the responsibility of the transit reporters, who generally fall into the following three categories: transit agencies, providers of purchased transportation services, and voluntary reporters (*5*). Transit reporters provide the NTD with the required data through the submission of the following four standardized reporting forms: the Annual Report, the Monthly Report, the Safety and Security Report, and the Rural Report (if applicable). Each of these documents consists of a series of forms that must be completed and submitted to the FTA by the transit reporter:

1. The Annual Report provides "a summary of transit characteristics for the fiscal year, including financial and nonfinancial operating statistics" (*7*).
2. The Monthly Report provides the NTD with a summary of the ridership and service provided by the transit agency over the past month (*7*).
3. The Safety and Security Report provides a summary of transit-related security and safety incidents for the year (*7*).
4. The Rural Report is a summary of transit data for rural systems receiving funding under the FTA Formula Program for Non-Urbanized Areas (*8*).

The data provided in the Annual Report, Monthly Report, and Rural Report are not primarily intended for safety analysis, but contain some information (e.g., measures of exposure to risk, vehicle revenue miles, etc.) that would be useful for that purpose. The Safety and Security Report is the primary source of the data required for safety analysis.

The two forms used to report safety and security data to the NTD are the S&S-40 Reportable Incident Report form and the S&S-50 Safety and Security Monthly Summary Report form. Both of these forms are described in greater detail in Appendix E. The collision data reported in the S&S-50 form is provided in a monthly summary format that is not conducive to safety analysis. Incidents are treated as aggregate datasets that provide no detailed information regarding the conditions or circumstances present at each incident. Therefore, the data used in safety analysis is drawn almost exclusively from the S&S-40 report form.

The S&S-40 form is used only to report incidents that satisfy the criteria of a "reportable incident" (formerly "major incident").

According to the *2008 Safety and Security Reporting Manual:* A reportable incident is an event that involves a transit vehicle or occurs on transit controlled property and meets one or more of the following conditions:

- A fatality (including a suicide or deaths resulting from other safety occurrences not otherwise classified),
- Injuries requiring immediate medical attention away from the scene for one or more persons,
- Property damage equal to or exceeding $25,000, or
- An evacuation for life safety (*7*).

The above criteria have undergone numerous significant changes between the years 2002 and 2008. In general, the reporting requirements have become increasingly sensitive to incidents resulting in injuries/fatalities, and less focused on reporting incidents that do not. For example, prior to the issue of the *2008 Safety and Security Reporting Manual,* an incident could not be classified as a major incident if a fatality was the result of a suicide, or if there were less than two injuries requiring immediate medical attention away from the scene. Table 4 shows criteria previously considered indicative of a major incident and the years they were included.

The implications of these changes in incident reporting should be considered when analyzing the data contained in the NTD. For example, prior to 2003, rail collisions at a grade crossing were subject to the same reporting criteria as all other incidents, while in 2003 the NTD made all rail collisions at a grade crossing reportable. From 2004 to 2007, collisions at grade crossings were given their own specific criteria (i.e., property damage exceeding $7,500, or one or more injuries) to be used in evaluating whether or not they were reportable. In the most recent edition of the NTD *Safety and Security Reporting Manual,* rail collisions at an at-grade crossing are once again subject to the same reporting criteria as all other collisions, but these have been changed since pre-2003. It should also be noted that the definition of a crossing can vary. For a while, some cities (such as San Francisco) only defined LRT crossings with gates as crossings.

Frequent changes in reporting standards result in some confusion among local transit agencies as to which incidents are reportable from year to year, and lack of uniformity in collision data between years results in reduced ability to make inferences from available data. Despite these disadvantages, the NTD has introduced changes to NTD reporting criteria as part of its effort to balance the need to maximize the quality and relevance of safety data in the NTD while minimizing unnecessary data collection and reporting at the local level.

The NTD Database

The NTD contained 66 data fields for each major incident. Table 5 shows the data fields in the NTD summarized by category of data.

As shown in Table 5, the data fields contained in the NTD provide comprehensive information for a variety of data categories. The date and time of each incident is clearly specified, and includes a field to indicate the time zone of the location where the incident occurred. The location of the incident is also clearly identified, and users are even provided with the option of specifying the exact longitude and latitude of the incident location. All parties involved in the collision are classified (i.e., pedestrian, motor vehicle) and described.

The key categories of data with regard to safety analysis are consequence of the incident, alignment/crossing controls, environmental factors, and exposure to risk. The consequence of the incident is quantitatively defined by the number of injuries, the number of fatalities, and the extent of property damage (in dollars) resulting from the incident. The alignment is identified based on the classification of the right-of-way as exclusive, semi-exclusive, non-exclusive, etc. The crossing control field indicates the presence or absence of passive or active control devices for road/rail grade crossings. If the incident occurred at a street intersection (common for LRT), the control device at the intersection is also provided. Environmental factors include illumination, weather, ROW condition (i.e., dry, wet, slush, etc.), ROW configuration (straight, curve, uphill, downhill, etc.), and ROW type (i.e., divided highway, intersection/grade crossing, etc.).

Although the NTD included data fields for measures of exposure, all five data fields in this category were blank for all of the recorded incidents. In addition, examination of the NTD *Safety and Security Manuals* between 2003 and 2008 indicated that the

Table 4. Reportable criteria.

Reportable Criteria	Years Included in Major Incident Reporting Criteria (Inclusive)
A collision at grade crossing	2003
A collision at grade crossing resulting in at least one injury requiring immediate medical attention away from the scene or property damage equal to or exceeding $7,500	2004–2007
A collision with person(s) on a rail right-of-way (ROW) resulting in at least one injury requiring immediate medical attention away from the scene for at least one person	2003–2007
A mainline derailment	2003–2007
A collision involving a rail transit vehicle resulting in at least one injury requiring immediate medical attention away from the scene for at least one person	2003–2007
Forcible rape	2006–2007
Confirmed terrorist events	2006–2007

Table 5. NTD data fields by category.

Data Category	No. Data Fields	Additional Details
Mode/Service	2	Transit Mode, Service
Date/Time	6	Date, Hour, Minute, AM/PM, Time Zone, Time Period Desc.
Location	7	Transit Agency, City, Location Desc., Latitude, Longitude
Description of Involved Parties	2	Involved Party Category/Desc.
Incident Classification	6	Event Level/Category/Type, Collision Manner, Local Level Desc.
Consequences of Incident	3	No. Injuries, No. Fatalities, Property Damage ($)
Alignment/Crossing Controls	4	Alignment Type, Grade Crossing Control, Intersection Control
General Descriptions (i.e., actions)	7	Incident/Passenger/Other Veh./Action/Other Action/Event Desc.
Environmental Factors	8	Weather, Lighting, ROW Conditions/Configuration/Type
Contact Info (User)	4	Name, Phone No., Title, E-mail
Data Record ID	6	Incident No., Revision No., Begin/End/Submitted Date
Exposure to Risk	5	Pass. Trips, Veh. Rev. Miles/Hrs, Weekly Trip Cnt., Volume Cnt.
Unknown/Other	6	
Total	**66**	

S&S-40 form did not provide the user with the opportunity to enter this data on the Internet reporting form. The reason for including the data fields in the NTD but not collecting data for them is unknown. The inclusion of these data fields on the S&S-40 form would provide valuable information to analysts.

Finally, the NTD database includes a number of records intended to track the status of the record itself, such as when it was submitted/edited, who submitted it, how many revisions it has undergone, etc. There were also six data fields that did not correspond to fields on the S&S-40 form whose purpose could not be determined.

NTD Data Quality Issues

This section outlines the deficiencies identified in the NTD database, the remedial measures employed to address them, and suggestions to avoid future data quality issues.

Data Cleaning Process

A preliminary examination of the NTD database revealed several significant issues with the quality of the data. In an effort to facilitate data analysis, the project team performed a series of "data cleaning" exercises aimed at remedying the most common data deficiencies. This was accomplished using a systematic approach involving two major steps. First, data records were examined to see if contradictions and omissions in key data fields could be eliminated using the available information. Second, records that were either not LRT collisions or duplicates of other collision records were removed from the database.

Data Record Correction. The first step of the data cleaning process was to identify and rectify any contradictory or omitted information in the collision records. Due to the number of observed errors in the records, it was critical to avoid including errors, as well as avoiding the exclusion of viable records from the analysis by addressing these deficiencies where possible. In general, most significant contradictions/omissions in the data records generally occurred in the following fields: event category, collision manner, lighting conditions, dates, injury counts, right-of-way type, and grade crossing control type.

Event Category. The "event category" field classified an incident either as a "collision," "evacuation," "security," "derailment," "fire," or "not otherwise classified (NOC)." During the data cleaning process, it was observed that 73 of the 2,226 records identified as LRT-related were classified incorrectly, either due to an error in data entry, or because the classifications were not mutually exclusive. For example, it was observed that some incidents classified as derailments were actually the result of a collision, as indicated in the description field for the record. There were also collisions that were categorized as NOC, or simply had a blank category field. The classification of these collisions was updated to reflect the information provided in the "event description field."

Collision Manner. The "collision manner" field described what other vehicles, objects, or individuals were involved in the collision. In 117 records, an entry of "with object: other object (describe)" was changed to "with motor vehicle" when the description field clearly indicated that another vehicle was involved.

Lighting Conditions. The "lighting conditions" field described the natural and artificial illumination present at the time of the collision. For 49 records, the fields that described the prevailing lighting/weather conditions and time of day produced seemingly contradictory accounts. For example, one record indicated the time of the incident to be 3:00 a.m., while the lighting conditions were listed as "daylight, clear." In such cases, it was usually not possible to determine whether the time of day or the lighting condition had been incorrectly entered. Therefore, it was not possible to reconcile some of the apparent contradictions relating to lighting condition.

Dates. The date of the incident was omitted in 27 of the records contained in the database. In some cases, it was possible to retrieve the date from records of the same incident in either the SSO or local transit agency database. For example, a comparison of the NTD database with the California PUC (SSO) database for the Sacramento Regional Transit District allowed the recovery of four missing dates in the NTD data. In total, eight NTD records had dates recovered from either the SSO or local data for incidents with the same reported year, time, and incident description.

Injury Counts. The number of injuries provided in the "injury count" field conflicted with the number of injuries provided in the "event description" field for 7 NTD records. For example, a record listed as describing one injury included a detailed description noting that six individuals were taken to the hospital to be treated for injuries. In these cases, the "injury count" field was revised to match the "event description" field.

Alignment Type. The "alignment type" field classified the ROW as exclusive, semi-exclusive, non-exclusive, etc. The classification of the right-of-way in the "alignment type" field was updated in 62 records where the text description provided a clear description. Unfortunately, the description fields provided insufficient information to update the alignment type for 176 of the data records.

Grade Crossing Control Type. The "grade crossing control type" field classified the control devices present at road/rail grade crossings. This data field was updated based on information contained in the description fields for 104 records. In most of these cases, the field was originally empty, but the text description provided a sufficiently detailed description of the type of crossing control.

Transit Vehicle. The type of transit vehicle was identified incorrectly in 19 of the data records. These records identified the transit vehicle involved in the collision as an LRT vehicle when the description indicated it was a bus. These records were later removed from the database (see the Non-LRT Vehicle section).

Many of the records in the NTD database suffered from incomplete and/or inaccurate information in key data fields, and required significant data cleaning in order to be included in subsequent data analysis. In many cases, the fields containing detailed descriptions of the incidents contained the information required to make the necessary corrections. However, in many instances it was not possible to make necessary corrections to the records because the record lacked sufficient descriptive information. This problem was partly due to the truncation of the detailed "event description" fields in both the NTD and SSO datasets. Discussion with FTA staff indicated that this was a database problem and that a fix would be forthcoming for the 2008 reporting that will eliminate this truncated data problem (e-mail communications with FTA staff, Feb. 2008). Unfortunately, the problem was only identified after part of the description had already been lost.

In current and past editions of the S&S-40 online reporting form, the user is required to enter information in certain mandatory data fields (indicated with an asterisk) before the user can either save or submit the report. The *NTD Safety and Security Manual* (on the NTD web site at http://www.ntdprogram.gov/ntdprogram/safety.htm) has included a statement requesting that users input information into all data fields but not all data fields are designated as mandatory. To prevent users from omitting information critical to safety analysis in the future, the NTD could expand the number of mandatory fields that require information to be entered by the user before a report can be submitted.

It is more difficult to solve the problem of inaccurate data. The *NTD Safety and Security Manual* already contains detailed explanation for each data field, including descriptions of available options/answers, and instructions for completion. The NTD continues to improve the *Safety and Security Manual* to address identified data reporting issues. To further mitigate the problem of incorrect data reporting, the NTD could produce an annual list of common mistakes made in data reporting, including an explanation of frequently misunderstood data fields. The feasibility of this may be an issue: to identify specific problems, the NTD would have to devote time and manpower to a data cleaning procedure similar to the one employed by the project team.

Data Record Removal. Following the data correction process outlined above, the database was examined to identify and remove records that were attributed to non-existent transit agencies, were the result of duplication of records for the same incident, or that incorrectly indicated the transit vehicle was an LRT vehicle. The following deletions were carried out:

Non-existent Transit Agency. Of the 2,226 records in the database, 2 were attributed to a non-existent "ABC Agency" and were deleted.

Duplicate Records. The NTD database allows users to access previously submitted incident records to make any necessary additions or changes subsequent to the submission of the data record. Each revised record is assigned a "revision number" corresponding to the number of revisions made to the record since original submission. Upon inspection of the NTD database, it appeared that duplicate records created for the same incident did not have a unique revision number. In most cases, the incident report was perfectly cloned for all but one or two characteristics which were likely added during the revision of the record. For example, two records would contain identical information, but one data record listed the number of fatalities and no injuries, while the second record listed the number of injuries and fatalities.

It was observed that many of the Southeastern Pennsylvania Transportation Authority (SEPTA) records suspected of being revisions contained slightly different information in many of the data fields. This made it very difficult to determine conclusively whether the two records represented one incident with a revised report, or two separate incidents.

In cases where it was clear that multiple records referred to the same incident, either the records were merged to create one record with all of the relevant information pertaining to the collision, or all of the records except the most recent update were deleted. In addition, the data records reported by SEPTA from the year 2005 onward contained many blank data fields. This further compounded the task of identifying duplicate records in the database. Thus, while some SEPTA records were repaired, the majority had to be left intact due to lack of available information.

Non-LRT Vehicle. As discussed in the Transit Vehicle section, 19 of the data records incorrectly classified the transit vehicle as an LRT vehicle when the description indicated it was actually a bus. These records were removed from the database.

Table 6 shows the number of records removed from the NTD dataset due to errors or omissions in data entry.

Table 6. Summary of records deleted from NTD dataset due to errors/omissions in data entry.

Transit Agency	Total Records	Deleted Records	% of Total Records	Remaining Records
ABC Agency	2	2	100.0%	0
Bi-State Development Agency	9	2	22.2%	7
Central Puget Sound Regional Transit Authority	1	0	0.0%	1
Dallas Area Rapid Transit	92	18	19.6%	74
Denver Regional Transportation District	23	6	26.1%	17
Hillsborough Area Regional Transit Authority	12	4	33.3%	8
King County Department of Transportation – Metro Transit Division	32	0	0.0%	32
Los Angeles County Metropolitan Transportation Authority	163	34	20.9%	129
Maryland Transit Administration	36	11	30.6%	25
Massachusetts Bay Transportation Authority	55	15	27.3%	40
Memphis Area Transit Authority	3	0	0.0%	3
Metro Transit	22	3	13.6%	19
Metropolitan Transit Authority of Harris County, Texas	104	14	13.5%	90
New Jersey Transit Corporation	2	1	50.0%	1
New Orleans Regional Transit Authority	13	4	30.8%	9
Niagara Frontier Transportation Authority	5	2	40.0%	3
Port Authority of Allegheny County	14	0	0.0%	14
Sacramento Regional Transit District	66	2	3.0%	64
San Diego Trolley, Inc.	41	7	17.1%	34
San Francisco Municipal Railway	185	17	9.2%	168
Santa Clara Valley Transportation Authority	21	6	28.6%	15
Southeastern Pennsylvania Transportation Authority	1130	108	9.6%	1022
The Greater Cleveland Regional Transit Authority	58	6	10.3%	52
Tri-County Metropolitan Transportation District of Oregon	90	17	18.9%	73
Utah Transit Authority	47	5	10.6%	42
Total	**2226**	**284**	**12.8%**	**1942**
Total without SEPTA	***1096***	***176***	***16.1%***	***920***

Table 6 shows that of the original 2,226 records, 284 records (12.8%) were deleted, resulting in a total of 1,942 records remaining. It should be noted that in the SEPTA data from the year 2005 onward, there was often insufficient information to determine whether one or more records were actually duplications of the same event. It is suspected that if more information had been available, the number of SEPTA records deleted due to duplication would have increased.

Based on the data records examined, it appears that the creation of duplicate records for the same incident is a problem that needs to be addressed. It is unknown whether this problem is the result of incorrect use of the NTD database by the user, or a malfunction in the database causing the creation of multiple records when revisions are made to an incident report.

The next step in the data cleaning process was the removal of records that were identified as being incidents other than collisions. The database provided by the NTD initially contained all incidents identified as meeting the criteria of a reportable incident and involving an LRT vehicle. However, because these incidents were reported based on the "reportable incident" criteria outlined in the Data Collected by NTD section, the records included incidents that did not involve an LRT vehicle colliding with a motor vehicle or pedestrian, which were the only incidents relevant to the project. Therefore, the project team conducted an examination of the data to remove these non-collisions from the database.

Prior to 2008, the online S&S-40 form required the user to specify a "primary event" and "secondary event(s)" under the "incident classification" heading. Both primary and secondary events listed in the S&S-40 form satisfied the NTD criteria of a reportable incident. The primary event was defined as the first harmful occurrence of the incident, while the secondary event(s) were event(s) resulting from the primary event. Based on this definition, the only incidents relevant to the analysis were those with the primary event classified as a collision. In total, 222 of the remaining 1,942 records were identified as non-collisions, based on the "collision classification" field, and removed from the database.

These records included:

- 5 records that had a blank "collision classification" field,
- 91 records identified as derailments with no evidence of a collision,
- 15 records identified as evacuations with no evidence of collision,
- 22 records identified as fires with no evidence of collision,
- 77 records identified as "NOC,"
- 3 records identified as security problems, and
- 9 records stating that the transit vehicle had left the roadway, which was assumed to indicate either a non-rail vehicle or a derailment, but in either case could not be confirmed to be the result of a collision.

In summary, the data cleaning process resulted in a total of 1,720 crash records remaining from the original 2,226 total records provided by the FTA. It is this remaining dataset that is analyzed in the following sections.

Disparity in Local Transit Agency Reporting to the NTD

Examination of the NTD database revealed a large disparity both in the number of collisions reported by transit agencies, and the total number of collisions reported by year. Table 7 shows the total number of collisions by year for each transit agency.

Some variation in the number of collisions is expected across transit agencies. Variation is inevitable because of differences in the size of LRT system, measures of exposure to risk (i.e., vehicle revenue miles), ROW classification, etc. However, it was suspected that differences in data reporting procedures across transit agencies also accounted for a significant portion of the variation observed. In particular, the number of collisions reported by SEPTA was very high from 2002 to 2005, and then dropped to levels the project team considered more in line with the approach and level of reporting expected.

As demonstrated in Table 6 and Table 7, SEPTA accounted for over half of the total number of collisions in the NTD database both before and after the data cleaning process. In contrast, agencies such as the New Jersey Transit Corporation reported only one collision over the course of six years. These two agencies represented the polar extremes of the observed collision reporting, so the project team contacted them in an effort to understand the cause of the variation observed across transit agencies.

SEPTA staff identified two primary causes that they believed contributed to the overrepresentation of SEPTA incidents in the NTD database. The first was the fact that incidents involving LRT were often reported by multiple departments within SEPTA. For example, a single incident could be reported through both the vehicle maintenance system and worker's compensation if it resulted in both damage to the LRV and injury to the operator. According to SEPTA, this over-reporting of incidents continued until 2005 when the problem was identified and rectified by SEPTA staff.

The second explanation offered by SEPTA was the nature of the transit system itself. The collisions classified as related to LRT included eight street trolley lines, five of which operate in mixed traffic conditions with high exposure to automobile traffic. A sample of the SEPTA records was checked using mapping software, and it was confirmed that a great proportion of the collisions actually occurred at locations of full streetcar operation, in mixed traffic for an extended section. These sections operate differently than separate or median operating alignments which do not share space with general traffic. While streetcar alignments in mixed-traffic are still

Table 7. Total crashes per year by transit agency from NTD database (2002–2007).

Agency	2002	2003	2004	2005	2006	2007	Total
Bi-State Development Agency	1	1	1	1		1	**5**
Dallas Area Rapid Transit	5	17	17	17	13	2	**71**
Denver Regional Transportation District			1	4	4	5	**14**
Hillsborough Area Regional Transit Authority	2	3		1			**6**
King County Department of Transportation – Metro Transit Division	7	9	8	8			**32**
Los Angeles County Metropolitan Transportation Authority	42	16	30	8	10	16	**122**
Maryland Transit Administration	8			1		5	**14**
Massachusetts Bay Transportation Authority	1	2	6	6	4	4	**23**
Memphis Area Transit Authority				1	2		**3**
Metro Transit			1	5	3	3	**12**
Metropolitan Transit Authority of Harris County, Texas			28	31	14	17	**90**
New Jersey Transit Corporation	1						**1**
New Orleans Regional Transit Authority			2	1		1	**4**
Niagara Frontier Transportation Authority		2					**2**
Port Authority of Allegheny County	6	3			2		**11**
Sacramento Regional Transit District	12	4	22	7	7	4	**56**
San Diego Trolley, Inc.	7	3	5	5	2	8	**30**
San Francisco Municipal Railway	41	18	11	10	17	19	**116**
Santa Clara Valley Transportation Authority	2	2	1	3	1	3	**12**
Southeastern Pennsylvania Transportation Authority	202	171	147	364	47	16	**947**
The Greater Cleveland Regional Transit Authority	10	5	14	10	5	3	**47**
Tri-County Metropolitan Transportation District of Oregon	16	13	9	17	7	5	**67**
Utah Transit Authority	9	9	1	5	6	5	**35**
Grand Total (Count)	**372**	**278**	**304**	**505**	**144**	**117**	**1720**
Grand Total (Percentage of Total Crashes)	**21.6%**	**16.2%**	**17.7%**	**29.4%**	**8.4%**	**6.8%**	**100%**
Total without SEPTA	***170***	***107***	***157***	***141***	***97***	***101***	***773***
Total without SEPTA (Percentage of Total Crashes)	***22.0%***	***13.8%***	***20.3%***	***18.2%***	***12.5%***	***13.1%***	***100%***

considered as LRT (Type c.1) according to the previously used classification system of *TCRP Report 69,* most new LRT systems tend to avoid sustained operations in mixed traffic and so SEPTA's mixed traffic operations are not typical, and are not the focus of this study.

A third possible explanation was that SEPTA had reported collisions that do not meet the NTD reporting criteria. It appears that before 2006, the S&S-40 Internet reporting form did not filter incidents based on whether or not they satisfied the NTD reporting criteria. This feature has been added to the most recent installment of the S&S-40 form (*7*).

The SEPTA collision database included two separate fields used to measure the severity of collisions reported. The first field was "NTD Reportable," which included a response of either "Yes" or "No" for each collision, based on whether the collision met the NTD criteria of a reportable incident. The second field was "NTD non-major/major," which classified collisions as "major," "non-major," or were left blank (unclassified). This field was used to classify each incident based on the NTD criteria for major incidents. Table 8 shows the number of collisions reported by SEPTA to the NTD based on their classification in the above two categories.

Since transit agencies are only required to report incidents meeting the criteria of a major incident to the NTD, it is expected that an incident SEPTA classified as "major" under the NTD classification would also have an entry of "yes" in

Table 8. SEPTA collision reporting by NTD classification (2002–2005).

NTD Classification in SEPTA Database	Flagged as NTD Reportable	Reported to NTD	Not Reported to NTD	Total
Major	Yes	114	99	213
	No	13	12	25
Non-major	Yes	10	9	19
	No	227	213	440
Unclassified	Yes	0	0	0
	No	392	242	634
Total		**756**	**575**	**1331**

the "NTD reportable" field. Similarly, if an incident were deemed "non-major," it should have an entry of "no" in the "NTD reportable" field. However, Table 8 shows that 25 of the 238 incidents classified as "major" were also identified as not reportable to the NTD. In addition, 19 of the 459 incidents classified as "non-major" were identified as reportable to the NTD. This shows that although the entries in the "NTD non-major" and "NTD reportable" fields for each incident coincided in most cases, they were not always consistent.

In addition, Table 8 also shows that the classification of each collision based on the above categories had little impact on whether the collision was reported to the NTD. For example, only 114 of the 213 collisions classified as "major" and reportable to the NTD were actually reported to the NTD. In addition, of the 440 incidents identified as both "non-major" and non-reportable to the NTD, 227 of them were reported to the NTD. Finally, 392 of the 634 "unclassified" incidents, all of which were determined to be not reportable to the NTD, were actually reported to the NTD. These data suggest that the primary explanation for the high proportion of SEPTA incidents in the NTD database was the reporting of incidents not meeting the NTD criteria for a "major" or "reportable" incident.

It is unknown why some of the incidents classified by SEPTA as "NTD major" were considered non-reportable, and why some of the NTD "non-major" incidents were marked as reportable in their data. Technically, the NTD "major" incidents should all be reportable, while NTD "non-major" incidents should not be reportable. Unfortunately SEPTA was unable to provide additional data or assistance for a more detailed review due to the staff time involved on their part.

In contrast to SEPTA, there were numerous transit agencies who reported very few collisions during the six years examined. For example, The New Jersey Transit Corporation and Niagara Frontier Transportation Authority reported only one and two incidents, respectively, to the NTD over a period of six years. The limited number of collisions can be partially explained by the fact that both of these transit agencies operate most of their light-rail network along exclusive rights-of-way. However, it seemed unlikely that this was the only factor involved in the low number of reported incidents for many of the transit agencies.

Discussions with staff from New Jersey Transit during the study team's site visit to the HBLR indicated that they had until recently only reported collisions to the SSO on the assumption that those reports would be routed to the NTD, although they still reported all other regulatory requirement data on operation etc. to the NTD; the roles of the NTD and SSO in this case were not clear to the agency. Examination of the partial collision database provided by New Jersey Transit during the site visit substantiates this explanation. The New Jersey database contained a total of 50 incidents that occurred between the years 2002–2008. Of these incidents, 19 resulted in at least one injury, and 49 resulted in property damage. Although the data provided contained no further detail as to the number of injuries or extent of property damage for each collision, it seems likely that at least some of these incidents would have met the NTD reporting criteria. Thus, it is a possibility that many of the transit agencies under-represented in the NTD were not reporting many incidents that satisfied the NTD reporting criteria.

The variation in the number of collisions reported across the years should relate in part to changes in NTD's criteria for a reportable collision (see the Data Collected by NTD section). In 2003, all collisions at grade crossings were identified as reportable, but from 2004 to 2007 collisions at grade crossings were only reportable if they resulted in at least one injury away from the scene, or property damage exceeding $7,500. This change should be reflected in a decline in the number of collisions reported from 2003 to 2004, but the number of reported collisions did not drop until 2006. In this case, it appears that the change in collision reporting criteria did not have a discernable impact on the number of reported collisions. The significant drop in collision reporting between 2005 and 2006 can be explained by the steep decline in incidents reported by SEPTA. The decline in SEPTA reporting corresponds with the identification and elimination of the problem of multiple SEPTA divisions submitting collision reports to the NTD for the same incident.

Analysis of the NTD Database

This section summarizes the main findings resulting from the analysis of the NTD database, which was conducted after the completion of the data cleaning procedure. Due to the potential impact of the large proportion of collisions reported by SEPTA, all findings are also presented with the SEPTA data excluded from the analysis.

Location of Collisions

Collisions by type of alignment (right-of-way classification) are summarized in Table 9. When the SEPTA collisions are eliminated from the analysis, it is clear that most of the collisions observed occurred on non-exclusive ROW, followed by semi-exclusive ROW. This table includes columns referring to the FRA, which does not normally have jurisdiction over LRT facilities, except in cases where the LRT system is connected to or shares track with the general railway network. (In these cases those local LRT agencies must also report to the FRA.)

In contrast, the vast majority (approximately 81%) of the collisions occurring within the SEPTA system were reported as occurring on exclusive ROW. One possible explanation for this phenomenon was the inclusion of collisions involving commuter rail vehicles run by the SEPTA Regional Rail division. However, the large proportion of SEPTA collisions reported under this ROW classification appears to preclude this explanation. The majority of the light rail lines run by SEPTA operate on a combination of exclusive ROW and non-exclusive ROW. It seems likely that the SEPTA collisions were reported not based on the ROW classification of the specific incident location, but instead on the ROW classification that characterized most or at least some of the rail route on which they occurred. This explanation is supported by inspection of the partial database provided to the project team by SEPTA.

Table 10 shows the number of SEPTA collisions included in the NTD for the years 2002–2005 based on route classification.

In Table 10, only the third-rail interurban RT route 100 runs totally on exclusive ROW. The other suburban trolley routes are run mostly on exclusive ROW, but include segments of rail that are not exclusive ROW. The subway-surface trolley routes each include a section run on exclusive ROW in the city center, but operate mainly on exclusive ROW in mixed traffic conditions. The data in Table 10 show that the vast majority of collisions reported on the SEPTA routes occurred on non-exclusive ROW operating LRT vehicles in mixed traffic conditions.

Collisions by type of crossing control are shown in Table 11. The majority of collisions occurred where the type of grade crossing control was reported to be traffic signals. The presence of traffic signals is often indicative of a semi- or non-exclusive ROW, as operations along exclusive ROW are often accompanied by flashing lights and/or crossing gates. It is interesting to note that approximately 81% of the SEPTA collisions were reported as occurring at intersections with traffic signals, despite the fact that 81% of collisions from the same dataset were reported as occurring along exclusive ROW in Table 9. This would seem to corroborate the theory that the majority of SEPTA collisions actually occurred along semi- or non-exclusive ROW.

Collisions by Measures of Exposure to Risk

Table 12 shows the number of collisions for each transit agency as a function of the number of road/rail crossings in the system. The numbers of crossings per system were obtained from APTA 2004 system summary reports.

In general, the number of at-grade road/rail intersections present in a system is likely to be an indicator of the total number of collisions that system will experience. A high number of crossings will expose rail vehicles to an increased risk of collision, particularly when the majority of the track is run on exclusive or semi-exclusive ROW.

The results of Table 12, however, do not show a generally consistent relationship between the number of collisions and the number of crossings. The ratio of annual collisions per crossing ranges from 0.008 to 0.636. It is likely that this wide range of values is due in large part to the differences in collision reporting across transit agencies, as discussed in the Disparity in Local Transit Agency Reporting to the NTD section, and to the amount of service provided. Another major difference between agencies is likely to be the exposure of the crossings, as both the road traffic volume and the frequency of LRT operations will have an effect on the number of collisions.

Table 13 shows the number of collisions per million vehicle revenue miles (VRM) for each agency.

