TCRP
REPORT 125

TRANSIT
COOPERATIVE
RESEARCH
PROGRAM

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Guidebook for Mitigating Fixed-Route Bus-and-Pedestrian Collisions

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 125

Guidebook for Mitigating Fixed-Route Bus-and-Pedestrian Collisions

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), Transportation 2000, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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FOREWORD

By Dianne S. Schwager
Staff Officer
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TCRP Report 125: Guidebook for Mitigating Fixed-Route Bus-and-Pedestrian Collisions will be of interest to public transportation systems that provide fixed-route bus services (Guidebook) and their communities. This Guidebook will assist small, medium, and large transit agencies and their community members in better understanding bus-and-pedestrian collisions and in determining preventative or remedial strategies for reducing the frequency and severity of these types of collisions.

The research involved obtaining information, data, and relevant input from a sample of small, medium, and large transit systems that are geographically diverse, as well as from a large array of stakeholders—including 22 pedestrians, 26 bus operators, and 60 agencies and organizations concerned with transit and pedestrian safety. The Guidebook is divided into four parts.

- Part I of the Guidebook discusses how to mitigate the four most common collision types and circumstances.
- Part II presents a variety of strategies, including operator training and outreach, safety checks, defensive driving techniques and policies, public outreach and education, traffic engineering and roadway design, bus mirror configuration and placement, bus design/modification, bus stop location planning and bus stop design, and bus stop lighting and illumination. Detailed information for over 80 applications of the strategies is presented, as well as information on many more suggested applications of the strategies.
- Part III contains 14 case studies, which provide in-depth examples for the best documented applications. The case studies include detailed information about what is known about the bus-and-pedestrian collision problem, the implementation of one or more mitigating strategies, the goals and costs of implementation, and the successful and problematic elements of strategy implementation.
- Finally, Part IV presents a discussion of important considerations for improving pedestrian safety around transit buses. This section includes a description of contributing factors that are not necessarily directly linked to one of the four primary types of bus-and-pedestrian collisions described in the Guidebook, but that were identified by transit agencies and other stakeholders as playing an important role in the occurrence of these collisions. This section also discusses how to approach strategy implementation and specifically how to combine two or more strategies to add to the potential for success in reducing bus-and-pedestrian collisions and improving overall safety.

The Guidebook provides transit agencies and stakeholders with an array of strategies from which to choose for mitigating the frequency and severity of bus-and-pedestrian collisions, as well as approaches for doing so.

CONTENTS

SUMMARY

Guidebook for Mitigating Fixed-Route Bus-and-Pedestrian Collisions

This Guidebook is the product of TCRP Project A-28, "Guidebook for Mitigating Fixed-Route Bus-and-Pedestrian Collisions." The goal of the project was to gather quantitative and qualitative data to determine the frequency of bus-and-pedestrian collisions, to understand factors that contribute to their occurrence, and to identify implemented and potential strategies to mitigate their occurrence and severity. This Guidebook will assist transit agencies and community members in understanding the problem of bus-and-pedestrian collisions and in determining preventative or remedial strategies for reducing the frequency and severity of these types of collisions.

During the 18-month investigation, a team composed of transportation researchers gathered information using a variety of sources, including literature and previous research, incident reports, focus group meetings, and one-on-one interviews. The research team focused on obtaining information and data from a sample that is geographically diverse; one that includes the needs and perspectives of small, medium, and large transit agencies; and one that includes input from a large array of stakeholders. In addition to 22 pedestrians and 26 bus operators, 60 agencies and organizations provided input that went into the development of this Guidebook.

This Guidebook is organized into four parts and presents a number of strategies to meet the needs of different users. Part 1 discusses how to mitigate the four most common collision types and circumstances as identified during the investigation, each of which is described and illustrated. Part 2 presents a variety of strategies, including operator training and outreach, safety checks, defensive driving techniques and policies, public outreach and education, traffic engineering and roadway design, bus mirror configuration and placement, bus design/modification, bus stop location planning and bus stop design, and bus stop lighting and illumination. Detailed information for more than 80 applications of the strategies is presented, as well as information on many more suggested applications of the strategies.

Part 3 contains 14 case studies, which provide in-depth examples for the best documented applications of the strategies. The case studies include single-agency case studies, which detail how individual agencies have addressed pedestrian safety issues, and multi-agency case studies, which compare the same applications implemented across multiple agencies. The case studies include detailed information about what is known about the bus-and-pedestrian collision problem, the implementation of one or more mitigating strategies, the goals and costs of implementation, and the successful and problematic elements of strategy implementation.

Finally, Part 4 presents a discussion of important considerations for improving pedestrian safety around transit buses. This section includes a description of contributing factors that

are not necessarily directly linked to one of the four primary types of bus-and-pedestrian collisions described in the Guidebook, but that were identified by transit agencies and other stakeholders as playing an important role in the occurrence of these collisions. This section also discusses how to approach strategy implementation and specifically how to combine two or more strategies to add to the potential for success in reducing bus-and-pedestrian collisions and improving overall safety.

This guidebook provides transit agencies and stakeholders with an array of strategies from which to choose for mitigating the frequency and severity of bus-and-pedestrian collisions, as well as approaches for doing so.

Introduction

This Guidebook has been developed to assist transit agencies and community members in understanding the problem of bus-and-pedestrian collisions and determining preventative or remedial strategies for reducing the frequency and severity of these types of collisions. A bus-and-pedestrian collision, for the purpose of this project and Guidebook, was defined as a collision between a fixed-route transit bus and a pedestrian. This Guidebook does not address collisions between pedestrians and other types of vehicles in the vicinity of transit stops, nor does it address accidents that involve pedestrians being injured when boarding or alighting buses.

Guidebook Development

The Guidebook is the product of an investigation for TCRP Project A-28, "Guidebook for Mitigating Fixed-Route Bus-and-Pedestrian Collisions." The goal of the project was to gather data (both quantitative and qualitative) to determine how often bus-and-pedestrian collisions occur, to understand factors that contribute to their occurrence, and to identify implemented and potential strategies to mitigate their occurrence. During this 18-month investigation, a team composed of transportation researchers gathered quantitative and qualitative information using a variety of sources, including literature and previous research, incident reports, focus group meetings, and one-on-one interviews. In all cases, the research team focused on obtaining information and data from a sample that is geographically diverse; one that includes the needs and perspectives of small, medium, and large transit agencies; and one that includes input from a large array of potential stakeholders.

Literature and Previous Research

The main literature sources for the research team were reports from FHWA, NCHRP, TCRP, NTSB, and federally funded university research, as well as state and local publications and newspaper articles.

Incident Reports

The research team obtained and reviewed 169 incident reports from 8 transit agencies across the country. The majority of the incident reports were from 2005 and 2006; however, a few of the reports went back as far as 2003. The detail in these reports ranged from brief incident synopses to detailed site illustrations, interviews, and police reports. The team developed a database cataloging the circumstances of the collisions as well as any reported contributing factors. Analysis was then performed to understand the most common and/or most important collision types

and associated factors. Due to inconsistent reporting across agencies and lack of detail in many of the reports, this data analysis revealed very little in terms of contributing factors.

Focus Group Meetings

Eight focus group meetings were conducted at several locations throughout the United States and one location in Canada with individuals who have a vested interest in mitigating bus-and-pedestrian collisions. The goal of these focus groups was to understand the different perspectives of stakeholders with regard to collision circumstances, contributing factors, and mitigation strategies. In total, approximately 80 stakeholders participated in these meetings including 21 transit agency representatives, 24 bus operators, 6 departments of transportation (DOT) representatives, 3 pedestrian advocate representatives, and 24 pedestrians and bus riders.

One-On-One Interviews

A total of 30 interviews were conducted. Twenty-two telephone interviews were conducted with transit agency staff holding positions such as safety manager, risk manager, or operator training supervisor. Additional interviews were conducted with four representatives from pedestrian advocacy groups, a city government pedestrian safety engineer, a state government bicycle and pedestrian program manager, a bus operators' union representative, and the deputy director of a transit insurance corporation who was interviewed via e-mail.

Following data collection, the research team synthesized all of the information collected to create categories of collision types and to identify the common mitigation strategies. These collision types and strategies are used to organize this Guidebook, and contributing factors are discussed throughout.

Guidebook Organization

For this purpose of this Guidebook, a "strategy" refers to a high-level approach to mitigation, such as operator training or public outreach. For each strategy, the Guidebook presents specific examples of "applications" of each strategy that were identified during the research process. An example of an application of an operator training strategy would be an instructional turning video.

The Guidebook, then, emphasizes applications of strategies for mitigating bus-and-pedestrian collisions, all of which were identified during the research process. The Guidebook is organized to present the applications in a variety of ways. Thus, any particular application may be described in multiple places throughout. This repetition is purposeful and is designed to help the reader find the appropriate information and level of detail suited to his or her needs.

Parts 1 and 2 complement one another and enable the reader to search for applications either by collision type or by strategy. Parts 3 and 4 provide more detail regarding well-documented applications of strategies and present an overall approach to implementing strategies for mitigating bus-and-pedestrian collisions. This organization enables easy reference of strategies and applications of the strategies in a variety of ways, depending on the needs of the reader. The four parts are as follows:

- **PART 1: How to Mitigate the Most Common Collision Types and Circumstances**
  This section guides readers to strategies and applications based on common problems. The section begins with a list of the most common collision types and circumstances between buses and pedestrians. From here the reader is directed to a more detailed description and a diagram of each collision type, as well as a discussion of the most likely contributing factors,

as reported by transit agencies and stakeholders. Finally, actual applications of strategies for mitigating each particular type of collision are listed.

- **PART 2: Applications of Strategies for Mitigating Bus-and-Pedestrian Collisions**
  This section guides readers to specific applications of strategies based on the type of strategy. The section begins with a list of 10 strategies as defined for this Guidebook. From here the reader is directed to a more detailed presentation of specific applications of each strategy as reported by agencies and stakeholders. The information on each application includes the purpose or goal of the application, a brief description of the application, and the reported effectiveness or success of the application (if available).
- **PART 3: Case Studies**
  This section presents in-depth examples, in the form of case studies, for the best documented application of strategies for mitigating bus-and-pedestrian collisions. The case studies include single-agency case studies, which detail how individual agencies have addressed their pedestrian collision issues, and multi-agency case studies, which present examples of similar applications across multiple agencies. The case studies include detailed information about what is known about the bus-and-pedestrian collision problem, the implementation of one or more mitigation strategies, the goals and costs of implementation, and the successful and problematic elements of strategy implementation.
- **PART 4: Important Considerations for Improving Pedestrian Safety Around Transit Buses**
  This section presents a discussion of other important considerations when implementing pedestrian-and-bus safety strategies. This section includes a description of other contributing factors, not necessarily directly linked to one of the four primary types of bus-and-pedestrian collisions. This section also discusses how to approach strategy implementation and, specifically, how to combine two or more strategies to add to the potential for success in reducing bus-and-pedestrian collisions and improving overall safety.

Important Note Regarding the Strategies and Applications Presented in This Guidebook

The strategies and applications presented in this Guidebook are not recommendations; rather, they are examples and, in some cases, suggestions given by transit agencies and community stakeholders who participated in focus groups or interviews during the research. As there is not a one-size-fits-all approach to mitigating bus-and-pedestrian collisions, each agency should examine the applicability and merit of the strategies and applications presented herein for their community or jurisdiction and then customize them accordingly. State and local laws, design regulations, and motor-vehicle codes should be consulted prior to any modifications, alterations, or additions being made.

PART 1

How to Mitigate the Most Common Collision Types and Circumstances

The purpose of this section of the Guidebook is to guide users to strategies and specific applications of the strategies based on the particular problems, collision types, or collision circumstances they are experiencing. Data regarding bus-and-pedestrian collisions were gathered from collision databases, from selected incident reports between 2003 and 2006, and from transit agencies and other stakeholders. Analysis of the collision data resulted in a number of collision circumstances that appear to account for the majority of all bus-and-pedestrian collisions.

The primary collision types and circumstances are shown in Table 1-1. The primary collision types are numbered (in no particular order) in the far left column. This numbering for collision type is important: it is used as a reference throughout this Guidebook. Then, for each collision type, the table shows the circumstances of the collision in terms of "bus action" and "pedestrian action." These actions depict what is happening just prior to the occurrence of each type of collision. Also noted in the table are the most likely points on the bus in which contact is made with the pedestrian for each collision type.

Throughout this Guidebook, the four primary types of collisions are defined in terms of the bus action, as shown in Table 1-1. These four collision types are (1) the bus turning right, (2) the bus turning left, (3) the bus pulling into a stop, and (4) the bus pulling away from a stop. Collision Types 1 and 4 have one or more variations of circumstances in terms of the pedestrian action. The collision circumstances, contributing factors, and associated mitigation strategies are discussed in more detail in this section of the Guidebook, as noted by the section number in the far right column of Table 1-1.

Of all the collision types, turns at intersections was the problem most frequently reported by transit agencies and other stakeholders, with left turns reported to be a problem more frequently than rights turns. Although turns were a common circumstance in the data, the data do not necessarily support the observation that turns are the most common problem. Of the incident reports reviewed, only 57 of these reports (34%) indicated that the bus was turning. However, amongst the 92 bus-and-pedestrian collisions that occurred at intersections, the data do show that 55 (60%) occurred when the bus was turning. The data also support the observation that, amongst the bus-and-pedestrian collisions that occurred while the bus was turning, left-turn collisions were more common than right-turn collisions: 69% involved a left turn, while 31% involved a right turn.

The other two collision circumstances most commonly cited by transit agencies and stakeholders were those occurring when the bus is either pulling into a stop or pulling away from a stop. Analysis of the incident data showed that 42 incidents (25%) occurred when the bus was at or near a bus stop. Of the 42 incidents that are known to have occurred at or near a bus stop, 23 (55%) involved a bus pulling into a stop, and 13 (31%) involved a vehicle pulling away from a stop.

Table 1-1. Most common collision types/circumstances (index table for Chapter 1).

Collision Type	Collision Circumstances			Point of Contact on Bus	Section
	Bus Action		Pedestrian Action		
1	Turning right…	at a green light	Crossing in parallel crosswalk	Front/front-right	1.1
			Waiting on curb or stepping into crosswalk	Rear-right	
		at a red light	Crossing in opposing crosswalk	Front	
2	Turning left		Crossing in parallel crosswalk	Front/front-right/ front-left	1.2
3	Pulling into a stop		Waiting at stop, crowding, or pushing	Front/front-right/mirror/door	1.3
4	Pulling away from a stop		Running next to bus	Right/rear-right/ rear duals	1.4
			Crossing in front of bus	Front/front-right/ front-left	

Another collision type that showed up in the collision data was when a bus was going straight and a pedestrian was struck. This collision circumstance is somewhat of an anomaly. Sixty-five (39%) of the bus-and-pedestrian incident records indicated that the bus was traveling straight when the collision occurred; however, this collision type was not frequently reported as a problem by transit agencies and stakeholders. Only a few agencies and stakeholders reported that they had experienced bus-and-pedestrian collisions when the bus was going straight, and the circumstances of these collisions varied. In some cases, pedestrians were hit mid-block, usually as a result of the pedestrian darting out from between parked cars. In other cases, pedestrians were hit crossing at intersections. Due to the differences across agencies in what and how much information was reported about the collisions, it was often times difficult to ascertain exactly what happened during the collisions. It is believed that at least some of the collisions in which the bus was reportedly going straight fall into one of the primary four collision types as just defined. For example, a bus pulling away from a stop that hits a pedestrian crossing in front of a bus could have been reported as going straight. Also, there were few strategies reported for specifically mitigating collisions in which the bus was going straight.

1.1 Collision Type 1: Bus Turning Right

Collision Type 1 occurs when a pedestrian is struck when a bus is turning right. Of the incident reports reviewed, 16 (10%) occurred when the bus was turning right. By far, the most frequently reported version of the right-turning collision is when the pedestrian is crossing in the parallel crosswalk and is struck by the front/front-right of the bus, as illustrated in Figure 1-1.

One variation of this collision type occurs when the bus, turning right, strikes a pedestrian who is waiting on the curb or who has just stepped from the curb into the roadway to begin crossing. In this case, the pedestrian is hit by the side of the bus near the rear. It should be noted that this particular variation was only reported as common by one transit agency and one stakeholder group.

Another variation of this collision type occurs when the bus is making a right-turn-on-red. In this case, the pedestrian is struck in the opposing crosswalk (the one perpendicular to the bus) with the front of the bus before the bus begins the turn.

Figure 1-1. Illustration of Collision Type 1—collision between pedestrian and right-turning bus.

While the location of the pedestrian varies, the circumstances of this collision type, its contributing factors, and mitigating strategies are quite similar regardless of the pedestrian position. These are discussed below.

1.1.1 Contributing Factors to Right-Turn Collisions with Pedestrians

This section presents and discusses a variety of factors that may contribute to right-turn collisions with pedestrians. The list is by no means exhaustive, and is presented here simply as a discussion of what appear to be the most probable contributing factors, based on the experience and expert opinions of the transit agencies and stakeholders who provided input to the development of this Guidebook.

1.1.1.1 Characteristics of Bus Turns

A key factor influencing the occurrence of right-turn collisions with pedestrians might be that pedestrians have difficulty recognizing that buses are about to turn. When buses turn, they pivot on the rear axle, moving forward and then sweeping an arc as the bus follows through the turn. At first glance, it may appear to a pedestrian that the bus is moving straight forward through the intersection when in fact the operator is initiating a right turn. Believing the bus is going straight, the pedestrian makes the decision to enter the crosswalk. Then, when the bus begins to move laterally into the right turn, the pedestrian is already in the roadway, setting up a situation in which a collision could occur.

1.1.1.2 Reduced Visibility of Pedestrians

There are a variety of reasons why pedestrians crossing in a crosswalk or standing at the curb may not be visible to a bus operator:

- Bus components—including the A-pillar, the farebox, and the side mirrors—might create blind spots, which obstruct the operator's view of a pedestrian.
- Visual obstructions outside of the bus such as posts, vendors, and signage may also block an operator's view of pedestrians.
- Various characteristics of pedestrians and the environment might make people more or less visible to a driver:
  - Someone who is small or slow-moving,
  - Someone who is wearing dark clothing, or
  - The absence or lack of adequate street or crosswalk lighting.

Often times when asked what happened following a bus-and-pedestrian collision, operators reported that they just did not see the pedestrian. The pedestrians seem to have come from "out of nowhere." This phenomenon is consistent with the visual cognition concept of "inattentional blindness" in which a person looks but does not see (*1*).

1.1.1.3 Failure to Scan

Failure of the operator to scan the crosswalk before initiating the turn can contribute to this type of collision. Even if the operator scans the crosswalk initially, failure to re-scan the crosswalks after initiating the right turn could lead to collisions with pedestrians in the crosswalk.