If all other characteristics of transit systems were equal, it would be expected that the number of collisions for a system would increase proportionately to the number of vehicle revenue miles, as revenue miles is a measure of exposure. The results of Table 13 suggest significant variation between transit agencies in the number of reported collisions per million vehicle revenue miles. Values ranged from 0.2 for Bi-State Development Agency (largely a type b.1 alignment with separate right-of-way and at-grade intersections) to 194.7 for the King County Department of Transportation (a street car operation).

Some variation among the rates of collisions is expected based on the different characteristics of the transit systems. Another known source of error for this dataset was the disparity in the number of collisions reported across transit agencies discussed in the Disparity in Local Transit Agency

Table 9. Collisions by alignment type (ROW classification) (2002–2007).

Agency	Exclusive ROW: At Grade	Exclusive ROW: Elevated Structure	Exclusive ROW: Tunnel	Non-exclusive ROW: LRT/ Pedestrian Mall	Non-exclusive ROW: Mixed Traffic/ LRT	Non-exclusive ROW: Transit Mall	Other Non-exclusive ROW	Semi-exclusive ROW	Shared Track (LRT/FRA): Non-temporal Separation	Shared Track (LRT/FRA): Temporal Separation	Not Categorized	Total
Bi-State Development Agency	3										2	**5**
Dallas Area Rapid Transit	10		1		21	14					25	**71**
Denver Regional Transportation District	1			2	11							**14**
Hillsborough Area Regional Transit Authority					2						4	**6**
King County Department of Transportation – Metro Transit Division	1				31							**32**
Los Angeles County Metropolitan Transportation Authority	1							105			16	**122**
Maryland Transit Administration	7				6			1				**14**
Massachusetts Bay Transportation Authority	4		2		3		1				13	**23**
Memphis Area Transit Authority	2				1							**3**
Metro Transit	7				3			2				**12**
Metropolitan Transit Authority of Harris County, Texas	1				87						2	**90**
New Jersey Transit Corporation	1											**1**
New Orleans Regional Transit Authority	3				1							**4**
Niagara Frontier Transportation Authority								1			1	**2**
Port Authority of Allegheny County	2				5						4	**11**
Sacramento Regional Transit District				2	26	1	1	24			2	**56**
San Diego Trolley, Inc.	14				8		3	5				**30**
San Francisco Municipal Railway	3		3	1	51	1		16	1		40	**116**
Santa Clara Valley Transportation Authority				1	8		1				2	**12**
Southeastern Pennsylvania Transportation Authority	766	4	1		12	3	3	3			155	**947**
The Greater Cleveland Regional Transit Authority	16				25			1			5	**47**
Tri-County Metropolitan Transportation District of Oregon	6				2						59	**67**
Utah Transit Authority	3				21		1			9	1	**35**
Grand Total (Count)	**851**	**4**	**7**	**6**	**324**	**19**	**10**	**158**	**1**	**9**	**331**	**1720**
Grand Total (Percent of Total Crashes)	**49.5%**	**0.2%**	**0.4%**	**0.3%**	**18.8%**	**1.1%**	**0.6%**	**9.2%**	**0.1%**	**0.5%**	**19.2%**	**100%**
Total without SEPTA (Count)	***85***	***0***	***6***	***6***	***312***	***16***	***7***	***155***	***1***	***9***	***176***	***773***
Total without SEPTA (Percent of Total Crashes)	***11.0%***	***0.0%***	***0.8%***	***0.8%***	***40.4%***	***2.1%***	***0.9%***	***20.1%***	***0.1%***	***1.2%***	***22.8%***	***100%***

Table 10. Collisions in SEPTA database reported to NTD by route classification (2002–2005).

Route Classification	SEPTA Route	Number of Collisions Reported by SEPTA to the NTD by ROW Classification (2002–2005)		
		Exclusive ROW	Mixed Traffic	Unknown
Interurban RT	Route 100	-	-	-
Suburban Trolley	Route 101	37	21	-
	Route 102	30	16	-
Subway-Surface Trolley	Route 10	1	198	-
	Route 11	-	97	1
	Route 13	2	113	2
	Route 34	1	54	-
	Route 36	18	97	1
Surface Trolley	Route 15	-	67	-
Total		**89**	**663**	**4**

Reporting to the NTD section. An example of the impact of this error can be seen in the decrease in average number of collisions per million vehicle miles observed between the years 2005 and 2006. The drop from 7.49 to 1.98 collisions per million vehicle revenue miles clearly corresponds to the steep decline in the number of collisions reported by SEPTA during this period.

Both the King County Department of Transportation and the Hillsborough Area Regional Transit Authority also reported a comparably high number of collisions per million vehicle miles. This can be explained by the comparatively low number of vehicle revenue miles travelled on both of these systems, which resulted in relatively few collisions significantly inflating the ratio. Due to the disproportionately high ratio of collisions to vehicle revenue miles observed for King County Department of Transportation, Hillsborough Area Regional Transit Authority, and SEPTA, the bottom row of Table 13 shows the results of the analysis with these agencies excluded. The number of collisions per million vehicle revenue mile is more consistent across the time period examined with the removal of these three agencies, although it is clear that significant variation between transit agencies still remains. Figure 4 graphically illustrates the ratio of collisions to vehicle revenue miles for all agencies excluding King County Department of Transportation, Hillsborough Area Regional Transit Authority, and SEPTA.

Table 11. Collisions at road/rail crossing by type of grade crossing control (2002–2007).

Agency	Active Devices: Flashing Lights	Active Devices: Gates (Median Barrier)	Active Devices: Gates (No Median Barrier)	Active Devices: Quad Gates	Active Devices: Traffic Signal	Active Devices: Train Approaching Sign	No Control Device	Other	Passive Devices: Cross bucks	Passive Devices: Stop sign	Unclassified	Total
Bi-State Development Agency							4				1	**5**
Dallas Area Rapid Transit		3	12		32	3	1		1	1	18	**71**
Denver Regional Transportation District		2			7		3			2		**14**
Hillsborough Area Regional Transit Authority	1				1		1				3	**6**
King County Department of Transportation – Metro Transit Division	1		2		11		12			6		**32**
Los Angeles County Metropolitan Transportation Authority	6	8	17	1	37	7	1				45	**122**
Maryland Transit Administration	1				9	1	1				2	**14**
Massachusetts Bay Transportation Authority					2		3	4			14	**23**
Memphis Area Transit Authority	2						1					**3**
Metro Transit		7			4	1						**12**
Metropolitan Transit Authority of Harris County, Texas			3		65	10	1	11				**90**
New Jersey Transit Corporation					1							**1**
New Orleans Regional Transit Authority							4					*4*
Niagara Frontier Transportation Authority	1				1							**2**
Port Authority of Allegheny County	6				4		1					**11**
Sacramento Regional Transit District		4	10		20	3	3			1	15	**56**
San Diego Trolley, Inc.	4	2	3		8		9			1	3	**30**
San Francisco Municipal Railway	4			1	29	8	9	4		18	43	**116**
Santa Clara Valley Transportation Authority					4	7					1	**12**
Southeastern Pennsylvania Transportation Authority	2				766		13		7	11	148	**947**
The Greater Cleveland Regional Transit Authority	8				28		3			2	6	**47**
Tri-County Metropolitan Transportation District of Oregon		2	1		20		1			1	42	**67**
Utah Transit Authority		7	2		18		4	1			3	**35**
Grand Total (Count)	**36**	**35**	**50**	**2**	**1067**	**40**	**75**	**20**	**8**	**43**	**344**	**1720**
Grand Total (Percent of Total Crashes)	**2.1%**	**2.0%**	**2.9%**	**0.1%**	**62.0%**	**2.3%**	**4.4%**	**1.2%**	**0.5%**	**02.5%**	**20.0%**	**100%**
Total without SEPTA (Count)	***34***	***35***	***50***	***2***	***301***	***40***	***62***	***20***	***1***	***32***	***196***	***773***
Total Without SEPTA (Percent of Total Crashes)	***4.4%***	***4.5%***	***6.5%***	***0.3%***	***38.9%***	***5.2%***	***8.0%***	***2.6%***	***0.1%***	***4.1%***	***25.4%***	***100%***

Table 12. Collisions per number of road/rail crossings.

Agency	Crossings	2004		Average 2002–2007	
		Collisions	Ratio	Collisions	Ratio
Bi-State Development Agency	24	1	0.042	1	0.042
Dallas Area Rapid Transit	98	17	0.173	12	0.121
Denver Regional Transportation District	39	1	0.026	4	0.090
Hillsborough Area Regional Transit Authority	21			2	0.095
King County Department of Transportation – Metro Transit Division	14	8	0.571	8	0.571
Los Angeles County Metropolitan Transportation Authority	104	30	0.288	20	0.196
Maryland Transit Administration	52			5	0.090
Massachusetts Bay Transportation Authority	65	6	0.092	4	0.059
Memphis Area Transit Authority	62			2	0.024
Metro Transit	45	1	0.022	3	0.067
Metropolitan Transit Authority of Harris County, Texas	68	28	0.412	23	0.331
New Jersey Transit Corporation	88			1	0.011
New Orleans Regional Transit Authority	238	2	0.008	1	0.006
Niagara Frontier Transportation Authority	8			2	0.250
Port Authority of Allegheny County	44			4	0.083
Sacramento Regional Transit District	104	22	0.212	9	0.090
San Diego Trolley, Inc.	96	5	0.052	5	0.052
San Francisco Municipal Railway	351	11	0.031	19	0.055
Santa Clara Valley Transportation Authority	119	1	0.008	2	0.017
Southeastern Pennsylvania Transportation Authority	1,702	147	0.086	158	0.093
The Greater Cleveland Regional Transit Authority	22	14	0.636	8	0.356
Tri-County Metropolitan Transportation District of Oregon	128	9	0.070	11	0.087
Utah Transit Authority	72	1	0.014	6	0.081
Grand Total	**3,564**	**304**	**0.081**	**310**	**0.082**
Total without SEPTA	***1,862***	***157***	**0.077**	***152***	**0.073**

Source: APTA 2004 data

Table 13. Collisions per million vehicle revenue miles (VRM) (2002–2006).

Agency	2002			2003			2004			2005			2006			Average		
	No.	VRM (10^6)	Ratio	No.	VRM (10^6)	Ratio	No.	VRM (10^6)	Ratio	No.	VRM (10^6)	Ratio	No.	VRM (10^6)	Ratio	No.	VRM (10^6)	Ratio
Bi-State Development Agency	1	5.16	0.2	1	5.23	0.2	1	5.02	0.2	1	4.44	0.2		4.38	0.0	1	4.85	0.2
Dallas Area Rapid Transit	5	3.97	1.3	17	5.63	3.0	17	5.15	3.3	17	5.17	3.3	13	5.10	2.6	14	5.01	2.8
Denver Regional Transportation District		2.98	0.0		3.76	0.0	1	3.87	0.3	4	3.73	1.1	4	4.37	0.9	3	3.74	0.8
Hillsborough Area Regional Transit Authority	2			3	0.08	37.4		0.08	0.0	1	0.08	11.9		0.09	0.0	2	0.08	24.0
King County Department of Transportation – Metro Transit Division	7	0.04	175.8	9	0.04	210.0	8	0.04	186.6	8	0.04	206.4				8	0.04	194.7
Los Angeles County Metropolitan Transportation Authority	42	5.78	7.3	16	6.78	2.4	30	7.70	3.9	8	8.11	1.0	10	8.05	1.2	21	7.29	2.9
Maryland Transit Administration	8	2.63	3.0		2.78	0.0		2.06	0.0	1	1.49	0.7		2.05	0.0	5	2.20	2.0
Massachusetts Bay Transportation Authority	1	5.69	0.2	2	5.73	0.3	6	5.68	1.1	6	4.54	1.3	4	5.58	0.7	4	5.44	0.7
Memphis Area Transit Authority		0.31	0.0		0.50	0.0		0.32	0.0	1	0.37	2.7	2	0.39	5.1	2	0.38	4.0
Metro Transit							1	0.51	2.0	5	1.55	3.2	3	1.79	1.7	3	1.28	2.3
Metropolitan Transit Authority of Harris County, Texas							28	0.47	59.2	31	0.81	38.5	14	0.86	16.3	24	0.71	34.1
New Jersey Transit Corporation	1	0.52	1.9		1.30	0.0		1.63	0.0		2.66	0.0		3.39	0.0	1	1.90	0.5
New Orleans Regional Transit Authority		0.65	0.0		0.73	0.0	2	0.97	2.1	1				0.16	0.0	2	0.63	2.4
Niagara Frontier Transportation Authority		0.84	0.0	2	0.76	2.6		0.76	0.0		0.74	0.0		0.77	0.0	2	0.78	2.6
Port Authority of Allegheny County	6	1.61	3.7	3	1.47	2.0		1.46	0.0		1.86	0.0	2	1.98	1.0	4	1.67	2.2
Sacramento Regional Transit District	12	2.13	5.6	4	2.17	1.8	22	2.88	7.6	7	3.43	2.0	7	3.89	1.8	10	2.90	3.6
San Diego Trolley, Inc.	7	7.05	1.0	3	6.92	0.4	5	6.98	0.7	5	7.06	0.7	2	8.18	0.2	4	7.24	0.6
San Francisco Municipal Railway	41	5.46	7.5	18	5. 53	3.3	11	5.66	1.9	10	5.52	1.8	17	5.36	3.2	19	5.51	3.5
Santa Clara Valley Transportation Authority	2	2.47	0.8	2	1.84	1.1	1	1.90	0.5	3	2.46	1.2	1	2.81	0.4	2	2.30	0.8
Southeastern Pennsylvania Transportation Authority	206	3.03	68.0	177	3.13	56.6	151	3.32	45.5	367	3.32	110.5	47	3.55	13.2	190	3.27	58.0
The Greater Cleveland Regional Transit Authority	10	0.94	10.6	5	0.95	5.2	14	1.01	13.8	10	1.01	9.9	5	0.87	5.7	9	0.96	9.2
Tri-County Metropolitan Transportation District of Oregon	16	5.66	2.8	13	5.82	2.2	9	6.02	1.5	17	6.67	2.5	7	6.38	1.1	12	6.11	2.0
Utah Transit Authority	9	2.32	3.9	9	2.28	3.9	1	2.97	0.3	5	2.74	1.8	6	2.83	2.1	6	2.63	2.3
Grand Total	**376**	**59.22**	**6.349**	**284**	**63.46**	**4.475**	**308**	**66.49**	**4.632**	**508**	**67.82**	**7.490**	**144**	**72.81**	**1.978**	**347.1**	**66.91**	**5.188**
Total Without Hillsborough, King, and SEPTA	***161***	***56.16***	***2.87***	***95***	***60.21***	***1.58***	***149***	***63.04***	***2.36***	***132***	***64.38***	***2.05***	***97***	***69.17***	***1.40***	***147.5***	***63.51***	***2.32***

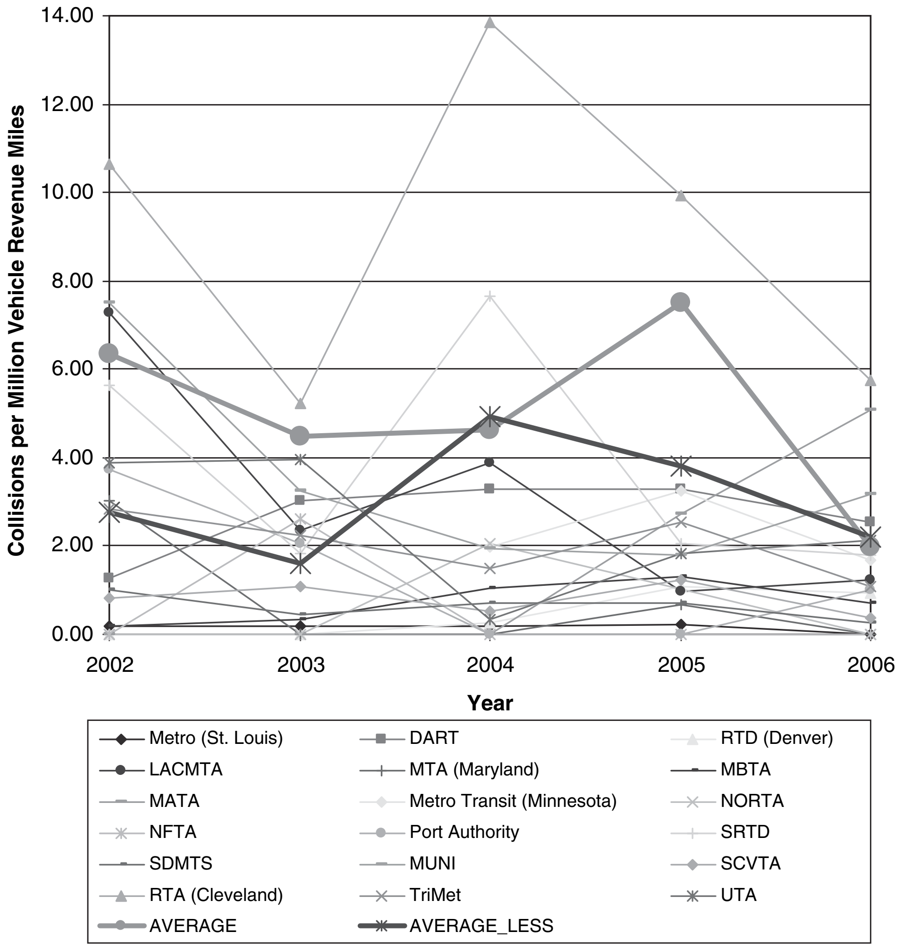

Figure 4. Safety performance: collisions per million vehicle revenue miles (2002–2006).

Collisions by Type of Impact

Table 14 shows the number of collisions classified by type of impact for each transit agency.

The type of impact refers to the orientation of the transit vehicle at time of impact. For example, "back" means that the transit vehicle was struck in the rear by another vehicle, while "angle" means that the other vehicle approached from an angle and struck the side of the LRT vehicle.

Table 14 shows that most of the collisions (56.4%) resulted in an impact to the front of the LRT vehicle. Review of the detailed description of the incidents indicated that most of these collisions were the result of a motor vehicle making a left-turn or U-turn in front of an oncoming LRT vehicle. The same pattern was reported in *TCRP Report 17: Integration of Light Rail Transit into City Streets.*

Collisions by Severity

Table 15 shows the number of collisions resulting in fatalities, injuries, and property damage only (PDO) by agency. The table also gives details of the manner in which the collisions occurred.

Of the 63 collisions resulting in a fatality (including SEPTA), 56 (89%) were the result of an LRT collision with a pedestrian or cyclist. The Los Angeles County Metropolitan Transportation Authority (LACMTA) and San Diego Trolley systems experienced a higher proportion of fatalities that the remaining systems. The LACMTA and San Diego collisions were almost exclusively the result of collisions with pedestrians/cyclists, and have the highest average vehicle revenue miles of all the transit agencies observed (Table 13). Detailed exposure information for the pedestrians and cyclists at each crossing on each system is required to make any more detailed meaningful comments on these collisions.

Of the 535 total collisions resulting in an injury, 362 (67.7%) were the result of an LRT collision with a motor vehicle, while 136 (25.4%) were the result of a collision with a pedestrian. These data suggest that in collisions between LRT vehicles and motor vehicles, the risk of fatality is relatively low when compared to the risk of injury. Conversely, the risk of fatality compared to injury is much higher for collisions between

Table 14. Collisions by type of impact (2002–2007).

Agency	Angle	Back	Fixed Object	Front-End	Side swipe	NOC	Other	Total
Bi-State Development Agency	1			2			2	**5**
Dallas Area Rapid Transit	25		1	38	6		1	**71**
Denver Regional Transportation District				11	2		1	**14**
Hillsborough Area Regional Transit Authority				4		1	1	**6**
King County Department of Transportation – Metro Transit Division	23			5	2		2	**32**
Los Angeles County Metropolitan Transportation Authority	9			97	7		9	**122**
Maryland Transit Administration	6			5	3			**14**
Massachusetts Bay Transportation Authority	2	1		7	3	1	9	**23**
Memphis Area Transit Authority	2			1				**3**
Metro Transit	1			10			1	**12**
Metropolitan Transit Authority of Harris County, Texas	8			76	4		2	**90**
New Jersey Transit Corporation	1							**1**
New Orleans Regional Transit Authority		2		2				**4**
Niagara Frontier Transportation Authority				2				**2**
Port Authority of Allegheny County	3			1	7			**11**
Sacramento Regional Transit District	34	1		13	8			**56**
San Diego Trolley, Inc.	1			20	4		5	**30**
San Francisco Municipal Railway	36	5		53	16		6	**116**
Santa Clara Valley Transportation Authority	1			8	2		1	**12**
Southeastern Pennsylvania Transportation Authority	258	94	2	357	188	13	35	**947**
The Greater Cleveland Regional Transit Authority	8			27	11		1	**47**
Tri-County Metropolitan Transportation District of Oregon	27			31	4	2	3	**67**
Utah Transit Authority	2		1	23	4		5	**35**
Grand Total (Count)	**448**	**103**	**4**	**793**	**271**	**17**	**84**	**1720**
Grand Total (Percentage of Total Crashes)	**26.0%**	**6.0%**	**0.2%**	**46.1%**	**15.8%**	**1.0%**	**4.9%**	**100%**
Total without SEPTA (Count)	***190***	***9***	***2***	***436***	***83***	***4***	***49***	***773***
Total without SEPTA (Percentage of Total Crashes)	***24.6%***	***1.2%***	***0.3%***	***56.4%***	***10.7%***	***0.5%***	***6.3%***	***100%***

LRT vehicles and pedestrians (79.4% of the 63 fatal collisions involved a pedestrian, and 24.8% of all LRT collisions involving a pedestrian were fatal).

Environmental Factors Contributing to Collisions

Table 16 shows the number of collisions for each transit agency and the lighting conditions at time of collision. Information on lighting conditions was available for 1,344 of the 1,720 collisions. Many collisions were unclassified (369 of 1,720, or 21.5%). The effect of this omission in terms of possible distortion of the results is unknown.

Most collisions (1,005 of 1,344, or 74.7%) occurred in daylight conditions. The proportion of collisions occurring during period of dawn or dusk (8.9%) may be significant because of the short duration of those time periods, but once again this could only be substantiated through the availability of exposure data for LRVs, road vehicles, pedestrians, and cyclists by hour and lighting conditions.

Figure 5 shows the percentage of collisions by time of day, excluding the data from SEPTA.

Table 15. Crashes by severity and type of collision by agency (2002–2007).

	Fatalities				Fatalities & Injuries	Injuries						Property Damage Only						
Agency	With Vehicle: Motor Vehicle	With Person (Pedestrian)	With Cyclist	**Total**	With Vehicle: Motor Vehicle	With Vehicle: Motor Vehicle	With Person (Pedestrian)	With Cyclist	With Rail Vehicle	With object: Other	**Total**	With Vehicle: Motor Vehicle	With Person (Pedestrian)	With Cyclist	With Rail Vehicle	With Object: Other	**Total**	**Total**
Bi-State Development Agency						1	3			1	**5**							**5**
Dallas Area Rapid Transit		5		**5**	4	20	8				**28**	32			1	1	34	**71**
Denver Regional Transportation District		1		**1**		9	4				**13**							**14**
Hillsborough Area Regional Transit Authority		1		**1**		1					**1**	2			2		4	**6**
King County Department of Transportation – Metro Transit Division						1	1				**2**	30					30	**32**
Los Angeles County Metropolitan Transportation Authority	1	13	4	**18**	2	41	18	4			**63**	31		1		7	39	**122**
Maryland Transit Administration		3		**3**		9	1		1		**11**							**14**
Massachusetts Bay Transportation Authority		1		**1**		5	12	1	3		**21**				1		1	**23**
Memphis Area Transit Authority						2					**2**	1					1	**3**
Metro Transit	2	2		**4**		5	2				**7**	1					1	**12**
Metropolitan Transit Authority of Harris County, Texas					1	54	11				**65**	24					24	**90**
New Jersey Transit Corporation						1					**1**							**1**
New Orleans Regional Transit Authority					1	2				1	**3**							**4**
Niagara Frontier Transportation Authority							1				**1**	1					1	**2**
Port Authority of Allegheny County						4					**4**	7					7	**11**
Sacramento Regional Transit District		2		**2**		12	5	4			**21**	31	1	1			33	**56**
San Diego Trolley, Inc.		10		**10**		11	7	1			**19**				1		1	**30**
San Francisco Municipal Railway	1	4		**5**	1	33	27	2	4		**66**	41	3				44	**116**
Santa Clara Valley Transportation Authority	2	1	1	**4**	1	3	2				**5**	2					2	**12**
Southeastern Pennsylvania Transportation Authority	1	3		**4**		101	19	2	7	2	**131**	769	12	3	13	15	812	**947**
The Greater Cleveland Regional Transit Authority		1		**1**		10					**10**	35			1		36	**47**
Tri-County Metropolitan Transportation District of Oregon		1	1	**2**		26	12	1			**39**	26					26	**67**
Utah Transit Authority		2		**2**	1	11	3	3			**17**	14				1	15	**35**
Grand Total (Count)	**7**	**50**	**6**	**63**	**11**	**362**	**136**	**18**	**15**	**4**	**535**	**1047**	**16**	**5**	**19**	**24**	**1111**	**1720**
Grand Total (Percent of Total Crashes)	**0.4%**	**2.9%**	**0.3%**	**3.7%**	**0.6%**	**21.0%**	**7.9%**	**1.0%**	**0.9%**	**0.2%**	**31.1%**	**60.9%**	**0.9%**	**0.3%**	**1.1%**	**1.4%**	**64.6%**	**100%**
Total without SEPTA (Count)	*6*	*47*	*6*	*59*	*11*	*261*	*117*	*16*	*8*	*2*	*404*	*278*	*4*	*2*	*6*	*9*	*299*	*773*
Total Without SEPTA (Percent of Total Crashes)	*0.8%*	*6.1%*	*0.8%*	*7.6%*	*1.4%*	*33.8%*	*15.1%*	*2.1%*	*1.0%*	*0.3%*	*52.3%*	*36.0%*	*0.5%*	*0.3%*	*0.8%*	*1.2%*	*38.7%*	*100%*

Table 16. Collisions by transit agency and lighting conditions (2002–2007).

Agency	Dark: No Street-lights	Dark: Street-lights	Dawn or Dusk	Daylight	Not Applicable	Unclassified	Total
Bi-State Development Agency				4		1	**5**
Dallas Area Rapid Transit	4	10	2	40		15	**71**
Denver Regional Transportation District		3	1	1		9	**14**
Hillsborough Area Regional Transit Authority	1	2		3			**6**
King County Department of Transportation – Metro Transit Division			1	31			**32**
Los Angeles County Metropolitan Transportation Authority		8	10	46		58	**122**
Maryland Transit Administration	2	3		4		5	**14**
Massachusetts Bay Transportation Authority				7	3	13	**23**
Memphis Area Transit Authority				1		2	**3**
Metro Transit		1		5		6	**12**
Metropolitan Transit Authority of Harris County, Texas		7	1	51		31	**90**
New Jersey Transit Corporation				1			**1**
New Orleans Regional Transit Authority			1	2		1	**4**
Niagara Frontier Transportation Authority				1		1	**2**
Port Authority of Allegheny County				9		2	**11**
Sacramento Regional Transit District	1	11	5	26		13	**56**
San Diego Trolley, Inc.	4	4	3	9		10	**30**
San Francisco Municipal Railway		8	6	27		75	**116**
Santa Clara Valley Transportation Authority				8		4	**12**
Southeastern Pennsylvania Transportation Authority		131	80	654	3	79	**947**
The Greater Cleveland Regional Transit Authority		9	6	22		10	**47**
Tri-County Metropolitan Transportation District of Oregon		7	2	34	1	23	**67**
Utah Transit Authority		3	2	19		11	**35**
Grand Total (Count)	**12**	**207**	**120**	**1005**	**7**	**369**	**1720**
Grand Total (Percentage of Total Crashes)	**0.7%**	**12.0%**	**7.0%**	**58.4%**	**0.4%**	**21.5%**	**100%**
Total without SEPTA (Count)	***12***	***76***	***40***	***351***	***4***	***290***	***773***
Total without SEPTA (Percentage of Total Crashes)	***1.6%***	***9.8%***	***5.2%***	***45.4%***	***0.5%***	***37.5%***	***100%***

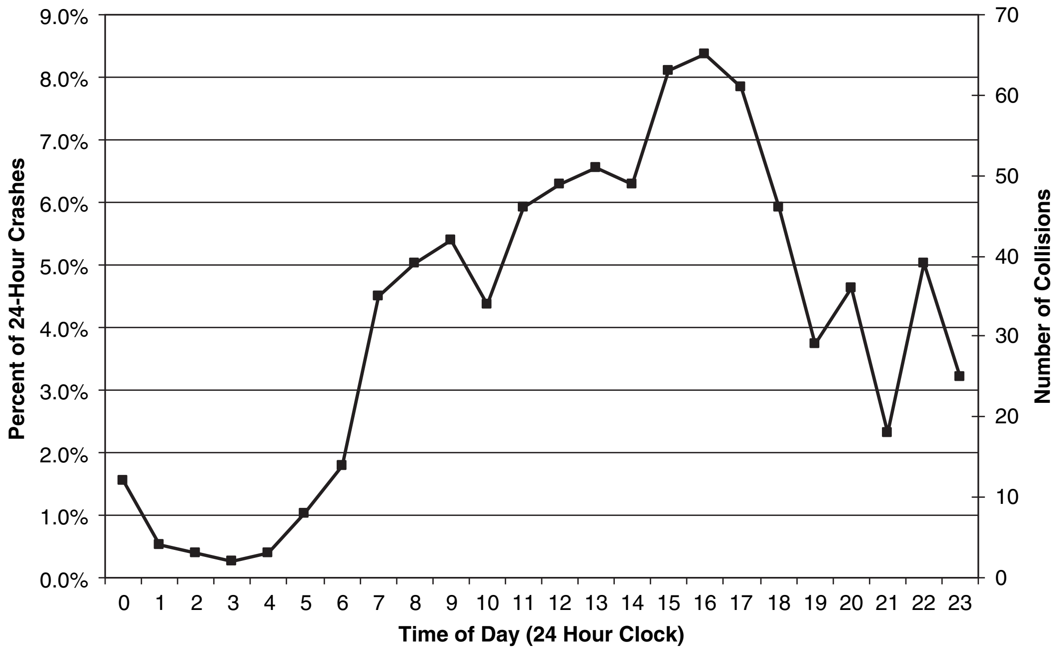

Figure 5. Collisions by hour of day (2002–2007) (excluding SEPTA).

Figure 5 shows that the peak period for collisions occurred between 3:00 P.M. and 5:00 P.M. The peak period may be connected with the end of the school day, and with greater pedestrian activity in the afternoon.

SSO Agencies

In 1991, the FTA received a list of recommendations from the National Transportation Safety Board (NTSB) outlining the need for state governments to provide safety oversight to rail transit agencies. These recommendations resulted in the issuing of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), which added Section 28 to the Federal Transit Administration Act (codified at 49 U.S.C. 5330). Section 28 required the FTA to issue rule 49 CFR Part 659 (referred to as the "SSO Rule"), which required state governments to "oversee the safety and security of rail fixed guideway systems through a designated oversight agency" (*4*).

Each state with a fixed rail guideway system was required to create a SSO agency responsible for rail transit safety and security (*9*). As of 2006, this program consisted of agencies in 27 states and the District of Columbia responsible for the oversight of 37 local transit agencies.

Purpose of SSO Agency Safety Data Collection

The role of the SSO is to establish standards for rail safety and security practices and procedures to be utilized by the transit agencies under its jurisdiction, and to oversee the implementation of these practices and procedures to ensure compliance with the regulations specified in the SSO rule. The SSO Rule specifies the criteria required to fulfill this mandate in detail. In general, the SSO is required to first develop and distribute to affected transit agencies a system safety program standard which both outlines the role of the SSO agency and provides the transit agency with guidance on meeting the requirements of the SSO Rule. The SSO agency must then require transit agencies to develop and implement both a system safety program plan and a system security plan that are in compliance with the SSO Rule and the specific system safety program standard developed by the SSO agency. These reports are reviewed by the SSO on an annual basis to ensure any subsequent revisions do not compromise compliance with the above standards. In addition, the SSO agency is responsible for conducting triennial on-site investigations to assess the implementation of the system safety and security plans developed by the transit agency.

In addition to this broad role, the SSO agency is responsible for ensuring that incidents meeting specified criteria are investigated and documented. The SSO agency must ensure the development and implementation of corrective action plans in response to these documented incidents and/or deficiencies identified during the annual reviews or triennial investigations. The SSO agency is responsible for submitting an annual report to the FTA outlining its activities over the previous twelve months. The annual report must include, in addition to other requirements, descriptions of the causal factors for investigated incidents and the status of recommended corrective actions. Thus, in addition to providing transit agencies with overarching safety and security standards, the SSO agency is actively involved in overseeing the improvement of safety conditions at specific locations in response to specific incidents.

Data Collected by SSO Agencies

According to the SSO Rule, SSO agencies are required to investigate, or cause to be investigated, incidents that satisfy one or more of the following criteria:

- A fatality at the scene, or where an individual is confirmed dead within thirty (30) days of a rail transit-related incident;
- Injuries requiring immediate medical attention away from the scene for two or more individuals;
- Property damage to rail transit vehicles, non-rail transit vehicles, other rail transit property, or facilities and non-transit property that equals or exceeds $25,000;
- An evacuation due to life safety reasons;
- A collision at a grade crossing;
- A main-line derailment;
- A collision with an individual on a rail right-of-way;
- A collision between a rail transit vehicle and a second rail transit vehicle, or a rail transit non-revenue vehicle (*4*).

Information on the data management practices of a range of SSOs was gathered though interviews with the key staff at each agency. Of the seven SSOs (Arizona, California, Colorado, Florida, Louisiana, Oregon, and Utah) contacted, both Louisiana and Colorado rely on hardcopy collision records from the local LRT agency. Arizona was contacted before their LRT system opened, and said that they intended to start collecting collision records using hardcopy. The other states receive their reports in some electronic form from the local LRT agency either through e-mail, an online entry system, or electronic documents.

A number of the SSOs are either pursuing increased electronic data handling or are already using some sort of electronic data management:

- Louisiana is working with the University of New Mexico to develop a web application capable of receiving all incident data electronically, and transferring the data to FTA electronically. This setup would avoid the manual entry of data into the FTA spreadsheet forms.
- Arizona would like to eventually move to a database system.
- Colorado enters the non-confidential data from its hardcopy collision reports into the FTA spreadsheet format.
- Florida has an online reporting system developed in-house based around the Oracle database management system. It handles electronic submission of collision notification, corrective action, and hazards forms from the local agencies, and groups the related files. Unfortunately the system handles each report file as a unit so it cannot support any sort of detailed analysis. They have a process by which reports are reviewed and approved by the SSO staff electronically, or sent back to the local agency for changes. When the reports are approved, the SSO simply provides a password and username to the FTA staff to allow access to the system and does not then need to send the hardcopy or digital reports to the FTA. Florida has shared this system with North Carolina, and is willing to share it with other states.
- Utah maintains a searchable log of collision notifications, but this is a tracking log and does not include the entire collision report. They prepare the annual report for the FTA using the reports they receive and send the report to the FTA electronically.
- California receives reports from the local LRT agencies and enters them into a database with an incident number. This is searchable by type and fatalities, but it is very limited. They are currently doing a feasibility study for a new database system that would contain more information. They use the FTA template to report information.
- Oregon receives collision notification reports by e-mail or telephone, and they are logged and tracked by agency. Portland TriMet submits collision reports electronically, while Portland Streetcar submits in hardcopy. Oregon issues the annual report to the FTA with all the data, coding it into the FTA templates.

SSO Databases

Of the seven SSO agencies contacted, only the CPUC provided a copy of their collision records initially. Utah DOT later provided some summary data which are also included in tables below where applicable. Some SSOs do not have databases, but instead have hard or soft copies of incident reports, while others could not release their databases for unspecified reasons. The CPUC database was provided in MS Excel format, and contained a total of 22 data fields. Table 17 shows the data fields contained in the CPUC database by data category.

The CPUC database contains basic description of the date, time, location, and classification of incidents. The consequence of the incident is quantified based on the number of injuries and fatalities sustained by both transit employees and other parties involved in the incident. The database also provides information regarding the crossing or intersection controls present. The "warning device" field indicated whether the crossing or intersection was controlled by lights, gates, traffic signals, passive control devices, etc. Driver action is recorded in the general "summary of incident" fields. The CPUC database also included a separate field indicating whether the collision was the result of a vehicle driving around a crossing gate.

Table 17. CPUC data fields by data category.

Data Category	Number of Data Fields in the NTD	Additional Details
Date/Time	2	Collision Date/Time
Location	4	Carrier, County, City, Street
Incident Classification	2	Collision Type
Consequences of Incident	4	Employee Injury/Fatality, Other Injury/Fatality
Alignment/Crossing Controls	4	Crossing (Y/N), Crossing No., Crossing Type, Warning Device
General Descriptions (i.e., actions)	2	Summary of Incident, Gate Drive Around (Y/N)
Data Record ID	4	Report Date/Time/No./Type
Total	**22**	

SSO Data Quality Issues

The data provided in the CPUC database lacks significant information required for detailed safety analysis. For example, no information regarding environmental conditions is included in the database. It is not possible to assess the relationship between lighting conditions, weather, or ROW condition and the collisions observed. In addition, there is no information provided regarding the classification of the ROW, geometry of the alignment, or measures of exposure to risk (i.e., traffic volumes). These data are critical for performing analysis of incidents.

As discussed previously, part of the mandate of the SSO is to ensure that all incidents meeting certain criteria are investigated to ascertain any causal/contributing factors. Subsequent to this, the SSO is mandated to develop or approve a corrective action plan that addresses the factors contributing to the specific incidents. The information provided in the CPUC database is insufficient for the type of analysis required to clearly identify all factors that may have contributed to each incident. It seems likely therefore that corrective action plans are developed using details from specific incident investigation reports, which include information that is not entered into the database. In order for the database alone to be used for detailed causal analysis, it would be necessary for environmental conditions, ROW classification, geometric design, and measures of exposure to risk be added.

Local Transit Agencies

Purpose of Local Transit Agency Data Collection

Local transit agencies collect incident data for a wide variety of purposes, such as loss prevention, crime reporting, safety analysis, and submitting incident reports to the NTD and SSO agencies. The incident data collected at the local transit agency level is the source of the data stored in the NTD and most SSO databases. For this reason, data collected at the local transit agency level must be the most detailed of the three levels of transit administration.

Data Collected by Local Transit Agencies

The project team conducted a survey of local transit agencies to determine the availability and quality of collision data at the local transit agency level. Of the 24 local transit agencies that responded to the survey, 21 had collision data stored in either hardcopy or electronic format. Table 18 provides a summary of the data available at each local transit agency based on the results of the survey and subsequent discussions with transit agencies.

The project team followed up on the survey by requesting collision data from most of the transit agencies identified in Table 18. Only eight local transit agencies provided collision data. In some cases no reason for the refusal was provided, but several agencies had legal or privacy concerns, and several others responded that they did not have the staff time available to respond to the request. Table 19 shows the format and time period for the collision data obtained from the eight local transit agencies.

None of the collision datasets presented in Table 19 were provided in database format. The majority of these datasets were records extracted from agency databases and reports. For example, the collision records provided by the LACMTA were extracted from the appendix of a report provided in PDF file format. The collision records provided by New Jersey Transit were written text summaries of individual incidents which were not compiled into a database/spreadsheet format. Santa Clara Valley Transportation Authority and Metro Transit provided collision data in PDF document format that were organized in the form of a table, but these data sets contained very few data fields. The databases provided in electronic format were all in MS Excel format.

Table 18. Summary of data available at local transit agencies.

Agency	Data Availability	
	Format	Time Period
Bi-State Development Agency (St. Louis)	Hardcopy	1984 to present
	Electronic	2000 to present
Edmonton Transit	Hardcopy	1980 to present
	Electronic	1980 to present
Kenosha Transit	Hardcopy	2000 to present
Los Angeles County Metropolitan Transportation Authority	Hardcopy	1990 to present
	Electronic	1990 to present
Memphis Area Transit Authority	Hardcopy	1999 to present
Metropolitan Transit Authority of Harris County, Texas	Hardcopy	2004 to present
	Electronic	2004 to present
Metro Transit (Minneapolis)	Hardcopy	2004 to present
Maryland Transit Administration	Electronic	1985 to present
New Jersey Transit – River Line	Hardcopy	2004 to present
	Electronic	2004 to present
New Jersey Transit – Hudson-Bergen Light Rail	Hardcopy	2000 to present
New Jersey Transit – Newark City Subway	Hardcopy	1991 to present
	Electronic	1991 to present
Port Authority of Allegheny County	Hardcopy	1998 to present
Regional Transit District, Denver	Hardcopy	1994 to present
Santa Clara Valley Transportation Authority	Hardcopy	1987 to present
	Electronic	1987 to present
San Diego Trolley Inc.	Hardcopy	1981 to present
	Electronic	1981 to present
Southeastern Pennsylvania Transportation Authority	Hardcopy	2000 to present
	Electronic	2002 to present
San Francisco MUNI	Electronic	1987 to present
Sound Transit Link, Tacoma	Hardcopy	2003 to present
Tri-Met Portland	Hardcopy	1986 to 1999
	Electronic	2000 to present
Toronto Transit Commission	Hardcopy	2004 to present
	Electronic	1991 to present
Utah Transit Authority	Electronic	1999 to present

Table 19. Local agency collision data obtained.

Agency	Collision Data Provided	
	Format	Time Period
Los Angeles County Metropolitan Transportation Authority	Hardcopy	1990 to 2006
Metro Transit (Minneapolis)	Hardcopy	2004 to 2008
New Jersey Transit	Hardcopy	2000 to 2008
Santa Clara Valley Transportation Authority	Hardcopy	1987 to 2007
Southeastern Pennsylvania Transportation Authority	Electronic	2000 to 2007
San Francisco MUNI	Electronic	2006 to 2007
Tri-Met Portland	Electronic	1994 to 2008

For a number of reasons, the local transit agencies were either unwilling or unable to provide collision data in a database format. For example, the Santa Clara Valley Transportation Authority declined to provide a database extract due to privacy concerns. San Francisco MUNI was initially willing to provide a database, but ultimately decided that they did not have the authority to release the information. SEPTA was also willing to provide a complete database, but was unable due to a lack of staff resources. Due to the inability of the local transit agencies to provide comprehensive collision databases, it was not possible to conduct a comprehensive, accurate assessment of the collision data available at the local agency level.

Analysis of Local Transit Agency Collision Data

This section summarizes the main findings of the analysis of the local transit agencies' collision data. As only eight local transit agencies supplied data, and there were gaps in the data provided, the analysis was limited. The analysis of the NTD data in the Analysis of the NTD Database section is more comprehensive.

Location of Collisions

Only the SEPTA database provided any detail regarding ROW classification. The data provided by the other local transit agencies consistently excluded information on the ROW classification of the LRT alignment, and indicated only whether each collision occurred on an exclusive ROW or in mixed-traffic conditions. Table 20 shows the number of collisions by ROW classification for SEPTA between the years 2002 and 2007.

Table 20 shows that the vast majority of LRT collisions on the SEPTA transit system occurred in mixed traffic. This is consistent with the findings of the NTD analysis outlined in the Location of Collisions section.

Collisions by Severity

Of the eight datasets provided by the transit agencies, three contained information regarding fatalities and three contained information regarding injuries resulting from LRT collisions. Table 21 and Table 22 show injuries and fatalities respectively. Both tables show the manner of collision by local transit agency.

The high vulnerability of pedestrians is very clear: pedestrians account for 75% of fatalities. They also account for 33% of injuries. The results of Table 21 are similar to those of Table 15, which also showed the vulnerability of pedestrians.

Comparison of Databases

The purpose of this section is to assess the consistency of collision data across the three levels of transit administration. Despite the limited response to requests for collision data, the databases obtained provide useful insight into how information is transferred between the different levels of transit agencies. The data provided by the local transit agencies contained sufficient detail to identify individual incidents that were contained in multiple databases. The hierarchical structure of data reporting provides the opportunity to assess the consistency of data across the levels of transit administration and determine whether there are significant differences in the data recorded in each that might have implications on their suitability for analysis.

The purpose of data collection differs for the NTD, the SSOs, and the local transit agencies. As local transit agencies may have their own specific reasons for collecting certain collision data, and are only required to report collisions meeting specific criteria to the NTD and SSO agencies, it is likely that some of their collisions are not included in the SSO of NTD database. All the collision data in the NTD and SSO agency database should, however, be found in the applicable local agency databases.

Table 20. SEPTA collisions by alignment type (ROW classification), 2002–2007.

Route Classification	SEPTA Route	Exclusive ROW	Mixed Traffic	Unknown
Interurban RT	Route 100	14		
Suburban Trolley	Route 101	66	41	1
	Route 102	72	33	1
Subway-Surface Trolley	Route 10	3	486	1
	Route 11		287	1
	Route 13	4	277	2
	Route 34	3	131	
	Route 36	36	236	1
Surface Trolley	Route 15		406	
Total		**198**	**1897**	**7**

Table 21. Injuries by transit agency and collision type (local data).

Agency	Collisions with Injuries: Collision with Motor Vehicle	Collision with Pedestrian	Collision with Cyclist	Other	Total Collisions with Injuries	Total Collisions in Local Database	Percent of Collisions Resulting in Injury	Data Period Available
Portland Tri-Met	53	68	30	–	151	542	28%	1994–2007
San Francisco MUNI	36	29	6	12	83	387	21%	2006–2007
Santa Clara Valley TA	95	18	2	–	115	476	24%	1987–2007
Total (Count)	**184**	**115**	**38**	**12**	**349**	**1405**		
Proportion of Total Collisions (Does not sum to 100%)	**13.1%**	**8.2%**	**2.7%**	**0.9%**	**24.8%**	**100.0%**		
Proportion of Injuries (Sums to 100%)	**52.7%**	**33.0%**	**10.9%**	**3.4%**	**100.0%**			

Table 22. Fatalities by transit agency and collision type (local data).

Agency	Collisions with Fatalities: Collision with Motor Vehicle	Collision with Pedestrian	Collision with Cyclist	Total Fatalities	Total Collisions in Database	Percent of Collisions Resulting in Fatality	Data Period Available
LACMTA	15	57	-	72	775	9%	1990–2006
Portland Tri-Met	0	12	2	14	542	3%	1994–2007
Santa Clara Valley TA	4	5	3	12	476	3%	1987–2007
Total (Count)	**19**	**74**	**5**	**98**	**1793**		
Proportion of Total Collisions (Does not sum to 100%)	**1.1%**	**4.1%**	**0.3%**	**5.5%**	**100.0%**		
Proportion of Fatalities (Sums to 100%)	**19.4%**	**75.5%**	**5.1%**	**100.0%**			

Comparison of Local Transit Agency and SSO Agency Databases

Table 23 shows the number of incidents recorded for each local transit agency in the California SSO (CPUC) database compared to the number of incidents recorded in the local transit agency databases.

As expected, the number of incidents contained in the SSO database is much lower than the number of incidents contained in the local transit agency database. It is interesting to note that the CPUC database contained between 27–31% of the number of incidents recorded in the LACMTA and SCVTA databases, but only 10% of the number of incidents contained in the San Francisco MUNI database.

Table 24 shows the number of incidents reported in three local transit agency databases in California, and the number of incidents reported in the CPUC (SSO) database for the time periods shown.

Only 17.6% of collisions recorded in the three local transit agency databases were also recorded in the CPUC database. The percentage varied from 4.8% of San Francisco Municipal Railway incidents to 28.8% of Los Angeles County Metropolitan Transportation Authority incidents. This variation may indicate that some local transit agencies were either reporting incidents that did not meet the SSO criteria for a reportable incident, or were not reporting incidents that did meet the SSO criteria. It is also possible that the disparity reflects the relative severity of incidents that occurred across the local transit agencies.

Table 23. Number of records in SSO databases compared to local transit agencies.

Agency Name	Number of Incidents Reported in Agency-Level Database	Number of Incidents Reported in SSO database	Size of SSO Database Relative to Size of Local Agency Database	Time Period
Los Angeles County Metropolitan Transportation Authority	278	86	30.9%	Jan. 2000–Dec. 2006
San Francisco Municipal Railway	292	28	9.6%	Jan. 2006–Jul. 2007
Santa Clara Valley Transportation Authority	185	49	26.5%	Jan. 2000–Jan. 2007
Total	**755**	**163**	**21.5%**	

Table 24. California local transit agency collision data transferred to the SSO.

Agency Name	Number of Incidents Reported in Agency-Level Database	Number of Incidents Reported in California SSO Database	% of Agency-Level Incidents Also Reported in SSO Database	Time Period
Los Angeles County Metropolitan Transportation Authority	278	80	28.8%	Jan. 2000–Dec. 2006
San Francisco Municipal Railway	292	14	4.8%	Jan. 2006–Jul. 2007
Santa Clara Valley Transportation Authority	185	39	21.1%	Jan. 2000–Jan. 2007
Total	**755**	**133**	**17.6%**	

Table 25. Proportion of SSO data records appearing in local transit agency databases.

Agency Name	Number of Incidents Reported in SSO Database	Number of Incidents also Reported in Local Agency Database	% of Agency-Level Incidents Also Reported in SSO Database	Years
Los Angeles County Metropolitan Transportation Authority	86	80	93.0%	Jan. 2000–Dec. 2006
San Francisco Municipal Railway	28	14	50.0%	Jan. 2006–Jul. 2007
Santa Clara Valley Transportation Authority	49	39	79.6%	Jan. 2000–Jan. 2007
Total	**163**	**133**	**81.6%**	

Table 25 shows the proportion of CPUC data records that also appear in the local transit agency database.

Table 25 shows that approximately 82% of the records contained in the CPUC database were also contained in the respective local transit agency databases. This suggests that the majority of incident data was supplied to the CPUC via local transit agency incident reports. However, there were 30 incidents recorded in the CPUC database that were not found in the local transit agency databases. Upon further inspection it was determined that of these 30 incidents, 10 were confirmed collisions, 17 were confirmed non-collisions, and 3 had insufficient data to determine whether they were a collision.

The fact that some incidents included in the CPUC database were not found in the local transit agency databases raises the question of how they were obtained by the SSO agency. One reason CPUC has a higher rate of reported accidents may be that CPUC has a designated representative for each transit agency that has a close working relationship with the local safety manager and usually participates with the transit agency in accident investigations. Depending on the severity, the CPUC may perform its own independent investigation. Besides engineers on the staff, CPUC also has FRA certified railroad inspectors, i.e., signal and train control, motor power and equipment, and track inspectors to conduct independent investigations. All incident reports originate from the transit agency, and are reported as required by FTA rules. It is also possible that the datasets provided by the three local transit agencies simply did not contain all of the records for the years examined.

Whatever the explanation for the differences found, the fact that each organization maintains their own database independent of each other is surely a significant contributor to the apparent discrepancy and the uncertainty that may arise in subsequent analysis. It is clearly important to have confidence that a dataset is complete in order to carry out statistical examinations.

Comparison of Local Transit Agency and NTD Databases

Local transit agencies are obligated to report incidents meeting the criteria specified in the Data Collected by NTD section to the NTD on a monthly basis. The NTD relies entirely on incident data submitted by local transit agencies; unlike the SSO agencies, the NTD is incapable of conducting independent investigations of transit incidents.

Table 26 shows the number of incidents recorded for each local transit agency in the NTD database compared to the number of incidents recorded in the local transit agency databases.

Table 26 shows that in total, the size of the NTD database was approximately half the size of the local agency databases over the same period of time. However, there was substantial variation observed in the relative number of incident records in the transit agency databases compared to the NTD database. For example, when the SEPTA records were removed, the total number of records in the NTD database was one-quarter the number in the remaining local transit agency databases.

Table 27 shows the proportion of incident records in the local transit agency databases also found in the NTD database.

Table 27 shows that, in total, almost 40% of the incident records contained in the local agency databases were also contained in the NTD database. However, this statistic was cut in half with the removal of the SEPTA database from the calculation. This difference may have been partially due to the severity of the incidents experienced on different transit systems. Some agencies may have experienced a high number of total collisions with relatively few meeting the NTD criteria. However, it is more likely that this difference reflects variation in collision reporting practice, either in what incidents local

Table 26. Number of records in NTD database compared to local transit agencies.

Agency Name	Number of Incidents Reported in Local Agency Database	Number of Incidents Reported in NTD Database	Size of NTD Relative to the Size of Local Agency Database	Years
Los Angeles County Metropolitan Transportation Authority	175	111	63.4%	2002–2006
Minneapolis Metro Transit	22	19	86.4%	2004–2007
New Jersey Transit Corporation	50	1	2.0%	2002–2007
San Francisco Municipal Railway	387	62	16.0%	2006–2007
Santa Clara Valley Transportation Authority	153	15	9.8%	2002–2007
Southeastern Pennsylvania Transportation Authority	1335	954	71.5%	2002–2005
Tri-County Metropolitan Transportation District of Oregon	253	72	28.5%	2002–2007
Grand Total	**2375**	**1234**	**52.0%**	
Total (without SEPTA)	**1040**	**280**	**26.9%**	

Table 27. Local transit agency data transferred to the NTD.

Agency Name	Number of Incidents Reported in Local Agency Database	Number of Local Agency Incidents Also Reported in NTD Database	% of Agency-Level Incidents Also Reported in NTD Database	Years
Los Angeles County Metropolitan Transportation Authority	175	95	54.3%	2002–2006
Minneapolis Metro Transit	22	9	40.9%	2004–2007
New Jersey Transit Corporation	50	0	0.0%	2002–2007
San Francisco Municipal Railway	387	36	9.3%	2006–2007
Santa Clara Valley Transportation Authority	153	9	5.9%	2002–2007
Southeastern Pennsylvania Transportation Authority	1335	726	54.4%	2002–2005
Tri-County Metropolitan Transportation District of Oregon	253	65	25.7%	2002–2007
Grand Total	**2375**	**940**	**39.6%**	
Total (without SEPTA)	**1040**	**214**	**20.6%**	

transit agencies were willing to investigate, or in what incidents local transit agencies chose to report to the NTD. This variation may have been the result of transit agencies failing to report incidents that satisfied the NTD reporting criteria, or reporting incidents which did not meet these criteria.

Table 28 shows the proportion of NTD incident records that also appeared in the local agency database.

Approximately 76% of the records contained in the NTD database were also identified in one of the local transit agency databases. As expected, this statistic revealed the reliance of the NTD on the incident records contained in the local agency databases, but it is difficult to identify the origin of the remaining records. The NTD does not conduct independent investigations of transit incidents, and relies entirely on the reports

Table 28. Proportion of NTD data records appearing in local transit agency data.

Agency Name	Number of Incidents Reported in NTD Database for Agency	Number of Incidents Also Reported in Local Agency Database	% of Agency-Level Incidents Also Reported in NTD database	Years
Los Angeles County Metropolitan Transportation Authority	111	95	85.6%	2002–2006
Minneapolis Metro Transit	19	9	47.4%	2004–2007
New Jersey Transit Corporation	1	0	0.0%	2002–2007
San Francisco Municipal Railway	62	36	58.1%	2006–2007
Santa Clara Valley Transportation Authority	15	9	60.0%	2002–2007
Southeastern Pennsylvania Transportation Authority	954	726	76.1%	2002–2005
Tri-County Metropolitan Transportation District of Oregon	72	65	90.3%	2002–2007
Grand Total	**1234**	**940**	**76.2%**	
Total (without SEPTA)	**280**	**214**	**76.4%**	

of local transit agencies. This suggests that the databases provided by the local transit agencies did not include all of the incidents that occurred over the time period examined. Since duplicate records were noted (and removed from) the NTD, there may also be some additional near-duplicate spurious records in the NTD data.

Comparison of SSO and NTD Databases

Although the SSO agencies are not responsible for reporting data directly to the NTD, both rely on the local transit agencies for their incident reports. In addition, the reporting requirements for the NTD and SSO agencies had many similarities over much of the time period examined. Examination of the differences between the data records available to each can shed light on how the different reporting criteria used by each administration level over the years has affected the amount of data made available to them by the local transit agencies. Table 29 shows the number of data records contained in both the SSO and NTD databases.

In general, more transit incidents were reported by the local transit agencies to the NTD than to the SSO. This was unexpected as one would expect the reverse. One significant exception was the Utah TRAX database, which contained substantially more incidents than the NTD. However, closer inspection revealed that the Utah TRAX database included a column indicating the NTD classification of each incident. Of the 110 incidents, only 14 were classified as "Major" while 4 were classified as "Suicide." Therefore, it is clear that in this case, the disparity was a reflection of a difference in reporting requirements.

Table 30 shows the proportion of SSO incident records that were also included in the NTD.

Approximately 34% of the records contained in the SSO databases were also found in the NTD database; this percentage increased to 42% when the Utah TRAX records were omitted.

Table 31 shows the proportion of NTD incident records that were also contained in the SSO databases.

Approximately 31% of the collision records contained in the NTD database were also present in the SSO database. Although this statistic is similar to the proportion of SSO data records found in the NTD, there is considerably more variability observed between transit agencies.

Conclusion

This chapter had several basic objectives. It describes and compares the NTD, SSO, and local transit agency data. It contains detailed analyses of the locations, types, and severity of accidents (crashes) reported in the NTD database.

Several implications are apparent. Firstly, it is desirable to achieve better consistency among the three reporting systems. Reporting should be both consistent and useful for researchers, transit system administrators, and oversight organizations (SSO and FTA). Secondly, the highest number of crashes involves same-direction LRV–motor vehicle collisions. Thirdly, the largest number of fatalities involves LRV–pedestrian collisions. These are the two areas, same-direction LRV–motor vehicle collisions and LRV–pedestrian collisions, where right-of-way design, operating policies, and traffic controls should be focused to reduce the number of collisions in both new starts and retrofit situations.

Table 29. Number of records in SSO database compared to NTD.

Agency Name	Number of Incidents Reported in SSO Database	Number of Incidents Reported in NTD Database	Years
California Public Utilities Commission (SSO)			
Los Angeles County Metropolitan Transportation Authority	74	128	2002–2007
Sacramento Regional Transit District	33	64	2002–2007
San Diego Trolley, Inc.	52	34	2002–2007
San Francisco Municipal Railway	85	168	2002–2007
Santa Clara Valley Transportation Authority	28	15	2002–2007
Utah TRAX	110	16	2004–2006
Total (SSO)	**382**	**425**	

Table 30. SSO data records included in the NTD.

Agency Name	Number of Incidents Reported in SSO Database	Number of Incidents Also Reported in NTD Database	% of SSO Incidents Also Reported in NTD Database	Years
California Public Utilities Commission (SSO)				
Los Angeles County Metropolitan Transportation Authority	74	38	51.4%	2002–2007
Sacramento Regional Transit District	33	14	42.4%	2002–2007
San Diego Trolley, Inc.	52	26	50.0%	2002–2007
San Francisco Municipal Railway	85	25	29.4%	2002–2007
Santa Clara Valley Transportation Authority	28	11	39.3%	2002–2007
Utah TRAX	110	16	14.6%	2004–2006
Total (SSO)	**382**	**130**	**34.0%**	**2002–2007**

Table 31. Proportion of NTD data records appearing in SSO database.

Agency Name	Number of Incidents Reported in NTD Database for Agency	Number of Incidents Also Reported in SSO Database	% of Agency-Level Incidents Also Reported in SSO Database	Years
California Public Utilities Commission (SSO)				
Los Angeles County Metropolitan Transportation Authority	128	38	29.7%	2002–2007
Sacramento Regional Transit District	64	14	21.9%	2002–2007
San Diego Trolley, Inc.	34	26	76.5%	2002–2007
San Francisco Municipal Railway	168	25	14.9%	2002–2007
Santa Clara Valley Transportation Authority	15	11	73.3%	2002–2007
Utah TRAX	16	16	100.0%	2004–2006
Total (SSO Data in NTD)	**425**	**130**	**30.6%**	**2002–2007**

CHAPTER 4

Safety Issues and Their Treatment

This chapter provides information about how data and observation can help to indicate why collisions happen and how that information can be used to determine treatments. The discussion starts with a general description of the concepts of safety analysis, including root causes and contributing factors.

After this initial overview, the chapter explores the major categories of root causes and contributing factors for collisions on LRT alignments, as suggested by the literature, the survey, the data analysis, the transit agency consultations, and the site visits. Such information can help practitioners understand their safety issues and identify how their concerns align with those of other systems.

The final section outlines four treatment strategies that address the causes and contributing factors for LRT collisions. These strategies are based on the cumulative judgment of the project team after compiling anecdotal and statistical information with safety engineering experience and in-situ observations during the site visits.

Root Causes and Contributing Factors

Safety initiatives are often intended to respond to one or a series of crashes. To reduce the number of future collisions, it is necessary to determine the root causes. In most cases, there are many factors that influence an incident. These factors come together in a specific way to influence the likelihood of collision, to result in the collision, and to affect the resulting severity of the collision.

Root cause analysis is a structured procedure for examining the reasons an undesirable event occurred, and for identifying ways to prevent the event from happening again. RCA is employed in the industrial and medical communities for safety and quality management, and it is particularly well documented by NASA. (See NASA Procedural Requirement NPR 8621.1.) A presentation explaining the relationship between root causes and contributing factors and how to conduct a RCA can be found on the NASA website at www.hq.nasa.gov/office/codeq/rca/rootcauseppt.pdf. The procedure recognizes the distinction between root causes and contributing factors.

Root causes are one or more fundamental flaws or problems in a system that lead to the undesirable outcome, and without the root cause(s), the undesirable outcome (in our case a collision) could not have occurred. It is noted that root causes are not the proximate (or direct) causes of a collision, but lead to those causes that in turn lead to the collision. This is an important distinction because direct causes often vary from incident to incident, and are beyond the reasonable control of the system. For example, a collision may be directly caused by a pedestrian walking in front of an LRV. A root cause could be a lack of sufficient warning to the pedestrian, but it may not be reasonable to expect that the system could have stopped that particular pedestrian and avoided that particular collision. It is, however, reasonable to expect the system to address the root cause that people in general do not have sufficient warning in the location or circumstances involved.