1.1.2 Strategies for Mitigating Right-Turn Collisions with Pedestrians

Table 1-2 presents strategies and specific applications of the strategies that have been implemented by one or more transit agencies or stakeholders. These applications could help mitigate

Table 1-2. Strategies for mitigating right-turn collisions with pedestrians.

Strategy	Application
Operator training	Instructional turning video
	Mirror adjustment training station
Operator outreach	"No trash on the dash" campaign
	"Watch for pedestrians" sticker on farebox
	Themed safety outreach slogans
Defensive driving techniques and policies	Operator moves in seat to see around obstructions
	Mandatory turning procedure
	Operator keeps eyes moving
	Slow down at intersections
	No right turn on red
Public outreach and education	Public outreach to schools
	Public outreach videos
Traffic engineering	Pedestrian scramble
	Pedestrian channelization
Bus mirror configuration and placement	Dual right-side mirrors
	Dual mirrors in single housing
	Smaller mirrors
Bus design/modification	Increased number of side marker lamps
	Blinking chevrons on right-side mirrors
	Audible turn signals
	Side strobe lights

right-turn collisions with pedestrians. For more detail on each application, refer to the corresponding section in Part 2.

In addition to the applications listed in Table 1-2, transit agencies and stakeholders provided suggestions that, in their opinions, might be ways to mitigate right-turn collisions with pedestrians. These suggestions included the following:

- Keep intersections and sidewalks clear of obstructions (such as heavy posts, signage, vendors, etc.) to improve the line of sight from the bus operator to pedestrians.
- Make crosswalks more noticeable through crosswalk enhancements (e.g., delineation, lighting) to enhance bus operators' expectations about the presence of pedestrians.
- Use split mirrors (with the convex mirror on top), larger convex mirrors, and mirrors in which the height could be adjusted (either manually or electronically).
- Install tactile strips on the edges of sidewalks to keep pedestrians away from the edge of the roadway after consulting ADA standards and guidelines.
- Implement public education and outreach campaigns to educate pedestrians about important issues such as watching for turning buses while crossing, keeping back from the edge of the roadway when waiting to cross, and the mechanics of a turning bus.

1.2 Collision Type 2: Bus Turning Left

Collision Type 2 occurs when a pedestrian is crossing the street in the crosswalk and a bus operator is making a permitted left turn onto the street that the pedestrian is crossing, as illustrated in Figure 1-2. Of the incident reports reviewed, 36 (22%) occurred when the bus was turning left.

This potential conflict between a pedestrian and a left-turning vehicle is intrinsic to many signalized intersections with pedestrian signals. This is because the pedestrian WALK phase occurs simultaneously with the permitted left turn phase for traffic (i.e., green ball). When there is a

Figure 1-2. Illustration of Collision Type 2—collision between pedestrian and left-turning bus.

protected left-turn phase for traffic (i.e., green arrow), the corresponding pedestrian signal will read DON'T WALK or will show a solid orange hand, thereby separating the movements and eliminating potential conflicts between left-turning vehicles and pedestrians by prohibiting pedestrians from crossing. In many locations, however, even when there is a protected left-turn phase, it is followed by a time when vehicles are allowed to make permitted left turns. Here, the left-turning vehicles must yield to oncoming traffic, as well as to pedestrians in the crosswalk.

1.2.1 Contributing Factors to Left-Turn Collisions with Pedestrians

This section presents and discusses a variety of factors that may contribute to left-turn collisions with pedestrians. The list is by no means exhaustive and is presented here simply as a discussion of what appear to be the most probable contributing factors, based on the experience and expert opinions of the transit agencies and stakeholders who provided input to the development of this Guidebook.

1.2.1.1 Characteristics of Bus Turns

A key factor influencing the occurrence of left-turn collisions with pedestrians might be that pedestrians have difficulty recognizing that buses are about to turn. When buses turn, they pivot on the rear axle, moving forward and then sweeping an arc as the bus follows through the turn. At first glance, it may appear to a pedestrian that the bus is moving straight forward through the intersection when in fact the operator is initiating a left turn. Believing the bus is going straight, the pedestrian makes the decision to enter the crosswalk. Then, when the bus begins to move laterally into the left turn, the pedestrian is already in the roadway, setting up a situation in which a collision could occur.

1.2.1.2 Reduced Visibility of Pedestrians

There are a variety of reasons why pedestrians crossing in a crosswalk or standing at the curb may not be visible to a bus operator:

- Bus components—such as the A-pillar and the side mirrors—might create blind spots, which obstruct the operator's view of a pedestrian.
- Visual obstructions outside of the bus such as posts, vendors, and signage may also block an operator's view of pedestrians.
- Various characteristics of pedestrians and the environment might make people more or less visible to a driver:
  - Someone who is small or slow-moving,
  - Someone who is wearing dark clothing, or
  - The absence or lack of adequate street or crosswalk lighting

Often times when asked what happened following a bus-and-pedestrian collision, operators reported that they just did not see the pedestrian. The pedestrians seem to have come from "out of nowhere." This phenomenon is consistent with the visual cognition concept of "inattentional blindness" in which a person looks but does not see (*1*).

1.2.1.3 Failure to Scan

Failure of the operator to scan the crosswalk before initiating the left turn can contribute to this type of collision. Even if the operator scans the crosswalk initially, failure to re-scan the crosswalks after initiating the left turn could lead to collisions with pedestrians in the crosswalk.

1.2.1.4 Attention to Opposing Vehicular Traffic

A unique characteristic of this collision type is that bus operators not only have to scan for pedestrians in the crosswalk before turning, but they also must watch for a gap in oncoming traffic before

turning. It was suggested that in some cases, the operator focuses so heavily on the oncoming traffic that not enough attention is paid to pedestrians. One stakeholder specifically reported that the combination of operators hurrying to keep schedule and waiting for a gap in both vehicle and pedestrian traffic causes them to lose sight of pedestrians.

1.2.2 Strategies for Mitigating Left-Turn Collisions with Pedestrians

Table 1-3 presents strategies and specific applications of the strategies that have been implemented by one or more transit agencies or stakeholders. These applications could help mitigate left-turn collisions with pedestrians. For more detail on each application, refer to the corresponding section in Part 2.

In addition to the applications listed in Table 1-3, transit agencies and stakeholders provided suggestions that, in their opinions, might be ways to mitigate left-turn collisions with pedestrians. These suggestions included

- Keep intersections and sidewalks clear of obstructions to improve the line of sight from the bus operator to pedestrians.
- Make crosswalks more noticeable to enhance bus operators' expectations about the presence of pedestrians.
- Reduce in-bus obstructions related to mirrors and the A-pillar.

1.3 Collision Type 3: Bus Pulling into Bus Stops

Collision Type 3 occurs when a bus is pulling into a bus stop and a pedestrian is struck. Of the incident reports reviewed, 25 (15%) occurred when the bus was pulling into a bus stop. When

Table 1-3. Strategies for mitigating left-turn collisions with pedestrians.

Strategy	Application
Operator training	Instructional turning video
	Mirror adjustment training station
Operator outreach	"No trash on the dash" campaign
	"Watch for pedestrians" decals on telephone/radio handsets
	Themed safety outreach slogans
Defensive driving techniques and policies	Operator moves in seat to see around obstructions
	Mandatory turning procedure
	Square left turns
	Operator keeps eyes moving
	Slow down at intersections
Public outreach and education	Public outreach to schools
Traffic engineering	Protected left-turn signal
	Pedestrian scramble
Bus mirror configuration and placement	Dual left-side mirrors placed lower on bus
	Dual mirrors in single housing
	Standardized left-side mirror height
	Smaller mirrors
Bus design/modification	Increased number of side marker lamps
	Blinking chevrons on left-side mirrors
	Audible turn signals
	Side strobe lights

the bus is pulling into a bus stop, the pedestrian's location and behavior varies: he or she might be waiting at the stop, crossing the road and arriving at the stop, or walking along the road or sidewalk near the stop. Figure 1-3 illustrates an example of this collision type.

1.3.1 Contributing Factors to Collisions with Pedestrians When Pulling into Bus Stops

This section presents and discusses a variety of factors that may contribute to collisions with pedestrians when buses are pulling into bus stops. The list is by no means exhaustive and is presented here simply as a discussion of what appear to be the most probable contributing factors, based on the experience and expert opinions of the transit agencies and stakeholders who provided input to the development of this Guidebook.

1.3.1.1 Crowded Bus Stop Locations

The primary contributing factor reported for collisions with pedestrians when pulling into bus stops was crowded bus stops due to

- A large demand for the bus,
- Limited sidewalk space, and
- Sidewalk obstacles.

Crowded bus stop locations can lead to various problems, including

- Pedestrians standing too close to the roadway as the bus arrives at the stop,
- Pedestrians pushing as the bus arrives at the stop, or
- Conflicts between intending passengers and passing pedestrians.

All of these situations can result in a pedestrian accidentally making contact with a bus in or near the roadway as the bus is pulling into the stop.

Figure 1-3. Illustration of Collision Type 3—collision between pedestrian and bus pulling into bus stop.

1.3.1.2 Lack of Visibility of Pedestrians at Bus Stops

Lack of visibility of pedestrians at bus stops is a problem that can be caused by a number of issues including

- Limited or no lighting, and
- Obstructions (e.g., wide columns, traffic signals, and signs) limiting an operator's view of pedestrians.

1.3.1.3 Bus Stop Placement

The location of a bus stop relative to the roadway may play a role in some collisions when buses are pulling into a bus stop:

- A bus stop that is located too close to the roadway provides no positive separation between pedestrians and passing vehicles.
- A bus stop that is set back too far from the roadway for the pedestrian to be seen by an approaching bus operator may lead the pedestrian to encroach into the roadway to be more visible.

1.3.2 Strategies for Mitigating Collision with Pedestrians When Pulling into Bus Stops

Table 1-4 presents strategies and specific applications of the strategies that have been implemented by one or more transit agencies or stakeholders. These applications could help mitigate collisions with pedestrians when buses are pulling into bus stops. For more detail on each application, refer to the corresponding section in Part 2.

In addition to the strategies listed in Table 1-4, transit agencies and stakeholders provided suggestions that, in their opinions, might be ways to mitigate collisions with pedestrians when buses are pulling into bus stops. Most of these strategies included creating "safe zones" for pedestrians. These suggestions included the following:

Table 1-4. Strategies for mitigating collisions with pedestrians when pulling into bus stops.

Strategy	Application
Operator outreach	"No trash on the dash" campaign
Defensive driving techniques and policies	Operator moves in seat to see around obstructions
	Operator keeps eyes moving
Public outreach and education	Stay alert around buses and trains campaign
Roadway design	Bulb-outs
Bus mirror configuration and placement	Dual mirrors in single housing
	Smaller mirrors
Bus design/modification	Side strobe lights
Bus stop location planning and bus stop design	Monitoring, relocation, and removal of bus stops
	Bollards, barriers, and striping
	Standee lines at bus stops
Bus stop lighting and illumination	Retro-reflective paddles
	Flashing beacons
	Retro-reflective bus stop signs
	Solar-powered shelter lights
	Pocket and pen lights

- Install pedestrian channelization to funnel pedestrians to safe and visible locations in which to wait for the bus.
- Install pedestrian channelization at crowded stops to prevent pedestrians from falling or being pushed into the roadway when a bus is pulling into the stop.
- Install bus nubs to give pedestrians a place to wait for the bus and to make them more visible to operators.
- After consulting ADA standards and guidelines, install tactile strips at curbs to keep pedestrians from standing too close to the roadway.
- Install painted bus "pads" to delineate where a bus will stop and where passengers should wait.
- Use video supervision at bus stops where pedestrians crowding, pushing, or roughhousing is known to be a problem.
- Keep sidewalks and bus stops free from obstructions to improve an operator's line of sight to pedestrians and to reduce objects that pedestrians can run into or trip over.

1.4 Collision Type 4: Bus Pulling Away from Bus Stops

Collision Type 4 occurs when a bus is pulling away from a bus stop and a pedestrian is struck. Of the incident reports reviewed, 16 (10%) occurred when the bus was pulling away from a stop.

By far the most common circumstance of this collision is when a pedestrian is running after the bus after it has already pulled away from the curb and the pedestrian, who is running alongside the bus, trips and falls under the bus (Figure 1-4). However, a few stakeholders reported a variation of this collision type, which involves a pedestrian crossing the roadway in front of the bus as the bus is pulling away from the curb (Figure 1-5).

1.4.1 Contributing Factors to Collisions with Pedestrians When Pulling Away from Bus Stops

This section presents and discusses a variety of factors that may contribute to collisions with pedestrians when buses are pulling away from bus stops. The list is by no means exhaustive and is presented here simply as a discussion of what appear to be the most probable contributing factors, based on the experience and expert opinions of the transit agencies and stakeholders who provided input to the development of this Guidebook.

Figure 1-4. Illustration of Collision Type 4—collision with pedestrian running alongside bus when pulling away from a bus stop.

Figure 1-5. Illustration of Collision Type 4—collision with pedestrian crossing in front of bus when pulling away from a bus stop.

1.4.1.1 Pedestrians Chasing Buses

One causative factor for this collision type is pedestrians chasing buses after they have left the bus stop. Pedestrians are often times running late, rushing, and unwilling to wait for the next bus. When pedestrians chase after buses, they are usually trying to get the bus operator's attention and will sometimes even tap on the side of the bus.

1.4.1.2 Lack of Information about Bus Arrivals

In some cases, pedestrians may choose to run after a bus because they are unaware of when the next bus will arrive (they may not be familiar with the schedule, they may think the next bus will be running behind schedule, etc.).

1.4.1.3 Visibility of Pedestrians at Bus Stop

Sometimes, this collision type is influenced by the difficulty of seeing pedestrians along the side of the road, especially at night. This could be because of the poor design of the bus stop or roadway influencing overall visibility of pedestrians, including poor bus stop location relative to the edge of the roadway and overall visibility of pedestrians.

1.4.1.4 Attention to Vehicular Traffic

At some bus stop locations, bus operators must merge into the traffic when departing a stop. In the case of some collisions, it is possible that the operator focuses on finding a gap in traffic, and not enough attention is paid to pedestrians who are approaching the bus along the right side.

1.4.1.5 Sidewalk Obstacles and Maintenance

When pedestrians are running for the bus, objects in the bus stop area (such as trash dispensers and signs) become obstacles that when hit, can "push" pedestrians into the roadway. Likewise, poorly maintained sidewalks (e.g., uneven sidewalks, cracks) can cause pedestrians to trip and fall, especially when pedestrians are chasing a bus.

Table 1-5. Strategies for mitigating collisions with pedestrians when pulling away from bus stops

Strategy	Application
Operator training	Service stop exit procedure
	No stopping after closing door
Public outreach and education	Bus safety campaign
	Pamphlets about not running after the bus
Bus mirror configuration and placement	Right convex mirror(s)
	Larger, wider mirrors mounted higher
Bus design/modification	Bus curb lights
	S1-GARD
Bus stop location planning and bus stop design	Far-side bus stops
	Bollards, barriers, and striping

1.4.2 Strategies for Mitigating Collisions with Pedestrians When Pulling Away from Bus Stops

Table 1-5 presents strategies and applications of the strategies that have been implemented by one or more transit agencies or stakeholders. These applications could help mitigate collisions with pedestrians when pulling away from bus stops. For more detail on each application, refer to the corresponding section in Part 2.

In addition to the strategies listed in Table 1-5, transit agencies and stakeholders provided suggestions that, in their opinions, might be ways to mitigate collisions with pedestrians when pulling away from bus stops. These suggestions included the following:

- Through public outreach campaigns, educate pedestrians about the specific dangers of running after buses.
- Install tactile strips on the sidewalk to keep pedestrians from running too close to the roadway.
- Maintain sidewalks and keep them free of obstructions.
- Install route number displays on the back of buses to provide information to riders that might stop them from running after a bus. An intending passenger may run after a bus thinking it is theirs, when it actually is not. Route number displays on the back of buses could help in this situation.
- Install route number displays and countdown timers on the back of buses to provide information to riders that might stop them from running after a bus. An intending passenger may run after a bus not knowing when the next bus will arrive, when in fact, the next bus may be only a few minutes away. Countdown times, displaying real-time bus arrival information could help in this situation. (It should be noted that real-time bus arrival information in some cases might also encourage pedestrians to run after the bus if they realize the next bus isn't for some time.)

PART 2

Applications of Strategies for Mitigating Bus-and-Pedestrian Collisions

The purpose of this section of the Guidebook is to guide the reader to specific applications of strategies. Eleven strategies were identified for the purposes of this Guidebook and are shown in the index table (Table 2-1).

For detailed information about applications of each strategy, refer to the section numbers listed in the table. Details of the applications were reported by transit agencies and stakeholders and include the following information:

- **Purpose**—The reason or objective for implementing the strategy/application.
- **Description**—A brief description of the application.
- **Effectiveness**—Reported effectiveness of the application. Reported in terms of a subjective rating or other comment regarding the effectiveness of success of an application. As the strategies are rarely evaluated empirically and in the absence of quantitative measures of effectiveness such as collision rates, these subjective ratings and comments could be thought of as surrogate measures of effectiveness. Agencies and stakeholders were asked to report the "effectiveness" or "success" of their applications in terms of
  - Reducing the frequency of bus-and-pedestrian collisions,
  - Reducing the severity of bus-and-pedestrian collisions,
  - Reducing claims,
  - Gaining bus operator acceptance, and
  - Gaining public acceptance.

Ratings were reported on a scale of 1 to 5 (with 1 being "very unsuccessful" and 5 being "very successful") or on a scale of 1 to 5 (with 1 being "very ineffective" and 5 being "very effective").

2.1 Strategy 1: Operator Training

Properly trained and qualified transit bus operators are vital to providing safe transit bus services. Training is the only means of ensuring that bus operators obtain safe driving skills. Training provides an opportunity to convey to the operator the characteristics of bus-and-pedestrian collisions as well as the knowledge to identify and to avoid, through defensive-driving techniques, bus-and-pedestrian conflicts that may result in a collision. As such, training is a critical component to mitigating bus-and-pedestrian collisions.

To be most effective, operator training must be closely coordinated with bus operations, risk/claims management, and safety staff. Risk management provides the accident statistics and claims costs associated with bus-and-pedestrian collisions. Safety provides information regarding the causal factors of bus-and-pedestrian collisions and the defensive-driving techniques to avoid collisions. The operations department provides input into the nature of the bus-and-pedestrian problem and the availability of operators for training.

Table 2-1. Strategies (index table for Part 2).