Contributing factors influence the occurrence or severity of a collision but are not actually root causes and if eliminated would not have prevented the collision. Contributing factors provide a context for the collision. As an illustration, consider the case of a fatality on an interstate highway facility. The collision occurred on a straight portion of roadway in good driving conditions. Police determine that the driver was fatigued, fell asleep, and left the right-of-way. Driver fatigue was a causal factor. Police also determine that the vehicle was traveling at 70 mph when it left the right-of-way. The speed was a contributing factor. It did not on its own cause the collision, but would have reduced the time available for the driver to recover control upon leaving the pavement (e.g., if awoken by a rumble strip), and it affected the severity once the incident occurred. In the same case, the driver would not have left the roadway had there been barriers, but the lack of barriers did not cause the crash. The absence of barriers is a contributing factor.

Understanding the roles of root cause(s) and contributing factors is important. If the fundamental weaknesses of the system are not identified and improved, the likelihood of incidents recurring is increased.

Ideally, safety treatments should address the root causes to have the best effect on conditions leading to a collision. If possible, a holistic approach should be used to determine root causes and contributing factors, and safety treatments that will provide the best overall safety effects for the system. By considering the entire system, practitioners can avoid taking a narrow view that may modify one aspect of the system without taking into account other issues and repercussions. It some cases where the root cause is difficult to control, it may be possible to mitigate the number and/or severity of crashes by treating a contributing factor in an effective matter.

Determining LRT Safety Issues and Identifying Treatments

Chapter 2 identified a list of the safety issues noted by agencies and SSOs. Chapter 3 outlined the data quality and quantity problems facing LRT safety analysis. Because of these data problems, it is difficult to determine the root causes of LRT collisions in a statistically significant analysis. It is also difficult to undertake a statistical analysis of the effectiveness of a given safety treatment.

This section outlines methods that can be used to determine LRT safety issues and identify treatments. Anecdotal information available from agency and SSO staff who work with LRT alignments, formal LRT safety analysis (where available), the safety literature, consultation with professionals, and the site visits to LRT agencies were used to identify some of the most common or severe LRT collision types. The section then identifies some surrogate (proxy) measures that can help agencies identify potential safety hazards.

Studying LRT Safety Issues and Treatments

Most previous studies of safety along LRT alignments have examined treatments using simple before-and-after comparisons of collisions, anecdotal evidence, collision surrogate measures such as violations, or a combination of two or three of these approaches. Standard "t" tests require sufficiently long periods to elapse both before and after studies. Where the number of years is limited and/or the numbers involved are small, an unusually "high" year and a "low" year after could reflect regression to the mean rather than an effect of the treatment.

Although the effectiveness of treatments (such as LRV-activated signs) in reducing the number of incidents of risky behavior on the part of motorists has been well demonstrated (*1, 2*), LRT safety studies to date have not been based on statistically significant analysis of the reduction in the number of collisions following the implementation of a given treatment. The state of the art in safety study methodology generally requires the use of empirical Bayes analysis, but contemporary statistical approaches such as empirical Bayes analysis are still relatively new to transportation studies, and have not been applied to the field of LRT safety. No references to LRT and empirical Bayes analysis were found during the literature review, survey, or other inquiries. The literature review found no statistical analyses of LRT collision data that were statistically defensible in terms of contemporary statistical analysis methods.

The lack of studies using statistically sophisticated and defensible methods can be attributed to several issues. Firstly, as suggested above, transportation and LRT safety practitioners are not usually familiar with contemporary statistical methods. In addition, data issues include the lack of essential and sufficient collision data; the lack of vehicular, pedestrian, and LRV volume data; and the lack of rail and highway inventory information, including the dates on which safety treatments were implemented. In the survey of local LRT agencies, for example, 10 of the 17 agencies that answered the question on four-quadrant gates did not record the installation date. The survey found that non-recording of date information ranged from 27% to 88%, depending on the treatment.

To determine the feasibility of adopting an empirical Bayes analysis to examine the safety impacts of selected treatments along LRT alignments, it is essential to first determine the data that are needed to carry out the analysis. (Data availability and data quality are discussed in Chapter 3.)

The studies available are generally limited in scope and do not examine the holistic safety impacts of the various treatments being studied. For example, devices such as pre-signals and advance signals have been widely implemented throughout North America. The focus of these studies of pre-signals and advance signals, however, is on signal violations or the impact on LRV–motor vehicle crashes. No studies have examined the system-wide impacts of such treatments—for example, the possibility that the implementation of a new traffic signal at a location could result in an increase in crashes, such as rear end collisions, that involve only motor vehicles.

Determining the Highest Risk LRT Safety Issues

Unlike motor vehicles, LRVs cannot swerve, and even emergency stop conditions do not enable the LRV to avoid pedestrians who are errant or walking counter to traffic control devices. Nevertheless, Korve et al. in *TCRP 17* (*2*) found that collisions between pedestrians and LRVs are the least common type of LRT-related collision. Collisions between pedestrians and LRVs in the systems reviewed represented only about 10%

of the total, but these collisions are the most severe and account for at least 50% of all fatalities resulting from LRT collisions (*3*). These general findings are supported by the data reviewed in Table 11 of Chapter 3, which showed that pedestrian collisions accounted for 168 (22%) of the 773 collisions (SEPTA excluded) in the NTD, but 80% of all fatalities (47 of the 59 fatalities in the years from 2002 to 2007).

Although the comparable numbers for cyclists was very small, with only 24 total collisions in the 2002–2007 NTD data, cyclists also appear to be overrepresented in terms of severity: they were involved in only 3% of collisions with LRVs, but accounted for 10% of all fatalities. Together, cyclists and pedestrians accounted for nearly 90% of all LRV collision fatalities. Improving pedestrian and bicycle safety is essential.

Conversely, road vehicles accounted for the majority of collisions with LRVs, but only a small proportion of the fatalities. On the other hand, motor vehicle occupants were involved in 65% (261) of the 404 injuries (Table 11, Chapter 3) in all injury-causing collisions, and almost 48% of all motor vehicle–LRV collisions resulted in injuries (261 of 545 motor vehicle collisions, as shown in Table 11 of Chapter 3).

It is clear that each group of road users has significant risks associated with LRV collisions, and that the risks vary. It is, however, difficult to hypothesize the root causes for these events without detailed exposure information and more information on the circumstances of each collision reported. More data, and more historical data than are currently available (many LRT systems are relatively new), are needed to determine the most appropriate and effective combination of safety treatments.

An additional concern in the evaluation of LRT collision data is that collisions between non-LRV vehicles and other vehicles or pedestrians that may have been related to the LRT facility or operations but did not physically involve an LRV are not recorded in the LRT collision data. For example, an incident in which a pedestrian is hit by a car while walking to or from a center-of-street transit stop is arguably related to the LRT, but the incident will not appear in LRT collision databases. A comprehensive analysis of LRT safety will therefore need to include information from local transportation agencies and police to determine whether any safety implications of LRT operations extend beyond the LRT right-of-way itself.

Building a Safety Analysis Toolkit

It is important that all agencies (transit agencies, SSOs, city transportation departments, police, and research organizations) take an active role in adding to the available knowledge. Good data collection guidelines are needed to increase the quality and quantity of LRT safety data assembled for analysis. As the database improves, it will become possible to perform more rigorous statistical analyses and to develop better information on the effectiveness of corrective actions. This study provides a starting point by gathering the LRT safety information available into one, easily accessible catalog of information about specific LRT safety treatments (Appendix A).

Even with excellent data collection processes in place, analysis of LRT collision data will still be limited by the number of collisions. LRT collisions are even more statistically rare than vehicle collisions. LRT data and the information obtained from the site visits suggest that a high accident location along an LRT alignment has about one incident per year. This collision frequency is too low for conducting before-and-after studies, or even for identifying problem locations. The site visit agencies all reported using various other measures to determine which locations may require safety treatment. These "surrogate" measures could be used in formal safety studies (before-and-after, empirical Bayes, etc.) to determine the effects of specific safety treatments without needing to wait for a significant number of collisions to occur.

Surrogate measures described by the LRT agencies consulted by the project team include:

- Operator reports of near misses or other significant safety-related events.
- Risky behavior:
  - Metro Transit in Minneapolis conducted a series of pedestrian violation counts at a downtown station. The counts showed a decrease in the number of pedestrians crossing the tracks illegally mid-station as the level of advertising and signage increased. The data and follow-up analysis allowed Metro to show that there was still significant risk of collision due to pedestrians crossing mid-station, despite the impact of advertising and signage. This led to the municipal authorities approving inter-track fencing at this location.
- Emergency braking:
  - Automated emergency braking records allowed UTA to identify a location where a pedestrian signal was badly timed. After the signal timing was changed, the number of emergency braking incidents was substantially reduced.
- Insurance and non-recoverable cost records:
  - UTA and Metro Transit both have detailed recordkeeping for insurance purposes. These records could be used to identify problem locations. UTA has a large number of locations with crossing gates and can identify potential problem locations by the frequency of crossing gate replacements.
- Customer complaints:
  - SF Muni keeps a detailed database of customer complaints. This could be used to identify problem locations, or operators with an unusual history that might indicate a need for additional training.

These surrogate measures can provide agencies the information required to identify potential hazards. They may also be useful as before-and-after studies and other safety research.

General Treatment Strategies

The analysis and agency input obtained during site visits enabled the project team to identify four general treatment strategies that would help to mitigate the safety issues and risks reported by local LRT agencies. The strategies listed below are a summary of commonly encountered observations and recommendations from the staff of the LRT agencies visited. Information about specific safety treatments is provided in Appendix A, and documentation of the site visits and discussions with the local staff are provided in the site visit memos in Appendix D.

The four strategies are:

1. **Give responsibility to the operators:** Representatives from NJT were especially clear on the need to give responsibility to the operators. An LRV is not a bus. LRV operators should be given special, intensive, and location-specific training. NJT LRT operators have four weeks of training, followed by one week of hands-on experience with a seasoned operator. NJT staff noted that operator training is essential where an agency cannot install the optimum treatment because of a physical limitation. NJT recommended giving operators increased responsibility, and suggested that automation should be limited. Other transit agencies visited also reported that their operators were trained to drive defensively. One agency noted the frequency of reviewing their operators was based on the operators' incident and complaint records.
2. **Increase motorist, pedestrian, and cyclist awareness by providing active, appropriate information:** All the transit agencies visited reported that motorists, cyclists, and pedestrians respond better to active signage than to passive signage. Agencies have observed that motorists, cyclists, and pedestrians who cross the LRT alignment on a regular basis can become desensitized to warnings. This problem is more pronounced where the warnings provide general information instead of specific information (e.g., train sign instead of a no turn sign), or where the duration of the warning is longer than necessary. The project team visited one NJT crossing location where pedestrians clearly disregarded the audible warning device. The agency guide noted that the warning sound was a standard length and much longer than required for a pedestrian to clear the tracks. Local pedestrians learned to disregard the warning because it did not provide relevant information about the approach of a train. In fact, because of the length of the signal, its warning seemed to sound "all the time."

   The same principle can be applied to second train (sometimes termed "approaching train") warning signs. None of the second train warning signs viewed during the site visits to transit agencies indicated the direction of the approaching train. The impacts of providing this additional information should be tested using before-and-after surrogate measures such as risky actions by pedestrians or emergency brake records at a crossing where a directional second train warning sign is installed.
3. **Education:** Agencies commented that the public does not seem to have the same respect for LRT as for freight and commuter rail trains. Further, in cities where LRT is new, motorists, cyclists, and pedestrians may not understand how to behave in the alignment. Safety campaigns improve public understanding of how to act in the light rail alignment. Arizona, for example, has included a section concerning driving around LRT in their driver training handbook. Other agencies broadcast safety reminders over their platform and LRV audio systems and/or run public awareness campaigns. Operation Lifesaver has an LRT branch that works with agencies to increase awareness. All of these strategies aim to teach citizens how to drive, walk, or cycle around LRT, but they also increase public awareness of the serious nature of LRV collisions.
4. **Separation of LRT space from the space occupied by other modes:** While active information (as described in strategy 2, "Increase motorist, pedestrian, and cyclist awareness by providing active, appropriate information") provides useful and direct information to motorists, cyclists, and pedestrians, the separation of LRT space can provide environmental cues for safety. The separation can be a clear physical barrier, such as landscaping or channelization, or a more subtle measure such as a change in pavement type. Pavement type has an effect: in the transit agency site visits, all the locations identified as problem areas because pedestrians crossed mid-station or mid-block had surface treatments that were conducive to walking between the tracks. The locations that had gravel between the tracks were not identified as problem areas for pedestrian incidents.

   The separation can also be complete by separating the grades (conversion to a type a.1 alignment) which precludes errant movements. This offers the additional benefit of reducing delay for road vehicles. There are, however, major drawbacks in terms of capital cost, land requirement, environmental impacts, disruption of existing operations, and so on. Complete separation of the ROW has not been considered as a practical safety treatment in this study (in terms of something that can be applied to a safety problem), but it would clearly improve safety if it can be designed-in before construction starts.

CHAPTER 5

LRT Catalog of Safety Treatments

LRT agencies should identify safety issues and then, working with or under the supervision of SSOs, and in cooperation with other bodies such as city transportation departments and the police, select appropriate safety treatments. The safety treatments may include active or passive physical devices or practices, education, and/or enforcement, and may be applied locally or on a location, line, or system-wide basis.

Introduction to the Catalog of LRT Safety Treatments

As part of Project A-30, the project team assembled a catalog that provides readily accessible information about LRT-related treatments than can be used to address the safety issues that arise where LRT alignments meet motorists, pedestrians, and cyclists. The catalog is intended to assist agencies in choosing and applying the appropriate treatment or combination of treatments for given safety problems, taking into account the specific circumstances of the agency. The catalog includes active and passive physical treatments as well as education- and enforcement-based treatments. To enhance usability, the catalog has been included as a separate document and attached in Appendix A.

The project team began assembling the catalog based on a list of treatments developed as part of the online survey during the last few months of 2006. Two types of treatments were included: commonly used treatments and new technologies. This list was assembled by the project team and provided to the Panel. After review by the Panel, the project team incorporated all comments received. The list of treatments was carried forward throughout the rest of the project.

The information in the catalog comes from the following sources:

- Directly from the five LRT agencies that cooperated with the project team during a series of site visits,
- Discussions in person and by phone with LRT agency staff,
- Phone consultations with SSOs, and
- Literature review.

The project team refined the list of treatments for inclusion in the catalog. Some treatments were removed or combined with other treatments to improve clarity and flow. Select innovative or interesting treatments identified during the site visits were added. The catalog, as presented here, is not exhaustive, and other treatments should be included in the catalog in future updates.

Some widespread treatments are not addressed in the catalog. These include:

- **Left turn prohibitions:** Most jurisdictions with type b and type c alignments use turn prohibitions at some intersections. The prohibitions are often applied in alignments where the LRT runs down the center of the roadway and are intended to prevent drivers from turning in front of an LRV in locations where they may not see or notice an LRV approaching. Agencies noted that drivers often violate turn prohibitions (as is common with turn prohibitions outside the LRT context) and that they are hard to enforce. Many agencies are moving towards blank out signs to prohibit left turns as an LRV approaches. Blank out signs are addressed in the catalog.
- **Two quadrant gates:** Where gates are installed along an LRT or railroad alignment, these are the most common type. Two quadrant gates block the approach lane(s) on each side as a train approaches. They do not block the opposing traffic lane; gates that block both the approaching and opposing traffic lanes are called four quadrant gates and these are addressed in the catalog. Gates seem to be more common in areas with existing railroad crossings and can be beneficial because of recognition by the local population. Areas without a history of railroad crossings seem to be more likely to install signals or other types of controls. There are no data indicating which treatment

Table 32. LRT alignment classification.

Class	Category	Description of Access Control
Exclusive	Type a	Fully grade separated or at-grade without crossings
Semi-exclusive	Type b.1	Separate right-of-way
	Type b.2	Shared right-of-way, protected by barrier curbs and fences (or other substantial barriers)
	Type b.3	Shared right-of-way, protected by barrier curbs
	Type b.4	Shared right-of-way, protected by mountable curbs, striping and/or lane designation
	Type b.5	LRT/pedestrian mall adjacent to parallel roadway
Non-exclusive	Type c.1	Mixed traffic operation
	Type c.2	Transit-only mall
	Type c.3	LRT/pedestrian mall

Source: *TCRP Report 69*

prevents more accidents. Gates in general can be problematic (bell noise, mechanism maintenance and durability) when the frequency of LRT service is very high.

- **Grade separation:** Exclusive alignments typically experience few (if any) collisions, and grade separation at intersections could be considered a safety treatment. Grade separation converts a type b alignment to a type a alignment for the length of the separation. However, exclusive alignments are not addressed in the catalog due to the extreme implementation costs in comparison with other treatments and the combination of space requirements and possible environmental impacts that make them likely to be a treatment of last resort.

The catalog could eventually be presented as a searchable database that could be updated by approved users. LRT Agencies, SSOs, and other users could be encouraged to access the database and to add treatments and information about the treatments as information becomes available. Statistical reports and research on treatments could be added to the database, and subscribers could be notified of changes.

As noted in the main body of the report, this project primarily addressed semi-exclusive alignments. The catalog includes a field suggesting the type of alignments to which each treatment can be applied. For clarity, the alignment types are given in Table 32.

LRT Safety Treatments Included in the Catalog

The information presented in the catalog was collected throughout the project. Much of the information came directly from LRT agencies that cooperated with the project team during a series of site visits. Additional information was gathered during the literature review and during phone consultations with LRT agencies and SSOs. The information was compiled in a catalog format and attached as Appendix A for ease of use.

The treatments included in the catalog are organized into seven categories. The categories are intended for reference organization purposes only, and some treatments may fall into more than one category, but every treatment has been listed only once. It is also noted in the catalog that some treatments have been referred to by several names.

The categories and treatments are:

1. Signals and active warnings
   a) Signal priority
   b) Transit signal pre-emption
   c) Audible crossing warning devices
   d) Constant warning time systems
   e) Pre-signals
   f) Flashing light signals
   g) Limits on downtime of gates
   h) Crossing horns—automatic and LRV–operator-activated
   i) Illuminated, active, in-pavement marking systems
   j) Blank out signs
   k) Pedestrian signals
2. Signs
   a) Stop and yield signs
   b) Retroreflective advance warning signs
   c) Flashing train-approaching warning signs
   d) Gate crossing status indication signals
3. Second train approaching treatments
   a) Second train approaching signals and active signs
   b) Second train approaching warning signs
4. Gates
   a) Pedestrian automatic gates
   b) Four-quadrant gates
5. Pedestrians
   a) Pedestrian fencing/landscaping

   b) Offset (or Z) pedestrian crossings
   c) Pedestrian swing gates
6. Channelization/markings
   a) Pavement marking, texturing, and striping
   b) Quick curbs
   c) Rumble strips
   d) Channelizations
   e) Illumination of crossings
7. Education and enforcement
   a) Photo enforcement
   b) Enforcement
   c) Education outreach programs
   d) CCTV/video recording

Safety Treatment Information Included in the Catalog

The catalog is designed for practitioners. It describes each treatment and gives the treatment's purpose, implementation effects, relative costs, and (where available) examples of the treatment's application. Actual cost estimates were not available; costs can also change dramatically over time and may depend on location.

The following information is provided for each treatment:

- The treatment name and alternative names,
- Basic summary of the treatment's intended operation,
- Picture(s) or illustrations of the treatment in operation,
- Purpose of the treatment,
- Suitable installation locations,
- Implementation effects,
- Contraindications to treatment (situations where the treatment is not appropriate or may be harmful),
- Relative cost,
- Other resources available,
- Links to related treatments,
- A short list of agencies that have experience with the treatment,
- Examples from agencies that have installed the treatment, and
- Information about agencies that are conducting trials.

CHAPTER 6

LRT Risk Analysis Methodology

This chapter develops a methodology for performing risk analysis for safety measures at LRT alignments. A successful methodology for risk analysis should consider these key factors:

- Each LRT site is different from the next in terms of physical conditions, traffic demands, control and safety devices, and the populations of motorists, pedestrians, and others using the site (e.g., ages, trip purposes, attitudes, degree of familiarity, etc.).
- The methodology must be simple enough to be carried out by local staff possessing specific knowledge about the site and local LRT operations, but without special equipment or extensive training in safety analysis.

It is useful to consider how risk analysis has been addressed in the highway safety field. Increased emphasis has been placed on explicitly addressing safety of alignments both at the design and the operational stages. The current best practice is centered on the concept of the road safety audit, which has become a standard practice in many jurisdictions across the United States and around the world. The safety audit process is discussed in the Introduction to the Concept of Safety Audits, Design Stage, In-use Stage, and Practical Methodology for Safety Audits sections.

Standards for assessing system safety are discussed in the Existing Standards section.

Cues taken from the success of the safety audit concept were used in the development of an LRT safety checklist. A simple checklist-based guide was created to assist local LRT staff in the critical review of safety conditions for a given set of circumstances defining a particular location. The checklist is discussed and presented in the LRT Risk Assessment Checklist section.

Introduction to the Concept of Safety Audits

The concept of safety audits is not a new one. Numerous publications outline the safety audit process. They include the Federal Highway Administration's "FHWA Road Safety Audit Guidelines" (http://safety.fhwa.dot.gov/rsa/rsaguidelines/html/table_contents.htm). The road safety audit is an approach designed to enhance safety proactively. The audit is a formal safety performance examination of an existing or future road or intersection by an independent audit team. The goal is to ensure the highest level of safety for all road users by identifying potential safety concerns and reducing the probability and potential severity of incidents. Safety audits also offer many other benefits, such as reducing the lifecycle cost of a design (when the cost of collisions is factored into analysis during the design process), minimizing the risk of collisions on adjacent transportation networks, and maximizing the application of safety engineering principles.

A safety audit uses a multi-disciplinary approach to identify potential collision risks through a detailed examination of all relevant design and environmental factors. When conducted on an existing road network, the interaction between the transportation environment and its users can also be observed. The safety audit should consider all potential users of the transportation network (i.e., pedestrians, buses, transport trucks, motorists, bikes, LRVs, etc.). Once potential safety concerns are identified, they can be addressed either by eliminating collision-producing elements from the design, and/or by including suitable safety features to mitigate remaining/existing problems.

Design Stage

Safety audits conducted during the design phase have the greatest potential for improving safety with lower expenditures than would be required at later stages of the project. A safety audit may be conducted during the preliminary design, the detailed design, or both. In general, the earlier in the project the safety audit is conducted, the greater the potential to improve safety while minimizing costs. These principles also apply, of course, to LRT designs.

This concept seems well-known to transit agency personnel as it was raised by local staff at several of the site visit workshops held for this project. However, the participants generally believed that more could have been done during design to improve safety on their various systems. It is certainly possible that cost or other constraints had an impact on safety features in the design stages.

Preliminary Design Stage

Safety audits during the preliminary design phase should be conducted once critical decisions regarding route choice and project design/layout have been determined. The safety audit should use both preliminary design drawings and site visits in the evaluation of a design. If multiple alternatives are still under consideration, or if the project will be implemented in stages, the safety of each alternative, stage, or transition between stages should be evaluated separately.

The primary objective of a safety audit is to evaluate the relative safety of the proposed design based on all information available. Typical components to be evaluated include horizontal/vertical alignment, sight distances, typical cross sections, intersection/interchange layouts, potential conflict points, and property accesses. Design consistency and user expectations should also be assessed. Any departures from accepted design standards and their effect on safety should be noted. In addition, adequate safety should be ensured in areas where multiple project elements meeting minimum standards interact. The safety audit should be conducted before land acquisition in case significant changes to the design are required. During the site visit(s), the audit team should examine the surrounding transportation network (roads, sidewalks, paths, etc.), and ensure that the proposed design is consistent from the perspective of all potential users. The ability to accommodate future design improvements should also be considered.

Conducting a safety audit during the preliminary design phase can avoid wasting valuable design time during the detailed design phase.

Detailed Design

Safety audits during the detailed design phase should be conducted when detailed design drawings and sufficiently detailed base maps are available. The base map should include all relevant environmental and topographical features in addition to existing infrastructure. Similar to the safety audit during the preliminary design phase, all alternative stages and transitions between stages should be evaluated separately.

A safety audit conducted during the detailed design phases will benefit from access to information not available at earlier stages of the project, but any significant changes to the design will require greater expenditure to implement. Typical components to be evaluated at this stage of the project include intersection details, lane markings, signals/signs, lighting, geometric layout, roadside clearances, and provisions for vulnerable road users. Field investigations conducted during the detailed design phase of the project can provide the safety audit team with an enhanced understanding of the project layout and potential interactions with surrounding transportation networks, particularly if some preparatory work has already begun. If a previous safety audit has been conducted, any issues identified or overlooked during that audit should be re-examined at this stage of the project. If applicable, the safety audit team should assess the potential impact of construction staging and traffic detour plans on the surrounding networks.

In-use Stage

A safety audit of an existing roadway/railway seeks to identify where collisions will occur and their potential severity. This is accomplished through an examination of available information, including as-built drawings, previous safety audits (if applicable), volume data, speed data, signal-timing plans, etc. Unlike safety audits conducted during the design phases, observations collected from site visits can be used to diagnose areas of elevated safety risk. Physical evidence such as skid marks, scuff marks, and damage to surrounding features can be used to identify potential hazards. In addition, the audit team can observe the behavior of various users interacting with the transportation facility and key features such as traffic control devices, and assess the potential impact on safety.

A safety audit differs from a safety review in that it is proactive and not reactive. While safety reviews are often initiated in response to a high number of incidents at a specific location, a safety audit seeks to identify potential problems *before* they occur. Therefore, a safety audit does not rely primarily on collision history to determine safety issues. Although collision data may be useful to supplement the findings of the safety audit, it may not reflect current and future conditions, and should not be relied upon too heavily.

LRT collisions are relatively infrequent events and therefore do not necessarily reflect all the safety issues at a site. The collision history may lead staff to early conclusions and recommendations that, while not incorrect, may overlook other safety concerns that exist but have yet to be implicated in an incident. The safety audit team may choose not to review the collision data until they have developed recommendations based on all other available information in order to avoid incorporating bias in the analysis.

Inspectors should also be mindful of any potential changes to the function or classification of the transportation facility since its construction. Changes might include increased traffic volumes and changes in vehicle mix, adjoining land use, or the intensity of development. Elements of the facility that were reasonable and effective in design may no longer serve their purpose if significant changes have occurred in the surrounding area.

Practical Methodology for Safety Audits

Numerous existing standards comprehensively address the methodology of safety audits. The methodology summarized below is based on a review of the following documents:

- Federal Highway Administration, *Road Safety Audit Guidelines,*
- Transportation Association of Canada, *Road Safety Audits: Canadian Guidelines,* and
- *National Cooperative Highway Research Program Synthesis of Practice 336: Road Safety Audits.*

The standard methodology for safety audits generally includes the following steps:

- Select the safety audit team,
- Provide background information to the safety audit team,
- Conduct a pre-audit meeting to review project information,
- Assess/analyze background information,
- Perform site inspections under various conditions,
- Prepare and submit safety audit report,
- Conduct safety audit completion meeting,
- Prepare formal response (completed by project owner/design team), and
- Incorporate safety audit findings into project (where appropriate).

Each of these steps is explained briefly below. Additional information is listed in the sources listed above, and in numerous other publications on the safety audit process.

Select the Safety Audit Team

The safety audit team should be an independent multidisciplinary team with the appropriate expertise and training to successfully conduct the safety audit. All team members should be impartial; therefore anyone previously involved in the design process should not be included. Auditors must be unconstrained in their ability to comment on potentially contentious safety issues. The size and structure of the safety audit team will vary based on the stage and complexity of the project.

Provide Background Information to the Safety Audit Team

It is the responsibility of the project team to provide the safety audit team with all of the relevant background information required to complete a comprehensive analysis. The safety audit team should have a broad view of the project objectives and challenges. Information to be provided depends on the stage of the project, but typically includes site data (i.e., traffic data, design standards used, etc.), plans, and drawings.

Conduct a Pre-audit Meeting to Review Project Information

The purpose of the pre-audit meeting is to clearly outline the scope of the safety audit and review all available information. The meeting should both familiarize the project team with the safety audit process and introduce the safety audit team to the project. The project and safety audit teams should agree on the delegation of responsibilities, the timetable, and suitable lines of communication. Arrangements for site visits can also be made at this time.

Assess/Analyze Background Information

Once the safety audit team has been provided with the background information, the next step is to begin to evaluate and analyze it. The first step is usually a brainstorming session involving all members of the multi-disciplinary team. This is typically followed by a desktop evaluation of all of the material provided by the project team. It is critical that this evaluation focus exclusively on safety concerns, and not digress into evaluation of matters outside of the scope of the safety audit (i.e., cost of alternative designs).

Perform Site Inspections under Various Conditions

The purpose of the site inspections is to provide the safety audit team with a clear picture of conditions at the project site. Team members are afforded the opportunity to experience the site and surrounding facilities from the perspective of all potential users (pedestrians, car drivers, heavy vehicle operators, LRV operators, cyclists, etc.), and visualize any potential safety concerns that may not be apparent from the design drawings alone. In many cases viewing the site at night in addition to daytime can provide valuable information not otherwise available. The observers should also consider the potential effects of transient conditions such as rainfall or snow storage as applicable. The stage of the project will ultimately determine what useful information can be gleaned from site inspections (see the Design Stage and In-use Stage sections).

Prepare and Submit Safety Audit Report

The safety audit report should be completed once the safety team has identified all potential safety concerns. The report should include a brief description of the project, including purpose, scope and any relevant background information. The main body of the report should clearly and concisely outline the design and operational elements reviewed and all potential safety concerns noted. All safety concerns identified should be specific, and a brief description of the potential risk posed to road users should be included. Safety concerns should be organized in a logical format with appropriate headings and subheadings to facilitate response from the project team. Recommendations for improvements are generally not the responsibility of the safety audit team, although they may suggest options; decisions about which remedial measures to take are the responsibility of the project team because the project team has a more comprehensive picture of the competing priorities of the project.

Conduct Safety Audit Completion Meeting

After the submission of the safety audit report, it may be beneficial to hold a completion meeting involving key members of the project team and the safety audit team. The purpose of the completion meeting is to formally present the findings of the report, clarify any uncertainties, and facilitate mutual constructive discussion. The purpose of this meeting should be clearly identified. The safety audit team's objective is to improve the overall safety of the project, not to assign blame or critique the design. The meeting is also not designed to provide the project team with an opportunity to dispute the findings of the safety audit. All participants should view the meeting as an opportunity to identify the safety concerns clearly and identify potential measures to improve safety.

Prepare Formal Response by Project Owner/Design Team

After reviewing the safety audit report, it is important for the project team to document a formal response to the findings of the safety audit report. The response should identify the actions the project team intends to take for each of the safety concerns identified. In the case when no action will be taken for a particular safety concern, the response should clearly identify the rationale behind the decision.

Incorporate Safety Audit Findings into Project

Once the formal response has been submitted to the safety audit team, the project team should proceed to incorporate the agreed recommendations into the project. The inclusion of improvements involving a significant increase in project cost or duration may not be feasible. If consensus cannot be reached regarding a particular issue, the safety audit team should document the differences.