Strategy Number	Strategy	Section
1	Operator Training	2.1
2	Operator Outreach	2.2
3	Safety Checks	2.3
4	Defensive-Driving Techniques and Policies	2.4
5	Public Outreach and Education	2.5
6	Traffic Engineering and Roadway Design	2.6
7	Bus Mirror Configuration and Placement	2.7
8	Bus Design/Modification	2.8
9	Bus Stop Location Planning and Bus Stop Design	2.9
10	Bus Stop Lighting and Illumination	2.10
11	Other	2.11

The cost of new-hire training is largely dependent on the number of training sessions conducted annually and the number of students per session. The cost is relatively moderate as wages for new hires during the training period are less than that while working as a permanent employee. For many transit agencies, refresher training in a classroom setting is considered to be high cost—usually in excess of $150,000 annually—due to the need to compensate operators for their time in the classroom and the cost of replacing the operator on their scheduled work or for conducting the training on overtime.

The use of specialized training aids permit training on specific areas of concern, including pedestrian safety. While the addition of a pedestrian training module into current curricula contributes little additional expense to the overall training session, training aids such as driver simulators may contribute significant additional costs (e.g., $200,000 for a simulator and $180,000 for six operator assessment seats).

2.1.1 Applications of Operator Training

In discussing applications of operator training to mitigate bus-and-pedestrian collisions, transit agencies reported a variety of applications. While all transit agencies conduct some sort of new-hire and refresher training, the range of instruction specific to bus-and-pedestrian collisions varies. Some of the training applications reported were somewhat general in that they were implemented to improve overall safety, including pedestrian safety. Some agencies reported new-hire or refresher training programs, which incorporate a pedestrian safety module. There were some operator training applications that were implemented specifically in response to bus-and-pedestrian collisions that had occurred. Most agencies that had specific programs with regard to bus-and-pedestrian collisions reported operator training to be highly effective in reducing the occurrence, severity, and costs of these collisions.

Specific applications of operator training, as reported by agencies, are shown in Table 2-2.

2.1.2 Suggested Applications of Operator Training

Beyond the specific applications of operator training shown in Table 2-2, one transit agency suggested another application of operator training that may mitigate bus-and-pedestrian collisions:

- Better familiarize bus operators with the routes they drive. This familiarization can be accomplished during different types of training. In the classroom, the operators can be

Table 2-2. Applications of operator training.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
Instructional turning video	To reduce turning collisions with pedestrians	A turning procedure training video developed following a series of pedestrian collisions involving turns. Video illustrates a newly developed turning procedure. All operators were shown the video. Video was subsequently incorporated into the overall training program. See further details in Section 3.1.1.	• Very successful • ~85% drop in bus-and-pedestrian collisions • Ratings: – 4.5 to 5 for reducing collisions – 4.5 for reducing claims
	To show operators how to properly make a left turn and to recognize how busy the intersection is	A left-turn training video developed in response to a spike in left-turn pedestrian collisions at an intersection. Is an over-the-shoulder view of an operator making proper left-hand turns (pedestrians were not involved in the videos). There is also a diagram showing the movement of a vehicle making a left turn. See further details in Section 3.2.1.	• Rated a 4 for reducing collisions • While there have been no statistical analysis, agency has seen a reduction of collisions at that sight
	To focus on blind spots encountered during turns	A 6-minute instructional turning video produced to show operators the importance of bobbing and weaving and to be aware of pedestrians. Has been shown over a 3-day period in the operators' room four times since 2000. An instructor is also present to answer questions. See further details in Section 3.2.1.	Ratings: – 4 for initial success – 2 (6 years later) as it has lost operators' attention
	To communicate to bus operators the need for extra caution during right and left turns	An operator safety training video produced in response to a finding that left turns were the primary type of bus-and-pedestrian collisions in the state. Right turns were later included in the video because a neighboring state found that right turns were more problematic. See further details in Section 3.2.1.	• Decline in bus-and-pedestrian collisions, but may not be linked to video • Very positive feedback from member agencies • Operators have reported finding the tips on the video helpful
Pedestrian safety elements of new-hire and refresher training	To emphasize elements of pedestrian safety	Examples include • Driving with instructor through worst pedestrian areas and put in difficult conditions (e.g., sun glare). • Director of Risk Management spends 3 hours discussing collisions, including a review of all bus-and-pedestrian collisions within the last few years. • Emphasizing monetary cost of bus-and-pedestrian collisions to the agency in terms of claims. • Reminding operators that a collision victim could be a family member. See further details in Section 3.1.4.	• Successful, since high pedestrian exposure but low rate of collisions • Operators take safety message more seriously when they understand the huge costs associated with settlements
Pedestrian safety training module	To improve defensive driving around pedestrians, help operators overcome blind spots, and safely exit from service stops	2.5-hour defensive-driving module focused on pedestrian safety. Includes blind spot demonstration training and a service stop exit procedure. See further details in Section 3.1.2.	Operators find it eye-opening and fun
Pedestrian-focused refresher training	• To improve the overall safety of bus operations • To raise the awareness of operators when it comes to addressing traffic safety, pedestrians and operator alertness • To reinforces standard operating procedures	A full-day training course developed with input from bus operators, superintendents, street supervisors, transit police, safety department staff, and the local DOT. The course combines classroom training with a field trip to a top pedestrian accident location to raise awareness and give operators a pedestrian's perspective. Allows operators to observe the behavior of pedestrians, bicyclists, and motorists. A worksheet is used to tally certain behaviors such as jaywalking, pedestrians standing on the curb, reckless drivers, etc. See further details in Section 3.1.3.3.	This is a new program
Pedestrian collision training	To educate operators about bus-and-pedestrian collisions and how to avoid them	1.5 hours during training, which focus on bus-and-pedestrian collisions. Covers the details of pedestrian collisions at terminals and intersections and how to overcome blind spots. Training gets into graphic details of previous bus-and-pedestrian collisions.	• Believes successful; no bus-and-pedestrian collision in 3.5 years • Some operators get upset by graphic nature of training – Ratings: – 5 for successfulness – 5 for operator acceptance. Experienced operators appreciate learning that they may not have their mirrors properly adjusted
Mirror adjustment training station	To help operators determine whether mirrors are properly set and to teach them to adjust mirrors in order to see cones	Established a mirror station in the agency's transit center. When bus is parked in a certain location, the operator should be able to see all the traffic cones. This was incorporated into new hire training. Takes 1 day for mirror adjusting.	
Simulator training	To put operators in a more realistic setting and to measure operator feedback	• The package that comes with the simulator contains about 12 different scenarios involving pedestrians. Custom scenarios can be built to match actual collisions. Driver assessment seats are used to measure driver reaction time before hiring.	• Too early to rate effectiveness • Rated a 5 on operator acceptance

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

shown photos or videos of the routes that identify points of confusion, hazards, or safety concerns. During on-the-road training, trainers can also point out these locations to operators. Then, operators can be told how to approach these situations in a defensive manner. The advantage of this type of training and familiarization is that operators are made aware of potential problem areas before they start driving a route rather than having to discover them during one of their runs. It will train them to be more defensive in situations that are already known to be potentially hazardous.

2.2 Strategy 2: Operator Outreach

Communicating safety messages to operators in an ongoing manner is an important component of an effective pedestrian safety program. One source reported that at their agency, pedestrian fatalities tend to occur in cycles. Immediately following a pedestrian fatality, everyone at the agency is extremely sensitive to the issue of pedestrian safety; however, over time they tend to relax. Therefore, it is important for agencies to search for ideas and ways to always keep the impacts of a pedestrian collision in the forefront of their minds and in the minds of operators.

Operator outreach is typically coupled with other strategies, such as training. Operator outreach techniques are used as a means to maintain operator awareness; however, their effectiveness, as a strategy in and of themselves, is not well known. To increase the potential for success, agencies recommend that messages be succinct, engaging, and something that will get operators talking about pedestrian safety. They suggest communicating the messages to operators through outreach campaigns; decals; flyers, signs, and bulletins; radio broadcasts; and safety meetings. Agencies recommend posting messages where operators are likely to see them—in the operators' room, restroom, on-board the bus, or broadcasting messages over the radio or by text message.

Transit agencies reported relatively low costs (less than $2,000) for decals, bulletins, posters, and other printed materials. However, the costs begin to rise significantly for applications that entail safety meetings as operators are frequently compensated for attendance. Because of their relative low cost, any potential reduction in bus-and-pedestrian collisions is viewed as a return on investment.

2.2.1 Applications of Operator Outreach

Specific applications of operator outreach, as reported by agencies, are shown in Table 2-3.

2.3 Strategy 3: Safety Checks

Safety checks are an approach to pedestrian safety that include observing bus operator behavior to determine whether the operator is acting according to operating procedure, according to policy, or in a manner that is believed to be safe. In some cases, safety checks occur on-board the bus (with or without the operators' awareness). In other cases, safety checks occur from the roadway, generally unbeknownst to the operators. Consequences of a failed safety check vary, but can include speaking with the operators about their behavior, required follow-up training, or a warning system that results in termination if the behavior is not corrected.

Safety checks can be an effective means of mitigating all bus-and-pedestrian collision types. Several agencies noted that they use safety checks as a way specifically to prevent the occurrence of bus-and-pedestrian collisions.

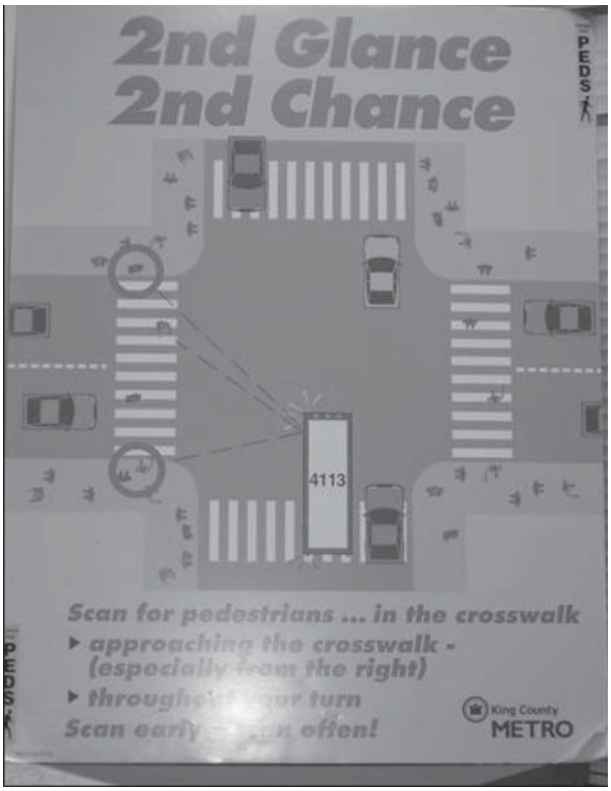
Table 2-3. Applications of operator outreach.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
"No trash on the dash" campaign	To reduce personal and other items from dash that could be obstructing operators' views of pedestrians	Message posted on LED boards in operator cruise room and on a portable message sign on the driveway from the transit station. Explained why it was important to keep the windshield clear of obstructions. Operators called in for 15 minutes of instruction with an instructor. Were told they would be monitored, and if they were seen to have anything on the dash, they would get a warning. Any subsequent incidents would result in formal discipline.	• It was effective as they don't really have a problem with this anymore, but didn't eliminate pedestrian accidents. • Rated a 4 for operator acceptance. The operators took it seriously because it was run for awhile.
Pedestrian safety campaign for contra-flow lanes	To change bus operator behavior in the areas of the dedicated contraflow bus lanes	Dedicated contra-flow bus lanes increased the occurrence of bus-and-pedestrian collisions and near-misses. Agency carried out a heavy campaign to change bus operator behavior. The campaign instructed bus operators to go slowly and to use their horns. The messages were communicated to the operators' in their route information and text messages.	The campaign was rated as very effective.
"Watch for pedestrians" decals on telephone/radio handsets (see Figure 2-1)	To remind operators to look for pedestrians when turning left	Yellow sticker with the words "Watch for Pedestrians" and a figure of person. Black lettering and a yellow background. Placed on the back of black handsets, which are located on left. Done following a pedestrian collision when making a left turn At one agency, two different sizes were used: 6⅛ × 1 in. and 3½ x 1 in., for two different size handsets for bus radios.	• Ratings: – 4 for reducing collisions – 4 for operator acceptance (some thought they were visually distracting) • There was a reported novelty effect Rated a 3–4 for operator acceptance (they were reportedly more effective when they were brand new)
"Watch for pedestrians" sticker on farebox	To remind operators to look for pedestrians when turning right	Stickers were placed on all fareboxes in conjunction with the agency's new video and special training on operator turning procedures.	Not reported
Posted signs of most dangerous intersections	To make operators aware of the most dangerous intersections and the routes that go through them	Annually posts signs of top 10 most dangerous local intersections. Information on which routes go through those intersections is included.	Not reported
Posted collision location map	To make operators aware of past collision locations	Annually post map with bus accident locations over past year for operators.	Not reported
Themed safety outreach slogans	To communicate important safety messages to operators and to saturate them with the messages	Over a 12-week period, the agency posted flyers inside each restroom stall (a.k.a., "outhouse journal"). A different flyer was placed in each stall. Banners and posters were also hung. Messages that focused on pedestrian safety included "Track them once. Track them twice." and "Second Glance. Second Chance." (see Figure 2-2). The idea behind these slogans was that, before the intersection, operators should be scanning for people who may want to cross and then upon entering the intersection, they should look to see where each of those pedestrians went.	Operators notice the signs and appreciate the reminders, but behavior is not likely changed with flyers once a week. By saturating the operators with safety messages, agency hopes that change will occur.
Radio broadcast of safety messages Safety flyers, bulletins, signs, general notices	To keep operators alert to safety issues To communicate important safety messages to operators	Safety messages broadcast over operators' radio 4 to 5 times a day. Examples: "Raining, watch your speed" or "Parade in this location, watch for pedestrians." • Posters, flyers, bulletins, and signs usually posted in operators' areas. Examples: • Tri-fold brochure, "Pedestrian safety tips all operators should know" • Signs and photos with detailed information about recent collisions and preventative recommendations • Bulletins reminding operators to be aware of pedestrians crossing the street • Notices of important rules to follow such as yielding to pedestrians, operating in congested areas, and clearing off the dash board. The rules are enforced by road supervisors who monitor operators. There are consequences when operators are caught not following the rules.	Not reported • Operators become accustomed to messages and no longer pay attention • Not all operators go into operators' room, so they miss signs • With saturation, may change behavior
Safety meetings with operators	To communicate important safety messages to operators	• Focus on preventing accidents at meetings. These meetings can include everyone in the agency or just the safety department and bus operators and can be held monthly, quarterly, or semi-annually. Examples: • Monthly between safety department and bus operators. • Twice a year with everyone in organization	Operators can give safety suggestions to safety department about things such as mirror placement.

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

Source: Cincinnati Metro

Figure 2-1. Watch for Pedestrians decal.



Source: King County Metro

Figure 2-2. Second Glance, Second Chance poster.

The cost for check rides generally ranges from low to moderately high. If in-house transit staff is used, the check rides only incur fixed labor costs. Costs rise moderately if the checks are performed by staff on overtime. Use of a contracted service to perform checks raises costs significantly. One very large transit agency reported an annual cost of $120,000 for its safety checks.

2.3.1 Applications of Safety Checks

Specific applications of safety checks, as reported by agencies, are shown in Table 2-4.

2.4 Strategy 4: Defensive-Driving Techniques and Policies

Defensive-driving techniques and policies can be developed in an attempt to mitigate the future occurrence of specific types of collisions, such as collisions with pedestrians. To be most effective, bus operators must apply the techniques with knowledge, judgment, and skill; therefore, operating techniques and policies are typically implemented as part of an operator training program, during both new-hire and refresher training.

When carried out as part of new-hire and refresher training, the cost of implementing specific operating techniques is relatively low as it is only one of several components of the training program. The cost of informing operators of a new or revised policy is also low as it may be as simple as issuing the information through bulletins. The cost, however, can be high if the techniques/policies are implemented outside of the usual operator training cycle or if operator meetings are required.

Table 2-4. Applications of safety checks.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
Bus safety ride checks	To improve safety through operator behavior	Evaluator rides on bus and observes behavior	Not reported
On-street safety checks	To improve safety through operator behavior	On street, supervisor watches for operator violations	Not reported
Safety audits	To improve safety through operator behavior	Safety audits conducted by committee of operators and supervisors. Stand on street corner to observe driver compliance with rules and procedures. Results are anonymous.	Not reported
Speed checks	To improve safety through operator behavior	Speed checks using radar gun	Not reported
Undercover safety observations	To improve safety through operator behavior	A member of the safety department rides the bus during a one-way trip and makes a complete observation of performance. If the results are negative, the operator may receive disciplinary action or retraining. Two types of observations: a random ride and a ride request. If someone is reported as having fatigue problems, the observer makes two rides within 72 hours to monitor safety as well as fatigue.	• Rated a 3 for effectiveness • Requires large amount of staff time and only get a partial picture of driver safety • Observations are complex to set up and administer

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

2.4.1 Applications of Defensive-Driving Techniques and Policies

Several agencies reported specific defensive-driving techniques or policies they developed or implemented to manage or control operations in locations where pedestrian safety is critical, such as intersections and service stops. The specific applications of these defensive-driving techniques and policies, as reported by agencies, are shown in Tables 2-5 and 2-6, respectively.

2.5 Strategy 5: Public Outreach and Education

Public outreach and education campaigns are intended to raise awareness of issues and perhaps to change even attitudes and behaviors. A well-designed public education campaign can make a positive impact on public opinion, target specific audiences, and be a cost-effective way of providing critical information to a large number of people. To be successful, campaigns should (*2*)

- Convey a compelling statement;
- Create urgency about the problem;
- Emphasize a local impact of the problem;
- Identify opponents;
- Propose concrete, easily understandable solutions (ideally expressed in one sentence); and
- Urge a specific action.

A successful outreach campaign begins with clear, realistic, and measurable goals. Campaigns should focus on ultimate outcomes rather than on intermediate objectives. They should not try to change entrenched attitudes in a short time period or with too few resources. Campaigns should proceed in steps or phases, and each phase should lay out a mechanism that leads to the desired effect. Staffers should set forth a causal link, showing how the results are likely to be achieved (*2*).

In collaboration with national and local pedestrian safety advocates, FHWA created the Pedestrian Safety Campaign Planner to educate pedestrians and operators about ways to improve pedestrian safety (*3*). The Pedestrian Safety Campaign materials included in the kit are research-tested and designed for use by any organization to promote pedestrian safety. For more

Table 2-5. Applications of defensive-driving techniques.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
Operator covers brake with foot when approaching crosswalk	To be able to react quickly to pedestrians entering the roadway	Operator covers brake with foot when approaching a crosswalk.	Not reported
Operator moves in seat to see around obstructions	To overcome limitations due to blind spots	Bob-and-weave technique—operator bobs and weaves in seat to see around obstructions	• Not effective for a short operator • Repetitive bobbing and weaving may damage operator's back and neck
		Rock-and-roll technique—before operator rolls, he/she rocks in seat to see around obstructions	Not reported
		Lean left–or–forward technique—operator leans left or forward in seat to see around obstructions	Leaning forward is effective for tall operators. Leaning left is effective for short operators.
Service stop exit procedure	To improve exits from service stops	Part of 2.5-hour safety module. Referred to as "checking left-right-left" before exiting service stop. See further details in Section 3.1.2.	Not reported
Mandatory turning procedure	To reduce turning collisions with pedestrians	Procedure was developed in response to a series of pedestrian collisions during turns. Procedure is critical when the bus is the first vehicle in line at a red light. Requires operators to stop at STOP bar or 6 feet before crosswalk. Requires continual scanning of the intersection and a 2-second wait before entering the intersection after the light turns green. Operators must re-scan crosswalk before completing turn. See further details in Section 3.1.1.	• Very effective • 75–80% drop in bus-and-pedestrian collisions. • Ratings: – 4.5 to 5 for reducing collisions – 4.5 for reducing claims
Square left turns	To put the crosswalk in front of the operators and get them out from behind the A-pillar	The advantage of the square left turns are that the driver only crosses through one lane width of the crosswalk and the crosswalk is in the operator's forward vision instead of off to the left as the driver goes through the crosswalk. If a driver makes an early turn or lazy left turn, the bus crosses through two lanes of traffic and a larger portion of the crosswalk.	• Tends to minimize the risk of striking pedestrians during a turn • Takes toll on operator's body, increases disability rates • Can cause those on-board to fall • Can be misleading to other operators
Operator keeps eyes moving	To teach operators to get the "big picture" by looking at the whole environment	Avoid the fixed stare. Keep moving eyes. Constantly sweep and periodically look at mirrors. Maintain a high eye level—don't focus on the tailgate of the car in front. Make sure that pedestrians see you.	Not reported

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

Table 2-6. Applications of policies.

Application	Purpose	Description	*Subjective Ratings and Other Comments on Effectiveness
Slow down at intersections	To increase safe operations around pedestrians	Operators must slow down when approaching an intersection.	Not reported
Stop at yellow lights	To increase safe operations around pedestrians	Operators must stop at yellow lights at signalized intersections.	Not reported
No right turn on red	To increase safe operations around pedestrians	Bus operators not allowed to make a right turn at a red light at an intersection where there is a near-side bus stop as pedestrians are likely to be crossing in front of the bus.	Not reported
No stopping after closing door	To increase safe operations around pedestrians	Bus operators are instructed not to stop to pick up passengers after closing the door. However, agency gives operators flexibility with the rule.	• There are customer service ramifications. If not in middle of traffic, operator will open door. Not very practical • Not effective as operators will not follow policy because of relationships with passengers
Written Standard Operating Procedures (SOP) regarding pedestrians	To help prevent collisions with pedestrians	Operators are trained on a written SOP, which includes a section that deals specifically with preventing pedestrian accidents. Procedures include what to do when pedestrians are ahead, behind, or alongside the bus as well as when they are alighting. SOP gives operators definite guidance on driving safely and defensively.	• Believes it is effective in reducing collisions • Rated a 4 or 5 on operator acceptance

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

information about the Pedestrian Safety Campaign materials visit safety.fhwa.dot.gov/local_program/pedcampaign/guide.htm#4.

During the research conducted for this Guidebook, stakeholders suggested that, to be successful, campaigns should focus on conveying one message (as opposed to multiple messages), campaigns directed toward pedestrians should be clever, and the message should come directly from the transit agency. In addition, it was suggested by pedestrians that the messages be accompanied with incentives for change from the transit agency as a "give and take." For example, if the transit agency asks for a change in attitude or behavior from its riders, the agency should offer something in exchange that will benefit the riders such as increased lighting at poorly lighted shelters, the idea being that the riders are more likely to change their behaviors if they feel they are getting something in return from the agency.

When correctly designed and implemented, public outreach and education has the potential of reducing all collision types. To be most effective, outreach and education should be implemented in close coordination with local DOTs, pedestrian advocacy groups, schools, and others having an interest in pedestrian safety. Many of the transit agencies surveyed reported great acceptance of the education programs by the public. It is important to remember that the most effective campaigns are ongoing and an integral part of an overall pedestrian safety program. The costs of many outreach and education campaigns are considered low, but can be moderately costly for professional production of digital videos or public service announcements.

2.5.1 Applications of Public Outreach and Education

Several agencies reported specific campaigns they have implemented, while others reported more general information about public outreach and education. Specific applications of public outreach and education, as reported by agencies and stakeholders, are shown in Table 2-7.

2.5.2 Suggested Applications of Public Outreach and Education

Beyond the specific applications of public outreach and education shown in Table 2-7, transit agencies and stakeholders offered a variety of suggested or proposed applications of public outreach and education that might help mitigate collisions with pedestrians. These ideas included educating the public about the following:

- Blind spots on buses and how they might impact pedestrian safety;
- Mechanics of the turning bus and what pedestrians should be aware of in areas where buses are turning; and
- How to catch a bus (e.g., be ready to board to help with schedule, be aware that the bus cannot stop on a dime, be at a bus stop or the bus will not pick you up).

Other suggestions included

- Conduct campaigns in combination with enforcement "stings" in order to invoke change,
- Place a reminder on the back of day passes not to run after the bus, and
- Broadcast the campaign messages via video at stops and transit buildings.

2.6 Strategy 6: Traffic Engineering and Roadway Design

There are a wide variety of ways in which traffic engineering and roadway design can be applied to improve safety. Traffic engineering applications include traffic signalization techniques (e.g., traffic-signal phasing); signage; roadway markings; and physical devices (e.g., bol-

Table 2-7. Applications of public outreach and education.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
"Look again" campaign	To increase pedestrian awareness of buses	Posters put on the outsides of buses.	One source reportedly as ineffective because agency did not partner with others
Bus safety campaign	To warn pedestrians about dangers of running after the bus, stepping in front of bus, etc.	Message signs will be printed to be a reminder of the danger in chasing buses or trains for both operators and pedestrians. Examples of messages are "Stay Safe, Don't Chase" and "Don't Run, There is Another One" (see Figure 2-3).	Not reported
Pamphlets about not running after bus	To warn pedestrians about dangers of running after the bus	Passed out pamphlets on the bus to riders.	Reported to be a reasonably good program
Stay alert around buses and trains campaign	To increase pedestrian awareness of buses	Billboards, bus back signs, interior bus signs, monthly newsletters with message on staying alert around buses and trains.	Not reported
Transit 101	To educate college students about bus safety	Transit 101 is a 1-hour presentation given by the local transit agency to incoming freshmen. The presentation focuses on how to safely use the system and brings students' attention to the pitfalls of the use of cell phones and portable music players, as well as the need for students to be aware of their surroundings when walking. As some of the students have never taken a bus prior to coming onto campus, the manager of operations instructs the students to board the bus at designated stops and what to do when getting off the bus.	• Ratings: – 5 for reducing collisions – 5 for reducing severity – 4 for reducing near misses • Students make up 70% of ridership, yet collisions are mainly with non-students and no collisions on campus • One of the most popular classes offered during fall orientation (usually about 200 students)
Public outreach to schools	To talk about safety to students	Agency staff goes to schools to explain that a bus does not behave in the same way as an automobile (different turning radius, the back end has a pivot point, longer stopping time). Agency educates students about transit safety in an interactive manner. They emphasize that transit buses are different than school buses and that with the transit buses you have to cross in back. Afterwards, the teachers have the kids send drawings as thank-you notes. They also have the schools put bus rider safety flyers in the school papers.	• Rated as 3–4 on public acceptance • Children are very receptive
Public outreach videos	To educate public on pedestrian safety issues around buses	Professionally developed videos focused on a number of pedestrian safety issues. One video focused on dangers and consequences of not being aware of a bus that is turning.	Very effective
Blinking red safety lights	To provide a signal light for early morning and late-night bus users going to and from bus stops	Bus operators distributed 3,000 blinking red safety lights to bus riders on routes throughout the system. The battery-operated lights are about the size of a campaign button with the message "Look Before You Cross" and can be clipped to jackets or other clothing.	Not reported

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

lards, channelization). Roadway design applications generally relate to geometric elements of the roadway and roadside.

The goal of applying traffic engineering and roadway design bus–pedestrian safety is to reduce the potential conflicts between buses and pedestrians by providing separation between the two modes. Buses and pedestrians can be separated physically by, roadway elements (e.g., curbs, refuge medians); devices (e.g., bollards, fences); structural elements (e.g., bridges, tunnels); and the use of aesthetics (e.g., shrubbery). Separation of buses and pedestrians can also be provided in time by allowing protected movements at different times with traffic-signal phasing. In addition, traffic engineering and roadway design strategies can be used to bring attention of one mode to the other. For example, roadway markings such as crosswalks and signage can be used to warn operators of the presence of pedestrians. Likewise, signs, markings, and even creative geometric design features can be used to warn pedestrians of the presence of buses.

Figure 2-3. Public outreach messages about bus safety.

Local and state roadway traffic engineering and roadway design are usually the responsibility of the transportation section within the local government and state, respectively. The cost of improvements can be minimized when incorporated during the early stages of roadway improvement projects. Implementation costs range from low for signal timing, striping, and traffic signs (no cost to hundreds of dollars); to moderate for special traffic signals and pedestrian channelization treatments (thousands of dollars); to high cost for major geometric treatments such as bulb-outs ($150,000–$250,000 per intersection).

2.6.1 Applications of Traffic Engineering and Roadway Design Strategies

Specific applications of traffic engineering and roadway design strategies, as reported by agencies and stakeholders, are shown in Table 2-8.

2.6.2 Suggested Applications of Traffic Engineering and Roadway Design

Beyond the specific applications of traffic engineering and roadway design shown in Table 2-8, there were a number of traffic engineering and roadway design applications that stakeholders felt might help to mitigate bus-and-pedestrian collisions. These suggestions included traffic signs and signalization techniques, signs and pavement markings, bus nubs, sidewalk improvements, pedestrian channelization, and pedestrian bridges or tunnels. Each of these suggested applications is presented in more detail below.

2.6.2.1 Traffic Signs and Signalization Techniques

Traffic signalization techniques or devices were suggested as strategies for mitigating bus-and-pedestrian collisions. Suggestions included the following:

Table 2-8. Applications of traffic engineering and roadway design.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
Protected left turn signal	To eliminate conflict between left-turn vehicles and crossing pedestrians	Green left-turn arrow for vehicular traffic, indicating that the left-turn movement is protected (i.e., no yielding is required during the left turn).	Rated a 5 in reducing collisions; signal in for over 1 year and no bus-pedestrian collisions (about 3 in that area in the past 20 years)
Pedestrian scramble (see Figure 2-4)	To eliminate conflicts between pedestrians and vehicle traffic by providing a protected pedestrian crossing phase	A traffic signal is timed to provide an all-pedestrian phase, meaning that pedestrians are allowed protected crossing movements in all directions, including diagonally across the intersection.	• Effective in separating movements • Can cause an increase in vehicle delay at the intersection • Could be beneficial at intersections where pedestrians are making transfers
Bulb-outs (see Figure 2-5)	• To make pedestrians waiting for the bus more visible to bus operators • To prevent pedestrians from stepping into the street to get the attention of the operator • To help pedestrians cross street safely	Extensions of the curb/sidewalk into the parking lane in the areas of bus stops (at intersections). They reduce the roadway width and crossing distance for pedestrians. They are used in traffic calming to help reduce traffic speeds. Buses stop in the traffic lane instead of weaving into and out of traffic to access a bus stop located in the parking lane.	Very popular with public
Leading pedestrian interval	To reduce intersection conflicts between pedestrians and turning vehicles	A leading pedestrian interval gives pedestrians the WALK signal 3 seconds before the motorists get the green light.	Has proven highly effective in reducing conflicts with turning vehicles and has been associated with crash reductions
Pedestrian countdown signals (see Figure 2-6)	To give pedestrians a better idea of when they can be in the crosswalk	Pedestrian signal heads that indicate to pedestrians how much time they have to cross the street (indicated by a count-down timer).	Not reported
Shrubbery, fences, and depressions	To separate and demarcate safe spaces for pedestrians	• Between sidewalk and Bus Rapid Transit (BRT) lane.	Not reported

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

- Install a static NO TURN ON RED sign (see Figure 2-7). This sign prohibits vehicles from making right turns when the traffic signal is installed in an effort to reduce potential conflicts between vehicles turning right on red and pedestrians crossing at the intersection.
- Install a dynamic NO RIGHT TURN ON RED sign or NO TURN ON RED sign (see Figure 2-8). This sign is activated either by the pedestrian push button or by automated pedestrian detection (e.g., infrared). When activated, the dynamic traffic sign displays the words

Figure 2-4. Pedestrian scramble—street view (left) and top view (right).

Source: Claude Morelli

Figure 2-5. Intersection bulb-out.

NO TURN ON RED to vehicle operators, prohibiting this maneuver and protecting pedestrians from potential conflicts with turning vehicles. The advantage of the dynamic sign is that operators are permitted to turn right on red when pedestrians are not present.

- Install audible pedestrian crossing signals. The idea behind this application is to alert the driver through the use of an audible tone that would be activated during the pedestrian crossing phase of the signal that a pedestrian may be in the crosswalk.

Figure 2-6. Pedestrian countdown signals.

Figure 2-7. Static NO TURN ON RED sign.

2.6.2.2 Signs and Pavement Markings

There were a number of suggested uses of signs and markings for mitigating bus-and-pedestrian collisions. These suggestions included the following:

- Install enhanced crosswalks for better delineating the crosswalk area for operators.
- Install larger than normal YIELD TO PEDESTRIAN signs at intersections to draw the attention of drivers to pedestrians in the crosswalks.
- Install tactile strips on the edges of sidewalks at bus stops (see Figure 2-9). As tactile strips are uninviting to stand on, they might be used as a "barrier" between buses and

Figure 2-8. Dynamic NO RIGHT TURN ON RED sign.

Figure 2-9. Application of tactile strips at a transit stop.

pedestrians. They may be a potentially effective method for keeping pedestrians away from the edge of the road (e.g., at intersections where buses are turning right) and for reducing the chance of pedestrians slipping and falling under a bus at bus stops and terminals. It is important to consider ADA standards and guidelines if implementing tactile strips.

2.6.2.3 Bus Nubs

Bus nubs were also suggested by several agencies or stakeholders as a possible application for mitigating bus-and-pedestrian collisions. A bus nub is essentially an extended version of a bulb-out to allow placement of the entire length of a bus stop adjacent to the travel lane. The primary motivations for installing bus nubs are to improve transit operations through the elimination of bus-weaving maneuvers into and out of a curbside bus stop and to reduce sidewalk congestion by adding sidewalk space with the bus nub design (*4*). In addition, bus nubs can reduce the crossing distance and time for pedestrians, make it easier for operators to see pedestrians waiting to cross the street or board the bus, slow right-turn movements, and reduce the use of bus pull-out areas for illegal parking. As these goals of nubs hit on several different issues surrounding bus-and-pedestrian collisions, nubs could be an interesting application, which could mitigate a variety of problems associated with bus-and-pedestrian collisions. Other names used for bus nubs include "curb extensions," "bus bulbs," and "bus bulges."

The cost of constructing nubs can range from $15000 to $55000 depending upon drainage needs, utility relocation, construction materials, and patron amenities (*5*). If street drainage systems need to be reconfigured, there is a steel-fabricated nub with a built-in shelter that can be installed over an existing street, allowing runoff to filter underneath; this system can be used to test a nub before a permanent installation is made (*6*).

2.6.2.4 Sidewalk Improvements

Sidewalk improvements were suggested as an application for mitigating bus-and-pedestrian collisions. Specific suggestions included

- Widen sidewalks to provide more space for pedestrians to walk and wait for the bus, reducing or eliminating conflicts between those walking and those waiting;
- Repair sidewalks that are in disrepair (e.g., fixing cracks and holes) to help reduce or eliminate tripping hazards that can cause pedestrians to fall into the roadway; and
- Maintain sidewalks before they fall into a state of disrepair.

2.6.2.5 Pedestrian Channelization

Pedestrian channelization was suggested by multiple agencies and stakeholders as a way to keep pedestrians from standing or crossing in areas where they are more likely to come into contact with buses. These suggestions included the following:

- Use pedestrian channelization at crowded bus stops where there is a problem of pedestrians being struck when buses are pulling into the stop. In this case, channelization can be accomplished through the use of fences, with openings indicating where the bus will stop.
- Use fences at intersection corners or signage (see Figure 2-10) to guide pedestrians to crosswalks and to keep them from entering the street in a place that would be unexpected to a bus operator.

2.6.2.6 Pedestrian Bridges or Tunnels

Pedestrian bridges or tunnels were suggested by pedestrian groups as a way to mitigate bus-and-pedestrian collisions. While grade-separated crossings achieve the goal of physically separating pedestrians from motor vehicles during crossing, pedestrian bridges are notoriously underused and tunnels can be dangerous for pedestrians due to crime and other activities. Therefore, the use of grade-separated crossings should be evaluated on a case-by-case basis and with

Figure 2-10. Applications of pedestrian channelization—fences (left) and signs (right).

input from the public. Agency partnering is also a good idea and can result in a better, more successful product.

2.7 Strategy 7: Bus Mirror Configuration and Placement

Mirrors are a major, ongoing issue for many agencies. Agencies and stakeholders discussed a variety of issues including mirror size, configuration, and placement. Mirrors were frequently reported by agencies, operators, and stakeholders as a contributing factor to bus-and-pedestrian collisions; consequently, specific mirror configurations and placements have been used as strategies for mitigating bus-and-pedestrian collisions. If not properly adjusted or configured in size and shape, mirrors may accentuate blind spots to the rear and to the forward left and right viewing areas. For example, mirrors can obstruct an operator's view of pedestrians in crosswalks during turning maneuvers at intersections or when pulling into a bus stop.

The cost of mirrors ranges greatly and is dependent on their complexity. Simple convex mirrors may be obtained for as little as $20 to $50 per mirror. Dual mirrors in a single housing are typically several hundreds of dollars. Remotely controlled and heated mirrors cost $1,200 or more per mirror. All costs are exclusive of labor. On a per-bus basis, these costs are relatively low; however, costs can be high when outfitting a fleet of buses with new mirrors.

2.7.1 Applications of Bus Mirror Configuration and Placement

Specific applications of bus mirror configuration and placement, as reported by agencies, are shown in Table 2-9.

2.8 Strategy 8: Bus Design/Modification

Beyond the applications associated with the size, configuration, and placement of bus mirrors, there are a number of bus design/modification applications that could help mitigate bus-and-pedestrian collisions, many of which involve installation of lights. It should be noted that modifications must be closely coordinated with the maintenance department and manufacturers to ensure changes do not create additional maintenance issues, nullify warranties, or violate federal or state motor vehicle regulations.