Existing Standards

A number of existing standards for assessing system safety are available. The most widely referenced work in the literature examined was the Department of Defense *Standard Practice for System Safety* (MIL-STD-882D) (U.S. Department of Defense, 2000). This document is discussed in the following section. In the FTA's publication *Hazard Analysis Guidelines for Transit Projects,* the FTA recommends conducting hazard identification, assessment, and resolution in conformance with the latest version of the MIL-STD-882D (*10*).

Information provided by local LRT staff during the site visits indicates that a number of LRT agencies are using the MIL-STD-882D standard to conduct risk analysis. For example, NJT noted that it uses the MIL-STD-882D standard to evaluate the design of any new system before it is built and operated. NJT emphasized the need to "design out" hazards at the design stage of a project, emphasizing the role of peer reviews in this process. In addition, whenever changes are proposed to the existing system, NJT conducts an operation hazard analysis to list possible hazards resulting from the change in operation, along with possible mitigating measures.

DoD *Standard Practice for System Safety* (MIL-STD-882D)

As mentioned above, the U.S. Department of Defense has published a document entitled *Standard Practice for System Safety* (MIL-STD-882D). Two agencies that participated in the site visits referenced their use of MIL-STD-882D as a basis for their risk management approach. The document provides standardized requirements for developing and implementing a system safety program. The standard is designed as a general guideline for use in a wide variety of contexts and is not focused primarily on transportation applications. The document provides a standard methodology for use in the identification of hazards, risk assessment, and mitigation of mishap risk through the implementation of design requirements and management controls. "Mishap risk" is defined as "an expression of the impact and possibility of a mishap in terms of potential mishap severity and probability of occurrence."

The document recommends a systematic procedure consisting of the following eight steps, which encompass the entire life cycle of the system:

1. Documenting of system safety approach;
2. Identifying hazards;
3. Assessing mishap risk;
4. Identifying mishap risk mitigation measures;
5. Reducing mishap risk to an acceptable level;
6. Verifying mishap risk reduction;

7. Reviewing hazards and acceptance of residual mishap risk by the appropriate authority; and
8. Tracking hazards, their closures, and residual mishap risk.

The concise standard is a guideline rather than an exhaustive treatment of system safety. The document also contains an appendix entitled "Guidance for the Implementation of a System Safety Effort" that offers further elaboration on the definitions and procedures contained in the main text.

The identification of potential hazards is highly system specific, so there is not much elaboration provided on the topic. The standard recommends a systematic hazard analysis process including evaluation of the system environment and intended application, including historical data and data available from similar systems.

The standard emphasizes the need to develop methods that accurately and meaningfully assess both the likely severity and probability of occurrence of potential mishaps. The appendix contains suggestions for describing mishap severity categories and probability levels, while noting that adaptation to the specific system is generally required. Severity categories are classified as catastrophic, critical, marginal, or negligible, based on the following factors: potential for death, disability, injury, or occupational illness; monetary loss; and environmental damage. Mishap probability, defined as the probability of the mishap occurring over the life of the system, can be classified either qualitatively or quantitatively. The recommended categories for mishap probability are frequent, probable, occasional, remote, or improbable.

Risk assessment values are determined using a combination of both mishap probability and potential severity. For example, a hazard classified as frequent and catastrophic would be assigned a risk assessment value of one, a hazard classified as probable and catastrophic would be assigned two, etc. These risk assessment values would be used to group individual hazards into mishap risk categories. These risk categories can then be used to prioritize treatments and determine the mishap risk acceptance level.

The standard recommends an iterative approach to the identification of mishap risk mitigation measures which terminates only when residual mishap risk has been reduced to an acceptable level. The four steps, in order of preference, are: eliminate hazards through design selection, incorporate safety devices, provide warning devices, and develop procedures and training. The standard reiterates the need to follow a comprehensive, systematic process in identifying risk mitigation measures as opposed to simply providing signage. The emphasis on verifying successful risk reduction and reviewing and tracking hazards shows that maintaining system safety is an ongoing process that does not terminate once the hazard is addressed.

LRT Risk Assessment Checklist

This section describes a way to perform risk analysis for safety measures along LRT alignments. A checklist was completed using information obtained through research and consultation with various transit agencies. Table 33 shows the

Table 33. Primary sources used in developing the safety checklist.

Title of Publication	Organization	Author(s)	Year
Pedestrian-Rail Crossings In California: A Report Compiling the Designs and Devices Currently Utilized at Pedestrian-Rail Crossings within the State of California	California Public Utilities Commission	Richard Clark	2008
TCRP Report 69: Light Rail Transit: Pedestrian and Vehicular Safety	Transit Cooperative Research Program	Hans W. Korve, Brent D. Ogden, Joaquin T. Siques, Douglas M. Masnsel, Hoy A. Richards, Susan Gilbert, Ed Boni, Michele Butchko, Jane C. Stutts, Ronald G. Hughes	2001
Investigation into Station Pedestrian Crossings (Including Pedestrian Gates at Highway Level Crossings)	U.K. Department of Transportation – Rail Accident Investigation Branch		2006
The Canadian Road Safety Audit Guide	Transportation Association of Canada	Sany Zein, Geoffrey Ho, Paul de Leur	2000
Road Safety Audit Guidelines	University of New Brunswick Transportation Group	Eric Hildebrand, Frank Wilson	2008

LRT Alignment Risk Assessment Checklist

This checklist is intended to provide a framework for a comprehensive risk assessment of a location along an LRT alignment. The risk assessment report would be prepared as a separate document or as an attachment to this form, using the form as a table of contents.

	Completed
Reason for assessment: Note the reason for assessment. Possible reasons include collisions(s), collision precursors (near misses or violations), operator or public complaints, and routine assessment of sites on a rotational basis.	☐
Area type: Describe the surrounding area (industrial, school, urban core, suburban, proximity to parks and seniors homes/centers, etc.)	☐
Collision history: List past collisions (LRT, vehicle, pedestrian, bicycle) and possible causes. If available, list collision precursors.	☐
Exposure: If available, record the a.m. peak, p.m. peak, and daily volumes for the location for all traffic types involved:	☐
Pedestrian volume	☐
Road vehicle volume	☐
LRV frequency	☐
Roadway design elements: Describe the roadway (if applicable). Include sketches or photos as necessary.	☐
Speed and classification	☐
Cross-section type (lanes, channelization, islands, barriers, etc.)	☐
Sight distance	☐
Warning devices	☐
Traffic control and Barrier devices	☐
Pedestrian environment design: Describe the pedestrian environment (if applicable). Include sketches or photos as necessary.	☐
Surface type, grade cross-slope, accessibility	☐
Horizontal and vertical clearance	☐
Obstacles to movement (e.g., crossing padding)	☐
Positive guidance, handrails	☐
Warning devices	☐
Barrier devices	☐
Conflict definition: Define the nature of the conflict (e.g., grade crossing, parallel alignment at grade), with sketch as necessary to show possible impact types.	☐
Lighting: Investigate the impacts of lighting at different times of day. Describe from the pedestrian, vehicle, and LRV operator perspectives.	☐
Driver sight lines: Determine if conflict points and the approaches to conflict points are visible by the LRV operator and other users for the expected speed(s).	☐
Obstructions (trees, poles, etc.)	☐
Horizontal and vertical alignment	☐
Potential problems with glare, haze, fog, foliage, snow storage, etc., for different times of day and seasons of the year.	☐
Clearance time: If applicable determine if the clearance time provided by vehicle, pedestrian, and train signals is sufficient to safely clear the intersection.	☐
Design Consistency: Are any aspects of the site features sufficiently unusual to be surprising or contrary to the reasonable expectations of the users? (describe)	☐
Operator/public complaints: Comment on any complaints that may have been received in context of the site review – are they reasonable and/or explainable?	☐
Propose possible solutions/mitigations to address reason(s) for assessment.	☐

Figure 6. LRT alignment risk assessment checklist.

publications referenced in the development of the LRT risk assessment checklist.

The publications reviewed and the discussions conducted with the various transit agencies visited suggested that the concept of a checklist was the preferred option for use in LRT risk assessments. A rigid framework was not supported as it would not be adaptable to the wide range of situations found in practice. At the Minneapolis workshop, it was suggested that due to the wide variety of information that may need to be collected for an LRT audit, the checklist should be organized into general categories for consideration and should avoid taking a more detailed approach.

In safety audits, checklists are intended to serve as a guide or memory aid to help identify safety issues and ensure something important is not overlooked. They are useful for supplementing knowledge and experience and for providing direction to an investigation. It is important to recognize that checklists should not be considered an exhaustive list of all possible issues to be addressed. The safety audit team must use judgment to establish the relevance of each item on the list to a project. Even if a particular item appears to be irrelevant, it may lead the investigator to consider other factors that may otherwise have been overlooked.

Taking into account the above considerations and the feedback received from the local LRT agency workshops, the project team developed the "LRT Alignment Risk Assessment Checklist," as shown in Figure 6.

The LRT Alignment Risk Assessment Checklist will provide guidance to LRT staff and other groups conducting a risk assessment. Its application will cover key factors and will help ensure that important considerations are not overlooked in the study of any given site. Individual agencies can expand the checklist as circumstances and the situation require. It is hoped that the checklist's broad descriptions will not be viewed too narrowly in practice and that important elements of a site users' perceptions will be included in the risk assessment.

CHAPTER 7

Improving the Accident Data Collection Process

This chapter develops recommendations designed to facilitate the compilation of accident data in a coordinated and consistent manner across LRT systems in the United States. The goal is to generate data that permits meaningful comparisons of accident rates across transportation modes, and more rigorous assessment of the effectiveness of safety measures, devices, and practices implemented on LRT alignments. The chapter provides an overview of existing data collection experience and the various report forms used by transit agencies. Additional detail regarding the accident data collection process is provided in Appendix E.

It is essential to have detailed and comprehensive information to accurately identify problems, rates, and trends in LRT accident data and to develop corrective actions and remedial measures. Accident data should be collected and stored in a consistent format that facilitates electronic data management and analysis. Diagrams of crossing conditions and characteristics depicting roadway/LRT geometry where collisions occur, and collision diagrams illustrating crash experience ("condition diagrams" and "collision diagrams," respectively, in MUTCD terminology), can be useful in pinpointing problems. The information contained in these diagrams is not, however, directly transferrable to the numeric format of electronic databases and thus cannot be used in the statistical analysis of large sets of collisions. It is desirable to have consistent accident reporting formats across transit agencies.

Transit Agency Data

The research team reviewed the incident reporting forms used by 12 LRT transit agencies. The incident report forms used by these transit agencies are included in Appendix E.

Agencies with Multiple Accident Report Forms

Most agencies provided only one incident report form, but three agencies provided more than one. These agencies were the TTC, SEPTA, and SF MUNI.

The TTC provided three separate incident reports: Occurrence Report, Surface Supervisory Occurrence Report 185L, and Assessment and Summary Disposition Report.

- The Occurrence Report and the Surface Supervisory Occurrence Report contained generally very similar information. However the Occurrence Report focused on collecting information only available at the scene such as the type of impact (i.e., sideswipe), the precise location of injured passengers, and whether or not each vehicle sounded its horn or had its headlights on before impact.

  The Surface Supervisory Report focused on reporting damage and factors contributing to the incident, such as detailed descriptions of the location and extent of damage, the specific actions of all drivers and pedestrians involved, classification of the severity of the incident and any injuries, and judgments (yes, no, or unknown) as to whether or not each environmental factor contributed to the occurrence.
- The Assessment and Summary Disposition Report focused on identifying any evidence that could implicate the TTC operator or the other motorist/pedestrian in legal responsibility for the incident.

SEPTA provided three separate incident report forms: Operator's Accident Incident Report, the Supervisor's Accident Investigation Report, and the SEPTA Public & Operational Safety Division Incident Report.

- As with the TTC, the data collected on the Operator's Accident Form and the Supervisor's Accident form were nearly identical. The Operator's Accident Form included descriptions of the specific actions of all parties involved in the incident, while the Supervisor's Accident Investigation Form contained additional information classifying the incident and indicating the presence and types of safety features and traffic control devices at the scene.
- The Public and Operational Safety Division Incident Report was a summary level report compiled using the previous two

accident reports in conjunction with other available information sources. A list of potential sources is provided with the report and includes: Operator Report, Supervisor Report, Interviews, Photographs, Vehicle Inspection, Event Recorder Log, CD-ROM, Field Notes, Sketch, Chain of Custody, Evidence, Control Centre Report, Police Report, D&A Report, Radio/Telephone Tapes, and Infrastructure Inspection.

SF MUNI also provided three incident report forms: The Employee Form, The Supervisor Form, and The Safety Form.

- The Employee Form focused on reporting information relevant to loss prevention and contained less detail regarding the environmental conditions or actions of persons involved.
- The Supervisor Form focused on determining whether the condition of the driver contributed to the incident (including drugs/alcohol), what emergency services attended the scene, and recommendations as to what training might be necessary for the driver to prevent another occurrence in the future.
- The Safety Form was clearly designed to facilitate reporting to the NTD. Many of the categories of data included in the form and their answers were taken directly from the NTD Reportable Incident Report Form. This form focused on including all the fields required by the NTD, such as classification of incident, ROW type, intersection controls, specific actions of drivers, etc.

Incident versus Accident Report Forms

Many of the report forms contained information pertaining to the collision of a transit vehicle with either another vehicle, a pedestrian, or a fixed object. Other report forms also included data related to other types of incidents, such as criminal activity on transit property, passenger illness, etc. From the perspective of safety analysis, it would be ideal to keep these types of incidents completely separate from collision reports. As indicated in the Collision Data Available, Requested, and Received section in Chapter 3, failure to do so often leads to incorrect reporting of incidents, resulting in the need to undertake significant data cleaning before databases can be used for analysis.

Categories of Information Included in Accident Reports

The accident report forms reviewed by the research team contained several categories of information that were common to many of the forms. These included: incident classification, location, weather, illumination, road/rail conditions, action of driver(s), safety equipment, damage, injuries/fatalities, witness information, and emergency services present. In addition, many forms contained sections for collecting data pertaining to pedestrian/passenger incidents. As mentioned in the Location section, a few of the incident report forms also contained information regarding incidents that were not related to transportation safety.

Table 34 shows the common categories of data reported in the hardcopy and electronic incident report forms supplied by the LRT agencies. The table also shows the data reporting format used for each category of data. The letters used for the data reporting format (C, T, etc.) are explained (checkbox, text field, etc.) in the table's footnote.

Incident Classification

Most incident report forms required the investigator to provide a classification of the incident. Generally, incidents were classified based on type of incident and/or severity. Forms intended for use in the investigation of a wide variety of incidents included an extensive list of possible incidents, most of which were not collisions. Incident reporting forms generally classified collisions based on the object or individual that collided with the transit vehicle.

Location

The most common method of identifying the location of collisions was to provide a text field on the incident report form. The limited amount of space dedicated to location on most of the forms suggested that most agencies expect a minimal description of the incident location. Some of the forms required both the street being travelled and the nearest cross-street to be reported. Most forms also included details pertaining to the transit agency such as the run number, route number, switch number, and line/branch number.

Some of the forms included more specific details regarding the incident location. The SF MUNI Safety Form reported the exact latitude and longitude of the incident location. A few forms further classified the location using a series of checkboxes. For example, the LACMTA form required the location of the rail vehicle to be classified as being on the mainline, shop, yard, or other location. The location of the other vehicle could be identified from the location of the person involved in the incident, which included the categories ROW, grade crossing, tunnel, or yard.

The TTC Supervisor's Accident Investigation Form provided the most detailed list of descriptors to classify the incident location, including whether the location was at an intersection, midblock, loop, garage, terminal, near side stop, far side stop, island, and/or curb. If the incident occurred at a bay or stop, the investigator could further indicate whether the

Table 34. LRT incident report forms: categories of data included and data format.

Agency/Report Name	Incident Classification	Location	Weather	Illumination	Road/Rail Conditions	Actions of Driver(s)	Safety Equipment (Vehicle/ROW)	Damage	Injuries/ Fatalities
Hardcopy Forms									
LACMTA	C	C/T	T			C	C	T	A/T
Santa Clara Valley TA	C	T	C	C	C	C/T		C	C
RTD Denver		T					C	T	C/T
Memphis Area TA		T	T			C/T		C/T/D	C/T
Portland Tri-Met	C	C/T	C	C	C	C/T/D	C/T	C/T/D	C/T
SEPTA									
Supervisor's Accident Investigation Form	C	T	C	C	C	C/D	C	C/T	C/T
Operator Accident Incident Report	C	T	C	C	C	C/D		T	C/T
St. Louis RT	T	T	T		T				T
Toronto Transit Commission									
Occurrence Report	C	T/D	C	C	C	C/T/D	C	T	C/T
Surface Supervisory Occurrence Report	C	C/T/D	C	C	C	C/T/D	C	C/T	C/T
Edmonton Transit System	C	T	T	T	T	T/D	T	T	C/T
City of Calgary Transit	C	T	C	C	C	C/T/D		T/D	
Electronic Forms									
SF MUNI									
Supervisor Form	T/P	T/P	T/P	P		T	T/P	T/P	T/P
Safety Form	C/T/P	T/P	P	P	T/P	T/P		P	T/Tb
Employee Form	T/P	T/P	P	P				T/P	T/P
Utah TRAX		T	P	P	P	P	P	P/T/D	P/T/Tb

Note: C – Checkboxes, T – Text field, D – Diagram, A – Alphanumeric Code, P – Pull-down Menus, Tb – Table. A blank indicates that the category was not included in the form examined.
Source: review of all referenced forms and reports received from LRT agencies

vehicle was entering, exiting, or dwelling at the bay or stop. Providing additional details regarding the location of the incident can give individuals unfamiliar with the location information pertinent to the determination of whether or not location contributed to the collision. This level of detail and categorization would be especially useful in the analysis of records at a national level.

Weather

Most of the incident forms required the investigator to report the weather conditions at the time of the incident. There was a high degree of consistency in the format of the weather reporting. Most agencies provided the investigator with a series of checkboxes from which he/she could select the appropriate response. As would be expected, the responses available were determined by the climate of each location. Northern locations, for example, tended to provide detailed responses for winter weather conditions.

Illumination

Most of the incident report forms included information about lighting conditions at the time of the incident. In almost all cases, the incident form provided the investigator with a series of checkboxes from which to select the appropriate response. Although virtually all agencies contained identical responses for environmental lighting conditions (i.e., daylight, dark, dawn/dusk), certain agencies also allowed the investigator to indicate whether glare or street lighting were present. These added details provide a more comprehensive picture of the lighting conditions at the time of the incident, and can help the analyst more accurately determine whether illumination was a factor contributing to the incident.

Road/Rail Conditions

The condition of the roadway or railway at the time of the incident was also included in most incident report forms. Almost all the forms that recorded road/rail conditions provided a series of checkboxes from which the investigator could select the appropriate response. Responses focused on environmental conditions that might reduce surface friction and contribute to a collision (i.e., leaves, water, ice, etc.).

The Toronto Transit Commission Occurrence Reports also required the investigator to indicate whether any of the following road conditions were applicable: asphalt or concrete, gravel or other, upgrade, downgrade, construction, straight, curve. The inclusion of this information on the incident reporting form provides a more comprehensive picture of how design and environmental road/rail conditions might contribute to collisions.

Action of Driver(s)

The actions of the drivers involved in the incident were reported to various degrees on the incident report forms. The most commonly reported driver actions were: direction and speed of travel; use of head lights, tail lights, or horns; and maneuvers being executed at time of impact. In many of the incident forms, diagrams were an important source of information regarding driver action. The level of detail provided was not consistent among transit agencies. For example, some of the incident forms only required the direction of travel of the vehicles, with potential for additional explanation in the statements and/or diagrams. In contrast, forms such as the TTC Occurrence Report reported speed prior to impact, type of impact (i.e., sideswipe, head-on, etc.), distance travelled after impact, headlights (on/off), and horn sounded (yes/no), in addition to providing room for diagrams and statements. An important point to note is that the source of information was not identified on many of the incident forms. This can be critical information when considering the validity of information about driver actions.

Safety Equipment

The presence of safety equipment was inconsistently reported across transit agencies, and often omitted entirely. The safety equipment information contained on the incident report forms included traffic controls at intersection; aspect of signals at time of crash; type and condition of switch; visibility and functionality of traffic signs/signals; presence, visibility and functionality of grade crossing devices; type of traffic lines; and presence, type, and indication of transit signal. Most incident forms included only a few of the above listed factors.

Damage

The accurate estimation of damage at the scene of a collision can be a difficult task. The incident report forms generally used one or more of the following three methods to indicate the extent of damage: diagrams, classification of damage, and description of damage. There were significant variations among transit agencies in the methods employed to report damage. UTA staff noted during the workshop that if the fault lies with the operator of the motor vehicle and not the LRT operator (which is almost always the case), the agency never receives formal reports of total damage on the auto or on the LRV. This made estimating damage a difficult and imprecise task.

Diagrams typically required the investigator to shade or mark the areas of damage on the transit vehicle and/or other vehicle. Classification of damage was based either on a qualitative description (minor/moderate/major) or quantitative estimate (greater or less than a dollar value). Description of damage relied on the investigator to provide a meaningful description of the damage to each vehicle.

The methods of reporting damage were generally inconsistent across transit agencies. Although there were some agencies that combined the above techniques in an effort to create a more comprehensive view of the damage, many agencies relied solely on a rough dollar value estimate or arbitrary classification of damage. In addition, the incident reporting forms generally did not provide any guidance as to how the user should decide between various classifications of damage. Finally, damage reported in either diagrams or text descriptions would likely be very difficult to translate into an electronic database in a format suitable for analysis.

Injuries/Fatalities

In general, the incident report forms focused on reporting the number of injuries, the classification of each injured person (e.g., transit agency employee, passenger, pedestrian, etc.), the extent of each injury, and how each injured person was transported from the scene. A combination of checkboxes and text fields was usually used to record the relevant information. The incident report forms also included sections where the contact information of each injured individual could be reported.

The method of reporting the number and severity of injuries used on the Utah TRAX Supervisor's Accident/Incident Report Form seemed particularly useful. While the majority of forms relied solely on a description of injuries provided by the investigator in a text field, the TRAX from also provided a table with three rows of injury classification: Class A (bruising, abrasions, minor to moderate bleeding, sprains, and strains), Class B (unconsciousness, fractures, severe bleeding), and Class C (death, paralysis, and dismemberment). Each vehicle involved in the incident was assigned a column in the table, and the user was required to indicate the number of individuals in each vehicle whose injuries fell under each category. This method of reporting injuries appears useful to concisely convey most of the information relevant to the transit agency, while providing the user with some concrete guidance on how to report the extent of injuries.

Contact Information

All the incident report forms included sections where the contact information of all individuals involved in the incident was reported. Almost all the forms collected contact information for all drivers, vehicle owners, witnesses, and emergency personnel present at the scene. The contact information of all employees involved in the investigation or reporting process was also collected.

Existing Accident Reporting Standards

The desire to promote uniformity and comparability of accident data and statistics across agencies and levels of government has led to the publication of a number of accident reporting guidelines that include:

- *American National Standard Manual on Classification of Motor Vehicle Traffic Accidents* (ANSI D16) (7th ed., American National Standards Institute, ANSI D16.1-2007, 2007)
- *Data Element Dictionary for Traffic Record Systems* (ANSI D20) (American Association of Motor Vehicle Administrators, ANSI D20-2003, April 2003)
- *Model Minimum Uniform Crash Criteria (MMUCC) Guideline* (3rd ed., 2008 http://www.mmucc.us/, accessed Aug 28, 2008)

Supervisory Agency Data

As discussed in Chapter 3, there are other agencies at the state and national levels that receive and compile data reported by local LRT agencies, and the reporting process is outlined below.

SSO Agency Data

SSOs fill multiple roles. They collect data to forward to the FTA, but their larger role is to oversee accident investigations and to undertake corrective action. All SSOs follow the same basic reporting process following an incident. Transit agencies are required to notify their SSO of an incident (which may or may not be a crash) over a certain severity threshold within two hours of the incident occurring. The SSO then proceeds with a more formal safety review. The SSO may conduct an investigation directly, or the transit agency may conduct the investigation and then report it to the SSO. If warranted, the SSO formulates a corrective action plan. The SSO submits all data to the FTA in an annual report. All SSO agencies interviewed for this study expressed interest in a consistent standard for accident data collection.

FTA/NTD Data

The National Transit Database is "the Federal Transit Administration's primary national database for statistics on the transit industry" (National Transit Database Federal Transit Administration *2008 Safety and Security Reporting Manual*). Transit agencies are required to report all safety and security incidents to the NTD using two forms. The Safety and Security Monthly Summary Form (S&S-50) is a monthly summary of the number of safety and security events that resulted in an arrest/citation but did not meet the criteria of a "reportable incident." Transit agencies are also required to submit data pertaining to a reportable incident using the Reportable Incident Report Form (S&S-40). This form must be submitted within 30 days of the incident occurrence.

Redundancies in Data Collection

As noted in the preceding section, agencies are responsible for collecting and reporting data twice. They collect and send data to the SSO (which reviews the data and may develop corrective action plans), and they collect and send data to the NTD through NTD reporting procedures. Agencies that operate on a shared alignment with heavy rail also send in-depth internal records and/or report incidents to the FRA. Local LRT agencies are tasked with the role of reporting the same information to multiple agencies, but all the local agencies visited reported that they rarely receive any feedback or results from the data they report.

A Potential National Standard Accident Data Collection Procedure

This section outlines a potential method to facilitate the compilation of transit accident data in a coordinated and consistent manner across the United States, with a focus on collecting data that can be used to assess the impact of safety treatments.

Two sources provide the data required for safety analysis:

1. The local LRT agency investigation of a collision, coupled with an associated report from police, necessary for assessment of causal factors.
2. The local authority responsible for traffic data management, which could provide exposure data such as road and pedestrian traffic volumes, necessary to establish rates.

Since both of these sources are at the local level, all data collection and entry should take place locally and electronically to minimize data manipulation and transcription problems later. The database format and structure should be designed to easily permit all data users (for whatever purpose) to extract the information they need with a minimum of manual effort. This will increase efficiency by reducing the redundancy of reporting differently to the various agencies involved at local, state, and national levels. It will also increase accuracy by avoiding subjective decisions and second-guessing of evidence (e.g., during transcription of one report into another system) that weakens the resulting data and any conclusions drawn later.

Standardized Electronic LRT Incident Reporting

To ensure that data relevant to assessing the safety of transit systems and impact of safety treatments are available, it is critical that these data should be consistently collected during the incident reporting process. Since incident report forms are the primary source of information used by transit agencies in incident investigation, site-specific conditions such as the right-of-way classification and the presence or absence of traffic controls, signage, and other safety devices should be consistently reported in the incident report forms used by transit agencies.

Develop and implement a standardized, comprehensive, electronic LRT incident reporting form. This form should be developed and implemented nationally to ensure that the same data are collected in all cases and to ensure that the same data are accessible to all who need them. The form should provide useful prompts and other support for the user entering data to improve clarity and reduce effort to a minimum.

Structure of Reporting Forms

The structure and format of incident report forms is also critical to ensuring that all relevant data are collected, easily transferred into an electronic database, and easily analyzed. Checkboxes and pull-down menus should be used for data fields, and the number of possible or relevant responses should be limited, avoiding free-form input where practical. The responses can be supplemented with text descriptions that can be used to report unusual circumstances. The text descriptions can also be used to verify data accuracy. For example, report forms may include a comprehensive list of safety treatments and require the investigator to indicate if each is present or absent, followed by a text field where the investigator can describe any relevant features not included on the list. This format will not only provide the investigator with a sense of what information is relevant to collect, but will also result in data that is more useful for analysis.

The responses in the checkboxes and pull-down menus should conform to national or industry standards where applicable (e.g., right-of-way classification by alignment type as developed as part of *TCRP Report 17* and described in Chapter 2). Sources such as the *Model Minimum Uniform Crash Criteria* (MMUCC) can be extremely useful in providing transit agencies with guidance as to what categories of information are critical to include in incident reporting. The use of data reporting methods such as hand-drawn sketches that cannot be used for queries in electronic databases should be minimized, and additional categorized data fields should be included to ensure that relevant information in sketches is also provided in a more usable format.

Provide a reporting form structure that can be easily transferred into a searchable electronic database. Utilize checkboxes and pull-down menus with a limited number of relevant responses, supplemented by text fields where necessary.

Record Exposure Data

The information required to calculate and conduct meaningful comparisons of LRT collision rates should also be reported. Such information includes traffic exposure information such as the number of vehicles crossing at a level crossing, the number of passengers boarding/alighting at a specific platform/station, and the number of pedestrians crossing the tracks per segment per unit time. As this information will not be available to the investigator at the scene of the collision, the information will have to be obtained from the relevant source within the local agency and will need to be linked to the incident report data after the on-scene data collection.

Ensure that LRT collision reports include fields for storing geometric and traffic exposure measures that apply to the specific incident site. These data may be sourced from local municipalities or traffic agencies, and the database system storing the data should record the data source because it will not likely be the same as that of the rest of the collision report.

LRT Crossing Database

As LRT collisions are relatively rare events, there may never be enough LRT-related collisions at one location to develop a statistically significant before-and-after study. To have enough collisions to determine the safety effect of a treatment, researchers could compare the number of incidents at physically similar locations throughout one or more LRT systems. To undertake such analyses, researchers need to have geometric and traffic control data for each crossing and information about any special safety measures or treatments that have been applied.

It is not enough to have this information only for locations where there are incidents. An analysis database should include all crossing locations to determine the impacts of different measures over the "do nothing" option in each of the alignment types. The FRA maintains a similar database for heavy rail crossings, but the database for LRT needs to be significantly larger as it needs to include information about crossings and segments between crossings where a vehicle or pedestrian may be able to enter the alignment. As compiling and updating the database is a significant undertaking and beyond the resources of most LRT agencies, a national program appears to be necessary.

To support analyses of LRT safety, an LRT crossing database could be created. This database could include, for each alignment location (crossing or segment), details of geometry, control devices, and traffic exposure. The database should be updated as alignments and traffic volumes change (perhaps on a five-year cycle and after major construction).

Summary of Information to Be Included in the LRT Collision Database and Reporting Form

Based on the analysis of the local, NTD, and SSO incident databases, the project team compiled a list of potential fields for an LRT collision reporting form and accompanying database.