Bus design modification costs can be minimized when incorporated as part of new procurements. Modifications to existing fleets range from several hundreds of dollars for increasing the number of marker lights and LED light strips on the front-top of bus to thousands of dollars for the installation of curbs lights. On-board video systems cost several thousands of dollars, with one transit agency reporting a cost of $12,000 for a six-camera installation on a single bus.

2.8.1 Applications of Bus Design/Modification

Specific applications of bus design/modification, as reported by agencies, are shown in Table 2-10.

2.8.2 Suggested Applications of Bus Design/Modification

Beyond the specific applications of bus design/modification shown in Table 2-10, stakeholders suggested a number of bus design/modification applications that might mitigate bus-and-pedestrian collisions. These suggestions included the following:

- Use low-floor buses to increase visibility.
- Reduce the height of the farebox.

Table 2-9. Applications of bus mirror configuration and placement.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
Dual right-side mirrors	• To eliminate blind spot on right side of bus allowing operator to see tire and actual curb as they are turning • To prevent collisions with stationary objectives, other vehicles, and pedestrians on side of bus	Mirrors consist of one flat mirror on the top and a convex mirror on the bottom. The convex mirror helps the driver to see down the right side of the bus.	Rated a 3 for preventing bus-pedestrian collisions. Agency does not think this is very effective because most of their collisions occur in the front of the bus.
Right convex mirror(s)	• To allow operator to see the entire front bumper • To avoid hitting pedestrians in front of the bus, particularly important if driver sits low in the seat	Convex mirror on right side with a downward slant so as to see the entire front bumper (see Figure 2-11). Motivation for strategy was that in some cases, the operator would claim he/she didn't see the pedestrian in front of the bus, particularly if the pedestrian was short.	• No data, but reported as probably very effective • Rated a 5 for operator acceptance (they complain if they do not have it)
		The mirrors are placed on the right A-pillar, left A-pillar, or roof depending on the bus model. For use when the bus is at a stop and riders are boarding. The farebox and boarding riders can be a major visual obstruction. Began installing the mirrors when began using 41-in. fareboxes.	Some operators have complained that there is a visual overload of mirrors on the buses, and some operators do not like that the mirrors can be in a different locations depending on the bus model.
Dual left-side mirrors placed lower on bus	To reduce blind spot on left side of bus	The dual flat and convex mirrors are on the left side and are separated instead of being housed in one panel with plastic casing. The mirrors are smaller. They give a wider view and are placed lower, below the line of sight.	• Ratings: – 4 for reducing collisions although not long enough to really know – 5 on operator acceptance (they fight to drive buses with prototype mirrors because they like them so much better) • Hope to have the whole fleet retro-fitted for these mirrors within a couple of years
		The dual left-side mirrors are oriented downward to minimize the sight obstruction (see Figure 2-12). The mirrors are placed lower, below the line of sight.	Found to be very effective
Dual mirrors in single housing	To help reduce blind spots	Dual flat and convex mirrors in single housing with flat mirror on top. The mirror angle and height can be controlled by operator from inside using a remote control (see Figure 2-13).	Ratings: • 4 for reducing collisions • 4 for reducing close calls • 3 for reducing claims • 5 for operator acceptance
Larger, wider, mirrors mounted higher	To allow bus operators to see the full range around back of bus	Mirrors were made larger and wider and were mounted higher on the bus.	Not reported
Standardized left-side mirror height	To allow operators to see over the top of the left-side mirror	Standardized mirror height to the average height of the majority of the operators. Safety committee did an assessment of the mirrors and found that the mirrors were at all different heights across their fleet. The operators were moving them based on their individual preferences. The drawback of this strategy is that one height doesn't work for everyone.	Ratings: • 3 for reducing collisions • 3 for reducing severity of collisions • 3 for reducing near misses • 5 for reducing claims • 3 for operator acceptance
Remote controlled mirrors	To allow operators to easily adjust mirrors and to customize for their needs	Mirrors that can be electronically controlled with a remote	Not reported
Left-side mirror placement	To improve sightlines for operators on the left side of bus	New brackets, which are installed for the mirrors on the driver's side of nine Orion V and six double-length, accordion-style buses. The brackets allow operators to adjust the mirrors four inches up or down. On other buses, the left-side mirrors have been lowered. See further details in Section 3.1.3.4.	Currently being tested
Smaller mirrors	To reduce blind spots	Mirrors made smaller.	This is being tested on five coaches and feedback is being solicited from operators. Not getting good reviews from operators

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

Source: New Jersey Transit

Figure 2-11. Convex mirror on right side with downward slant.

- Develop and install a pedestrian detection and warning system for buses. While there are object warning systems in use or under development, their effectiveness in detecting pedestrians is generally thought to be limited. The University of California at Berkeley has developed a collision warning system that would detect pedestrians. It is currently being tested. The system appears to work quite well; however, it is very large.
- Install count-down timers on the front and/or back of buses. The idea behind this strategy is to provide bus riders with better and more accurate bus arrival information. By providing

Source: APTA

Figure 2-12. Dual left-side mirrors oriented downward and placed lower on bus.

Source: New Jersey Transit

Figure 2-13. Dual mirrors in single housing (flat mirror on top).

information about how far away the next bus is, riders may not feel like they need to run to catch the bus. On the other hand, if the next bus is not due to arrive soon, this type of information may actually encourage pedestrians to run for the bus.

- Rotate the A-pillar on both the right and left sides of the bus to reduce the blind spot created by the A-pillar.
- Reduce the size of the A-pillar to approximately 1-in. wide and 2-in. deep to help reduce the blind spot caused by large A-pillars.
- Improve brakes and tires so that buses can stop more effectively.

2.9 Strategy 9: Bus Stop Location Planning and Bus Stop Design

Bus stop location planning and bus stop design applications include selecting a proper location for a stop, relocating a bus stop, designing the bus stop zone, and monitoring stops. The location and design of a bus stop play a role in improving the safety of passengers boarding and alighting buses. A bus stop with insufficient room to accommodate passenger loads may cause a passenger to inadvertently step into the path of an approaching bus. The location of bus stops and the related curb treatments and amenities contribute to bus operations and the safety of passengers.

Bus stops should be designed to minimize crowding and to protect passengers from passing traffic. As bus stops are typically controlled by the local municipality, the placement of—or improvements to—the stops must be coordinated with the appropriate municipal department.

Cost associated with bus stop location planning and bus stop design range from moderately low to high. Relocating a bus stop may incur a series of costs, depending on the location and stop amenities: moving the bus stop sign and shelter (if applicable) and accessibility improvements such as curb cuts and concrete pads for mobility devices. While each of these costs may be

Table 2-10. Applications of bus design/modification.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
Increased number of side marker lamps Blinking chevrons on side mirrors	To provide warning to pedestrians and other drivers that the bus is turning or about to turn To provide warning to pedestrians and other drivers that the bus is turning or about to turn	Added three side marker lamps on the right and left side of the bus (one between the doors and front bumper, one midway down the bus, and one near the rear of the bus). Marker lamps are activated by the turn signal and hazards. Replaced the incandescent lights (only allow 5 candlepower) to LED (effective light is about 20 candlepower) so that it can be seen in the daytime. Added a blinking chevron on the side mirrors, which is activated by the turn signal and hazards.	• Use of LEDs greatly increases illumination of each light over single incandescent bulb while staying within regulation • LEDs last longer than incandescent lights • Do not know effectiveness as only about 12% of fleet has new lights
Audible turn signals	To provide warning to pedestrians and other drivers that the bus is turning or about to turn	Agency tested a version about 5 or 6 years ago that used a backup beeper. Now they are looking at a right-turn voice warning system similar to "bus turning right…bus turning right" that would be activated when the turn signal is activated and when the bus hits a certain degree of turning on the wheel. About 60 decibels is heard. The problem is getting someone to come forward with an audible chip and speaker.	Back-up beeper warning was not effective—people thought the bus was backing up and it was too loud
		Another agency wired a small noise-emitting device on all buses. Noise was about 70 decibels.	Public forced them to take them off as they objected to hearing it go off at 1:00 A.M.
Safety warning strobe light atop buses (see Figure 2-14)	To help pedestrians and other motorists spot buses operating along city streets and to provide additional lighting for early morning and evening bus users	Flashing yellow strobe light on top of buses. See further details in Section 3.1.3.6.	Not implemented due to the following: • Did not conform to state motor vehicle regulations • Residents complained of light being too bright • It was not evident to people where the light was coming from
LED light strip on front-top of bus (see Figure 2-15)	To get the attention of pedestrians and ultimately to improve safety	A LED strip of flashing lights across the front (top) of bus. Unlike the one single strobe light atop buses (as noted in previous application), these lights move back and forth and are meant to increase awareness about the presence of buses when it's dark. See further details in Section 3.1.3.6.	Currently being tested
Side strobe lights (see Figure 2-16)	To indicate to motorists and pedestrians that a bus is making a turn	Two lights are placed on each side of 40-foot buses. Three lights are placed on each side of the articulated buses. Lights are controlled by the turn signal and flash at a higher frequency than a typical turn signal. The articulated buses also have an audible signal during right turns, which is the same beep signal that is used to indicate that the ramp is being deployed. The 40-foot buses are not equipped with audible signals to avoid unwanted noises in residential areas and where pedestrian traffic is low.	Not reported
Bus curb lights (see Figure 2-17)	To increase operators' view of pedestrians running alongside the bus at night	Several lights along the lower right side of the bus activated by opening the bus door. To give the bus enough time to pull away from the curb, the lights stay on for about 16–20 seconds after the door has closed. See further details in Section 3.1.5.	Rated a 5 in reducing collisions involving pedestrians falling under the bus at night (since curb light installation, nighttime collisions of this type have been nearly eliminated)
Video clips as a forensic tool for accident investigation	• To use clips of accidents as a training aid for operators • To do accident investigations • To make recommendations on how to avoid accidents in the future	Six cameras are mounted on the buses. They are allowed to review 5 minutes of video prior to the incident occurrence.	Very successful. Much more able to defend themselves in law suits. Ratings: • 4 for reducing collisions • 3 for reducing severity • 1 for reducing close calls • 5 for reducing claims • 3 on operator acceptance • 4 on public acceptance
S1-GARD	To reduce the severity of injuries resulting from accidents involving pedestrians coming in contact with the rear right wheels of transit buses	Flexible plastic shield placed at the rear duals to deflect a person away from the path of the right rear dual.	Unknown

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

moderately low, the combination of costs could be high. The addition of striping and bollards and other barriers at bus stops are considered to be moderately low (thousands of dollars) in cost, depending on site conditions and the extent of the improvement.

Figure 2-14. Safety warning strobe light atop bus.

2.9.1 Applications of Bus Stop Location Planning and Bus Stop Design

Easter Seals Project Action developed the Toolkit for the Assessment of Bus Stop Accessibility and Safety, which is primarily targeted toward staff at transit agencies and public works departments that are responsible for bus stop design and placement. The Toolkit is intended to be a resource that can be used to enhance the accessibility of specific bus stops or to help in the development of strategic plans to achieve systemwide accessibility. Application of the information and guidance presented in this Toolkit would not only help the disability community, but the general population of pedestrians and bus riders as well. The Toolkit includes good suggestions regarding the design of bus stop areas, landing pads, and lighting (*7*).

Specific applications of bus stop location planning and bus stop design strategies, as reported by agencies and stakeholders, are shown in Table 2-11.

2.9.2 Suggested Applications of Bus Stop Location Planning and Bus Stop Design

Beyond the specific applications of bus stop location planning and bus stop design shown in Table 2-11, stakeholders suggested a number of bus stop location planning and bus stop design applications that might mitigate bus-and-pedestrian collisions. These suggestions included real-time bus arrival information, bus stop supervision, traffic control, bus nubs, painted bus "pads," and better bus stop planning. Each of theses suggestions is discussed in more detail below.

2.9.2.1 Real-time Bus Arrival Information

Providing real-time bus arrival information was suggested by the pedestrian groups, as well as the stakeholder groups that participated in the research. The premise behind real-time bus arrival information as an application for mitigating bus-and-pedestrian collisions is that better information will help pedestrians make better decisions. For example, if riders know that the next bus is only a few minutes away, they may be less inclined to run after the bus that is pulling out of the stop. Conversely, however, if the next bus is known to be more than a few minutes away, it may encourage patrons to run after the bus that is just leaving the stop. The real-time information could be provided on LED signs in the bus shelters or on the exterior of the buses.

Figure 2-15. LED light strip on front-top of bus.

Source: Champaign–Urbana Mass Transit District

Figure 2-16. Side strobe lights.

2.9.2.2 Bus Stop Supervision

Bus stop supervision was suggested by a stakeholder group and a bus operator group. The suggestions included

- Place supervisors at busy stop locations to help with boarding and alighting, and
- Provide supervision through video cameras at busy or problematic stops.

These strategies are meant to monitor pedestrian activity while waiting at stops. Supervision, either in-person or via video, could help mitigate crowding and pushing at busy stops and roughhousing, all of which can lead to pedestrians being pushed into the roadway under the bus.

2.9.2.3 Traffic Control

Traffic control was suggested as a necessary ingredient when locating bus stops: bus stops should not be located where there is no traffic control. The presence of some traffic control might

Figure 2-17. Bus curb lights.

Table 2-11. Applications of bus stop location planning and bus stop design.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
Monitoring, relocation, and removal of bus stops	• To identify bus stop locations that lead to unsafe behaviors	Agency monitors bus stops and removes those stops that are creating unsafe pedestrian behaviors.	Not reported
	• To identify bus stop locations that improve the visibility of pedestrians • To relocate or remove stops that are unsafe	A bus stop committee is composed of safety representatives and police officers. The committee looks at bus stop locations. They look at the place that will allow the bus to get into the stop safely and smoothly. They also (re)locate stops to make pedestrians more visible.	Not reported
Far-side bus stops (see Figure 2-18)	To reduce collisions between pedestrians who have just alighted the bus and the departing bus	By locating the bus stop on the far side of the intersection, pedestrians who have just alighted the bus cross the street at the intersection behind the bus. This is opposed to a near-side bus stop, where pedestrians who have just alighted the bus cross at the intersection in front of the bus.	Highly recommended by various agencies and groups
Bollards, barriers, and striping	To keep people from being in the bus area	A line of bollards, barriers, or striping.	Not reported
Standee lines at bus stops	To reduce pushing at crowded stops	Multiple buses lined up. Only the leader has doors open and they would have light duty personnel assigned. They help the passengers to board. Monitor pedestrians entering bus. Once bus is loaded, the following bus moves up into lead position and then opens the doors. Passengers form lines to board.	Not reported

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

assist pedestrians in understanding when it is safe to cross and in allowing pedestrians to obtain a sufficient gap to cross.

2.9.2.4 Bus Nubs

Bus nubs were suggested by one or more agencies and stakeholders as a possible strategy for mitigating bus-and-pedestrian collisions. A bus nub is essentially an extended version of a bulb-out that allows placement of the entire length of a bus stop adjacent to the travel lane. The primary motivations for installing bus nubs are to improve transit operations through the elimination of bus-weaving maneuvers into and out of a curbside bus stop and to reduce

Figure 2-18. Bus stop located on far-side of intersection.

sidewalk congestion by adding sidewalk space with the bus nub design (*4*). In addition, bus nubs can reduce the crossing distance and time for pedestrians, make it easier for operators to see pedestrians waiting to cross the street or board the bus, slow right-turn movements, and reduce the use of bus pull-out areas for illegal parking. As these goals of nubs hit on several different issues surrounding bus-and-pedestrian collisions, nubs could be an interesting strategy that could mitigate a variety of problems associated with bus-and-pedestrian collisions. Other names used for bus nubs include "curb extensions," "bus bulbs," and "bus bulges."

The cost of constructing nubs can range from $15000 to $55000 depending upon drainage needs, utility relocation, construction materials, and patron amenities (*5*). If street drainage systems need to be reconfigured, there is a steel-fabricated nub with a built-in shelter that can be installed over an existing street, allowing runoff to filter underneath; this system can be used to test a nub before a permanent installation is made (*6*).

2.9.2.5 Painted Bus "Pads"

Two types of bus pad installations were suggested by stakeholders for mitigating bus-and-pedestrian collisions:

1. Install painted bus "pads" on the pavement to delineate to pedestrians where the bus will stop, or
2. Install landing pads to provide pedestrians with a clear, level area with which to maneuver while waiting for, boarding, or alighting buses. Landing pads could reduce the frequency with which a pedestrian might trip or get "pushed" by stationery objects (such as waste receptacles) into the roadway or an oncoming bus.

2.9.2.6 Better Bus Stop Planning

Better bus stop planning, in general, was recommended by many stakeholders. It was reported that, in some instances, bus stop placement is a "second thought" and not part of the overall planning process. Bus stops are sometimes developed as a result of citizen requests and do not include sufficient collaboration or design analysis. Older stops are often not updated to integrate with new roads, traffic volumes, or routes. Additionally, in areas where construction is ongoing or weather is an issue (e.g., flooding, snow), stops are not always accessible or visible, causing pedestrians to make unsafe and unexpected maneuvers.

2.10 Strategy 10: Bus Stop Lighting and Illumination

Bus stop lighting and illumination are important issues. The primary concern, as it relates to bus-and-pedestrian collisions, is the visibility of pedestrians waiting at bus stops. This is a frequent concern expressed by pedestrians as well as bus operators and stakeholders. Passengers worry that they will not be seen by operators and, as a result, will be passed by. In an attempt to be seen, they may inadvertently step into the path of an approaching bus trying to "flag down" the operator.

In general, the bus stop lighting and illumination strategy is moderate in cost. For example, the cost of a flashing beacon ranges from $1,200 per bus stop for solar-powered lights to $200–$300 per bus stop for non-solar-powered lighting systems. Similarly, bus stop solar illumination units average around $1,600 per stop location. Although conventional illumination systems are less expensive, they require an immediate power source. Costs rise sharply when power must be brought to the stop, potentially increasing the costs by several thousands of dollars. Non-technology solutions—such as the retro-reflective "paddles" used by one agency ($20 per paddle) and retro-reflective bus stop signs—are low in cost.

2.10.1 Applications of Bus Stop Lighting and Illumination

In response to bus stop lighting concerns, an interesting and unique mix of applications have been employed by several different agencies. These applications include passive and active systems that indicate to an operator that an intending passenger is present at a stop. These systems may be as simple and inexpensive as a flashlight or retro-reflective paddle held by the waiting pedestrian or a pedestrian-activated flashing beacon located atop a pole at a stop. Specific applications of bus stop lighting and illumination, as reported by agencies and stakeholders, are shown in Table 2-12.

2.11 Strategy 11: Other

This section first presents other strategies that have been implemented by transit agencies and stakeholders and then presents suggested strategies that could mitigate bus-and-pedestrian collisions.

2.11.1 Other Strategies

Other strategies reported by transit agencies and stakeholders include

- Focus on operator health issues,
- Develop working relationship with local DOT, and
- Analysis of root cause of collisions.

These strategies and specific applications are presented in more detail below.

Table 2-12. Applications of bus stop lighting and illumination.

Application	Purpose	Description	Stakeholder Subjective Ratings and Comments on Effectiveness*
Retro-reflective paddles (see Figure 2-19)	To alert the operator of a pedestrian at the stop	A round paddle made of aluminum (1-ft diameter) with retro-reflective tape. The paddles are attached to the shelters with a 6-ft piece of cable that allows patrons to pick it up and move it around when waiting at the stop. The headlights of the bus reflect off the tape alerting the operator that someone is waiting at the stop. Drawback: new riders may not know how to use paddles.	Ratings: • 4 for reducing collisions • 5 for reducing severity • 5 on operator acceptance • 5 on public acceptance (if stop does not have them, patrons call and ask for them)
Flashing beacons (see Figure 2-20)	To alert the operator of a pedestrian at the stop	A simple flashing light is mounted on top of the stop and hooked to a user switch. Riders push the button or switch and the light flashes for about 2 minutes. One agency uses the paddles (see above strategy) at stops without power. Beacons can be used at stops with very poor sight lines. Beacons are electric or solar powered.	• Operators love it. They report that it makes their job easier and they are more alert to a rider waiting. • High public acceptance. Agency has received phone calls from the public saying how much they like it.
Retro-reflective bus stop signs	To increase the visibility of the bus stop	Signs designating the bus stop location that are high in retro-reflectivity.	Rated a 2 or 3 for reducing collisions Reportedly much better than the standard *Manual for Uniform Traffic Control Devices (MUTCD)* bus stop signs in terms of visibility
Solar-powered shelter lights	To provide light for pedestrians and bus operators	The lights put out a subtle glow rather than a glare, just enough to light the shelters. The shelters are solar powered. One drawback is that chemicals used to treat snow and ice on roads interfered with functioning of solar panels and electronics. One agency reported they had to clean them twice a day and eventually stopped using them.	Not reported
Pocket and pen lights (see Figure 2-21)	To allow a bus driver to see more easily a rider waiting at a bus stop	Small hand-held light that pedestrians can activate when walking to and from a stop and standing at the stop. Operators hand them out primarily to riders who catch the bus in dark conditions.	Rated a 5 for bus stops on rural and high-speed roads although difficult to rate because agency rarely has a bus and pedestrian collision. Very high public acceptance—"people love them," according to the director of the transit agency.

* Stakeholder subjective ratings are based on a scale of 1 to 5, with 1 being "very ineffective" and 5 being "very effective" or with 1 being "very unsuccessful" and 5 being "very successful."

Source: Roaring Fork Transportation Authority

Figure 2-19. Retro-reflective paddle.

2.11.1.1 Focus on Operator Health Issues

The purpose of this strategy is to improve operator performance through better health. One agency that focuses on operator health issues reported several applications of this strategy, including

- Fatigue awareness training,
- On-sight physical therapist, and

Source: Pierce Transit

Figure 2-20. Bus stop flashing beacon.

Source: Island Transit

Figure 2-21. Pocket light.

- Redesign of the interior operator compartment to reduce collisions, improve operator health by making compartment more comfortable and ergonomically correct, and decrease driver distraction (see Figure 2-22).

See Section 3.1.8 for further details on this strategy.

2.11.1.2 Develop Working Relationship with Local DOT

The purpose of this strategy is to improve pedestrian safety through a coordination of efforts. One agency reported that it meets and communicates regularly with the local DOT. For example, when the DOT makes roadway improvements, the transit agency simultaneously improves the bus stop areas.

2.11.1.3 Analysis of Root Cause of Collisions

The purpose of this strategy is to determine the root cause of collisions as there is often more than one root cause. One agency uses commercially produced software, which forces the agency to step through all potential root causes of its collisions. The software considers such things as equipment, policies and procedures, and management responsibilities.

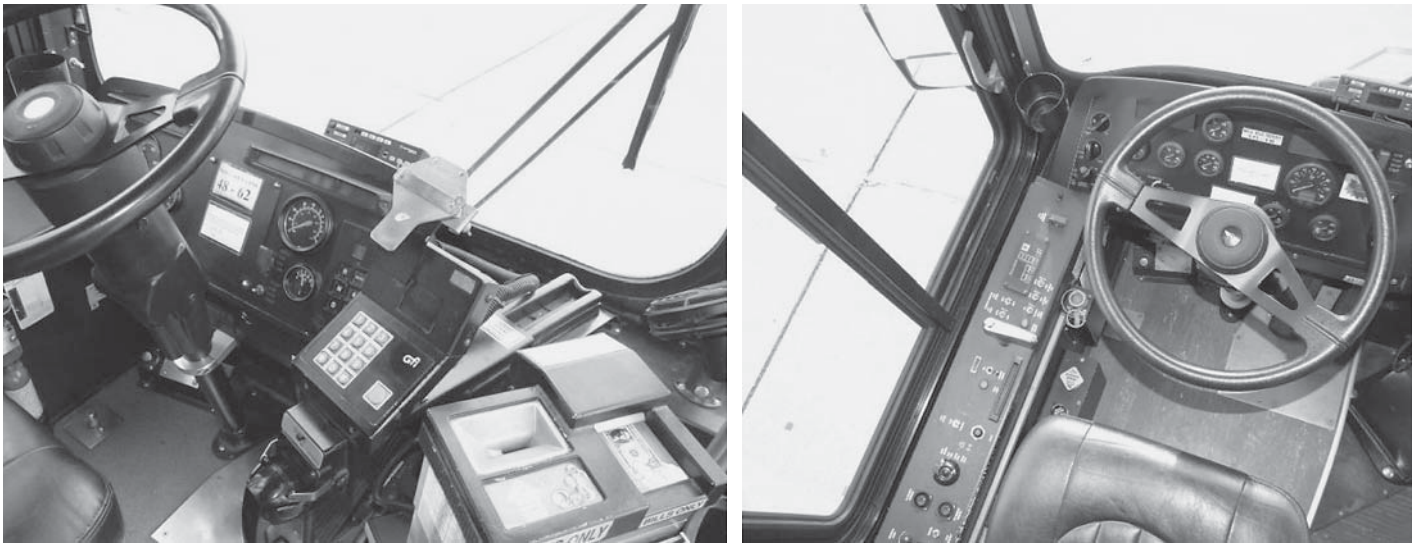
2.11.2 Other Suggested Strategies

Transit agencies and stakeholders suggested a variety of other strategies as well. These suggested strategies, along with specific applications of the strategies, are discussed in more detail below.

2.11.2.1 Enforcement

One source suggested the following as potential ways to mitigate bus-and-pedestrian collisions:

- Enforce no parking laws on bus routes (e.g., no double parking and no parking in bus pull-out areas).
- Place supervisors at problem stops to enforce safe behaviors of those waiting for the bus.



Source: Pierce Transit

Figure 2-22. Example of new interior operator compartment design.

2.11.2.2 Improve Bus Scheduling and Routing

Pedestrians and operators alike felt that bus schedules could play an indirect role in the occurrence of bus-and-pedestrian collisions. There were also a number of strategies involving bus schedules and routing:

- Bring together the scheduling department with the operators to talk about how the schedules could be improved. This would give operators the opportunity to voice concerns about routes with problematic schedules and the potential safety consequences.
- Develop and run schedules that include more time to complete routes. When operators are pushed to maintain schedules that do not allow enough time to complete, they may be inclined to rush and, as a result, may lose sight of pedestrians. If schedule times are more appropriate for the routes, buses are more likely to stay on schedule.
- Keep buses on schedule. Some felt that keeping buses on schedule (versus buses bunching at a bus stop) would help somewhat with pedestrians running after buses. If a passenger sees that all of the potential buses are at the stop, he or she will realize that it may be awhile before another bus arrives and may hurry or run to try to catch one.
- Modify bus routes to avoid high conflict situations, like right or left turns at busy pedestrian intersections.
- Run buses more frequently.

2.11.2.3 Remove Sidewalk Obstructions

A few agencies and stakeholders suggested keeping intersections and sidewalks free of obstacles and objects—such as trash receptacles or fire hydrants—near bus stop locations (see Figure 2-23). Freeing sidewalks of obstacles could have several positive benefits:

- Increasing the amount of space where intending passengers wait and other pedestrians pass by, reducing conflicts between the two;
- Reducing visual obstructions that can block operators' views of pedestrians; and
- Reducing the objects that pedestrians could trip on or run into, both of which could result in them falling into the roadway or in front of oncoming buses.

Figure 2-23. Sidewalk obstructions near bus stop.

PART 3

Case Studies

The purpose of this section of the Guidebook is to provide the reader with in-depth examples of the best-documented strategies and applications for mitigating bus-and-pedestrian collisions. In some instances, the examples are presented in the form of single-agency case studies, which detail how individual agencies have addressed pedestrian safety issues. In other instances, the examples are presented as multi-agency case studies, which compare the same strategy implemented across multiple agencies. The case studies include detailed information regarding what is known about the bus-and-pedestrian collision problem, the implementation of one or more mitigating strategies, the goals and costs of implementation, and the successful and problematic elements of strategy implementation. The 14 case studies are listed in Table 3-1.

3.1 Single-Agency Case Studies

This section discusses the single-agency case studies. These agency case studies present one or more strategies implemented by an agency, the motivation for the strategy, how the strategy was implemented, and the cost and effectiveness of the strategy if available.

3.1.1 Case Study 1: Turning Procedure Video and Training

In 2003, Cincinnati Metro developed a supplemental operator training program following a series of approximately 17 pedestrian collisions over a 14-month period. In 2002 and 2003, Metro equipped each of its buses with four video cameras. After examining the accident scene and speaking with operators and witnesses, Metro's safety specialists made educated guesses as to why the collisions occurred, but could not find a definitive answer. The operators claimed that they did not see the pedestrians. This motivated Metro's safety specialists to study the video footage from the collisions to look for clues. After reviewing the videos, they realized that many of their assumptions were incorrect. By reviewing videos from several accidents, the safety specialists found a consistent pattern and determined why these collisions were occurring. They noticed this pattern to occur when an operator pulled up as the first vehicle in the queue at a red light and then sat at the light for more than 20 seconds. In each case, the operator looked at the crosswalk when pulling up to the light but after waiting for more than 20 seconds, the operator was no longer monitoring the crosswalk, but had become focused on traffic. When the light turned green, both the operator and the pedestrian immediately started into the intersection.

In response, Metro developed the following mandatory six-step turning procedure:

1. Activate your turn signal as you approach the intersection.
2. When pulling up to a red light as the first vehicle in line, stop at the marked stop line before the marked crosswalk. If there is no marked stop line, stop at least 6 feet back

Table 3-1. Case studies (index table for Part 3).

Case Study Number	Case Study Name	Section
Single-Agency Case Studies		
1	Turning Procedure Video and Training	3.1.1
2	Pedestrian-Focused Operator Training	3.1.2
3	Multi-Faceted Approach to Improving Pedestrian Safety	3.1.3
4	Multi-Faceted Operator Safety Program	3.1.4
5	Bus Curb Lights	3.1.5
6	Driving Simulator	3.1.6
7	Safety Impact Team	3.1.7
8	Focus on Operator Health Issues	3.1.8
Multi-Agency Case Studies		
9	Left- and Right-Turn Training Videos	3.2.1
10	Public Outreach Programs	3.2.2
11	Safety Posters and Flyers for Operators	3.2.3
12	Use of Bus Cameras to Determine Cause of Collision	3.2.4
13	Left-Side Mirror Design and Placement	3.2.5
14	S-1 Gard	3.2.6

from the crosswalk. All four corners of the intersection should be clearly visible from the driver's seat.

3. Continually scan the intersection as you wait for the light to change. Pay particular attention to the appropriate crosswalk and corners that will be affected by your turn. **Do not "creep up" while waiting for the light to change. Stay still! Do not jump the green light!**
4. When the light changes to green, *wait 2 seconds* before moving into the intersection. While waiting, look at the appropriate corner and crosswalk and look for any pedestrians.
5. After the 2-second delay, slowly accelerate into the intersection and begin your turn. When you come to the crosswalk you are turning into, *check around all blind spots, stopping if necessary* to make sure it is clear.
6. Once you have determined it is clear, safely complete your turn.

The supplemental training given in 2003 lasted 1 hour and consisted of a short video demonstrating the procedure for making safe left and right turns. The training also included a presentation that described how Metro safety specialists determined through bus videos why operators were striking pedestrians. During the training, they also show the operators the video of bus-and-pedestrian collisions so that they believe the reasons given for the accidents. In addition, operators are warned to "use extreme caution when turning, even when pedestrians don't have the right-of-way," "expect the unexpected," and "check and recheck . . . make whatever effort is necessary to overcome potential blind spots. . . ." Stickers are also placed on all fareboxes, reminding operators to look for pedestrians.

This supplemental training has since been incorporated into new-driver training, and reminders about the turning procedures are put out every 6 months for the operators. The agency's safety specialist rates the new training program as very effective in reducing collisions. In 2006, the agency had two bus-and-pedestrian collisions: a reduction of approximately 85% from before the training program.

3.1.2 Case Study 2: Pedestrian-Focused Operator Training

In the fall of 2003, Portland's TriMet developed a 2½-hour defensive-driving module focused on pedestrian safety in response to a fatal pedestrian collision that occurred when a bus made a

left turn. The module was part of an 8-hour class given to 837 of their approximately 1,250 operators between March 16 and November 29, 2004, for a total of 110 classes. This class was part of TriMet's 2004 Operator Training Campaign. TriMet holds special training campaigns for operator professional development about once a year on topics ranging from security awareness, to operator fatigue, to serving customers who are elderly or disabled. The pedestrian safety module developed in 2003 is now part of TriMet's ongoing defensive-driving training.

The pedestrian safety module included defensive-driving material from the Smith System, commercially produced driver safety training, crosswalk safety, line of sight, and the effective use of eyes. The safety module taught operators how the eye works and the need for the driver to keep his or her eyes moving so that stares do not develop and peripheral vision does not decrease. An additional exercise includes writing on a flip chart all of the things that keep operators from using their eyes properly: from drinking coffee to cell phone usage. TriMet reviewed with operators a recent change to an Oregon pedestrian safety law stating that automobiles must stop for any pedestrian in a crosswalk in the driver's lane or an adjacent lane. The module also went through specific locations in the region where operators need to be extra cautious and to reduce speed for pedestrians such as service stops, transit malls, or any place where pedestrian clearance is reduced. Operators were taught a six-step procedure for exiting service stops, internally referred to as "Checking Left–Right–Left." The six steps are shown below. If a driver is delayed before exiting, the driver must re-do Steps 4, 5, and 6:

1. Check doorway for clearance.
2. Close doors, but keep hand on the door control and eyes on doorway until fully shut.
3. Check central mirror for passenger stability.
4. Check left mirror for traffic.
5. Check back to right for pedestrians and other hazards that may have come up—also check right-side blind spots.
6. Check left again in mirror and blind spots.

The module also included two exercises for demonstrating blind spots to operators. For the first exercise, operators are asked to stare at the center of a card containing a grid. As the driver pulls the card toward his or her face, a red dot on the right side of the card disappears. The operators find this exercise revelatory and great fun. For the second exercise, the operators sit in the driver's seat of the bus and are asked to only look at the left mirror as if they were exiting a service stop. The instructor asks the driver to tap on the horn when the driver sees the instructor pass out of their line of sight as the instructor moves across the front of the bus from curbside to street side and then again a second time when the instructor reappears in their vision from out of their left blind spot. The instructor then quickly runs at an angle up to the left front corner of the bus. The instructor is typically out in front of the bus before the driver can honk the horn a second time, demonstrating the dangers of the blind spot on the left side of the bus.

During the 2007 operator professional development training session, half of the day was dedicated to a defensive-driving module that focused on a review of key skills, used video clips of difficult driving situations in the area, and asked operators to spot potential hazards including pedestrian conflicts. Tri-Met has not measured the effectiveness of this program in decreasing pedestrian and bus collisions.

3.1.3 Case Study 3: Multi-Faceted Approach to Improving Pedestrian Safety

To address the bus-and-pedestrian collision problem, the Washington Metropolitan Area Transit Authority (WMATA) implemented a comprehensive set of actions to improve the safety

of pedestrians with regard to transit buses. The actions build on the concept of "Education, Engineering, and Enforcement." The actions included the following:

- Assessing high-accident routes and locations to reduce the risk of accidents at these locations,
- Contacting bus operators,
- Establishing a new bus operator training module on pedestrian safety, and
- Installing flashing amber lights atop buses to make buses more visible.

3.1.3.1 Pedestrian Safety Design

The District of Columbia DOT (DC DOT) collaborated with WMATA in the identification and evaluation of high-accident intersections within the District of Columbia. Intersection selection was based on number of pedestrian fatalities, injuries, and other damage of all types and not just those involving transit buses. The preliminary list was then compared with the top 100 crash intersections to determine any correlation with pedestrian accidents. No correlation was found. For each site identified, site conditions, the vehicle and pedestrian environment, traffic control devices (including signal phasing), road alignments, transit interface, land use, traffic operations, vehicle speed, parking, lighting, and other factors were evaluated.

As a result of the study, 12 locations were identified for improvement. The improvements varied from location to location. In general, the improvements included

- Updating crosswalk striping to ladder-style striping;
- Modifying pedestrian signal timing;
- Replacing all flashing WALK pedestrian heads with the solid WALK pedestrian head;
- Installing fluorescent-yellow/green pedestrian signs (W-11-2) and advance warning signs on all approaches;
- Upgrading light intensity;
- Repairing sidewalk deficiencies;
- Relocating pedestrian signal heads on pole closest to the relevant crosswalk on all corners;
- Relocating the bus stop;
- Renewing pavement markings; and
- Installing pedestrian informational signing at pedestrian crossings.

3.1.3.2 Outreach

Before starting work, bus operators received a handout reminding them to give particular care to pedestrians crossing streets and of defensive-driving techniques. Posters with similar reminders were placed at all bus facilities. Additionally, WMATA safety representatives solicited suggestions on what can be done to improve pedestrian safety. This effort resulted in the development of a new pedestrian safety training program for bus operators and modifications to mirror placement.

3.1.3.3 Training Strategy

WMATA recently started a bus operator refresher training course that focuses on pedestrian safety in an effort to improve the overall safety of WMATA Metrobus operations. Content for the course, Street Smart, was developed with input from bus operators, superintendents, street supervisors, Transit Police, safety department staff and the DC DOT. Street Smart is a full-day training course that combines classroom training with a field trip to a top pedestrian accident location to raise awareness and give operators a pedestrian's perspective. The field trip allows bus operators to walk the area and observe the behavior of pedestrians, bicyclists, and motorists. A worksheet is used to tally certain behaviors including jaywalkers, pedestrians standing on the curb line, bicyclists or vehicles running red lights, reckless drivers, vehicles blocking intersections, distracted drivers using cell phones, discourteous drivers blowing their horns, cursing or yelling, and drivers turning right in front of stopped buses. The course aims to raise the aware-

ness of operators when it comes to addressing traffic safety, pedestrians, and operator alertness. It also reinforces standard operating procedures.

3.1.3.4 Mirror Placement

As a result of the bus operator outreach, a pilot program was launched to determine the placement of the side mirrors. Buses were equipped with mirrors at varying heights and brought to the operating bases for evaluation by bus operators. Based on operator input, mirrors were lowered. Currently, WMATA is evaluating a bracket that permits an operator to adjust the height of the mirror.

3.1.3.5 Passenger Safety Lights

In an effort to improve the visibility of passengers waiting for a bus in the dark during early morning and evening hours, the WMATA Safety Department purchased safety flasher lights for distribution by bus operators to passengers who board buses in poorly lighted areas. When waiting for a bus, intending passengers activate the red flashing light by pushing a button and then clip the light onto bag straps or clothing. The light is designed to help bus operators and other motorists spot pedestrians who are crossing a street or waiting for a bus in the dark. The lights include the message "Look Before You Cross."

3.1.3.6 Roof-Mounted Strobe Lights

WMATA installed strobe lights on top of buses as part of a pilot program to improve pedestrian safety. The yellow warning strobe lights were designed to help pedestrians and motorists spot WMATA buses on city streets and to provide additional lighting for early morning and evening bus users. Initially, strobe lights were affixed to the buses. However, an early evaluation found the lights to be too bright and non-directional. The lights were replaced with a LED light strip that was visible only to those viewing the front end of the bus. The lights within the strip were designed to flash from left to right. The effectiveness of the strip is currently under evaluation. Because of motor vehicle regulations within Virginia and Maryland, use of the light strip is limited to DC. WMATA is working with Virginia and Maryland to grant an exemption to transit buses.

3.1.3.7 Enforcement

The safety of pedestrians boarding and exiting buses has been a particular concern in the DC area. A new law, Protection Bus Safety Amendment Act of 2006, specifically prohibits a motor vehicle driver from passing to the left and pulling in front of a bus in order to make a right turn when a bus is at a bus stop or at an intersection to receive or discharge passengers.

3.1.4 Case Study 4: Multi-Faceted Operator Safety Program

One transit agency has implemented a multi-faceted driver safety program that includes driver training classes, accident awareness sheets posted in the operators' room, bi-annual safety meetings, and safety reminders broadcast over the radio system. About 5 weeks of classroom instruction and behind-the-wheel training is given to operators when they join the agency. The agency purposefully has the operators navigate through the toughest pedestrian areas in the city and teaches them how to handle tough situations such as sun obscuring the view of the crosswalk.

Before being released from training, the Director of Risk Management spends 3 hours with the drivers, discussing traffic accidents, passenger injuries, and pedestrian-and-bus collisions. The Director of Risk Management reviews with the drivers all of the bus-pedestrian collisions that have occurred within the last couple of years, including details on how the collisions happened and what drivers can do to prevent them. Operators learn about monetary costs of pedestrian collisions and are reminded that a bus-and-pedestrian collision victim could be a family member. The director emphasizes the importance of maintaining a safe speed even when the drivers

get behind schedule. The transit agency also holds retraining for drivers who have had accidents and for all drivers every 2 or 3 years. The Director of Risk Management reports that with as much pedestrian traffic as they have at the downtown centers, their low rate of pedestrian collisions shows that the training is working.

When a bus accident occurs involving a pedestrian or another vehicle, the transit agency posts a bulletin in the operators' room that describes the accident including location and date, includes photos, and provides any recommendations that were made for preventing the accident. This strategy was rated a 4 in operator acceptance and reducing collisions. The Director of Risk Management notes that the bulletin does not reach all of the operators since some of them do not go into the operators' room.

Annually, the Director of Risk Management posts a street map in the operators' room showing the location of all types of bus accidents that occurred in the previous year. This alerts the operators to locations where extra caution is needed. The transit agency holds approximately two company-wide safety meetings a year where operators and other employees discuss accidents and strategies for preventing them.

The bus dispatchers also broadcast safety reminders over the driver radio four to five times a day. The messages pertain to current conditions such as, "It is raining, watch your speed," or the dispatcher will advise the operators of the location of a parade and tell them to watch for pedestrians.

3.1.5 Case Study 5: Bus Curb Lights

In response to nighttime accidents involving pedestrians running after and falling under a bus, New Jersey Transit began to use buses with several lights along the lower right side of the bus, referred to as "curb lights" (see Part 2, Figure 2-17). The lights are activated during the day and night by opening the bus door. To give the bus enough time to pull away from the curb, the lights stay on for 16–20 seconds after the door has closed. The curb lights were intended to increase operators' view of pedestrians running up alongside the bus at night because several urban areas along New Jersey Transit bus routes had moderate-to-poor lighting.

New Jersey Transit began ordering buses with curb lights in 1998 as a small pilot project, and by fall 2002, almost all New Jersey Transit buses had the lights. The curb lights are built into the specifications for new buses.

New Jersey Transit estimates that the curb lights have been very effective in reducing accidents involving pedestrians running alongside and falling under the bus at night. Since curb light installation, New Jersey Transit has nearly eliminated that type of accident at night. The curb lights have not impacted this type of accident during the day, but this has not been as much of an issue as the nighttime accidents.

Bus curb lights were rated a 5 in reducing the frequency and severity of accidents and reducing near misses involving the pedestrian moving along the right side of the bus and falling under the bus as it is pulling away at dark. They were rated as very effective in reducing claims. The curb lights were well received by the operators and given an acceptance rating of 5 out of 5 by the Director of Safety. Public acceptance was hard to evaluate, but was estimated as very high. The cost of the hardware and the installation performed during the manufacturing of the bus was estimated roughly at just under $1,000 per bus.

3.1.6 Case Study 6: Driving Simulator

In North Carolina, Charlotte Area Transit System (CATS) began using a driving simulator in September 2006 as a training tool in an effort to reduce all types of accidents, including pedes-

trian accidents. CATS purchased one virtual reality simulator and six driving assessment seats. The virtual reality simulator allows the operators to sit in a bus seat behind a bus dashboard and feel the bumps and movement that would normally be associated with driving a bus. It allows the trainers to alter driving conditions, such as weather, and to build their own scenarios. All new operators, operators involved in an accident, and operators who have been out for a long period of time receive training on the virtual reality simulator. CATS intends to train each driver on the simulator once a year. A variety of scenarios are used with the virtual reality simulator including potential collisions with pedestrians. The virtual reality driving simulator has been very well accepted by the operators and was rated a 5 out of 5 for driver acceptance. CATS uses its driving assessment seats to screen operators before hiring and to assist the agency in hiring highly skilled operators since the driving assessment seats measure reaction time as well as other skills that were previously difficult to assess. The virtual reality simulator cost $200,000, and the six driving assessment seats cost a total of $180,000. The General Manager for Safety and Security at CATS noted that the simulator will pay for itself if it prevents even one accident.

3.1.7 Case Study 7: Safety Impact Team

The New Jersey Transit Director of Safety is part of a safety impact team (SIT)—a collaborative effort among New Jersey DOT (NJDOT), local municipalities, public safety, engineers, consultants, the American Automobile Association (AAA), and New Jersey Transit. Based on crash information provided by NJDOT, the team evaluates specific roadways or corridors that have been problematic. Crash data are separated so that the team can see locations of bus and pedestrian collisions. Each corridor that SIT evaluates is a 3-day project. The corridors range from 1 to 3 miles in length. On the first day, the SIT members study the crash data of the corridor to get a better idea of where they should spend their time during the remaining 2 days. They look at the roadway geometry, pictures, traffic counts, pedestrian volumes, bus volumes, and frequency of buses. On the second day of the evaluation, the team goes into the field to evaluate roadway design and to find the reasons for the collisions. On the third day, the team prepares recommendations for short-, medium-, and long-term improvements in three categories: education, enforcement, and engineering. NJDOT and the other stakeholders work to implement the strategies.

Examples of recommended applications that would help to mitigate bus-and-pedestrians collisions include

- Relocate bus stops to a better location with curb cut-outs.
- Install sidewalks from pedestrian's origin to bus stop.
- Implement pedestrian countdown signals, pedestrian crossing push buttons, and roadway markings.
- Use fences and other barriers to control pedestrian access to the roadway so that pedestrians cross in designated locations.
- Install pedestrian signage such as YIELD TO PEDESTRIANS that is visible at night.
- Remove obstructions such as trees and overgrown brush that could impede an operator's view of pedestrians.
- Improve overhead lighting especially near bus stops.
- Enforce speed limits and no parking at bus stops.

3.1.8 Case Study 8: Focus on Operator Health Issues

In Seattle, Pierce Transit has been teaching a 2½-hour segment on fatigue awareness to operators, and it has been a huge success. They have had about 30 operators diagnosed with some type of sleep disorder—most commonly, sleep apnea. The fatigue awareness training includes a presentation with three videos: circadian rhythms, micro sleep, and a comparison showing the

difference between alcohol and fatigue. The goal of this training module is to increase driver safety and prevent all types of bus accidents. Additionally, the agency wants drivers to have better lives. The Safety and Training Manager at Pierce Transit rated the overall training a 5 for reducing pedestrian-and-bus collisions, but only 3 for reducing collision severity. It is too early to estimate the effectiveness of the fatigue awareness training.

Pierce Transit, an agency with an aging workforce, also has an on-sight physical therapist who works with operators on job-related injuries. Operators can schedule appointments with the physical therapist. This program began about a year ago and has been very popular with operators. It was rated a 5 on operator acceptance. The Safety and Training Manager believes that the physical therapy has had a positive impact on safety because operators are in better condition although the program is so new that there is no supportive evidence yet.

Pierce Transit has also taken into account driver focus and health by working with a bus manufacturer to re-design the interior operator compartment of the bus (see Part 2, Figure 2-22). Currently, about 20% of their fleet has this new design. The re-design includes moving the controls that are most commonly used to a location that is ergonomically correct and within easy reach.

TriMet also presented training modules on security and driver fatigue during its 2006 Operator Training Campaign.

3.2 Multi-Agency Case Studies

This section presents the multi-agency case studies. These case studies describe common applications across a number of different agencies and how the applications compare across the agencies.

3.2.1 Case Study 9: Left- and Right-Turn Training Videos

Motivated by a pattern of pedestrian incidents involving left turns at a downtown intersection, one agency created an in-house training video to demonstrate to operators proper left-turn procedures and to raise awareness of the potential dangers of that particular intersection. The video provided an over-the-shoulder view of a driver making a left turn at the target intersection using a bus in the agency's fleet. Cost effectiveness was the primary advantage of this strategy as reported by the agency. It took approximately 8 hours to create. While there have been no statistical analyses, they have seen a reduction of collisions at that site and rated the effectiveness of the video a 4 out of 5.

In the early 1990s, Metro Transit in Minneapolis created an instructional video for operators that focused on blind spots encountered while making right turns, especially the blind spot created by the middle of the passenger door. In response to collisions, in 2000 Metro Transit augmented the video to include training in avoiding pedestrian collisions during left turns. The video stresses the importance of bobbing and weaving in the seat to see around blind spots and of overall awareness of pedestrians. The video is about 6 minutes in duration and was developed in house. The cost is unknown, but Metro Transit estimates that it was developed in less than 16 hours. The video has been shown in the Metro Transit operators' room four times since 2000. Each showing is over a 3-day period where the 6-minute video loops on a TV screen and an instructor is present to answer questions from the operators. Metro Transit would like to make this an annual event. The video is also part of new operator training. When the video was first shown to operators, it was rated a 4 in effectiveness in reducing pedestrian-and-bus collisions. Six years later, Metro Transit believes the video's effectiveness has decreased to a 2 because it no longer draws the attention of the operators. There were fewer pedestrian-and-bus

collisions after the video was released, but the decrease could likely be a reaction by the operators to recent fatalities.

Transit Mutual Insurance of Wisconsin developed a short training video to communicate to bus operators the need for extra caution during right and left turns. The purpose of the video is to reduce the number and severity of bus-and-pedestrian collisions occurring during left and right turns. The video was produced in response to a finding by Transit Mutual that left turns were the main contributing factor to pedestrian accidents in Wisconsin. During 2000–2003, there was an increase in the number of pedestrian-and-bus turning claims in Wisconsin. Right turns were included in the video because findings in Michigan indicated that right turns were problematic. The video was filmed, edited, and produced by a production company, and the script was written by Transit Mutual's in-house counsel. Transit Mutual Insurance received a grant from Wisconsin DOT to cover 80% of the cost of this video along with a couple of safety-oriented videos.

The video has been distributed to the directors of all 19 member agencies of Transit Mutual, but the usage of the video varies by transit agency. Some agencies use the video as part of new-hire training, and other agencies require all operators to view the video. Transit Mutual has received very positive feedback from its member agencies, and operators have reported that the tips on the video are helpful. The impact the video has had in reducing pedestrian-and-bus collisions is unknown. There has been a decline in pedestrian incident claims since the film was produced, but this could be due to a number of factors.

3.2.2 Case Study 10: Public Outreach Programs

In Indiana, the Greater Lafayette Public Transit Corporation has taken an aggressive approach to teaching college students about bus safety. The majority of the Greater Lafayette Public Transit Corporation service is on the campus of Purdue University, and approximately 70% of its riders are students. Incoming freshmen arrive 1 week before classes start for orientation, and during this time, the transit agency offers a 1-hour class on the Purdue University campus titled Transit 101. According to Greater Lafayette's Manager of Operations, it is one of the more popular offerings during orientation and typically draws approximately 200 students.

Given by the Greater Lafayette Manager of Development, Transit 101 is a presentation on how to safely use the bus system. The presentation brings students' attention to the pitfalls of cell phone and portable music player use and the need for students to be aware of their surroundings when walking around. Since some of the students have never taken a bus prior to coming onto campus, the manager of operations instructs the students to board the bus at designated stops and what to do when getting off the bus. The Manager of Operations at Greater Lafayette believes that Transit 101 has been successful as evidenced by the absence of pedestrian-and-bus collisions on a pedestrian-heavy campus environment. Transit 101 was rated a 5 for its effectiveness in reducing collisions and severity of collisions and was rated a 4 for its effectiveness in reducing near misses. It is highly accepted by the public (rated a 5 out of 5), and the cost to the agency for Transit 101 is very minimal.

Some agencies conduct bus safety outreach programs at local schools. Since 1988, Washington State's Island Transit has gone to local elementary schools to teach 3rd and 4th graders about public transit safety in an interactive manner using music, an Island Transit bus, and a puppet named Buster. Island Transit targets elementary schools for safety education because a major segment of their riders are children taking public transit to and from school. Another agency provides an outreach session to schools that make a request for one. Agency representatives explain to the students the differences between a bus and a family vehicle including a larger turning radius, a pivot point at the back end, and longer stopping distance. The agency

receives approximately one request per year and estimates public acceptance of the sessions at about a 3 or 4 out of 5.

3.2.3 Case Study 11: Safety Posters and Flyers for Operators

Several transit agencies reported the use of posters and flyers to encourage safe driving around pedestrians and to communicate important pedestrian safety procedures to bus operators. As mentioned in a single-agency case study above, one agency posts bulletins to alert operators to past accidents in order to learn from past experiences. CATS hangs safety bulletins reminding operators to be aware of pedestrians crossing the street in its two transit stations.

Seattle's King County Metro developed a themed safety campaign each week for its operators and refers to the program as the "Outhouse Journal." Banners are hung and flyers are posted on the back of restroom stall doors to communicate each week's safety message. The themes commonly have a pedestrian focus and use slogans such as "Track them once. Track them twice." The idea behind this particular message is that even before entering an intersection, operators should be scanning for people who may want to cross and then upon entering the intersection, operators should look to see where each of those pedestrians went. The cost is minimal since the flyers and banners are made in house. One of Metro's safety administrators reports that operators notice the signs and appreciate the reminders, but realizes that behavior is likely impacted with flyers posted once a week, so Metro works to saturate the operators with safety messages in order to affect change.

Pennsylvania's Port Authority of Allegheny County uses general notices posted in the operator room to communicate to operators important rules to follow. The paper notices are posted on a "hot board" located in the operator room with other new announcements. The notices are collected in a binder kept in the Instructor's office. The rules highlighted by the notices pertain to yielding to pedestrians, operating in congested areas, clearing off the dash board, and others. These rules are enforced by road supervisors who monitor operators and all road activity. Discipline is issued to employees who are caught not following rules specified in the general notices.

When a bus accident occurs involving a pedestrian or another vehicle, one agency posts a bulletin in the operators' room that describes the accident including location and date, shows photos, and provides any recommendations that were made for preventing the accident. This strategy was rated a 4 in operator acceptance and reducing collisions. The Director of Risk Management notes that the bulletin does not reach all of the operators since some of them do not go into the operators' room. The bus dispatchers also broadcast safety reminders over the driver radio four to five times a day with messages pertaining to current conditions such as weather and special events.

3.2.4 Case Study 12: Use of Bus Cameras to Determine Cause of Collision

In addition to Cincinnati Metro's use of video to determine what was causing turning collisions with pedestrians, three other transit agencies use or have used video cameras on their buses to aid in determining the cause of an accident. Although one agency's primary purpose for installing cameras was to assist the agency in defending itself against claims in accidents and onboard security, the videos have been useful in determining the causes of bus-and-pedestrian accidents. Video clips of accidents from the six cameras on Miami-Dade Transit's buses are used as a training aid for other operators. The video enables Miami-Dade Transit in making recommendations on how to avoid accidents in the future. The cameras used on CATS buses have been helpful in determining the actual series of events during pedestrian-and-bus collisions and helps

to keep operators in check. One agency reported the cost of outfitting a bus with six video cameras to be approximately $12,000 per bus.

3.2.5 Case Study 13: Left-Side Mirror Design and Placement

One agency has worked with a bus manufacturer to design new left-side view mirrors to reduce the blind spot caused by the mirrors. This agency experiences a number of collisions with vehicles and pedestrians during left turns in which the operators reported not seeing the vehicle or pedestrian. The two left-side mirrors on the buses involved in the accidents were held in a single plastic casing that enlarged the blind spot caused by the mirrors. In one of the configurations, it was reported that the operator could lose an entire semi-truck on the left behind a side-view mirror when stopped at a traffic light. The agency was able to develop prototype mirrors for the left side that were separated, not in a single plastic panel, and brought down below the driver's line of sight. The flat mirror was also reduced in size. The agency began retrofitting some of their buses with these mirrors 2 years ago and hopes to have them on their entire fleet within the next 2 years. According to the Manager of Safety Training and Security, the operators are fighting to drive the buses with the re-designed mirrors because they like them so much better. The effectiveness of the mirrors was rated a 4 out of 5 in reducing pedestrian-and-bus collisions as there has been a reduction in the occurrences of accidents where the driver did not even see the pedestrian or car; however, the mirrors have not been used enough to gather sufficient data. Driver acceptance was rated a 5. The cost for the mirror including labor for installation is estimated at under $50 per bus.

3.2.6 Case Study 14: S-1 Gard

The S-1 Gard is a device designed to reduce the severity but not the likelihood of injuries resulting from accidents involving pedestrians and bicyclists coming in contact with the rear right wheels of transit buses only. Further research is needed to determine its effectiveness.

PART 4

Important Considerations for Improving Pedestrian Safety Around Transit Buses

Parts 1 through 3 of this Guidebook provide a presentation of strategies for mitigating bus-and-pedestrian collisions in several different ways. Part 1 of this Guidebook presents some contributing factors to the four primary types of bus-and-pedestrian collisions, as well as a list of strategies for mitigating collisions. Part 2 presents strategies and provides detailed information about particular agency and stakeholder applications of each strategy. Part 3 presents case studies of actual situations in which agencies have implemented strategies to mitigate pedestrian collisions; why and how the strategies were selected; and the results, if any, of the implementation.

This fourth section of the Guidebook presents a discussion of pedestrian-and-bus safety from a more top-down, holistic approach. First, this section discusses contributing factors that are not necessarily directly linked to one of the four primary types of bus-and-pedestrian collisions. While not directly linked to a particular collision type, the contributing factors discussed here were reported by transit agencies and other stakeholders as playing an important contributing role in bus-and-pedestrian collisions. By understanding the indirect links these factors have to bus-and-pedestrian collisions, agencies and stakeholders can develop mitigation strategies that could not only improve pedestrian safety, but that also might result in an overall improvement in safety. Second, this section looks at how the combination of two or more strategies presented in this Guidebook can add to the potential for success in reducing bus-and-pedestrian collisions and in improving overall safety.

4.1 General Factors that Contribute to Bus-and-Pedestrian Collisions

Part 1 of this Guidebook discussed factors that contribute to each of the four primary types of bus-and-pedestrian collisions. However, during the research process, transit agencies and stakeholders reported a large number of contributing factors they felt were important, but that could not necessarily be directly linked to one of the primary four collision types. Rather, these contributing factors could contribute to any of the collision types and even to collisions with other vehicles. These factors include

- Operator distraction, multi-tasking, and fatigue;
- Pedestrian inattention and distraction;
- Tight or problematic schedules;
- Timing/scheduling of buses;
- Lack of training and follow-up enforcement by transit agency; and
- Lack of pedestrian friendly environments.

Understanding the indirect links that these general issues have to bus-and-pedestrian collisions can foster the development of mitigation strategies. These strategies, then, are not only

likely to reduce the occurrence of bus-and-pedestrian collisions, but are also likely to reduce other types of collisions, resulting in improved overall safety. Each of these contributing factors is discussed in more detail below.

4.1.1 Operator Distraction, Multi-Tasking, and Fatigue

The issue of operator distraction was raised by transit agencies and different stakeholders, including operators. Operator distraction does not necessarily suggest negligence on the part of the operator: distractions were often linked to the "stressful and distracting" environment in which the operators work, as a variety of things are constantly competing for the operators' attention (e.g., vehicle traffic, passengers, on-board electronic equipment, inclement weather, and poor lighting). It is a common belief amongst the agencies and stakeholders participating in this research that the occurrence of collisions with pedestrians during left-turns is linked to the fact that the operators must focus on finding a gap in oncoming traffic to make the turn and, while doing so, lose sight of pedestrians in the crosswalk.

Exacerbating the problem of a distracting environment is the issue of operator multi-tasking. An operator's workload includes performing multiple physical and cognitive duties from simple driving behaviors, to implementing procedures unique to bus operations, to providing good customer service and monitoring a route schedule. While the issues of distraction and multi-tasking are somewhat overlapping (operators are sometimes distracted due to their multi-tasking), strategies for countering operator multi-tasking may be different than strategies for countering operator distraction; therefore, it is important to note the distinction of the issues, as well as the overlap.

Bus operator fatigue was also reported as a potential contributing factor to bus-and-pedestrian collisions by a number of agencies and stakeholders. Fatigue is a result of both time spent driving and length of wakefulness (i.e., amount of time since the operator last slept). When overly tired, humans do not function optimally, which can result in slower reaction times and errors or misjudgments that they otherwise may not normally make in the same situation.

Analysis of the collision data showed that operator time on duty does in fact appear to play a role in the occurrence of bus-and-pedestrian collisions. The length of time that the operator was on duty was reported in 94 of the incident records. As shown in Figure 4-1, the number of inci-

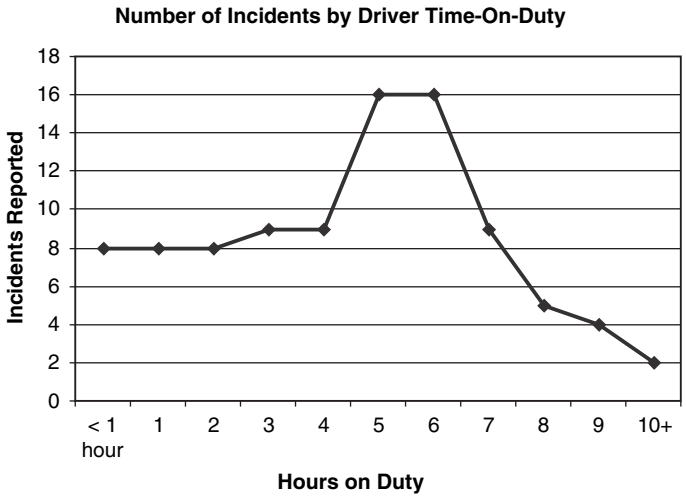


Figure 4-1. Number of bus-and-pedestrian collisions by driver time on duty.

dents compared with the number of hours on duty remained steady (at about 8 to 9 incidents) for every hour worked until 5 hours. After 5 hours on duty, the number of incidents almost doubled. At 5 and 6 hours on duty, the number of incidents jumped to 16. Above 6 hours on duty, the number of incidents begins to fall. This drop is most likely due to the fact that there are fewer shifts that extend beyond 6 to 7 hours.

Operator distraction, multi-tasking, and fatigue could lead to any type of collision; however, the relevance of discussing these issues in this Guidebook is that pedestrians are the most vulnerable road users. Due to pedestrians' size (as compared with automobiles) and the speed at which they move relative to a bus, operators—if distracted or overly tired—are more likely to overlook a pedestrian than they are to overlook another vehicle. For example, a distracted or multi-tasking operator may just happen to catch a moving vehicle in his or her peripheral vision in enough time to avoid a collision. Due to the size and movement of pedestrians, in the same situation the pedestrians are far less likely to catch the eye of the operator before a collision occurs.

Therefore, the environment in which the operator operates, the tasks he or she is asked to manage, and the number and combination of hours and days an operator works in a week are important issues to consider when thinking about pedestrian safety. One suggested strategy was to minimize on-board operator tasks such as eliminating the need for operators to collect fares by using smart cards.

4.1.2 Pedestrian Inattention and Distraction

Bus-and-pedestrian collisions involve two parties: the bus operator and the pedestrian. While bus operator distraction, multi-tasking, and fatigue can lead to collisions with pedestrians, pedestrian inattention and distraction can also lead to collisions. Getting pedestrians to understand, appreciate, and respect their role in their own safety is an important part of reducing the occurrence of bus-and-pedestrian collisions. Pedestrians are often times distracted by the use of cell phones and other portable electronic devices. For instance, pedestrians who use earphones may not be paying attention to their surroundings; however, they also may not be able to pick up important audible cues that could warn them of potential danger.

Even pedestrians admit to being in a hurry too often. Pedestrians, like operators, are less likely to respect other road users when they are in a hurry or running late, especially if they are trying to catch a bus that is about to leave. Other pedestrian behaviors that were reported as contributing factors to bus-and-pedestrian collisions included not using crosswalks, challenging the right-of-way, and violating the traffic signals.

With all of these pedestrian-related contributing factors, there is a place for well-planned and well-developed pedestrian outreach and education in an overall pedestrian safety program. Education programs like Transit 101 (see Table 2-7 and Section 3.2.2) have been successful at keeping pedestrians on a college campus from being involved in bus-and-pedestrian collisions and are relatively low in cost.

4.1.3 Tight or Problematic Schedules

Tight or problematic schedules were also reported by agencies, pedestrian groups, and operators as a contributing factor in collisions, particularly in bus-and-pedestrian collisions. Schedules that are too tight or unrealistically set can lead to operators getting off schedule, which can result in the operators being counseled by their supervisors. In an attempt to avoid counseling, operators may feel they have to rush to stay on schedule and to make up time on their runs. It is human nature that when we rush, we lose sight of things that we otherwise would not.

There were a number of suggested strategies involving bus schedules. Stakeholders, particularly bus operators, suggested more realistic schedules and more time to complete routes. One interesting suggestion was to bring together the scheduling department and the operators to talk about the schedules. By doing this, operators would have the opportunity to voice their concerns about routes with problematic schedules and their potential safety consequences.

4.1.4 Timing/Scheduling of Buses

There was a lot of discussion during both pedestrian focus groups about safety issues surrounding the timing of buses at transfer locations. Most of the pedestrians felt that when the buses are not well timed or do not arrive when they should (i.e., they are behind schedule), it can put bus riders in a position of running to catch a bus. In addition, the actual bus stop placement at these locations (usually intersections) can add to the problem. For example, if bus riders must alight one bus and then cross to the far side of the intersection to catch their next bus, bus schedules, heavy traffic, and poorly timed signals (e.g., not providing enough time for pedestrians to cross or providing too much time to the major street as compared with the minor street) can make it nearly impossible for a rider to make a smooth transfer.

At locations where a number of bus lines stop at the same location, bus stops should be well thought out and well laid out, and bus schedules should be developed to accommodate riders making transfers. Signal timing—such as the pedestrian scramble (i.e., all pedestrian phase)—might also be altered to accommodate pedestrians at busy times of the day.

4.1.5 Lack of Training and Follow-up Enforcement by Transit Agency

Agencies should take responsibility for providing quality training that places a focus on operator retention; the rules, policies, and procedures that are set forth in the training program should be enforced. For example, while operator cell phone use while driving is almost always forbidden, it was reported that it is not always enforced. When policies are not enforced and operators are not held accountable, they will have no respect for the policy. A reward system could be put in place to provide praise to operators who uphold safety policies and procedures, which will also contribute to operator retention. In the long run, the agency will save money as there will be more experienced operators and fewer new hires who need training. Experienced, well-trained operators with good safety records will result in fewer collisions and fewer claims.

4.1.6 Lack of Pedestrian Friendly Environments

Another big issue voiced by the pedestrian groups was the need for more pedestrian-friendly environments. There was a reported "lack of sensitivity about investing in walkable, pedestrian friendly environments around transit stops and along transit corridors." Pedestrians also reported they had seen collisions that occurred when people slipped or tripped on poor sidewalks and fell under a bus. In fact, broken and uneven sidewalks, narrow sidewalks, sidewalk obstacles, and lack of sidewalks or other positive separation were all rated as being some of the most common hazards to pedestrians by the pedestrian focus groups.

Improving sidewalks, removing obstacles, and providing pedestrian-friendly amenities at and around bus stop locations could be an effective way of reducing collisions involving pedestrians falling under the bus. Partnerships with the local department of transportation or public works, as well as pedestrian advocacy groups and input from the public, will assist with the identification of stops most in need and strategies most likely to improve pedestrian safety.

4.2 Combining Strategies for Added Potential for Success

This research has shown that the circumstances of and contributing factors to bus-and-pedestrian collisions are multi-faceted. For any collision type, the bus operator, the pedestrian, and the environment (i.e., bus design, bus stop location, and roadway geometry) play a part. There is no simple single answer to mitigating collisions. Instead, various approaches may reduce collision frequency, severity, or both. In many cases, implementing two or more strategies in combination might make the most sense and provide the "biggest bang for the buck." Some principles for successful strategy selection include the following:

- **Consider all circumstances.** When a collision occurs, it is tempting to focus on the assignment of fault. However, this research shows that it is likely that multiple factors contributed to a collision—the pedestrian, the bus operator, and the environment. Implementing a strategy that focuses only on one aspect of the collision overlooks the depth of the collision problem. For instance, we must assume that humans are prone to error. Thus, bus operators and pedestrians must both behave defensively when navigating roads, assuming the worst about the other's intentions. The extra energy and costs involved in fully addressing the collision problem (versus narrowly focusing on one aspect) might in the long-run be the most economical approach.
- **Collaborate and partner.** When a collision occurs, the results are felt most directly by the pedestrian, the bus operator, their families, and the transit agency. Also impacted, however, are many in the community at large (pedestrians and bus riders, law enforcement officials, transportation engineers, etc.). When implementing a collision mitigation plan, it is wise to take advantage of all of these stakeholders through brainstorming, collaboration, and partnership to implement a pedestrian-and-bus safety plan. Bringing together a "meeting of the minds" will contribute to greater success of the mitigation strategies and the safety program as a whole.
- **Follow-up.** Once an application is in place, follow-up is required in order to promote success of the application. Follow-up could include enforcement of a policy or procedure (through on-board or roadside safety checks or observations) or of a law (through police enforcement). Follow-up could include refresher training or safety reminders posted at regular intervals, counts of near misses and related incidents, and candid discussions with operators and pedestrians.
- **Evaluate.** One challenge of this research was to assess the success and effectiveness of the applications. Bus-and-pedestrian collisions, while often catastrophic, are relatively infrequent. Thus, before-and-after measures of the number of collisions are often an inappropriate approach to measuring success due to the length of time needed to gather and analyze a statistically significant set of data. Instead, candid discussions with operators and pedestrians and subsequent analysis of the information should be used to assess whether the application is having the intended results. Measures of effectiveness could be near misses; claims; and ratings of success by operators, bus riders, and community stakeholders. In addition, the accurate, consistent, and detailed reporting of information associated with bus-and-pedestrian collisions will greatly improve the ability to determine causal factors, as well as appropriate solutions.

The following are some examples of how to combine two or more different types of strategies in order to increase the success of the individual strategies implemented alone.

4.2.1 Policy and Pedestrian Outreach

Running after buses was one of the most commonly reported behaviors resulting in bus-and-pedestrian collisions across all stakeholder groups. One suggested application to counter this

problem was to set the policy of not stopping to let passengers on after the bus has left the stop. While some agencies have these policies, many leave it up to the operator's discretion to determine whether it is safe to stop and let a rider on the bus. Stopping at non-stop locations can be very dangerous, not only to the pedestrian, but also to other operators. When operators do stop to let passengers on after they have left the stop, it reinforces the running behavior because passengers know the bus will stop for them. On the other hand, if the operator does not stop, it is viewed as poor customer service by bus patrons.

When it comes to this situation, there is a definite conflict between safety and customer service. Ironically, not stopping for pedestrians is in the their best interest, as well as in the interest of other road users who could be impacted by a bus stopping where it is not supposed to.

This situation requires a multi-faceted approach. The policy of not stopping for passengers who are not at a stop is a good one; however, the transit agency must uphold its duty to provide reliable bus service. If buses arrive at stops in "clumps," passengers will have no reason to wait for the next bus because there is no telling when the next bus will arrive—and passengers know it. If running after buses is an issue on routes where bus service is reliable, the policy of not stopping outside of designated stop locations could be implemented hand in hand with a public education and outreach program. Posters could be hung at stops, shelters, or on-board buses, and flyers could be handed to passengers letting them know of the new policy and why it is going into effect. It should be explained to them that it is for their own safety as well as the safety of others. In return for riders not running after the bus, the transit agency might let the riders know how they are working to keep the buses on schedule so that riders will not have to wait too long for the next bus or that the agency is adding extra service or an extra bus at the end of the day. By doing so, riders will be more understanding and accepting of the policy and will feel that there is a "give-and-take" exchange on the part of the transit agency not only to improve safety, but also to improve service.

4.2.2 Defensive-Driving Techniques, Policies, Training, and Enforcement

Defensive driving can be an effective way of improving bus safety around pedestrians. Defensive-driving techniques and policies can be developed in an attempt to mitigate future collisions. After developed, the bus operator must apply the techniques and policies with knowledge, judgment, and skill; therefore, operating techniques and policies should be implemented as part of an operator training program. New hires should be taught the techniques and policies, and these techniques and policies can be reinforced through refresher training. But this is not enough. In order to have continued success with special techniques and policies, the transit agency must be committed to keeping the ideas in the forefront of operators' minds. This can be done relatively inexpensively through bulletins, posters, flyers, and videos that express the importance of the techniques and policies, as well as the commitment of the agency and drivers to upholding them. Finally, operator use of the strategies can be checked or reinforced through on-board and roadway observations. Check rides or proficiency checks may be performed by agency staff or a contracted service.

When carried out as part of new hire and refresher training, the cost of implementing specific operating techniques and policies is relatively low since it is only one of several components of the training program. The cost, however, can be high if the techniques and policies are implemented to address a particular pedestrian safety issue and are outside of the usual operator training cycle.

4.2.3 Lack of Lighting and Visual Obstructions

Lack of lighting and visual obstructions were both big issues voiced by many stakeholders. Both issues deal with the ability of the operator to see pedestrians whether waiting at a stop or

shelter or when crossing the street. An operator's visibility is reportedly limited due to bus features (e.g., mirrors, farebox, or door) and roadway features that block the line of sight from the driver's seat to pedestrians (e.g., light poles, traffic signals, trash cans, electrical boxes, and vendors). Therefore, when a location is found to have problems with bus operators reportedly not seeing pedestrians, the problem should be addressed from different angles.

Lack of lighting was rated by both pedestrian groups and one stakeholder group as one of the most common hazards to pedestrians. Agencies should solicit information from operators and the public about locations with particular lighting problems. There are a variety of low-cost solutions that can be implemented, including retro-reflective paddles, flashing beacons, and pocket and pen lights (see Table 2-12). The cost effectiveness of these strategies will be improved if potential problem locations are examined on a case-by-case basis rather than taking a one-size-fits-all approach.

Bus design and its impact on operator visibility are controversial. Some agencies reported that bus features can cause obstructions that play a role in collisions, while others did not agree. Bus operators almost always reported that bus features can cause visibility problems that can lead to collisions. To counter visual obstructions on buses, agencies should work with operators and manufacturers to minimize the impacts of the bus-related obstructions (e.g., mirror size and placement). As mirror size, configuration, and placement are challenging and ongoing issues for many transit agencies, agencies could participate in peer-exchange activities to share ideas, successes, and failures.

To counter visual obstructions outside of the bus, transit agencies should develop partnerships and working relationships with their local DOT or public works—as well as pedestrian advocacy group—to identify problem locations and to create workable solutions that involve removing or re-locating objects and bus stops and shelters to locations where obstructions are minimized or eliminated.

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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
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
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