Consider including the following fields on the LRT collision reporting form when it is developed:

- Incident classification:
  - Clear collision/incident distinction
  - Type of object or individual involved
  - Type of impact
- Location: exact location (cross referenced with separate LRT crossing database)
- Location detail: entering, exiting or dwelling in crossing or stop
- Weather conditions
- Illumination: daylight, dark, dawn/dusk, glare, streetlighting (and condition of repair)
- Road/rail conditions: dry, leaves, water, ice, asphalt/concrete/gravel, upgrade/downgrade/level, construction, straight/curve
- Action of driver(s):
  - Direction and speed of travel
  - Use of head lights, tail lights, horn
  - Maneuver being executed
  - Source of information: driver, investigator, police, witnesses
- Safety equipment:
  - Crossing type
  - Traffic controls
  - Transit signal presence, type, indication of transit signal
  - Aspect of signals
  - Type and condition of switch
  - Visibility and functionality of traffic signs/signals
  - Visibility and functionality of grade crossing devices (i.e., gates)
  - Presence and type of other safety treatments
- Property damage: a repair cost estimate for all vehicles involved, but with an option to provide a simpler classification of damage with clear definitions (i.e., repairable/irreparable damage to LRV, repairable/irreparable damage to private vehicle)

- Injuries/fatalities:
  - Number of injuries of each class (predetermined classes of severity) in each vehicle.
- Contact information: for drivers, vehicle owners, witnesses, emergency personnel, agency employees involved in investigation
- Exposure (to be completed following contact with the appropriate agency):
  - Annual average daily traffic volume, number of pedestrians boarding/alighting, number of pedestrians per segment per unit time
  - Source of exposure data

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APPENDIX A

LRT Catalog of Safety Treatments

List of Treatments

The treatments included in the catalog are organized into seven categories. The categories are intended for reference purposes only, and some treatments may fall into more than one category; every treatment has been listed only once. The categories and treatments are listed below:

1. Signals and active warnings
   a) Signal priority
   b) Transit signal pre-emption
   c) Audible crossing warning devices
   d) Constant warning time systems
   e) Pre-signals
   f) Flashing light signals
   g) Limits on downtime of gates
   h) On-vehicle audible warning devices—automatic and LRV–operator-activated
   i) Illuminated, active, in-pavement marking systems
   j) Blank out signs
   k) Pedestrian signals
2. Signs
   a) Stop and yield signs
   b) Retroreflective advance warning signs
   c) Flashing train-approaching warning signs
   d) Gate crossing status indication signals
3. Second train approaching treatments
   a) Second train approaching signals and active signs
   b) Second train warning signs
4. Gates
   a) Pedestrian automatic gates
   b) Four-quadrant gates
5. Pedestrians
   a) Pedestrian fencing/landscaping
   b) Offset (or Z) pedestrian crossings
   c) Pedestrian swing gates
6. Channelization/markings
   a) Pavement marking, texturing, and striping
   b) Quick curbs
   c) Rumble strips
   d) Channelizations
   e) Illumination of crossings
7. Education and enforcement
   a) Photo enforcement
   b) Enforcement
   c) Education outreach programs
   d) CCTV/video recording

How to Read the Catalog Pages

The following fields are used in the catalog. Field descriptions are provided next to each field:

General Description	Definition of the treatment, including alternative names, basic operation, and function.
Purpose of Treatment	Safety and operational issues the treatment is intended to address.
Alignment Type	The classifications of alignment where the treatment is applicable, according to the detailed definition provided in *TCRP Report 69* and described in Section 2.
Intersection Treatment	Whether the treatment is specific to intersections (yes) or is generally applied throughout a section of the alignment (no).
Implementation Effects	Examples of the impact of the treatment, both statistical (if available) and anecdotal; quantitative information is rarely available, so the catalog depends largely on anecdotal and unquantified information.
Implementation Notes	Anecdotal and literature information about how the treatment has been implemented, and special considerations for implementation;

again, little quantitative information is available and the catalog depends largely on anecdotal and unquantified information.

Contraindications to Treatment	Situations in which the treatment should not be installed. Any situations or factors that increase risk when the treatment is installed.
Relative Cost	Relative cost: "low," "medium," or "high."
Included in MUTCD Chapter 10?	Whether the treatment is included in Chapter 10 of the MUTCD. If the treatment is included, the MUTCD section number in which the treatment is addressed is provided.
See Also	List of related treatments.
Agencies Reporting Using this Treatment	Agencies that reported using this treatment at one or more locations. The information for this field was obtained from the project's survey of agencies. The information has not been edited and is reported exactly as received. Because some of the treatments are relatively new, and because naming conventions change from location to location, the lists may not reflect exact applications on site.
Resources	References to articles, reports, websites, or other sources with additional information about the treatment. Contact information for agencies or individuals who have agreed to list their information and act as a resource to other professionals about the treatment.

Agencies Reporting Using Treatments

The catalog includes a category that lists which agencies reported using each treatment in the survey of agencies. Agency acronyms are used for succinctness. Agency names, locations, and acronyms are listed in Table A-1. The locations

Table A-1. List of LRT agencies responding to the online survey.

Map No.	Locations	System
2.	Baltimore, MD	MTA-MD (Maryland Transit Administration)
5.	Camden, NJ	NJT (New Jersey Transit – River LINE)
8.	Denver, CO	RTD (Regional Transit District)
10.	Houston, TX	Metro (Metropolitan Transit Authority of Harris County)[1]
11.	Jersey City, NJ	NJT-HBLR (New Jersey Transit–Hudson-Bergen Light Rail)
12.	Kenosha, WI	KT (Kenosha Transit)
13.	Los Angeles, CA	LACMTA (Los Angeles County Metropolitan Transportation Authority)
14.	Memphis, TN	MATA (Memphis Area Transit Authority)
15.	Minneapolis, MN	MT (Metro Transit)*
19.	Philadelphia, PA	SEPTA (Southeastern Pennsylvania Transportation Authority)
20.	Pittsburgh, PA	PAAC (Port Authority of Allegheny County)
21.	Portland, OR	TriMet (Portland TriMet)
22.	Sacramento, CA	SRTD (Sacramento Regional Transit District)
23.	Saint Louis, MO/IL	BSDA (Bi-State Development Agency)
24.	Salt Lake City, UT	UTA (Utah Transit Authority)
25.	San Diego, CA	SDTI (San Diego Trolley Inc.)
26.	San Diego, CA	NCTD (North County Transit District)
27.	San Francisco, CA	SF Muni (San Francisco Municipal Railway)
28.	San Jose, CA	SCVTA (Santa Clara Valley Transportation Authority)
29.	Seattle, WA	WFSC (King County Metro)
30.	Tacoma, WA	ST (Sound Transit, Link)
32.	Calgary, Alberta	C-Train
33.	Edmonton, Alberta	Edmonton Transit System
35.	Toronto, Ontario	TTC (Toronto Transit Commission) Streetcars

[1]Note: Houston and Minneapolis both use the name "Metro". In the catalog, "Metro Transit" always refers to Minneapolis, while "Metro" refers to Houston.

of the agencies are shown on the map in Figure A-1; all locations that received the survey are shown on the map, only agencies that responded to the survey are included in the table. A summary of the agencies that reported using each treatment is provided in Table A-2. Note that through the study process the names and final list of treatments was altered and the agencies using each treatment were updated as more information was made available.

Figure A-1. Location of LRT systems in the United States and Canada included in the survey.

Table A-2. Treatments in use by agency.

Locations	System	Signals and Active Warnings											Signs				Second Train Approaching Treatments		Gates		Pedestrians			Channelization/Markings					Education and Enforcement				
		Signal priority	Transit signal pre-emption	Audible crossing warning devices	Constant warning time systems	Pre-signals	Flashing light signals	Limits on downtime of gates		On-vehicle audible warning devices	Illuminated, active, in-pavement marking systems	Blank out signs	Pedestrian signals	Stop and yield signs	Retroreflective advance warning signs	Flashing train-warning signs	Gate crossing status indication signals	Second approaching signals and active signs	Second train warning signs	Pedestrian automatic gates	Four-quadrant gates	Pedestrian fencing/landscaping	Offset pedestrian crossings	Pedestrian swing gates	Pavement marking, texturing, and striping	Quick curbs	Rumble strips	Channelizations	Illumination of crossings	Photo enforcement	Enforcement	Education outreach programs	CCTV/video recording
Baltimore, MD	MTA-MD (Maryland Transit Administration)						●						●	●		●									●			●	●				
Camden, NJ	NJT (New Jersey Transit – River LINE)	●	●	●			●	●		●		●	●	●	●	●	●	●		●				●	●					●	●	●	●
Denver, CO	RTD (Regional Transit District)	●		●	●	●	●	●				●		●	●	●	●	●	●				●	●	●			●	●		●	●	●
Houston, TX	Metro (Metropolitan Transit Authority of Harris County)	●	●	●	●	●	●				●			●	●		●	●				●	●		●		●	●			●	●	●
Jersey City, NJ	NJT-HBLR (New Jersey Transit Hudson-Bergen Light Rail)	●		●						●		●	●	●	●	●	●	●	●	●		●		●	●	●		●	●			●	
Jersey City, NJ	NJT-NCS	●				●									●			●	●						●			●				●	
Kenosha, WI	KT (Kenosha Transit)													●	●										●								
Los Angeles, CA	LACMTA (Los Angeles County Metropolitan Transportation Authority)	●	●	●		●	●	●					●		●	●		●	●	●	●			●	●	●		●	●	●	●	●	●
Memphis, TN	MATA (Memphis Area Transit Authority)						●						●	●		●		●							●			●					
Minneapolis, MN	MT (Metro Transit)	●	●	●	●	●									●			●	●						●			●				●	
Philadelphia, PA	SEPTA (Southeastern Pennsylvania Transportation Authority)	●	●											●	●			●										●				●	
Pittsburgh, PA	PAAC (Port Authority of Allegheny County)		●		●	●	●					●		●	●	●			●					●	●	●					●		●
Portland, OR	TriMet (Portland TriMet)		●	●	●		●	●		●		●	●	●	●	●	●	●	●	●			●	●		●		●	●	●	●	●	●
Sacramento, CA	SRTD (Sacramento Regional Transit District)		●	●		●	●			●		●	●	●	●	●	●	●					●	●	●	●		●		●	●	●	●
Saint Louis, MO/IL	BSDA (Bi-State Development Agency)																	●			●												
Salt Lake City, UT	UTA (Utah Transit Authority)	●				●	●	●		●		●	●	●	●	●		●		●		●			●	●		●				●	
San Diego, CA	SDTI (San Diego Trolley Inc.)	●	●	●			●	●		●		●	●	●		●	●	●					●		●	●	●	●				●	●
San Diego, CA	NCTD (North County Transit District)				●	●		●					●	●	●			●						●	●			●			●	●	●
San Francisco, CA	SF Muni (San Francisco Municipal Railway)	●				●							●	●		●		●				●	●	●	●	●		●		●	●	●	●
San Jose, CA	SCVTA (Santa Clara Valley Transportation Authority)	●	●	●	●	●	●	●		●		●	●	●	●	●	●	●		●	●		●	●	●			●	●		●	●	●
Seattle, WA	WFSC (King County Metro)																																
Tacoma, WA	ST (Sound Transit, Link)	●				●	●											●	●						●			●				●	
Calgary, AB	C-Train		●	●	●											●	●		●	●			●						●				
Edmonton, AB	Edmonton Transit System			●			●						●				●	●		●					●			●	●				●
Toronto, ON	TTC Streetcars	●	●			●		●						●						●				●		●		●				●	

Catalog of Treatments

Signals and Active Warnings

TRANSIT SIGNAL PRIORITY

Photo (courtesy José Farrán) shows the triangular aspect used in several systems (this is from San Jose) that tells the LRV operator that the train is now being detected by the signal priority computer.

General Description: Transit signal priority modifies the normal signal operation process to better accommodate transit vehicles. The objective is to provide more opportunities for transit within the coordinated system operation of the traffic signal without significantly impacting other traffic. Since LRT service is typically more frequent than heavy rail or emergency vehicle service, the use of priority rather than pre-emption allows the street system to maintain a higher level of overall performance.

Signal priority works within the existing signal cycle and coordination strategy to provide additional green time to the LRV where possible. While signal priority may be implemented through a variety of different strategies, the two most popular types are:

- *Early Green*. When the priority vehicle is detected, the green time of the opposing direction is shortened to expedite the return to green for the priority vehicle.
- *Green Extension*. For a priority vehicle which is approaching the intersection, the green time is extended to allow the vehicle time to pass.

Early green and green extension may be applied together to maximize the preferential treatment for the light rail vehicle (but they are not applied in the same cycle).

Purpose of Treatment: The objectives of transit signal priority include improved schedule adherence, reduced transit travel time, improved transit efficiency, a contribution to enhanced transit information, and increased road network efficiency. No safety impact has been identified.

$$ Medium Cost

Alignment Type: b.1, b.2, b.3, b.4, b.5, c.1

Active Treatment

Intersection Treatment: Yes

Implementation Effects: Implementation effects include reduced priority signal delay, reduced travel time, and increased schedule reliability. Non-priority vehicles experience increased delay on cross streets.

Implementation Notes: *TCRP Report 17* made a recommendation to "coordinate traffic signal phasing and timing near LRT crossings to preclude cars stopping on and blocking the tracks." As it is important that appropriate clearance intervals are maintained for other movements even when LRV priority is used, sufficient lead time for clearance of vehicle traffic must be available from the initial detection of the priority request signal to the time the LRV arrives at the intersection.

Signal priority does not guarantee that an LRV will receive green time when it arrives at an intersection (see Exhibits 4-39 and 4040 in *TCRP Report 118*). An LRV may still be required to stop at a priority signal location if the vehicle has missed the green phase. This is different from signal pre-emption, in which the green phase is held until the receiver is no longer receiving the pre-emptive indication.

TCRP Report 118 provides information about transit signal priority for bus rapid transit (BRT). Much of the information provided in that report also applies to LRT. The report recommends that transit stops be placed on the far side of the intersection to maximize the benefit of priority from an operational standpoint. For BRT with signal priority, typical travel time savings between 8% and 12% were reported.

Contraindications to Treatment: The main constraints are the possibly increased delays to cross street traffic.

Relative Cost: Medium

Included in MUTCD Chapter 10: No

See Also: Transit Signal Pre-emption

Agencies Reporting Using This Treatment: SCVTA, LACMTA, RTD, NJT – River LINE, ST, SDTI, UTA, Metro, Metro Transit, SF Muni, NJT-NCS, NJT-HBLR, SEPTA, TTC

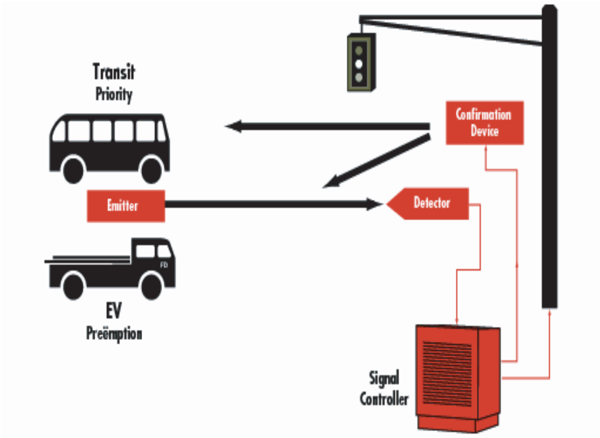
Resources:

Ogden, B. D. Salt Lake City Integrated Traffic-Control System for Street-Running Light Rail: Impact of Roadway-Trackway Geometry on Traffic Priority-Control Design Options. In *Light Rail: Investment for the Future, 8th Joint Conference on Light Rail Transit* (CD-ROM), Transportation Research Board of the National Academies, Washington, D.C., 2000, pp. F-16/1–F-16/11.

Smith, H. R., Hemily, B., and Ivanovic, M. Transit Signal Priority (TSP): *A Planning and Implementation Handbook.* ITS America; U.S. Department of Transportation, 2005.

Kittelson & Associates, Inc., Levinson, H., and DMJM Harris, *TCRP Report 118: Bus Rapid Transit Practitioner's Guide*. Transportation Research Board of the National Academies, Washington, D.C., 2007.

TRANSIT SIGNAL PRE-EMPTION



General Description: Transit signal pre-emption uses coordinated traffic signal controllers that interrupt the normal signal timing plan to provide a pre-empted phase for light rail as soon as possible. Pre-emption is often used for emergency vehicles, but can also be applied to LRVs.

During pre-emption, the transit vehicle sends a message to the signal controller. This message interrupts the normal signal cycle, provides sufficient time to clear the intersection, and immediately switches the signal to a protective phase for the LRV movement through the intersection.

Purpose of Treatment: The main purpose of signal pre-emption is to maximize efficiency for the transit vehicle. No safety impact has been identified.

Alignment Type: b.1, b.2, b.3, b.4

Intersection Treatment: Yes

Implementation Effects: Reduced signal delay to LRT, reduced travel time, and increased schedule reliability. Since normal timing plans are interrupted, coordination will be lost in the traffic signal network, potentially increasing delay to road traffic for a period of time.

Implementation Notes: Signal pre-emption can be applied at isolated locations where LRTs run across high speed roadways or make complicated or conflicting movements. The intention is to improve safety by separating conflicts in time.

Contraindications to Treatment: In cities where emergency vehicles have priority, all operators (LRV and emergency vehicles) must understand which vehicle has priority at an LRV crossing. Because an LRV is more difficult to stop, it is normal to give priority to the LRV. This must be communicated to emergency vehicle operators to avoid a collision. (Metro Transit reported a collision in Minneapolis where the driver of an ambulance believed he had priority over an LRV.) In some cases, pre-emption may disrupt the progressive movement of street traffic.

Relative Cost: Medium

$$ Medium Cost

Active Treatment

Included in MUTCD Chapter 10: No. Signal pre-emption for heavy rail is discussed in Chapter 8: Section 8D.7

See Also: Transit Signal Priority

Agencies Reporting Using This Treatment: TTC, SCVTA, LACMTA, SRTD, CTrain, PAAC, NJT – River Line, SDTI, Metro, MetroTransit, SEPTA, TriMet

Resources: No information available

AUDIBLE CROSSING WARNING DEVICES

Photo (courtesy José Farrán) shows an example of the most common type, a synthesizer bell from San Jose.

General Description: Audible warning devices such as bells, horns, and synthesized tones installed either onboard the LRV or wayside along the tracks are used in conjunction with flashing light signals at grade crossings. The key design issues to consider are appropriate placement of the device, and tuning the sound produced so that the warning sound can easily be distinguished from the environmental noise in the area. Improving placement and the type of tone are believed to be more effective than simply increasing the device volume.

Purpose of Treatment: The main purpose of audible crossing warning devices is to provide supplemental warning for motorists, pedestrians, and cyclists.

Alignment Type: All b

Intersection Treatment: Yes

Implementation Effects: No quantitative data that directly evaluate the effectiveness of audible warnings have been found.

Contraindications to Treatment: In some communities, the audible warnings are considered a nuisance by nearby businesses and/or residents. As a result, some audible warnings have been eliminated or had their duration shortened. For example, at a few locations on the Minneapolis Hiawatha line, there are gates with flashers and bells, but the bells stop ringing once the gates are down.

Irwin noted that "a pedestrian LED flashing sign and audible warning device is not required in the traffic signal controlled environment."

Relative Cost: Medium, unless the crossing already has flashers or another LRV detection device, in which case audible warnings are a relatively low-cost upgrade

$$ Medium Cost

Active Treatment

Pedestrian Safety

Motorist Safety

Included in MUTCD Chapter 10: Yes

See Also: On-Vehicle Audible Warning Devices—
Automatic and LRV–Operator-Activated

Agencies Reporting Using this Treatment: SCVTA, LACMTA, RTD, SRTD, Ctrain, NJT – River LINE, SDTI, Metro, Edmonton Transit, Metro Transit, NJT-HBLR, TriMet

Resources:

Korve Engineering, ATS Consulting, LLC, Fidell Associates, Center for Education and Research in Safety, and Bear Consulting. *TCRP Research Results Digest 84: Audible Signals for Pedestrian Safety in LRT Environments.* Transportation Research Board of the National Academies, Washington, D.C., May 2007.

Korve Engineering. *Appendixes to TCRP Research Results Digest 84: Audible Signals for Pedestrian Safety in LRT Environments*. Transportation Research Board of the National Academies, Washington, D.C., 2007. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_webdoc_35.pdf.

Irwin, D. Transportation Research Circular E-C058: Safety Criteria for Light Rail Pedestrian Crossings. In *9th National Light Rail Transit Conference*, TRB, National Research Council, Washington, D.C., 2003.

AUDIBLE CROSSING WARNING DEVICES – EXAMPLES

Description: Audible crossing warning device at a pedestrian crossing. Installed with pedestrian signal and LOOK/ SECOND TRAIN COMING sign.

Location: Hiawatha line, Minneapolis

Additional Notes: None

CONSTANT WARNING TIME SYSTEMS

General Description: Constant warning time systems, also known as grade crossing predictors, provide a uniform advance warning time between the activation of warning devices and the light rail vehicle arrival. A uniform or constant warning provides motorists, pedestrians, and cyclists with the same duration of warning in every cycle. The warning must be sensitive to both the speed and position of the LRV and not just the position, as in other detection systems. Constant warning time systems are particularly useful where light rail vehicles travel at significantly different speeds or stop frequently.

A constant warning time is most useful at crossings that are shared with railroads and where the difference in speed between the two types of rail is greater than 15 km/h (10 mph).

Purpose of Treatment: A warning device that gives a consistent indication of when the light rail vehicle is expected to pass is desirable. It is believed that road users are less likely to grow impatient and exhibit risky behavior if they receive accurate information about an approaching transit vehicle.

Alignment Type: All b

Intersection Treatment: Yes

Implementation Effects: Constant warning time systems are effective in providing both a uniform amount of time for the advance warning and in reducing motorist violation of the warning system. Systems with constant warning time systems generally have lower collision rates than systems without.

Implementation Notes: No information available.

Contraindications to Treatment: No information available

Relative Cost: Medium

Included in MUTCD Chapter 10: No

See Also: Second Train Approaching Treatments, Limits on Downtime of Gates

$$ Medium Cost

Active Treatment

Pedestrian Safety

Motorist Safety

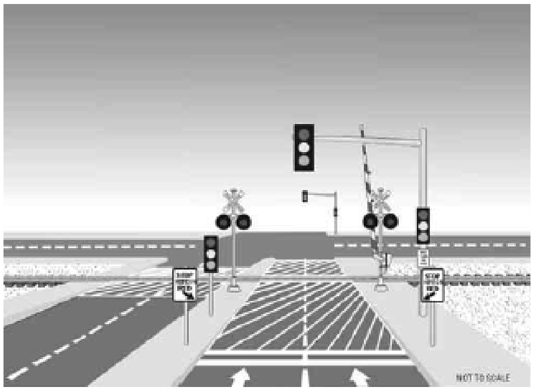
Agencies Reporting Using This Treatment: SCVTA, RTD, Ctrain, PAAC, Metro, NCTD, Metro Transit, TriMet

Resources:

Bowman, B. L. The Effectiveness of Railroad Constant Warning Time Systems. In *Transportation Research Record No. 1114*, Traffic Control Devices and Rail-Highway Grade Crossings, TRB, National Research Council, Washington, D.C., 1987. pp. 111–122,

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

PRE-SIGNALS



General Description: Pre-signals, also known as advanced signals, are defined as traffic signals located upstream of a highway–rail grade crossing that is adjacent to a roadway–roadway intersection. The pre-signals are connected to the downstream traffic signal and to the rail signal controller. Pre-signals allow for an adequate lag time between the pre-signal and the downstream signal so that vehicles past the pre-signal can clear the tracks and approaching vehicles are stopped outside of the clear storage distance and outside of the intersection when the LRV arrives.

$$$ High Cost

Active Treatment

Motorist Safety

Purpose of Treatment: The purpose of pre-signals is to reduce, and ideally, to eliminate the likelihood of vehicles stopping in the track area during the red phase of the traffic signal cycle.

Alignment Type: All b, c.1

Intersection Treatment: Yes

Implementation Effects: TCRP field tests reported in *Report 69* found that after the implementation of pre-signals:

- The number of vehicles in the clear storage distance at two study sites declined by an average of 80% and 93%, respectively.
- The number of vehicles that made a prohibited right turn on red decreased by an average of 82%.
- Fewer than 3% of the vehicles stopped by a red signal at the pre-signal proceeded through the signal into the clear storage distance or conducted a right turn on red.

Implementation Notes: The main intersection vehicle signals should use louvered or programmable visibility signal heads so that the downstream green indication does not confuse drivers stopped at the pre-signal.

Contraindications to Treatment: No information available.

Relative Cost: High

Included in MUTCD Chapter 10: No. Pre signals for heavy rail are discussed in Chapter 8: Section 8D.7.

Agencies Reporting Using This Treatment: SCVTA, LACMTA, RTD, SRTD, PAAC, ST, UTA, Metro, NCTD, Metro Transit, SF Muni, NJT-NCS, TTC

Resources:

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

FLASHING LIGHT SIGNALS

General Description: Various types of flashing light signals are used by transit agencies. The most common are the standard railroad crossing lights.

Purpose of Treatment: The purpose of flashing light signals is to warn motorists that an LRV is present or about to enter the crossing area, and to prevent motorists entering the trackway of the LRV.

$$ Medium Cost

Active Treatment

Motorist Safety

Alignment Type: All b, all c

Intersection Treatment: Yes

Implementation Effects: No information available.

Implementation Notes: No information available.

Contraindications to Treatment: Research suggests that motorists using crossings located in an area characterized by signalized intersections respond well to traffic signals. As most LRT systems are constructed in urban areas, traffic signals are familiar and generally more credible than flashing light signals.

Relative Cost: Medium

Included in MUTCD Chapter 10: Yes

See Also: Constant Warning Time Systems; Audible Crossing Warning Devices; Illuminated, Active, In-Pavement Marking Systems

Agencies Reporting Using This Treatment: MATA, SCVTA, LACMTA, RTD, SRTD, PAAC, MTA-MD, NJT - River LINE, ST, UTA, SDTI, Metro, Edmonton Transit, TriMet

Resources:

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

FLASHING LIGHT SIGNALS – EXAMPLES

Description: Standard railroad crossing flashing lights with gate arm

Location: Salt Lake City, Utah

Additional Notes: None

LIMITS ON DOWNTIME OF GATES

General Description: Limits on gate downtime are designed to ensure that gates are not in the down position for a period that appears excessive to the public, for example when an LRV is stopped at a station sufficiently close to the crossing to trigger the gates, but is not in motion. Some mechanism is required to activate the gates when the LRV does start moving towards the crossing.

$$ Medium Cost

Active Treatment

Motorist Safety

Purpose of Treatment: When gates are down for an extended period of time, motorists, pedestrians, and cyclists may become frustrated and may engage in risky behavior. Motorists and pedestrians may also believe that the gates have malfunctioned. Limiting the downtime of gates is intended to reduce doubts, frustration, and risky behavior.

Alignment Type: All b (with gates)

Intersection Treatment: Yes

Implementation Effects: *TCRP Report 69* reported positive feedback regarding wayside detectors and delayed gate activation.

Implementation Notes: *TCRP Report 69* notes that a number of agencies have installed wayside detectors that delay gate activation while an LRT is dwelling at a station. This approach limits the total downtime of the gates and prevents the gates from being down when no train is actually about to cross.

Contraindications to Treatment: No information available

Relative Cost: Medium

Included in MUTCD Chapter 10: Gates in 10D.03 and 10D.04. Timing information not provided.

Agencies Reporting Using This Treatment: TTC, SCVTA, LACMTA, RTD, NJT – River LINE, UTA, SDTI, NCTD, TriMet

Resources:

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

ON-VEHICLE AUDIBLE WARNING DEVICES—AUTOMATIC AND LRV–OPERATOR-ACTIVATED

General Description: According to *TCRP Research Results Digest 84*, on-vehicle audible warning devices may be referred to as bells, gongs, whistles, quackers, clackers, low horns, high horns, or horns. They are used intermittently, and produce sound levels from 60 dBA to more than 100 dBA at 100 feet. The devices warn motorists, pedestrians, and cyclists that an LRV is approaching the crossing. Automatic devices can be triggered by the position and sometimes the speed of the train (see Constant Warning Time Systems), while LRV–operator-activated are triggered by the operator at their discretion. No information concerning automatic on-vehicle audible warning devices was available to the project team.

Purpose of Treatment: On-vehicle audible warning devices are intended to reduce risky or inattentive behavior by motorists, pedestrians, and cyclists.

Alignment Type: All

Intersection Treatment: Yes

Implementation Effects: The effects of on-vehicle audible warning devices have not been quantified.

Implementation Notes: Rules regarding the sounding of on-vehicle warning devices are usually outlined at the agency level, and vary greatly depending on the agency. Many LRVs are equipped with multiple sound types, and operators may use different levels of sound in different situations.

Because audible warnings may disturb residents, the warning may be limited where there is residential development near the LRT line. *TCRP Research Results Digest 84* acknowledges that different agencies have different philosophies about sounding audible warnings and outlines a general overall practice for evaluating rules for sounding onboard audible warning devices at crossings. The evaluation system is based on three characteristics: emergencies, sight distance, and surrounding conditions. More details can be found in the report.

$$ Medium Cost

Active Treatment

Motorist Safety

Pedestrian Safety

UTA, Metro Transit, NJT, SF Muni, and SCVTA have regulations outlining where operators should use different types of audible warnings. In some locations, audible warnings are prohibited except in emergency situations. At others, bells or horns are required before crossing.

Metro Transit, NJT, and SCVTA indicated that horns are effective, but not completely effective at combating motorist, pedestrian, and cyclist inattention. The agencies noted that personal music devices and headphones were thought to be linked to pedestrian and cyclist inattention and collisions.

Contraindications to Treatment: Noise

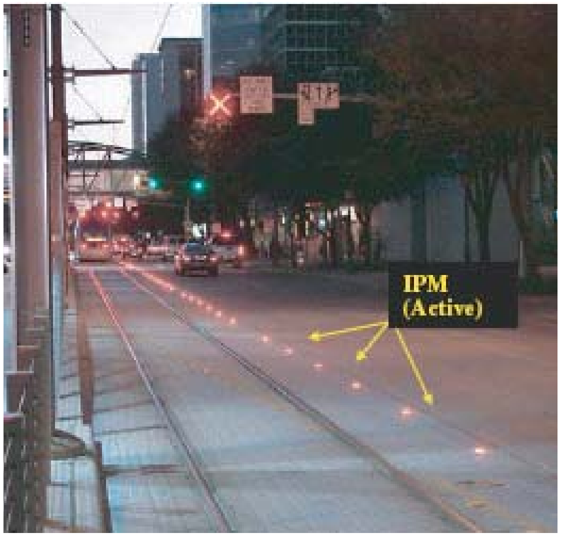
Relative Cost: Medium

Included in MUTCD Chapter 10: No

Agencies Reporting Using This Treatment: SCVTA, SRTD, NJT – River LINE, UTA, SDTI, NJT-HBLR, TriMet

Resources:
Korve Engineering, ATS Consulting, LLC, Fidell Associates, Center for Education and Research in Safety, and Bear Consulting. *TCRP Research Results Digest 84: Audible Signals for Pedestrian Safety in LRT Environments.* Transportation Research Board of the National Academies, Washington, D.C., May 2007.

ILLUMINATED, ACTIVE, IN-PAVEMENT MARKING SYSTEMS



Source: *NCHRP Synthesis 380*

General Description: Illuminated active in-pavement marking (IPM) systems provide a series of markers that are embedded in the pavement surface and light up in the presence of certain conditions. They can be installed parallel to the LRT alignment or at a stop bar. Illuminated IPM can also be installed in combination with other active treatments. Houston has installed parallel IPM with blank out "X" signs to indicate when a lane should not be used by vehicles. Houston has also installed blank out train signs along with IPM.

Purpose of Treatment: IPM systems are used to reduce the violations and crashes that occur when vehicles drive on the tracks as an LRV approaches. When installed at a stop bar, IPM systems are intended to reduce red-light running and right-turn-on-red violations.

$$$ High Cost

Active Treatment

Motorist Safety

Alignment Type: Type b.4, c.1

Intersection Treatment: In some applications.

Implementation Effects: According to *NCHRP Synthesis 380*, Houston Metro had positive results for both stop bar installation and installation parallel to tracks, but success depended on motorists understanding the device's message.

Implementation Notes: Houston Metro installed illuminated IPMs in two different configurations along the light rail alignment. Both installations light up red when an LRT approaches the location of the markers.

Lack of marker adhesion to the surface can be a problem for IPM systems.

Contraindications to Treatment: No information available

Relative Cost: High

Included in MUTCD Chapter 10: No

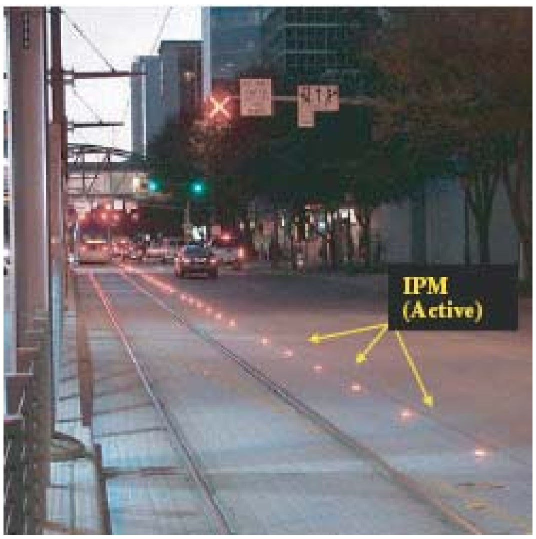
Agencies Reporting Using This Treatment: Houston Metro

Resources:

Carson, J. L, Tydlacka, J., Gray, L. S., Voigt, A. P. *NCHRP Synthesis 380: Applications of Illuminated, Active, In-Pavement Marker Systems.* Transportation Research Board of the National Academies, Washington, D.C., 2008.

Korve Engineering, ATS Consulting, LLC, Fidell Associates, Center for Education and Research in Safety, and Bear Consulting. *TCRP Research Results Digest 84: Audible Signals for Pedestrian Safety in LRT Environments.* Transportation Research Board of the National Academies, Washington, D.C., May 2007.

ILLUMINATED, ACTIVE, IN-PAVEMENT MARKING SYSTEMS – EXAMPLES



Source: *NCHRP Synthesis 380*

Description: Houston Metro installed a single row of red illuminated IPM system markers to separate the vehicle lane from the shared left turn/LRT lane.

The markers are activated along with an overhead red "X" to indicate that traffic should not use the left turn lane when trains are approaching. Left turns are prohibited in this case. When the markers are not activated, the blank out sign shows a "green arrow" indicating that the lane can be used and left-turn movements are permitted. The signs and markers are activated when an LRV approaches from either direction.

Location: Houston, TX

Additional Notes: A review of IPM was included in *NCHRP Synthesis 380*. Comprehension studies conducted before installation of IPM systems found that:

- For the IPM and blank out "x":
  - 82% of respondents understood the meaning to be "do not enter the left lane."
  - 50% of respondents believed that the IPM and blank out "x" sign indicated that a train was coming.
- For IPM and blank out "train" sign
  - 18% of respondents did NOT include "a train is coming" or "do not turn left" in their response.

An analysis of the following types of violations of left turn restrictions indicated that the total number of violations was either unchanged or slightly higher:

- Turning left against "red x"
- Turning left against "red x" from another lane
- Turning left from another lane during "green arrow"
- Entering left turn lane during "red x" and not completing the left turn
- Entering left turn lane during "green arrow" and not completing the left turn

The total number of violations involving vehicles entering the left-turn lane against the "red x" and completing a left turn decreased.

Source: *NCHRP Synthesis 380*

Description: Houston Metro also installed illuminated IPM at stop bars at a signal on the approach to LRT tracks. The installation was intended to reduce red-light running.

Location: Houston, TX

Additional Notes: A review of IPM was included in *NCHRP Synthesis 380*. Comprehension studies conducted before the first installation showed that over 80% believed that the IPM indicated where to stop at the signal lights. The first installation showed a minor reduction in red-light running and a major reduction in right-turn-on-red maneuvers.

BLANK OUT SIGNS

General Description: Blank out signs can be illuminated to display a message to motorists, pedestrians, and cyclists. They are an active treatment, and may indicate the presence of a train or a second train (second train approaching signs). The signs may also be used to notify motorists, pedestrians, and cyclists of a left or right turn prohibition due to a train coming.

Purpose of Treatment: Blank out signs are used to advise motorists and pedestrians of increased risk due to the presence of an LRV at a crossing location. According to *TCRP Report 17*, blank out LRV signs warn motorists of the increased risk associated with violations of the signal indications in the presence of an LRV.

$$ Medium Cost

Active Treatment

Alignment Type: All b, all c

Intersection Treatment: Yes

Implementation Effects: Agencies reported that blank out signs are more effective than static signs, but no quantifiable effect information was available.

Implementation Notes: All agencies visited by the project team had installed some type of blank out sign. The agencies also reported increased effectiveness when blank out signs provided more specific useful and timely information to motorists, pedestrians, and cyclists. For example, in most cases the project team heard more positive feedback about turn restriction blank out signs than about blank out signs with the "train" symbol. Blank out signs should be illuminated long enough to allow motorists and pedestrians to respond and to clear the tracks, but not so long that the sign becomes ineffective (perceived as incorrect) or easy to ignore.

Contraindications to Treatment: No information available.

Relative Cost: Medium

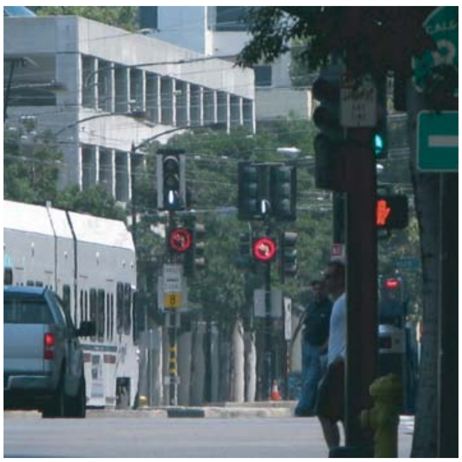
Included in MUTCD Chapter 10: Yes

See Also: Second Train Warning Signs, Pedestrian Signals

Agencies Reporting Using This Treatment: SCVTA, RTD, SRTD, PAAC, NJT – River LINE, UTA, SDTI, NJT-HBLR, TriMet

Resources:
Korve, H. W., Farran, J. I., Mansel, D. M., Levinson, H. S., Chira-Chavala, T., and Ragland, D. R. *TCRP Report 17: Integration of Light Rail Transit into City Streets*. TRB, National Research Council, Washington, D.C., 1996.

BLANK OUT SIGNS – EXAMPLES



Description: Blank out no left turn signs for LRT crossing intersection. The photo shows that the LRT has a straight bar to indicate that it can proceed, through traffic is also permitted (green ball), and left turns are restricted.

Location: Santa Clara Valley, California

Additional Notes: None

Description: Blank out no right turn signs for at-grade crossing with LRT turning right across intersection

Location: San Jose, California

Additional Notes: None

BLANK OUT SIGNS – EXAMPLES CONT'D.

Description: Blank out train sign at an intersection

Location: San Francisco, California

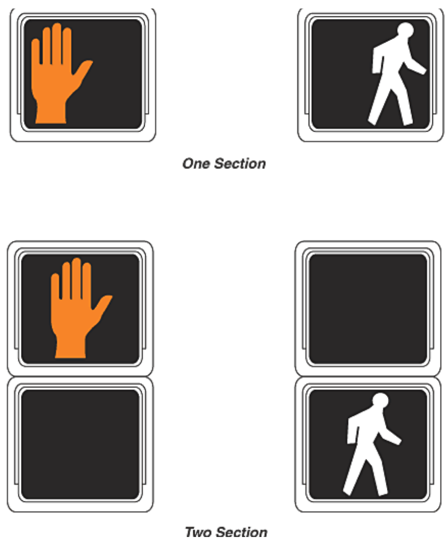
Additional Notes: This sign is activated when a train is approaching.

Description: Blank out no right turn signs for at-grade crossing with traffic lanes turning right across LRT line

Location: Minneapolis, Minnesota

Additional Notes: This sign shows the no left turn arrow over an illustration of LRT tracks.

PEDESTRIAN SIGNALS



General Description: Pedestrian signals are active signal devices that tell pedestrians when it is safe to cross the roadway or right-of-way. The simplest approach is to use standard MUTCD pedestrian crossing signal heads. The signs are composed of a walk symbol that indicates when it is safe to walk, a flashing hand that indicates that a crossing should not be started, and a solid hand that indicates when it is not safe to cross. Countdown signals may also be incorporated. Countdown signals may be activated by train detection systems or GPS.

Purpose of Treatment: The purpose of pedestrian signals is to control pedestrians' crossing movements by indicating when a safe right-of-way is available for pedestrians to cross the LRV track.

$$ Medium Cost

Alignment Type: All b, c.1, c.2

Active Treatment

Intersection Treatment: Yes

Implementation Effects: No information available

Pedestrian Safety

Implementation Notes: According to MUTCD Chapter 10, pedestrian signals for LRT crossings should be designed in accordance with MUTCD Section 4E.04. Chapter 10 also recommends that "where light rail transit tracks are immediately adjacent to other tracks or a road, pedestrian signalization should be designed to avoid having pedestrians wait between sets of tracks or between the tracks and a road. If adequate space exists for a pedestrian refuge and is justified based on engineering judgment, additional pedestrian signal indicators, signing, and detectors should be installed."

All site visit locations had some pedestrian signals. Minneapolis' Metro Transit had pedestrian signals at every crossing.

A number of other treatments are commonly installed along with pedestrian signals. The supporting treatments include pedestrian count-down signals, flashing light signals with crossbucks, and second train warning signals.

Contraindications to Treatment: As the standard MUTCD mounting heights for pedestrian signals may be too high for the short distance across just one or two tracks, a lower placement more central to a pedestrian's field of vision may be better, but the signal head location needs to be carefully selected to avoid the signal head becoming a pedestrian hazard in itself.

Relative Cost: Medium

Included in MUTCD Chapter 10: Yes

See Also: Second Train Approaching Signals and Active Signs

Agencies Reporting Using This Treatment: MATA, SCVTA, LACMTA, SRTD, MTA-MD, NJT – River LINE, UTA, SDTI, Edmonton Transit, NCTD, SF Muni, NJT-HBLR, TriMet

Resources:

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

Federal Highway Administration. Traffic Controls for Highway-Light Rail Transit Grade Crossings, *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition, Part 10, pp. 10A-1–10D-11.

Clark, R. *Pedestrian-Rail Crossings in California*. California Public Utilities Commission, 2008.

PEDESTRIAN SIGNALS – EXAMPLES

Description: The signals indicate to pedestrians when it is safe to cross. They are equipped with an audible warning device. Variations on this type of pedestrian signal, paired with the LOOK sign, are provided on all crossings on Metro Transit's Hiawatha line in Minneapolis.

Location: Hiawatha line, Minneapolis

Additional Notes: Pedestrians, especially regular system users, often violate the signals. Metro Transit also noted that although the signals were installed at standard MUTCD height, they are out of the pedestrian site line because LRT track crossings are not as wide as standard intersection crossings. Pedestrian signals may need to be installed at a lower height to be within the sight line of pedestrians.

Description: Pedestrian signals can be installed along with other measures. This picture shows pedestrian signals with the LOOK sign installed with standard flashing light display. The location also has an audible warning device.

Location: Hiawatha line, Minneapolis

Additional Notes: None

PEDESTRIAN SIGNALS – EXAMPLES CONT'D.

Description: Pedestrian signals with countdown timers

Location: Salt Lake City, Utah

Additional Notes: None

Description: Double pedestrian signal heads

Location: San Francisco, California

Additional Notes: The double pedestrian heads installed along a streetcar alignment in San Francisco are presumably intended to increase visibility on this wide crossing in bright light conditions. Two signal heads are installed on the same pole, as shown in the figure on the left.

Signs

STOP AND YIELD SIGNS

Photo (courtesy José Farrán) shows an example of a stop sign at an LRT crossing in San Jose.

Purpose of Treatment: Stop and yield signs tell motorists to obey traffic right-of-way laws (stop and yield) designed to prevent potential conflict between LRVs and vehicles.

Alignment Type: All b, all c

Intersection Treatment: Yes

Implementation Effects: No specific information about the effect of stop and yield signs along an LRT alignment was available.

Implementation Notes: This is a regulated sign.

Contraindications to Treatment: Stop and yield signs should not be used where the sign would cause vehicles to stop on the LRT tracks. Stop and yield signs result in lower vehicle speeds over the tracks. This means that the tracks are occupied for an increased period of time.

Relative Cost: Low

Included in MUTCD Chapter 10: Yes

See Also: Blank Out Signs

General Description: Stop and yield signs are fixed standard signs that tell motorists to stop or yield to an approaching LRV. These signs may also be placed at intersections close to LRT crossings. Stop signs close to the LRT alignment should not cause vehicles to stop in the path of the LRV. The MUTCD recommends using LRT-activated blank out turn-prohibition signs where an intersection adjacent to a highway–LRT crossing is controlled by stop signs. An LRT–approaching-activated blank out warning sign may also be used at stop or yield controlled locations.

It was noted that most stop signs encountered in the site visits included crossbucks on the same pole.

$ Low Cost

Passive Treatment

Motorist Safety

Agencies Reporting Using This Treatment: MATA, SCVTA, RTD, SRTD, PAAC, MTA-MD, KT, NJT – River LINE, UTA, SDTI, Metro, NCTD, SF Muni, NJT-HBLR, SEPTA, TriMet, TTC

Resources:

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

STOP AND YIELD SIGNS – EXAMPLES

Photo courtesy José Farrán

Description: Stop sign on same pole with railroad crossbucks

Location: Sacramento, CA

Additional Notes: None

RETROREFLECTIVE ADVANCE WARNING SIGNS

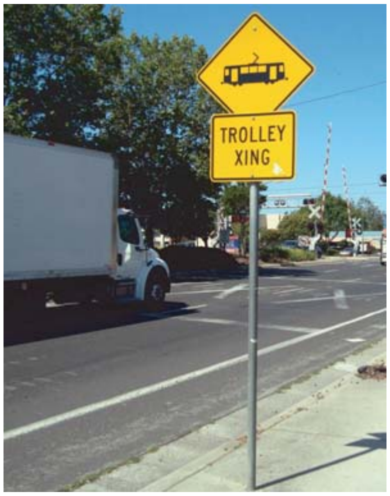


Photo (courtesy José Farrán) shows a typical retroreflective advance warning sign from San Jose.

General Description: MUTCD Chapter 10 stipulates that "all signs used in highway-light rail transit grade crossing traffic control systems shall be retroreflectorized or illuminated as described in Section 2A.08 to show the same shape and similar color to an approaching road user during both day and night."

Purpose of Treatment: The purpose of retroreflective advance warning signs is to present the same information to motorists during both the day and the night so that limited illumination of the crossing area does not limit visibility of the signs. Motorists' vehicles need to have working headlights for the signs to be effective.

$ Low Cost

Passive Treatment

Motorist Safety

Alignment Type: All

Intersection Treatment: Yes

Implementation Effects: Unquantified

Implementation Notes: No information available

Contraindications to Treatment: No information available

Relative Cost: Low

Included in MUTCD Chapter 10: Yes

See Also: None.

Agencies Reporting Using This Treatment: SCVTA, LACMTA, RTD, SRTD, PAAC, KT, NJT – River LINE, UTA, Metro, NCTD, Metro Transit, NJT-NCS, NJT-HBLR, SEPTA, TriMet

Resources:

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

FLASHING TRAIN-APPROACHING WARNING SIGNS

General Description: Flashing train-approaching warning signs are LED turn-prohibition signs that are only lit as the train approaches. The signs can reinforce other measures such as gates, other static signage, signal priority, turn prohibition (as in the Salt Lake example on the left), pre-emption, etc.

Purpose of Treatment: Flashing train-approaching warning signs are intended to attract the attention of motorists, pedestrians, and cyclists and to encourage them to prepare for the potential risks involved in entering the LRV crossing area.

$$ Medium Cost

Alignment Type: All

Active Treatment

Intersection Treatment: Yes

Implementation Effects: The TriMet light rail operation has found that flashing train signs are an effective warning device for motorists, pedestrians, and cyclists. UTA, Minneapolis Metro Transit, and NJ Transit all gave positive feedback on flashing signs and use these signs at problem locations, typically in response to one or more serious collisions. Flashing train signs have been employed for right and left turn situations.

Pedestrian Safety

Motorist Safety

Implementation Notes: No information available

Contraindications to Treatment: Irwin noted that "a pedestrian LED flashing sign and audible warning device is not required in the traffic signal controlled environment."

Relative Cost: Medium

Included in MUTCD Chapter 10: Figure 10C-3, sign W10-7

See Also: None

Agencies Reporting Using This Treatment: MATA, SCVTA, LACMTA, RTD, SRTD, Ctrain, MTA-MD, NJT – River LINE, UTA, SF Muni, NJT-HBLR, TriMet, PAAC, SDTI

Resources:

Irwin, D. Transportation Research Circular E-C058: Safety Criteria for Light Rail Pedestrian Crossings. In *9th National Light Rail Transit Conference*, TRB, National Research Council, Washington, D.C., 2003.

FLASHING TRAIN-APPROACHING WARNING SIGNS – EXAMPLES

Description: Flashing/blank out train warning sign used on the T-line in San Francisco. The blank out sign warns that there is a train approaching, and operates in conjunction with regular traffic signals.

Location: San Francisco, California

Additional Notes: None

GATE CROSSING STATUS INDICATION SIGNALS

General Description: Gate crossing status indication signals provide LRT operators with information about upcoming gate arms and signals. The crossing indication signals are positioned to provide the LRT operator with information on whether automatic gates are functioning correctly or not. Systems may use white "lunar" lights or some other type of indication, including in-cab systems for LRV operators. The indication is coupled with a detection system, which may be laser detection or other detection methods.

Purpose of Treatment: Gate crossing status indication signals inform the LRT operator whether or not a gate is operating correctly. The signals can also inform the operator about the presence of vehicles or other objects that interfere with the operation of the gate. The systems are designed to give the operator sufficient time to slow down and/or stop if necessary.

$$ Medium Cost

Active Treatment

Alignment Type: All b (where there are gates)

Intersection Treatment: Yes

Motorist Safety

Pedestrian Safety

Implementation Effects: Metro Transit reported being pleased with the operation of the signals. No quantifiable data is available.

Implementation Notes: Metro Transit and UTA use "lunar" (white circle) lights to inform the LRT operator about a gate that has not been completely deployed or about a vehicle or object that is interfering with the operation of the gate.

Agencies report that crossing gate indication signals are especially useful at locations where LRVs approach a crossing from around a blind bend that prevents the LRV operator from seeing the automatic gates until the LRV is at the crossing. The signal must be located so that the operator can stop the LRV short of the grade crossing under normal service braking.

Contraindications to Treatment: No information available

Relative Cost: Medium

Included in MUTCD Chapter 10: No

See Also: None

Agencies Reporting Using This Treatment: SCVTA, RTD, SRTD, Ctrain, NJT – River LINE, SDTI, Metro, Edmonton Transit, NJT-HBLR, TriMet, UTA

Resources:

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

GATE CROSSING STATUS INDICATION SIGNALS – EXAMPLES

Description: Lunar gate crossing indication signal

Location: Minneapolis, Minnesota

Additional Notes: A *flashing* "lunar" light informs the LRV operator that the gate is down properly and in position to block road traffic. A *solid* light indicates that the gate is still in motion and suggests to the operator that additional caution is needed in approaching the crossing as the gate may be blocked by a vehicle or other object on the tracks.

Minneapolis staff indicated that the convention in other systems is to have the light solid when the gate has gone down. When the Minneapolis system was designed, a signal engineer recommended that the gate crossing indicators be designed to be failsafe. Flashing lights require two wires to work and solid lights require only one; the system is programmed to be flashing if everything is okay (most complicated) and solid (or nothing) if something is wrong.

GATE CROSSING STATUS INDICATION SIGNALS – EXAMPLES

Description: Lunar gate crossing indication signal

Location: Salt Lake City, Utah

Additional Notes: Lunar gate crossing status indication signals used in Utah flash when the gates are activated and still in motion. This indicates to the operator that they should approach the crossing with caution. The lights go solid when the gates are fully down and in position to block traffic. This is the opposite of the configuration in Minneapolis, which could be very confusing for an experienced operator who moves from one city to another.

Second Train Approaching Treatments

SECOND TRAIN APPROACHING SIGNALS AND ACTIVE SIGNS

General Description: Second train signals are active signs illuminated to indicate that a second train is approaching. The sign may be a blank-out LED sign or it may use flashing lights or another type of indication (such as backlit illumination) to an otherwise static sign.

Purpose of Treatment: The main purpose of second train approaching signals and active signs is to provide motorists, pedestrians, and cyclists with a specific warning that a second train is coming so that they do not start to cross the tracks after the first train has passed.

$$$ High Cost

Alignment Type: All b, all c

Active Treatment

Intersection Treatment: Yes

Implementation Effects: Second train approaching signals and active signs must be designed and placed where they can be clearly seen. The signals are more effective when the warning is within a short time of the second train approaching. Signs that are on for too long may be ignored. The effectiveness of the signs is increased if they deliver specific and valuable information to motorists, pedestrians, and cyclists, e.g., the direction from which the second train is approaching. No quantified information on the safety impacts of these engineering treatments has been found.

Pedestrian Safety

Motorist Safety

Implementation Notes: Second train approaching signs can give two messages: They can indicate only that a second train is approaching, or they can indicate the direction that the second train is approaching from. The second message would be more useful to pedestrians and motorists, but the project team did not see this method applied. In some cases, the sign appeared to be able to provide this information but was not wired to do so. In some cases, signs intended to be second train warning signs malfunctioned and acted as flashing train approaching signs.

Contraindications to Treatment: No information available

Relative Cost: High

Included in MUTCD Chapter 10: Figure 10C-3 sign W10-7 is an activated blank out sign that could be used as a flashing train approaching sign or a second train approaching active sign.

See Also: Constant Warning Time Systems, Blank Out Signs, Second Train Warning Signs

Agencies Reporting Using This Treatment: BSDA, MATA, SRTD, ST, SCVTA, LACMTA, RTD, NJT-HBLR, NJT – River LINE, MetroTransit, SF Muni, NJT-NCS, NCTD, SEPTA, TriMet, UTA, SDTI, Metro, Edmonton Transit

Resources:

Sabra, Wang, & Associates, Inc. and PB Farradyne. *TCRP Research Results Digest 51: Second Train Coming Warning Sign Demonstration Projects*. Transportation Research Board of the National Academies, Washington, D.C., 2002.

SECOND TRAIN APPROACHING SIGNALS AND ACTIVE SIGNS – EXAMPLES

Description: "LOOK" signs with internally lit "SECOND TRAIN COMING" were installed at all pedestrian intersections along the Hiawatha line in the original design.

Location: Pedestrian at-grade crossing on exclusive alignment, Hiawatha Line, Minneapolis, MN.

Additional Notes: These signs are installed consistently on the Hiawatha alignment giving a consistent message that there is an increased risk associated with crossing the LRT tracks, but the illumination in the signs is very difficult to see during the day, and pedestrians do not pay attention to the signs.

SECOND TRAIN APPROACHING SIGNALS AND ACTIVE SIGNS – EXAMPLES

Description: Blank-out second train coming sign. The arrows flash back and forth regardless of train direction. They do not indicate the direction of the second train.

Location: Pedestrian access to LRT and shopping mall along Hudson–Berger line in New Jersey.

Additional Notes: The blank out sign was installed in anticipation of an express route that would skip this station. The agency noted that if the blank out sign is lit too long before a train arrives, pedestrians will ignore the sign.

SECOND TRAIN WARNING SIGNS

General Description: Second train warning signs are static signs that remind pedestrians and motorists to look both ways and to be aware of trains on all tracks. A wide variety of "Look" and "Look both ways" signs are in use. They are considered "second" train signs because they are often installed where pedestrians and motorists may not look for a second train approaching in addition to one that is immediately visible. This is especially important where pedestrians are looking at a train stopped at a station (i.e., a train they wish to board) and rush across the tracks without looking for a second train.

Purpose of Treatment: The main purpose of train warning signs is to increase motorist, pedestrian, and cyclist awareness of the possibility of a train approaching from either direction, even when a visible train is already present on the track. The signs are intended to remind pedestrians to look both ways and to prevent collisions with a second train.

$ Low Cost

Passive Treatment

Pedestrian Safety

Motorist Safety

Alignment Type: All b, all c

Intersection Treatment: Yes

Implementation Effects: The presence of too many signs can lead to confusion. Like all static signs, second train warnings are often ignored by motorists, pedestrians, and cyclists.

Implementation Notes: No information available

Contraindications to Treatment: No information available

Relative Cost: Low

Included in MUTCD Chapter 10: The standard "LOOK" sign is included in Section 10C.03 Figure 10C-2. Other second train warning signs, as seen on site visits, are not included.

See Also: Second Train Approaching Signals and Active Signs

Agencies Reporting Using This Treatment: LACMTA, RTD, Ctrain, PAAC, ST, Metro Transit, NJT-NCS, NJT-HBLR, TriMet

Resources: No information available

SECOND TRAIN WARNING SIGNS – EXAMPLES

Description: Non-MUTCD "LOOK BOTH WAYS" sign with trolley symbol

Location: Pedestrian crossing in Salt Lake City, Utah

Additional Notes: The trolley symbol used on this sign is not in the MUTCD, but is used in a number of cities.

Description: Non-MUTCD "LOOK BOTH WAYS" with trolley symbol painted on approach to crossing

Location: Pedestrian crossing in Salt Lake City, Utah

Additional Notes: The trolley symbol used on this sign is not in the MUTCD, but is used in a number of cities.

Description: MUTCD "LOOK" sign with arrow

Location: Pedestrian crossing in Santa Clara, CA

Additional Notes: None.

Gates

PEDESTRIAN AUTOMATIC GATES

General Description: Pedestrian automatic gates are arms that block the pedestrian/cyclist path across the tracks. The principle is similar to the use of gates on roadways to stop motorists and cyclists when a train is approaching. Pedestrian automatic gates may be provided in addition to roadway gate(s). On narrow streets, the pedestrian gate may be a part of the vehicle gate, with both pedestrians and vehicles blocked by a single gate that is placed behind the sidewalk. A second gate is required on the downstream side of the rail crossing for pedestrians approaching the crossing from the opposite direction. Pedestrian swing gates can be provided together with pedestrian automatic gates to allow pedestrians and cyclists to exit the right-of-way if they began crossing before the gates went down and also in the case of an emergency.

Purpose of Treatment: Pedestrian automatic gates are provided to discourage pedestrians and cyclists from making dangerous crossing movements and to provide pedestrians and cyclists with additional time to check whether an LRV is entering the pedestrian crossing.

Alignment Type: b.1, b.2, b.3

Intersection Treatment: Yes

Implementation Effects: Not available

Implementation Notes: No information available

Contraindications to Treatment: It is possible for pedestrians and cyclists to walk around the gate in much the same way that motorists violate vehicular gates.

Relative Cost: High

Included in MUTCD Chapter 10: Section 10D.08 and Figure10D-4

See Also: Four-Quadrant Gates, Pedestrian Swing Gates

$$$ High Cost

Active Treatment

Pedestrian Safety

Agencies Reporting Using This Treatment: TTC, SCVTA, LACMTA, Ctrain, NJT – River LINE, UTA, Edmonton Transit, NJT-HBLR, TriMet

Resources:

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

Irwin, D. Transportation Research Circular E-C058: Safety Criteria for Light Rail Pedestrian Crossings. In *9th National Light Rail Transit Conference*, TRB, National Research Council, Washington, D.C., 2003.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

PEDESTRIAN AUTOMATIC GATES – EXAMPLES

Description: Pedestrian automatic gates used in combination with pedestrian swing gates

Location: Mountain View, California. Transfer between SCVTA Light rail and CalTrain commuter rail

Additional Notes: Pedestrian automatic gates restrict movement onto the track. Pedestrian swing gates used in combination with pedestrian automatic gates allow pedestrians and cyclists to exit the right-of-way if they began crossing before the gates went down and also in the case of an emergency.

Description: Pedestrian and vehicle automatic gates

Location: San Jose, California

Additional Notes: Vehicle traffic is one way at this grade crossing. Automatic gates on one side of the intersection block motorists, pedestrians, and cyclists. Pedestrian automatic gates on the other side are designed to block pedestrians and cyclists only.

FOUR-QUADRANT GATES

General Description: Four-quadrant gates are a system of gate-type barriers and lights that are activated when an LRV approaches. They are an alternative to the more common two quadrant gates. The gates are installed on all four quadrants of the crossing to prevent vehicles from swerving around a lowered gate and entering the right-of-way. The system may include warning bells or whistles. The effectiveness of the approach may be enhanced by the addition of a median treatment where appropriate. In some cases, a median island may make four-quadrant gates unnecessary. Without a median, the gates become more important.

Purpose of Treatment: Four-quadrant gates are installed to prevent vehicles from crossing the track when the train is approaching and to prevent vehicles from driving around closed gates.

Alignment Type : b.1, b.2, b.3, b.4

Intersection Treatment: Yes

Implementation Effects: LCMTA found a 94% reduction in violations through the use of four-quadrant gates.

Implementation Notes: Gates must be timed carefully to allow vehicles to clear the second gate and not be trapped on the tracks as a train approaches. Many agencies expressed concern about the impacts of gate timing. Gates may prevent vehicles from crossing onto the track, but when LRVs arrive frequently, the gates are employed many more times per hour than traditional heavy rail gates. This may cause motorist frustration, encourage motorists to violate the gates, interrupt traffic flow, and/or disturb local residents and businesses.

Contraindications to Treatment: Possibility of trapping vehicle on tracks

Relative Cost: High

Included in MUTCD Chapter 10: Yes

Agencies Reporting Using This Treatment: LACMTA, BSDA, SCVTA

$$$ High Cost

Active Treatment

Motorist Safety

Resources:

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

Pedestrians

PEDESTRIAN FENCING/LANDSCAPING

General Description: Pedestrian fencing/landscaping is designed to channel pedestrian movements to designated crossing areas. The treatment provides a way to control pedestrian movements and limit the number of potential pedestrian–LRV conflict points. Fencing and landscaping also indicate to pedestrians that the LRT alignment is a special area with a different level of risk.

$$ Medium Cost

Passive Treatment

Pedestrian Safety

Motorist Safety

Purpose of Treatment: The major purpose of pedestrian fencing and landscaping is to indicate the LRT right-of-way and to deter pedestrians from crossing at inappropriate locations. The treatment defines the LRT alignment as a special space that is different from the road right-of-way, and may also serve as a barrier to vehicles.

Alignment Type: a, b.1, b.2, b.3, b.4, b.5, c.2, c.3

Intersection Treatment: Yes

Implementation Effects: *TCRP Report 17* recommends "channel[ing] pedestrian flows on sidewalks, at intersections and at stations to minimize errant or random pedestrian crossings of the LRT track environment." One channelization option is fencing or landscaping. UTA, Metro Transit, and NJT all reported fewer concerns at locations where pedestrian activity was restricted by landscaping or fencing. In a report for the CPUC, Clark comments that "pedestrian-rail at-grade crossing design is only effective if pedestrians actually cross at the designated point and take a path that allows them clear observation of the warning devices." Fencing and landscaping, along with signage and markings, encourage pedestrians to cross at designated crossings.

Physical channelization is also necessary for the effective installation of all types of automatic or manual pedestrian gates. Pedestrians will violate pedestrian gates at sites with inadequate channelization. Various types of pedestrian landscaping and fencing were observed in Salt Lake City, Minneapolis, New Jersey, San Francisco, and Santa Clara.

Implementation Notes: No information available

Contraindications to Treatment: Pedestrians must not be trapped within the dynamic envelope of the LRV: it is important to leave room for a pedestrian between the fencing and the dynamic envelope. According to Clark, when pedestrian channelization using fencing and landscaping is combined with automatic gates, an exit device must be provided. Clark also recommends that the height of fences and barriers near crossings be limited to ensure the visibility of approaching trains. The California MUTCD recommends a maximum height of 3 feet 7 inches.

Relative Cost: Medium, varies with extent and aesthetic concerns

Included in MUTCD Chapter 10: No

See Also: Channelizations, Pedestrian Automatic Gates

Agencies Reporting Using This Treatment: UTA, Metro, NJT-HBLR, SF Muni

Resources:

Korve, H. W., Farran, J. I., Mansel, D. M., Levinson, H. S., Chira-Chavala, T., and Ragland, D. R. *TCRP Report 17: Integration of Light Rail Transit into City Streets*. TRB, National Research Council, Washington, D.C., 1996.

Clark, R. *Pedestrian-Rail Crossings in California*. California Public Utilities Commission, 2008.

PEDESTRIAN FENCING/LANDSCAPING – EXAMPLES

Description: Pedestrian fencing and landscaping in a busy pedestrian/vehicle corridor in a downtown area

Location: Hudson–Bergen Light Rail Line, New Jersey

Additional Notes: The LRT line separates two groups of buildings that have significant pedestrian traffic between them. The agency reported that the landscaping and fencing are successful in controlling pedestrian movement and channelizing movements to the appropriate crossing.

Description: Pedestrian fencing in and near the 2nd and King (Stadium) stop of a semi-exclusive Type b.2 alignment. The fencing is designed to keep heavy crowds off of the track before and after games in the stadium.

Location: SF Muni's T and N lines, San Francisco, California

Additional Notes: Before and after games, additional crowd control by SF Muni staff using portable barriers is also provided at and around crossings, but the permanent fencing was observed by the project team to help control general trespassing on the tracks.

OFFSET PEDESTRIAN CROSSINGS

General Description: An offset pedestrian crossing, commonly referred to as a Z pedestrian crossing, channelizes pedestrian movements. The treatment that may be implemented where there are pedestrian safety concerns near stations or where pedestrians must cross tracks. Offset pedestrian crossings include fencing or barriers designed to direct pedestrians to walk facing oncoming LRVs before crossing the tracks to increase pedestrian awareness of oncoming LRVs.

$$ Medium Cost

Passive Treatment

Pedestrian Safety

Purpose of Treatment: The purpose of offset pedestrian crossings is to improve pedestrian safety by forcing pedestrians to look in the direction of oncoming LRVs so that pedestrians can be well prepared before crossing the LRV tracks.

Alignment Type: b.1, b.2, b.3, b.4, b.5, c.1, c.2, c.3

Intersection Treatment: Yes

Implementation Effects: Offset pedestrian crossings increase pedestrian safety and alertness by slowing and channeling pedestrian movements. The crossings are often installed as a reaction to a collision with a pedestrian. The treatment is not effective when trains are running reverse track or along a single track as the pedestrian would be oriented to face the wrong direction in those cases. In some configurations, however, pedestrians can be forced to turn 180 degrees thereby having a view of both directions as they approach the tracks.

Contraindications to Treatment: Sufficient right-of-way width is needed to construct the fencing in compliance with Americans with Disabilities Act (ADA) guidelines. Offset pedestrian crossings should not be used where LRVs operate in both directions on a single track because pedestrians may be looking the wrong way in some instances.

Although pedestrians may also look in the wrong direction during LRV reverse running situations, reverse running should not negate the value of offset pedestrian crossings as reverse running is infrequently used (typically only during maintenance or emergencies), and is performed at lower speeds such that the LRV operator has more opportunity to sound a horn or apply an emergency stop if necessary to avoid an errant pedestrian.

Relative Cost: Medium

Included in MUTCD Chapter 10: Yes, Figure 10D-8.

Agencies Reporting Using This Treatment: SCVTA, RTD, SRTD, Ctrain, SDTI, Metro, SF Muni, TriMet

Resources:

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

OFFSET PEDESTRIAN CROSSINGS – EXAMPLES

Description: Offset pedestrian crossing at a station on the Hudson–Bergen line in New Jersey. The fencing was installed after a non-fatal pedestrian incident.

Location: Hudson–Bergen Light Rail Line, New Jersey

Additional Notes: None

PEDESTRIAN SWING GATES

General Description: Pedestrian swing gates, sometimes called pedestrian fence gates, are gates that pedestrians and cyclists must open manually to cross the tracks.

Purpose of Treatment: Pedestrian swing gates, like other pedestrian barriers and gates, are installed to discourage pedestrians and cyclists from making dangerous crossing movements. The gates force crossing users to have additional time to check for an approaching LRV.

$$ Medium Cost

Passive Treatment

Pedestrian Safety

Alignment Type: All b

Intersection Treatment: No

Implementation Effects: No information available

Implementation Notes: No information available

Contraindications to Treatment: Irwin suggested using pedestrian swing gates where: 1) "pedestrian to train sight lines are restricted, 2) a high likelihood exists that persons will hurriedly cross the trackway, 3) channeling or other barriers reasonably prevent persons from bypassing the gates, and 4) acceptable provisions for opening the gates by disabled persons can be provided."

Relative Cost: Medium

Included in MUTCD Chapter 10: Section 10D.08 and Figure 10D-6.

See Also: Pedestrian Automatic Gates

Agencies Reporting Using This Treatment: TTC, SCVTA, LACMTA, RTD, SRTD, PAAC, NJT – River LINE, NCTD, SF Muni, NJT-HBLR, TriMet

Resources:

Irwin, D. Transportation Research Circular E-C058: Safety Criteria for Light Rail Pedestrian Crossings. In *9th National Light Rail Transit Conference*, TRB, National Research Council, Washington, D.C., 2003.

PEDESTRIAN SWING GATES – EXAMPLES

Description: Pedestrian swing gate at combined LRT and heavy rail crossing

Location: Salt Lake City, Utah

Additional Notes: This gate was originally installed for the railroad crossing (before construction of the LRT line).

Description: Decorative pedestrian swing gates

Location: San Jose, California

Additional Notes: Gate function is reduced because the springs are no longer effective. The gates do not automatically close.

PEDESTRIAN SWING GATES – EXAMPLES CONT'D.

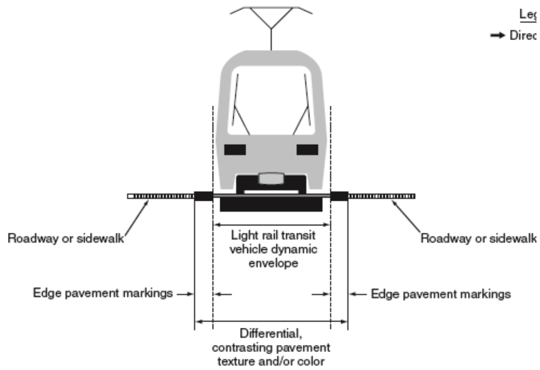
Description: Combination of pedestrian automatic gates and pedestrian swing gates

Location: Mountain View, California

Additional Notes: This gate combination is installed at the heavy rail crossing at the Mountain View VTA LRT and CalTrain station where commuter rail and LRT stations are located directly next to each other on parallel alignments.

Channelization/Markings

PAVEMENT MARKING, TEXTURING, AND STRIPING



General Description: Pavement marking, texturing, and striping are changes to the pavement appearance or texture to denote the LRT right-of-way or dynamic envelope.

Purpose of Treatment: The main purpose of pavement marking, texturing, and striping is to indicate the right-of-way of the LRV and alert motorists, pedestrians, and cyclists to the possible presence of an LRV so that they can be prepared for its arrival or passing.

$ Low Cost

Passive Treatment

Pedestrian Safety

Motorist Safety

Alignment Type: All b, all c

Intersection Treatment: Yes

Implementation Effects: Pavement marking, texturing, and striping are assumed to be effective in conveying information, but the effect of pavement marking, texturing, and striping on LRT crashes has not been quantified. Pavement markings and texturing require ongoing maintenance. They are effective in areas where snow and/or ice do not cover the markings. Rain can make markings difficult to see.

Implementation Notes: No information available

Contraindications to Treatment: No information available.

Relative Cost: Low

Included in MUTCD Chapter 10: Yes

See Also: N/A

Agencies Reporting Using This Treatment: MATA, SCVTA, LACMTA, RTD, SRTD, PAAC, MTA-MD, KT, NJT – River LINE, ST, UTA, SDTI, Metro, Edmonton Transit, NCTD, Metro Transit, SF Muni, NJT-NCS, NJT-HBLR, SEPTA

Resources:

Korve, H. W., Farran, J. I., Mansel, D. M., Levinson, H. S., Chira-Chavala, T., and Ragland, D. R. *TCRP Report 17: Integration of Light Rail Transit into City Streets*. TRB, National Research Council, Washington, D.C., 1996.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

PAVEMENT MARKING, TEXTURING, AND STRIPING – EXAMPLES

Description: Painted "CROSS ONLY AT CROSSWALK" facing the opposite platform on each side of the tracks. Also applied on street side of 6-inch curbs on other portions of the alignment.

Location: Median-running and side-running alignments in Salt Lake City, Utah

Additional Notes: Applied to deter pedestrians from illegally crossing tracks, or in other locations, from crossing the roadway and tracks mid-block to access the platform.

Description: Paint and texture on the edges of the station platform. Left side of image shows finished treatment. Right side has textured surface, but has not yet been refinished with color and lettering.

Location: Station platform edges, Hudson–Bergen line, New Jersey

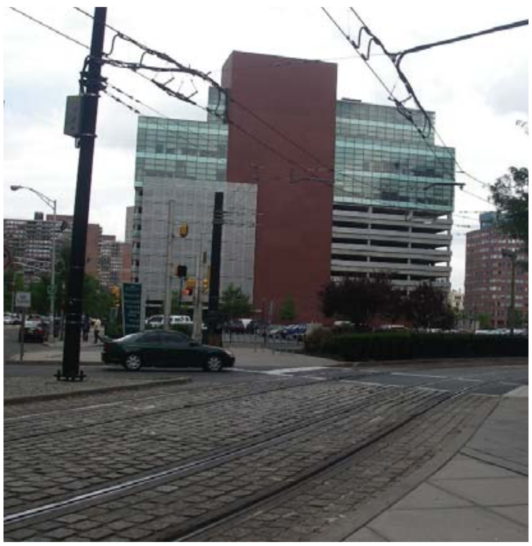
Additional Notes: Implemented to better denote the edge of the platform and the dynamic envelope of LRV

PAVEMENT MARKING, TEXTURING, AND STRIPING – EXAMPLES CONT'D.

Description: Painted lines denoting the LRT alignment in a median-running section of the Hiawatha line in downtown Minneapolis

Location: Downtown Minneapolis, Hiawatha Line

Additional Notes: The area has unusual lane configurations that may contribute to motorist confusion. Pavement markings and a small curb are often not enough to prevent vehicles from entering the alignment, but they allow for emergency access and prevent motorists from getting stuck on the tracks.



Description: Texturized concrete denoting the LRV-only track area in the financial district of New Jersey

Location: Hudson–Bergen Line, New Jersey

Additional Notes: NJT staff report that the tactile feel of the texturized concrete gives motorists and pedestrians a clear indication that they should not drive or walk on this portion of the roadway.

PAVEMENT MARKING, TEXTURING, AND STRIPING – EXAMPLES CONT'D.

Description: Painted non-MUTCD "STOP FOR TRAINS" on concrete pedestrian path before crossing

Location: Salt Lake City, Utah

Additional Notes: None

Description: Painted non-MUTCD "STOP FOR TRAINS" on concrete pedestrian path before crossing

Location: Salt Lake City, Utah

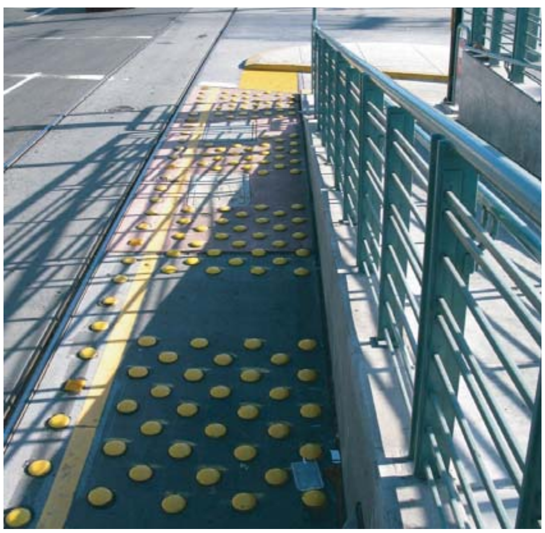
Additional Notes: None

PAVEMENT MARKING, TEXTURING, AND STRIPING – EXAMPLES CONT'D.

Description: White bumpers on red pavement in median running Type b.3 LRT alignment

Location: San Francisco, California

Additional Notes: The white bumpers provide both a visual and tactile cue to motorists to stay out of the LRT alignment. SF Muni staff report positive results from the bumpers, but the bumpers can create a maintenance issue as they are easily destroyed by vehicles. Black scuff marks on the bumpers indicate that the bumpers are hit by tires on occasion.



Description: Yellow bumpers alongside median station

Location: San Francisco, California

Additional Notes: The yellow bumpers provide a visual and tactile cue to motorists and pedestrians to stay off of the thin strip of pavement between the shared LRT/vehicle lane and the median station.

QUICK CURBS

General Description: Quick curbs are removable barriers that act as a channelization countermeasure mainly for pedestrians and cyclists. The curbs can be installed temporarily to restrict pedestrian and cyclist movements for limited periods of time and/or for infrequent events.

In the case of SF Muni, portable steel barriers are supplemented by yellow fabric caution tape and numerous transit staff and police who manage large crowds crossing the LRT alignment adjacent to the baseball stadium.

Salt Lake's UTA also reported using considerable numbers of staff to control crowds in the LRT stations adjacent to sports events.

Purpose of Treatment: Quick curbs are used to restrict the crossing movements of pedestrians and cyclists and prevent them from randomly entering LRV trackways.

$$ Medium

Alignment Type: b.4, b.5, c.1

Passive Treatment

Intersection Treatment: No

Pedestrian Safety

Implementation Effects: Light rail agencies such as UTA and Minneapolis have found quick curbs to be effective at locations with high volumes of pedestrian traffic. Examples of such locations are regularly scheduled events at sports centers.

Contraindications to Treatment: No information available

Relative Cost: Medium

Included in MUTCD Chapter 10: No

See Also: Pedestrian Fencing/Landscaping

Agencies Reporting Using This Treatment: LACMTA, SRTD, PAAC, UTA, SDTI, SF Muni, NJT-HBLR, TriMet, TTC

Resources: No information available

RUMBLE STRIPS

General Description: Rumble strips are strips along the roadway that are engraved or raised to create a tactile and audible vibration when a vehicle drives over the strip. Rumble strips can run parallel to a traffic lane and alert drivers when they leave their lane, or they can be installed transverse to the lane to warn drivers of an approaching hazard.

Purpose of Treatment: Transverse rumble strips produce noise and vibration that inform motorists that they are approaching an LRV trackway. When an LRT is operating on a street with mixed traffic, rumble strips can delineate the traffic area and provide a tactile and audible warning for motorists not to drive out of their own traffic area into the travel path of the LRT.

$ Low Cost

Passive Treatment

Motorist Safety

Alignment Type: Non-exclusive

Intersection Treatment: No

Implementation Effects: Numerous research studies have shown significant transverse rumble strips safety benefits for road vehicles, but no research has addressed the safety benefits for LRV alignments. UTA reported that their track sections with curbs experience less vehicle, pedestrian, and cyclist trespassing than track sections with transverse rumble strips.

Implementation Notes: Transverse rumble strips were used in downtown Salt Lake City to address emergency services concerns about accessing fire-prone downtown buildings. It was decided that blocking fire trucks from making emergency U-turns by installing curbs was not acceptable.

Contraindications to Treatment: Transverse rumble strips are not generally used in urban environments because of the noise levels.

Relative Cost: Low

Included in MUTCD Chapter 10: Yes

See Also: Pavement Marking, Texturing, and Striping

Agencies Reporting Using This Treatment: SDTI, Metro

Resources:

Korve, H. W., Farran, J. I., Mansel, D. M., Levinson, H. S., Chira-Chavala, T., and Ragland, D. R. *TCRP Report 17: Integration of Light Rail Transit into City Streets*. TRB, National Research Council, Washington, D.C., 1996.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

RUMBLE STRIPS – EXAMPLES

Description: Rumble strips used in combination with pavement markings to delineate the LRT dynamic envelope

Location: Salt Lake City, Utah

Additional Notes: UTA reported that their track sections with curbs experience less vehicle, pedestrian, and cyclist trespassing than alignments with rumble strips, but rumble strips were installed instead of curbs to provide emergency access across the alignment. However, during the project team's site visit, general traffic was observed making the occasional illegal U-turn.

CHANNELIZATIONS

General Description: Channelization devices are longitudinal barriers designed to control motorists' movements in the vicinity of an LRT alignment. The channelization may involve parallel longitudinal barriers of various types used to separate the road lanes from the tracks. Channelization is also used to define and restrict motor vehicle movements at street junctions.

The most restrictive channelization device is the median barrier. At a crossing, a median barrier prevents motorists who are approaching the LRT crossing from using the opposite lane to cross the tracks when the gates are down. The median barrier also prevents motorists from bypassing a queue of stopped vehicles at flashing lights or when the gates are down.

Purpose of Treatment: Channelization devices are to restrict the path of motor vehicles and prevent vehicles from crossing the tracks when it is unsafe to do so.

$$$ High Cost

Passive Treatment

Motorist Safety

Alignment Type: Non-exclusive

Intersection Treatment: No

Implementation Effects: According to RTD in Denver, raised medians with barrier curbs at two LRT crossings have reduced the rate of violations to almost zero.

Contraindications to Treatment: No information available

Relative Cost: High

Included in MUTCD Chapter 10: Yes

Agencies Reporting Using this Treatment: MATA, SCVTA, LACMTA, RTD, SRTD, MTA-MD, ST, UTA, SDTI, Metro, Edmonton Transit, NCTD, Metro Transit, SF Muni, NJT-NCS, NJT-HBLR, SEPTA, TriMet, TTC

Resources:

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

CHANNELIZATIONS – EXAMPLES

Description: Barrier curbs and pole-mounted delineators used to separate LRT in median from vehicle lanes on a Type b.3 alignment

Location: Salt Lake City, Utah

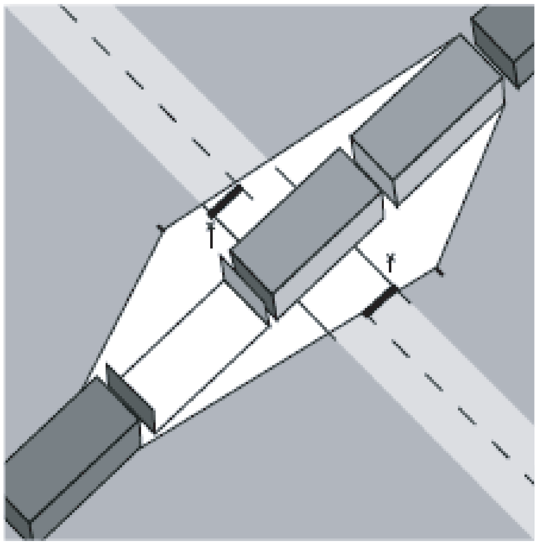
Additional Notes: UTA reported that their track sections with curbs experience less vehicle, pedestrian, and cyclist trespassing than alignments with transverse rumble strips. Vehicle tire marks can be seen in this photo, indicating that vehicles would have entered the alignment if the curbs were not there.

Description: Barrier curbs used in combination with a tactile treatment (paving bricks) to channelize vehicles and to indicate the edge of the dynamic envelope of the LRV

Location: Hudson–Bergen Line, Jersey City, New Jersey

Additional Notes: While the curb end at the intersection is tapered to avoid impacts, a 90 degree barrier is presented against the asphalt lane.

ILLUMINATION OF CROSSINGS



General Description: Illumination of crossings refers to lighting systems installed to increase the visibility of crossing LRVs to motorists at night. Luminaires are directed to the sides of the rail vehicles to increase the conspicuity of the LRVs.

MUTCD Chapter 10 suggests that "where light rail transit operations are conducted at night, illumination at and adjacent to the highway-light rail transit grade crossing should be considered."

Purpose of Treatment: The purpose of illuminating crossings is to improve the conspicuity of LRVs and reduce the likelihood that motorists, pedestrians, and cyclists will cross the tracks when an LRV is passing or about to arrive.

$$ Medium Cost

Passive Treatment

Motorist Safety

Pedestrian Safety

Alignment Type: All b, all c

Intersection Treatment: Yes

Implementation Effects: No information available

Contraindications to Treatment: No information available

Relative Cost: Medium

Included in MUTCD Chapter 10: Yes

See Also: No information available

Agencies Reporting Using This Treatment: MATA, SCVTA, RTD, Ctrain, MTA-MD, Edmonton Transit, NJT-HBLR, TriMet

Resources:

Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2003 Edition.

PHOTO ENFORCEMENT

General Description: An automatic photo enforcement system detects vehicles that deliberately violate closed gates at a crossing. The system is used to enforce traffic laws.

Purpose of Treatment: The main purpose of automatic photo enforcement is to discourage vehicles from deliberately crossing the tracks after a gate closure by enforcing traffic laws.

$$$ High Cost

Alignment Type: Non-exclusive

Intersection Treatment: All b, c.1

Active Treatment

Implementation Effects: An FHWA study by McFadden and McGee estimates that automated enforcement can result in a 20 to 60% reduction in violations, but there has been no quantitative link to crash effects.

Motorist Safety

Contraindications to Treatment: No information available

Relative Cost: High

Included in MUTCD Chapter 10: No

See Also: Enforcement

Agencies Reporting Using This Treatment: LACMTA, SRTD, NJT – River LINE, SF Muni, TriMet

Resources:

McFadden, J., and McGee, H. W. *Synthesis and Evaluation of Red Light Running Automated Enforcement Programs in the United States*. FHWA-IF-00-004. FHWA, U.S. Department of Transportation, 1999.

Korve Engineering, Inc., Richards & Associates, Interactive Elements, Inc., and University of North Carolina, Highway Safety Research Center. *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety*. TRB, National Research Council, Washington, D.C., 2001.

Illinois Commerce Commission. *Photo Enforcement at Highway-Rail Grade Crossings*: *2001 Status Report to the General Assembly*. Research & Analysis Section,

Transportation Division Working Paper 2002-02, 2002.

ENFORCEMENT

General Description: Enforcement includes ticketing of pedestrians, cyclists, and motorists who are found in the right-of-way when it is unsafe. Enforcement campaigns include jaywalking enforcement, turn prohibition violation enforcement, and parking enforcement.

Laws pertaining to grade crossing violations are likely to be ineffective if they are not enforced. A1996 task force report to the Secretary of Transportation recommended increased penalties for repeated offenses culminating in the forfeiture of the driver's license for especially serious violations. The task force also proposed re-investing the fines collected by the courts into grade crossing education and enforcement.

Purpose of Treatment: Enforcement is designed to prevent deliberate violations of the LRV right-of-way by enforcing the traffic law to motorists, pedestrians, and cyclists.

Alignment Type: All

Intersection Treatment: Yes

Implementation Effects: No information available

Contraindications to Treatment: Targeted enforcement events have been carried out (e.g., against jaywalking) several times by UTA police, but UTA staff have noted no ongoing benefits. It appears that when the enforcement ends, people continue to violate the law. Only the immediate threat of a penalty seems to be a deterrent.

Relative Cost: High

Included in MUTCD Chapter 10: No

See Also: Photo Enforcement, Education Outreach Programs

$$$ High Cost

Motorist Safety

Pedestrian Safety

Agencies Reporting Using This Treatment: SCVTA, LACMTA, RTD, SRTD, PAAC, NJT – River LINE, Metro, NCTD, SF Muni, TriMet

Resources:

U. S. Department of Transportation. *Accidents That Shouldn't Happen: A Report of the Grade Crossings Safety Task Force to Secretary Federico Pena*. 1996.

EDUCATION OUTREACH PROGRAMS

General Description: Education outreach programs (safety education) include a number of different types and intensities of programs. Programs can range from general safety advertising to specific targeting of problem locations or anticipated problem locations such as schools or community centers that are close to LRT crossings. Communities can choose to run their own programs, run programs in coordination with other jurisdictions, or use resources provided by a national organization like Operation Lifesaver.

Many communities have reported that motorist, pedestrian, and cyclist education is one of the most important and effective safety treatments.

Safety education initiatives should be repeated on a regular basis. Annual renewal of presentations and initiatives is recommended.

Purpose of Treatment: Education outreach programs are designed to reduce risky behavior by motorists, pedestrians, and cyclists.

Suitable Locations: Education outreach programs may be system-wide or may address local problems. Initiatives include school and community center visits, poster campaigns on trains, poster campaigns in areas surrounding tracks, and motorist training through state driver training.

Intersection Treatment: No

Implementation Effects: Anecdotal reports of reductions in risky behavior by motorists, pedestrians, and cyclists are available for education outreach programs. The success of safety education is highly dependent on educating the appropriate socio-economic group (i.e., the group most likely to engage in the risky behavior).

Contraindications to Treatment: No information available

Relative Cost: Medium

Included in MUTCD Chapter 10: No

See Also: Enforcement

$$ Medium

Motorist Safety

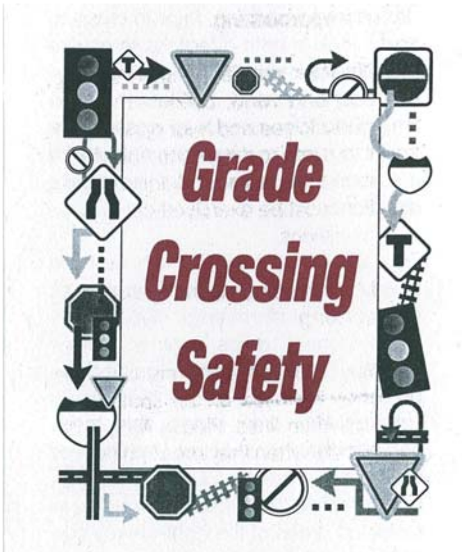
Pedestrian Safety

Agencies Reporting Using This Treatment: SCVTA, LACMTA, RTD, SRTD, NJT – River LINE, ST, UTA, SDTI, Metro, NCTD, Metro Transit, SF Muni, NJT-NCS, NJT-HBLR, SEPTA, TriMet, TTC

Resources:

Operation Lifesaver Light Rail Program, www.oli-lightrail.org

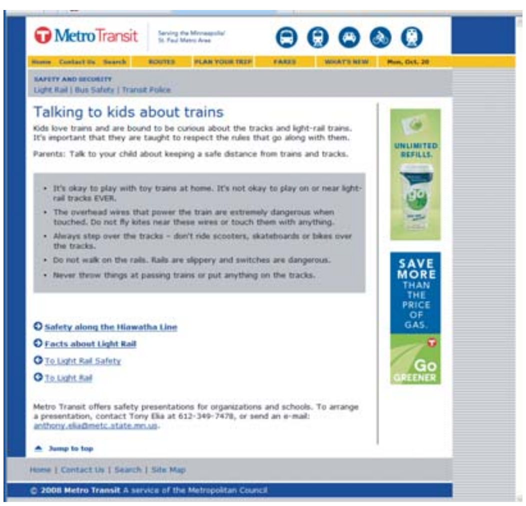
EDUCATION OUTREACH PROGRAMS – EXAMPLES



Description: The Greater Cleveland Regional Transit Authority produces a pamphlet to educate motorists, pedestrians, and cyclists about crossing rail lines safely.

Location: Cleveland, Ohio

Additional Notes: None



Description: Minneapolis Metro Transit has a web page dedicated to children's safety along light rail corridors. The page can be found at: http://www.metrotransit.org/safetySecurity/safetyKids.asp.

Location: Minneapolis, Minnesota

Additional Notes: None

CCTV/VIDEO RECORDING

General Description: Closed Circuit Television (CCTV) systems monitor activity at stations or intersections through a network of video cameras. Footage from these cameras can be displayed on screens at the location or at central control. Video footage can be recorded for later use. In some systems, cameras can be controlled from a central location. In other systems, the cameras provide a fixed view only.

Purpose of Treatment: CCTV systems are normally installed for security purposes. When installed as a safety measure, the purpose of the system is to reduce risky behavior.

$$$ High Cost

Passive Treatment

Motorist Safety

Pedestrian Safety

Alignment Type: All

Intersection Treatment: System-wide applications

Implementation Effects: No information is currently available about the non-security safety impacts of CCTV or video recording.

Contraindications to Treatment: No information available.

Relative Cost: High, but a system could be implemented very gradually

Included in MUTCD Chapter 10: No

Agencies Reporting Using This Treatment: SCVTA, LACMTA, RTD, SRTD, PAAC, NJT – River LINE, SDTI, Metro, Edmonton Transit, NCTD, SF Muni, TriMet

Resources: No information available

APPENDIXES B THROUGH E

- Appendix B Literature Review—State of the Knowledge
  Appendix B is available on the TRB Website (www.trb.org) by searching "TCRP Web-Only Document 42."
- Appendix C1 Transit Agencies and Contact Information of the Persons Who Participated in the Survey
  Appendix C1 is available on the TRB Website (www.trb.org) by searching "TCRP Web-Only Document 42."
- Appendix C2 Treatment Usage as Reported by the Survey Participants
  Appendix C2 is available on the TRB Website (www.trb.org) by searching "TCRP Web-Only Document 42."
- Appendix C3 Survey Responses
  Appendix C3 is available on the TRB Website (www.trb.org) by searching "TCRP Web-Only Document 42."
- Appendix D Technical Memoranda
  Appendix D is available on the TRB Website (www.trb.org) by searching "TCRP Web-Only Document 42."
- Appendix E Review of the Accident Data Collection Process
  Appendix E is available on the TRB Website (www.trb.org) by searching "TCRP Web-Only Document 42."

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation