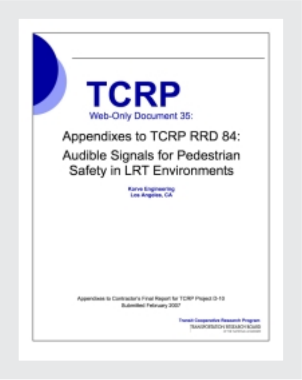

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Appendixes to TCRP RRD 84:
Audible Signals for Pedestrian
Safety in LRT Environments

Korve Engineering
Los Angeles, CA

Appendixes to TCRP RRD 84: Audible Signals for Pedestrian Safety in LRT Environments

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Appendix A
Synopsis of Prior Research (Literature Review)
(Prepared November 2003)

INTRODUCTION AND PURPOSE

The purpose of this literature review is to summarize the relevant literature and research that has been conducted in the area of audible warnings for pedestrians at light rail transit (LRT) grade crossings. The numerous references outlined in this report provide research findings and recommendations for grade crossing treatments or for pedestrian audible warnings; however, there has been limited research conducted on the effect of audible warning devices on pedestrian behavior at LRT grade crossings. This report provides a summary of the research separated into the following areas:

- Pedestrian Treatments at LRT Grade Crossing
- Human Factors
- Audible Warnings
- Considerations for Persons with Disabilities

Following the summary of each area is a list of selected references and short summary of each reference that describes the particular aspects of the literature reviewed. It is clear through the literature review that although research has been conducted which evaluates various factors of audible devices at grade crossings, a study has not yet been conducted that clearly identifies the impacts of pedestrian audible devices at LRT grade crossings. Therefore, TCRP Project D-10 will be the first comprehensive review of pedestrian audible devices at LRT grade crossings which conducts research of the effects of innovative devices on pedestrian behavior.

PEDESTRIAN TREATMENTS AT LRT GRADE CROSSING

Much attention has traditionally been given to safety issues associated with motor vehicle/light rail vehicle (LRV) crossings. There has been somewhat less attention given, however, to issues associated with pedestrian/light rail vehicle conflicts, including collisions, near misses, evasive actions, and illegal pedestrian movements. While there are generally fewer pedestrian/light rail vehicle collisions, the results of such collisions are often severe given the inherent vulnerability of the pedestrian. Compounding this problem, new generations of light rail vehicles are quieter than previous designs. As such, pedestrians are not as aware of oncoming light rail vehicles, potentially increasing conflicts.

The most comprehensive literature to date that provides a review of grade crossing treatments at LRT grade crossings can be found in *TCRP Report 17: Integration of Light Rail Transit into City Streets* (Korve et al, 1996*)* and *TCRP Report 69: Light Rail Service – Pedestrian and Vehicular Safety* (Korve et al, 2001*)*. These two reports identify effective traffic control devices, public education devices and enforcement techniques for LRT grade crossings. The information in the two reports is based on interviews with 14 LRT systems throughout North America, additional data collection and field testing of grade crossing treatments.

TCRP Report 69 reports that at LRT grade crossings where the LRV operates at speeds up to 55 km/h (35mph), 18% of pedestrian collisions result in fatalities. Where the LRV operates at speeds in excess of 55 km/h (35 mph), 29% of pedestrian collisions result in fatalities. In addition, many of the injuries obtained by pedestrians are life altering, including dismemberment and long term trauma.

With respect to pedestrian audible devices at LRT grade crossings, TCRP Report 69 describes that at higher speed LRT crossings controlled by flashing light signals and automatic gates, some LRT agencies turn off the bell once the automatic gates have descended. Cessation of the wayside crossing bells is sometimes necessary in residential neighborhoods where excessive noise is usually a concern. The report recommends that some form of audible wayside warning should be provided for the visually impaired. As an alternative to crossing bells, small audio devices (similar to a back-up alarm on a truck, such as those found on portions of the Sacramento LRT system) could be installed in the crossing hardware to warn pedestrians of an approaching LRV. These small audio devices could be softer than a clanging bell and also focused on the sidewalk itself.

In addition to grade wayside devices such as those described above, LRVs are equipped with bells, whistles and/or horns. TCRP Report 69 describes that usage of LRV bells, whistles, and horns at LRT crossings varies widely based on local practices, ranging from “silent” crossings during the evening hours where the LRV operator only sounds the horn if there is imminent danger to crossings where the LRV operator sounds the horn in the long blast-long blast-short blast-long blast” pattern all hours of the day (every time the LRV passes through the crossing). The use of the bells or horns is based on the operating procedure of the transit agency and may be based on considerations such as the speed of the LRV through the crossing as well as community impacts. Some agencies require the train operator to sound the horn at all crossings, while other agencies request that the operator to only sound the (quieter) bell through crossings and sound the horn at their discretion if there is an imminent hazard.

Another research study which focused on the use of audible devices at LRT grade crossings is entitled *Effects of Pedestrian Treatments on Risky Pedestrian Behavior* (Siques, 2002). This paper discusses a research study conducted at the Portland, Oregon LRT System (Tri-Met) which evaluated the effects of various pedestrian treatments on risky behavior. The report describes that the Portland LRT System has installed pedestrian audible devices at various locations in a demonstration project to determine the effect of the audible device on risky pedestrian behavior. The audible device announces the message “Train Approaching, Look Both Ways” in both Spanish and English when a train activates the crossing control devices. The results of the device were mixed based on the type of behavior observed.

Pedestrian Warning and Control Devices, Guidelines and Case Studies (Siques, 2001) also provides recommendations on how to identify potentially hazardous crossings and appropriate treatments. The paper identifies four basic factors that govern the level of pedestrian safety at crossings. These factors are:

- pedestrian awareness of the crossing,
- pedestrian path across the trackway
- pedestrian awareness of the approaching LRV
- pedestrian understanding of the potential hazards at grade crossing

Each factor is discussed and case studies are presented where innovative treatments have been used to increase pedestrian safety at LRT grade crossings.

The use of audible devices, either wayside or on train, is also related to the alignment type of the LRT crossing. Alignments where the LRV travels in a separate right-of-way or is gated have different operating procedures than alignments where the LRV is operating in mixed flow or on-street environments controlled by traffic signals. Audible devices at traffic signaled controlled intersections are discussed further in the *Human Factors* and *Considerations for Persons with Disabilities* sections of this literature review.
The following summary of selected studies provides background on additional studies conducted on pedestrian warning devices at grade crossings:

APTA Rail Safety Committee—Grade Crossing and Pedestrian Safety Task Force. *LRT Grade Crossing Design Features*. June 12, 1994.

This report provides a synopsis of the various approaches to grade crossing design taken by LRT systems in the U.S. and Canada. It represents one component of the ultimate objective of the task force, which is "to investigate and report on the state of the art of grade crossings and pedestrian safety and to develop recommendations. The information presented includes detailed descriptions of the grade crossing design features of several of the North American light rail systems.

Coifman, B. and Hansen, M. *IVHS Warning Systems for Light Rail Grade Crossings*. Institute of Transportation Studies, University of California at Berkeley. 1994.

This report quantifies the costs of light rail grade crossing accidents with left-turning vehicles and identifies the causal events leading up to a collision and the factors that may contribute to the probability of injury. A classification of costs is developed to motivate the discussion of collision countermeasures. It is noted that compared to automobile accidents, pedestrian and bicycle accidents tend to have significantly higher claims and legal costs. The report concludes with a discussion of technologies for an intelligent system to respond to hazard conditions. The specific technologies discussed are classified according to the tasks they accomplish — automobile detection, hazard prediction, and graduated response based on predicted hazard level.

Federal Highway Administration, U.S. Department of Transportation. *Manual on Uniform Traffic Control Devices for Streets and Highways*. Millennium Edition. Washington, DC (2000).

This manual sets forth the basic principles that govern the design and usage of traffic control devices for different classes of road and street systems. These devices include "signs, signals, markings, and devices placed on, over or adjacent to a street or highway by authority of a public body or official having jurisdiction to regulate, warn, or guide traffic." Chapter 8 of this manual sets forth guidelines for traffic control systems for railroad-highway grade crossings.

Chapter 10 of this manual presents standards and guidelines for the design, installation, and operation of traffic control devices, such as signs, markings, and automatic gates, at grade crossings of highways and light rail transit. Many of the guidelines presented are different from those prescribed for crossings of railroads and highways because the operating characteristics of LRVs are different from conventional trains. The situations when such devices should be installed and precise specifications for installation are described in great detail. Pedestrian grade crossings are given special attention, with a description of specific pedestrian treatments.

Institute of Transportation Studies. "Special Report: Pedestrian Safety." *Tech Transfer*, No. 45. Washington, DC (April 1994), pp. 2-7.

This report contains several articles describing the California pedestrian safety plan, sources of local funding for pedestrian safety programs, and two pedestrian enhancement projects. An annotated bibliography of recent publications addressing pedestrian safety issues is also included with this report. The report identifies some of the pedestrian safety concerns of local and state agencies.

Stokes, R. W., Rys, M. J., and Russell, E. R. "Motorist Understanding of Selected Warning Signs," *ITE Journal*. Washington, DC, (August 1996) pp. 36 - 41.

This report documents the results of a survey taken in the state of Kansas to test driver understanding of common warning signs. In this study, driver understanding was tested using a multiple choice test administered at selected survey stations in several counties within Kansas that were deemed to have similar demographics as the state of Kansas as a whole. Open-ended surveys were also administered as part of this research. As the survey results reveal, the use of

multiple choice surveys introduces bias by limiting the choice set of possible interpretations of the warning signs. With the multiple choice surveys, test subjects had a better chance of identifying the correct response from the options listed. The use of open-ended questions helped to compensate for this bias. One shortcoming of this survey methodology that the authors acknowledge is that the surveys focused on assessing on whether or not the driver understood the exact meaning of the traffic warning signs, rather than assessing if the driver's understanding of the sign would generate an appropriate behavioral response.

Transportation Research Board, National Research Council. *TCRP Report 17: Integration of Light Rail Transit into City Streets.* National Academy Press, Washington, DC. 1996.

This report presents the safety and operating experiences of ten North American light rail transit systems operating in shared (on-street or mall) rights-of-way at speeds that do not exceed 35 miles per hour. Although LRT systems are safer than the motor vehicle-highway system, accidents remain a problem due to motorist and pedestrian inattention, disobedience of traffic laws, and confusion about the meaning of traffic control devices. Research found that traffic control treatments for safety and efficient operations at LRT grade crossings vary from system to system and even between different locations in the same system. This report proposes several guidelines to be adopted by the National Committee on Uniform Traffic Control Devices for signs and traffic control systems for uniform application at light rail-highway grade crossings.

Transportation Research Board, National Research Council. *TCRP Report 69: Light Rail Service – Pedestrian and Vehicular Safety.* National Academy Press, Washington, DC. 2001.

This report identifies, validates and recommends safety enhancements to reduce incidents at higher speed LRT grade crossings, including a study on the effectiveness of pre-signals. Pedestrian treatments at LRT grade crossings are discussed in detail and a Pedestrian Controls Decision Tree is presented that describes what types of pedestrian treatments should be used at LRT grade crossings. The use of pedestrian treatments are based on various warrants, including sight distance, school zones, LRT speed and the level of pedestrian activity.

HUMAN FACTORS

Typical warning systems currently used to alert pedestrians to potential threats include horns or bells operated at the grade crossing. Some of these devices are sounded until the gates are down while others are sounded until the train has passed. These warnings are typically quite loud and can generate significant community opposition. Pedestrians often engage in risky behaviors at crossings (Siques, 2002), and it is not likely that their failure to respond to audible warnings is a result of them not being sufficiently loud. However, they may not be sufficiently salient or informative.

The present use of audible warnings is based on limited research and historical practice. At this juncture the research community is faced with the choice of improving the old system of warnings designed and implemented at a time when best guesses predominated over carefully controlled research studies or to design a more effective warning system based on current knowledge of factors influencing human behavior and utilizing modern technology. Selecting the later strategy will not only produce a more effective system but will also better meet the needs of persons with disabilities. Novel approaches that should be evaluated include: 1. The effectiveness of auditory icons such as the sound of the train *emanating from the direction the train is approaching from*, with or without the sound of the train's horn (such directional cues have been shown to reduce the time and effort to identify a potential threat in other applications); 2. The addition of voice messages along with auditory icons, which could provide a specific warning of the occurrence of a second train coming; and 3. The integration of auditory icons with visual icons, in order to provide redundant information in two sensory channels. An integrative approach that includes all three components should produce the best level of pedestrian compliance as well as best meet the needs of the visually and hearing impaired communities. The adoption of this approach could also lead to the use of lower sound levels if good human factors practices are followed. The remainder of this review focuses on research that bears upon adopting this approach.

Pedestrians in urban areas move through a richly textured visual environment. As intelligent transportation system (ITS) displays are introduced, they need to compete with other stimuli in this complex environment. Auditory messages can supplement some of these displays. System engineers often fail to take into account the behavioral principals that influence the behavior of pedestrians when designing auditory warning systems, reducing their efficacy. Many of these systems rely on audible warnings operated at excessive volume, which provide limited information in a non-intuitive manner. These warnings can create a startle response and lead to confusion if they are poorly designed. A more reasonable approach involves the use of auditory icons rather than arbitrary symbols. An auditory icon is a noise normally associated with the object that someone is being warned about such as the sound of breaking glass, or screeching brakes (Mynatt, 1994). In a light rail environment icons could consist of the noise associated with an approaching train and its horn or whistle delivered via a wayside speaker. One would expect that the reaction to auditory icons to be more intuitive than the response to arbitrary warning stimuli, and available evidence indicate that auditory icons are more effective warning stimuli than arbitrary symbolic sounds (Belz, Robinson, & Casali, 1999). Auditory icons can also be presented in a directional manner, which facilitates orientation in the direction of a potential threat. Wayside horns are one way to deliver an auditory icon and the *noise of an approaching train* presented along with the train whistle or horn might be the most intuitive warning icon.

Verbal warnings presented in one or more languages could also be used to support audible warnings. One advantage of audible warnings is that they can convey a more specific message than a simple auditory warning or even an auditory icon. One disadvantage is determining how many languages the verbal warning should be presented in for multi-cultural communities. The behavior modification literature has consistently shown that specific prompts or reminders produce better compliance than general prompts or warnings such as a simple auditory alarm. One study examined the use of verbal prompts delivered when pedestrians pressed the push button at a crosswalk controlled by traffic signals (Van Houten, Malenfant, Van Houten & Retting, 1998). When the pedestrian pushed the button the dynamically controlled speakers immediately delivered the verbal message “PLEASE WAIT FOR WALK SIGNAL” and at the start of the WALK indication the message “PLEASE WATCH FOR TURNING VEHICLES WHEN CROSSING _______ STREET” was presented. The percentage of pedestrians not looking for turning vehicles decreased from 16% to 4% and the percentage of pedestrian/motor vehicle conflicts decreased from 2% to 0.5% after the voice warning was introduced.

One problem, which needs to be addressed by any light rail auditory, warning system, is the risk of being struck by a second train. A voice message could indicate whether trains are approaching from both directions, or when two trains are approaching from the same direction (e.g., “WARNING TRAINS APPROACHING FROM BOTH DIRECTIONS” vs. “WARNING TWO TRAINS ARE APPROACHING FROM THE EAST”.

Research on the intelligibility of speech in a 3-D environment suggests that voice messages originating from the *side* of the listener produce the best comprehension (MacDonald, Balakrishnan, Orosz, & Karplus, 2002). This finding is interesting given that many warning devices are typically presented from a location ahead of the pedestrian rather than their side. Not only do warnings originating ahead of the pedestrian not optimize interpretation but they also provide no information on the direction that the train is approaching. A sound originating from the side of the pedestrian along the track at a level grade crossing would facilitate the pedestrian using the sound icon to discriminate the direction of the threat. The addition of a supplemental voice message when a second train is approaching should also be most easily interpreted when the pedestrian can hear trains approaching from both directions. The train or whistle sounds can also convey second train coming information by presenting them from both directions with a difference in the sound (difference in the doppler effect for the train whistle could confirm the perception that both trains are both approaching the crossing). This approach could also be used at station locations.

The Beltz, Robinson and Casali (1999) study on auditory icons also found better performance when visual icons indicating the direction of the threat were presented along with auditory icons. Van Houten and Malenfant (1999) reported the results of a study at passive rail crossing controlled by a stop sign. The speed distribution of drivers showed a marked decline when an icon showing animated LED eyes that looked both ways was activated when vehicles approached the crossing. In an other study Van Houten and Malenfant (2001) found that a visual display that showed drivers the direction that a pedestrian was crossing, as well as whether pedestrians were crossing from both directions was more effective than a non directional, non iconic flashing warning beacon (analogous to a simple auditory warning device). Both devices were operated by pedestrian detection. The electronic warning sign used in this study could be adapted to warn pedestrians of an approaching train at a level grade crossing by showing an icon of a train approaching from the pedestrians left or right. This device also has the advantage of allowing one to present both icons together when trains are approaching from both directions. One would suspect that integration of a directional electronic sign and a directional auditory display would generate the best pedestrian performance at level grade crossings and station locations. A study is currently underway to evaluate a second train coming warning sign on the Los Angeles County Metropolitan Transportation Authority's (LACMTA's) Metro Blue Line (Khawani, 2001).

The following summary of selected studies provides background on additional studies conducted on human response to warning devices:

Belz, S.M., Robinson, G.S. & Casali, J.G. (1999). A new class of auditory warning signals for complex systems: auditory icons. *Human Factors, 41*, 608-618.

This simulator based study compared conventional auditory warnings (tonal sounds) with auditory icons (sounds that represented a particular threat) with or without a visual iconic display, which indicated the type of threat. Measures included brake response time and accident occurrence. Participants were commercial drivers. The auditory icon selected for front-to-rear crash avoidance was the sound of screeching brakes, and the auditory icon for side collision avoidance was a long horn honk. Response time with auditory icons was markedly less than with the traditional auditory warning stimuli. It is interesting to note that no significant difference was found between the traditional auditory warning and the no-display condition. Participants also had markedly fewer side collisions with the auditory icon than the traditional auditory warning.

Khawani, V. (2001). "SECOND TRAIN COMING" warning sign demonstration project. *Transportation Research Record, 1762*, 32-36.

This paper describes a project currently underway to evaluate an ITS sign to warn pedestrians of the hazard of a second train arriving. This scenario has resulted in 14 pedestrian crashes and 4 fatalities at the LACMTA's Vernon Avenue HRI since the start of operation in 1990. This study describes the outreach and awareness program associated with the sign and the method being used to evaluate its effectiveness. Results of the effectiveness of the sign were not presented in the report, as the study was ongoing when the report was published.

MacDonald, J.A., Balakrishnan, J.D., Orosz, M.D. & Karplus, W.J. (2002). Intelligibility of speech in a virtual 3-D environment. *Human Factors, 44*, 272-286.

Researchers used a simulated air traffic control environment to evaluate the effects of special configuration on the detection of auditory speech warnings in an environment with multiple sound feeds. The simultaneous presentation of multiple sounds in an environment increases the difficulty of interpreting and responding to speech messages. This research was conducted in both a virtual 3-D environment and a free field (real space) environment. The results indicated that the left/right axis is the critical factor to consider in auditory display design. Speech was interpreted best when presented from the side rather than presented ahead. These findings are interesting because the most “natural” position for a sound source (in front of the speaker) was the least effective for “intelligibility”.

The TCRP Project D-10 team suspects that looking at the source is considered most natural because it allows detection of non-verbal social cues from speakers and because of the importance of vision has an early warning detection system.

Van Houten, R. & Malenfant, J.E.L. (2001). ITS Animated LED Signals Alert Drivers to Pedestrian Threats, *ITE Journal, 71, p. 42-47*.

An iconic electronic sign was evaluated which indicated to drivers approaching a indoor parking garage exit or a multilane crosswalk, the presence and direction of a pedestrian crossing in front of them. In the first location the view of the pedestrian was visually screened by the walls of the parking garage and in the second location the view of the pedestrian could be visually screened by a vehicle that yielded in another lane. When a pedestrian was crossing from the driver’s right, an LED pedestrian symbol walking from the right was illuminated on the right of the sign and animated LED eyes located in the center of the display looked repeatedly to the right. When the pedestrian was crossing from the left the LED pedestrian display an LED pedestrian symbol walking from the left was illuminated on the left of the sign and the animated eyes looked to the left. When pedestrians approached from both directions, both pedestrian symbols were illuminated and the eyes looked back and forth. This sign increased the percentage of drivers looking for the pedestrian, increased driver yielding to the pedestrian, and produced a marked decrease in the incidence of pedestrian/motor vehicle conflicts that involved either the pedestrian or driver taking evasive action. A flashing yellow beacon that was illuminated when pedestrians were present produced much smaller effects than the iconic sign.

The TCRP D-10 team believes that this sign could easily be adapted to warn pedestrians of approaching trains indicating the direction that train is approaching from. It can also indicate when trains are approaching from both directions.

Van Houten, R., Malenfant, L. Van Houten, J., & Retting, R.A. (1998). Auditory Pedestrian Signals Increase Pedestrian Observing Behavior and Reduce Conflicts at a Signalized Intersection. *Transportation Research Record,* No. 1578, 20-22.

A voice message was used to remind pedestrians to watch for turning vehicles when crossing with the WALK signal. The voice message increased pedestrian observing behavior and reduced pedestrian motor vehicle conflicts after it was introduced. Behavior improved the longer the system was in effect showing that the results were not a novelty effect. Such a system could also be useful to visually impaired pedestrians.

AUDIBLE WARNINGS

Audible warnings at protected grade crossings typically consist of some combination of train horns, train bells, and crossing gate bells. There has also been some recent effort to reduce community noise impacts by using wayside audible warnings in place of the train horns. These are commonly referred to as “wayside horns.”

Almost all of the published research on audible warnings at rail grade crossings is based on mainline rail systems, either freight, passenger or commuter rail. Over the past 10 to 15 years there has been a considerable amount of research sponsored by the FRA on the safety benefits and the corresponding noise impacts of sounding train horns before rail-highway grade crossings. The conclusion of this research is that, at least for mainline rail, sounding the train horns prior to grade crossings significantly reduces the potential for motor vehicle/train accidents. This information is particularly relevant for grade crossings with whistle bans. Most of this research has not considered pedestrian safety and has only focused on motor vehicle related incidents. Although the FRA research demonstrates the safety benefits from sounding train horns prior to highway-rail grade crossings on mainline rail systems, it is not clear whether and how this research applies to light rail pedestrian crossings. Because there is substantial evidence indicating that the routine sounding of train horns in advance of grade crossings has the potential to reduce motor vehicle/train accidents at grade crossings, it is reasonable to expect that the train horns also reduce the potential for pedestrian incidents.

One question is how applicable the research on mainline rail systems is to light rail systems. Some of the important differences between the audible warnings used on mainline rail and those used on light rail systems are:

- **Train Horn Sound Levels**. 49 CFR, Chapter 11, part 222.129(a) requires that train locomotives be equipped with horns that generate a minimum sound level of 96 dBA at 100 feet. In practice, many locomotive horns measure 100 dBA. Although there are no federal standards on the loudness of LRT audible warning devices, state and local regulations, as well as standard industry practice, are typically much lower. For example, light rail vehicles in California are required to have two audible warning devices: one measuring at least 75 dBA at 100 feet and the other at least 85 dBA at 100 feet.

- **Duration of Horn Sounding**. Freight and passenger trains are commonly required to start the horn sequence 1/4 mile from grade crossings and complete the sequence as the lead locomotive passes through the crossing. It is traditional for freight trains to use a long-long-short-long horn sequence as they approach grade crossings. Experience is that there is significant variation in how locomotive engineers perform the sequence. The requirement for sounding LRT horns before grade crossings varies widely. On systems where horn sounding is standard practice, they are usually sounded starting 500 to 1,000 feet before the grade crossing.

- **Type of Horn**. Mainline freight and passenger locomotives are equipped with air-horns that include 3 to 5 chimes whereas light rail vehicles commonly have either electric horns or air horns with only one chime. The electric horns can be programmed with any sound; many are programmed to sound like a freight train horn so the sound will be instantly recognized as a warning of an approaching train.

- **Horn Position**. Locomotive horns are usually mounted on the top of the cab and therefore tend to propagate in a 360° plane. In place of a horn, some commuter rail systems use a whistle mounted on the front of the lead locomotive that is located about 3 feet above the ground. Many horns on light rail vehicles are mounted under the front of the vehicle 2 to 3 feet above the ground. Horns mounted on top of the cab cause the most community noise impact. Locating the horn on the front or under the front of the vehicle tends to focus the warning sound towards the crossing broadcasting less of the sound into adjacent communities.

Much of the published literature on audible warning at grade crossings related to the proposed FRA rule on use of locomotive horns at grade crossings (FRA 1995 -2000). As discussed above, this research has shown a clear correlation between routine sounding of train horns prior to grade crossings and the accident rate. This research has all focused on motor vehicle safety. The proposed rule provides guidelines for establishing “quiet zones” where sounding the train horns prior to grade crossings is not required. The primary requirement is that supplementary safety measures be taken that will substitute for the train horn. The supplementary safety measures include four quadrant gates and photo enforcement.

Wayside horns are another alternative that is being used in place of sounding train horns. The use of wayside horns has been evaluated for both freight rail and light rail systems. Wayside horns consist of an audible warning that simulates a train horn and is supplemental to the bells and flashing lights at gate-protected crossings. The use of wayside horns has been investigated at a number of highway-rail crossings. Although the focus has been on motorist safety and community noise impacts, there are applications of this technology to pedestrian LRT environments, as well as for communities along LRT lines. Because the wayside horn sound is focused at the grade crossing, the area affected by the warning noise is greatly reduced. One study indicates that, by using the wayside horns, the total land area inside the 70 dBA and 90 dBA maximum sound level contours was reduced by 86% and 98%, respectively. Preliminary feedback from adjacent communities is that they strongly support the use of wayside horns and perceive the wayside horns as a noticeable improvement.

Wayside horn systems are now commercially available and have been installed at a number of mainline rail grade crossings. Although the wayside horn concept was evaluated for an LRT system in Los Angeles (Saurenman, 1995), we are not aware of any such systems being installed on North American LRT systems. It is clear that wayside horns can substantially reduce community noise impact, particularly on freight and commuter rail systems where horn maximum sound levels often exceed 100 dBA at residences. Questions still exist on the applicability of wayside horns in an LRT environment where horn sound levels are 10 to 20 dBA lower than on freight rail systems and whether wayside horns can maintain adequate levels of pedestrian safety.

Although wayside horns have been found to greatly reduce community annoyance, questions regarding motorist safety have not been fully answered. This is in part due to the difficulty of separating out the numerous factors that affect motorist behavior. For instance, at highway-railroad crossing, motorists are influenced by the crossing arms, flashers, bells, other motorist behavior, and past experiences. Also, motorists are accustomed to hearing the train horn come from either up or down the tracks. Potentially important acoustic cues related to the direction of train are eliminated with existing wayside horn systems. However, some long-term studies suggest that wayside horns provide an effective alternative to train horns.

Crossing bells are the other audible warning signal at most highway-rail and pedestrian-rail grade crossings. Protected highway-rail grade crossings on light rail systems are almost always equipped with some combination of gates, bells and flashing lights, often with all three. For protected pedestrian-only crossings, it is common to have bells and lights, sometimes with gates that pedestrians must pull open to cross the tracks. In spite of crossing bells being very common, the AREMA Communications and Signals Manual seems to be the only document with recommended noise limits for crossing bells.[1] The sound levels in the standard are:

- Section 3.2.60 Recommended Design Criteria for Highway-Rail Grade Crossing Electromechanical Bell (Revised 2000): The recommended specification is: “In the 180° plane occupied by the gong the peak sound reading in decibels (A scale) measured in an Anechoic test chamber at a point 10 ft. from the face of the gong and in increments of 20° should not be more than 105 dBA and not less than 85 dBA.” Under “alternate recommendations” sound levels of not more than 85 dBA and not less than 75 dBA are given.

- Section 3.2.61 Recommended Design Criteria for an Electronic Highway-Rail Grade Crossing Bell (Reaffirmed 2000): The recommended specification is: “In a 360° plane the peak sound reading in

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[1] American Railway Engineering and Maintenance of Way Association, Communications and Signals Manual or Recommended Practices.

> decibels (A scale) measured in an Anechoic test chamber at a point 10 ft. from the face of the sound horn and in increments of 20° should not be more than 105 dBA and not less than 75 dBA."

The following summary of selected studies provides background on additional studies conducted on audible warning devices:

49 CFR Parts 222 and 229, *Use of Locomotive Horns at Highway-Rail Grade Crossings; Proposed Rule*, Federal Register, January 13, 2000.

This proposed rule on use of locomotive horns at highway-rail grade crossings is applicable to all grade crossings that are part of the national rail system. This means that it is applicable to freight, passenger and most commuter rail systems, but it is not applicable to LRT systems. The FRA is still in the process of preparing a final rule. Perhaps the most controversial aspect of the proposed rule is that existing grade crossing whistle bans would be eliminated unless supplementary safety measures are implemented. Adopting the rule would require upgrading safety measures at numerous grade crossings where whistle bans are currently in place through local ordinances or other agreements. As part of developing the proposed rule, the statistics of train and motor vehicle accidents were evaluated to determine whether, and how much, use of train horns affected the accident rate at grade crossings. The conclusion was that whistle bans result in an elevated accident rate.

The proposed rule would result in uniform requirements for sounding train horns at grade crossings. It also provides specific guidance for state and local groups on supplementary safety procedures that are required before the FRA will consider an application for a quiet zone where train engineers are not required to sound the horns. Based on a presentation made by the FRA at the National Grade Crossing Safety Conference in San Antonio, Texas, on November 5, 2003, the Interim Rule will be released by the FRA by the end of 2003 for a 60-day comment period. The Final Rule will be released in the summer of 2004. The rule will also address the use of wayside audible horns.

Technical Supplement to the Draft Environmental Impact Statement of the Proposed Rule for the Use of Locomotive Train Horns at Highway-Rail Grade Crossings. FRA, U.S. Department of Transportation, December 1999.

This report is a supplement to 49 CFR Parts 222 and 229. The primary goal of the study was to estimate the number of people who would be adversely affected by the noise exposure increases that would result from a nationwide elimination of all current whistle bans. A generalized model of grade crossing horn noise was developed to allow estimating the population that would be affected by eliminating whistle bans. This study is specific to the freight rail system and only has peripheral application to light rail systems.

Florida's Train Whistle Ban, 2nd Edition. September 1992. and *Nationwide Study of Train Whistle Bans*. FRA, Office of Safety, U.S. Department of Transportation, April 1995.

In response to Congressional inquiries, FRA investigated the number of accidents at crossings with nighttime whistle-bans. FRA found that the accident rate for the Florida East Coast Railway Company at 511 grade crossings nearly tripled after the nighttime whistle-bans were imposed. This increase is statistically greater than the increased accident rate at 89 comparable crossings where the whistle-ban had not been imposed. After the whistle ban was eliminated, the accident rate returned to the pre-ban rates.

Updated Analysis of Whistle Bans. FRA Office of Safety, U.S. Department of Transportation, January 2000.

This study and the update in 2000 represents a careful evaluation of the comparative accident rates at crossings with and without whistle bans. The conclusion of the 2000 update is that "…an average of 63% more collisions occurred at whistle ban crossings with gates than at similar crossings across the nation without bans." The analysis excluded all events where pedestrians were struck.

Safety of Highway-Railroad Grade Crossings, Railroad Horn Systems Research, Volume II, DOT/FRA/PRD-DPOT-VNTSC-FRA, Final Report. Research and Special Programs Administration, John A. Volpe National Transportation Systems Center, U.S. Department of Transportation, 1993.

As part of on-going research into the effectiveness of various methods of reducing the number of accidents at highway-railroad grade crossings, the Volpe Center evaluated the use of locomotive horns for warning motorists and their impact on local communities. Acoustic data was used to compute the community noise exposure in the vicinity of grade crossings, which was compared against "normally acceptable" sound levels. The insertion loss and baseline interior noise levels of motor vehicles were obtained to evaluate the detectability of train horns. The interior noise level of the vehicle with the air-conditioning ventilation turned on and with the radio turned on had impacts on the audibility of the exterior noise.

Gent, S., Logan, S., and Evans, D. *Evaluation of an Automated Horn Warning System at Three Highway-Railroad Grade Crossings in Ames, Iowa*. Mid-Continent Transportation Symposium Proceedings, 2000.

This research investigated the effects of automated horn warning systems (wayside horns) on community annoyance and overall motorist safety. It was determined that the wayside horn dramatically decreased the land area affected by horn noise and was perceived as a significant improvement by a majority of nearby residents. Although the overall safety provided by the wayside horn could not be accurately determined, the study found no evidence that they are less safe than typical locomotive train horns.

Saurenman, H., Roberts, W. *Testing of Wayside Horn Concepts for Audio Warnings at Grade Crossings*. Harris Miller Miller & Hanson, Inc., September 1995.

This report summarized a feasibility study of using a wayside horn system in place of train horns at a grade crossing on the Los Angeles County MTA Blue Line, a light rail line connecting Los Angeles and Long Beach. Because the LRT tracks share right of way with freight rail tracks, the horns on the Blue Line vehicles were set to the FRA standard of 96 dBA at 100 ft in front of the train, which is about 10 dBA louder than the horns on most Californian light rail systems. The wayside horn concept was investigated as a method to achieve the same public safety with less noise impact to residences adjacent to grade crossings. A focus group from the surrounding community was used to evaluate both the warning effectiveness and annoyance potential of the wayside horns. The testing indicated that wayside horns are a valid concept that could provide equal or greater public safety as train horns while reducing community noise levels. The results are equally applicable to pedestrians and motorists.

Wayside Horn Sound Radiation and Motorist Audibility Evaluation. Association of American Railroads, May 2000.

This study tested a commercially-available wayside horn system in terms of community noise levels and motorist warning.

Roop, S. *A Safety Evaluation of the RCL Automated Horn System*, Texas Transportation Institute, Rail Research Center, May 2000.

This study looked at the change in Type 1 and Type 2 violations before and after the installation of a wayside horn system in Gering, Nebraska. The report concluded that, after five years in operation, the wayside horn at this location is an effective alternative to the more intrusive locomotive horn.

Horn Investigation Report, Southern California Regional Rail Authority, prepare by LTK Engineering Services, November 1993.

This memorandum summarizes noise measurements performed on the horns and whistles installed on Metrolink trains in Los Angeles. Approximately 10 years ago, Metrolink locomotives and cab cars were all equipped with chime air whistles in an effort to reduce community complaints about noise near grade crossings. The whistles were mounted on the front of the locomotives and cab cars approximately 3 feet above the ground. In contrast, the horns were located on top of the vehicles about 15 feet above the ground. The horns and whistles were adjusted to meet the FRA regulations directly in front of the train. In a perpendicular direction, the data show the whistles are 10 to 20 dBA quieter than the roof mounted horns.

State Regulatory Requirements Governing Warning Signals for Light Rail Vehicles

The requirements for audible warning signals of light rail vehicles operated by state-chartered transit authorities are regulated principally by state agency and/or transit authority policy. These requirements are customarily based on a codification of experience and common practice, rather than on systematic research or quantitative analysis. For example, a single paragraph (§3.04) of California Public Utility Commission General Order 143-B establishes that every light rail vehicle operated by one of the state's transit authorities

> "shall be equipped with a bell or horn capable of producing a clearly audible warning measuring at least 75 dBA at a distance of 100 feet from the vehicle. In addition, every LRV operating on a separate right-of-way over motor vehicle grade crossings shall be equipped with a horn or whistle measuring at least 85 dBA at a distance of 100 feet from the LRV."[2]

The criteria for warning effectiveness that these requirements are expected to satisfy are not explicit. It is thus unclear what minimal warning time such signals are expected to provide to pedestrians or motorists at various light rail running speeds; whether the warning signals are expected to be as effective at crossings in noisy urban or industrial ambient noise environments as they are at quieter suburban crossings; whether the warning signals are intended to protect people with some degree of hearing impairment; what rate of complaints about warning signals from residents of neighborhoods near light rail rights-of-ways are considered tolerable; and so forth.

Further, the requirement for the lower level warning signal implies that "a bell or horn" at an A-weighted sound level of 75 dB at 100 feet is in fact "clearly audible" — at least to pedestrians — under unspecified circumstances. The requirement for a warning "horn or whistle" capable of producing a sound level 10 dB higher is presumably intended to warn motorists at grade level crossings. This 10 dB differential is evidently viewed as sufficient to overcome the roughly 30 dB acoustic insertion loss of motor vehicles of recent manufacture, and to produce an adequate signal-to-noise ratio with respect to the interior (driver-controlled) sound environment of motor vehicles.

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[2] The literal requirement for "horns", "bells", and "whistles" on light rail vehicles is loosely interpreted as permitting a variety of front-mounted, electrically-activated warning signals rather than the usual top-mounted, high pressure air horns generally installed on federally-regulated heavy rail locomotives.

General Order 143-B is silent about a technical rationale to support the requirements of §3.04. However, this rationale presumably includes tacit assumptions not only about issues of warning effectiveness, but also about commonly encountered urban and automobile interior ambient noise environments, typical spectral content of warning devices, the manner of activation of warning signals for light rail vehicles, and adverse community reaction to excessively loud horns, bells, and whistles. These assumptions are unlikely to be met in at least some circumstances of current interest, because they are not directly linked to the acoustic determinants of warning signal effectiveness: the bandwidth-corrected signal to noise ratio of the warning signal at the listener's ear. An A-weighted sound level for a warning signal does not constrain the frequency composition of the signal, and has nothing whatever to do with the influence of background noise levels on warning signal audibility.

Related Federal Regulatory Requirements

49 CFR Ch. VI §659.21 delegates oversight responsibility for safety-related matters of intra-state transit agencies to individual states. Even though the provisions of the Federal Railroad Administration's 49 CFR Ch. II §229.129 apply to interstate freight rather than transit systems, however, they are of at least passing relevance to current concerns. The first paragraph of this three-paragraph-long section requires only that a lead locomotive must be "provided with an audible warning device that produces a minimum sound level of 96 db(A) *(sic)* at 100 feet forward of the locomotive in its direction of travel." This language is usually interpreted as applying to an as-installed condition, although it could arguably be interpreted as applying to the audible warning device itself. Manufacturers often claim that air horns marketed as audible warning signals for locomotives produce A-weighted levels considerably (15 dB or more) higher than the regulatory minimum.

The acoustic measurement provisions of the remaining two paragraphs of §229.129 permit compliance with the nominal requirements of the first paragraph by warning signals about 5 dB lower in level than nominally specified. Paragraph (b) permits measurements of sound levels of locomotive warning signals to be made with a non-precision, Type II sound level meter. Paragraph (c) further states that "A 4 dB(A) measurement tolerance is allowable for a given measurement."

ANSI S1.4, "Specification for Sound Level Meters", permits a tolerance of 1.5 dB in Type II meters in the mid-frequency range that generally contains the greatest concentration of energy emitted by train horns. To this tolerance must be added the tolerance of the field calibrator, which can be as great as 0.3 dB. Thus, the true A-weighted sound level produced by a train horn that meets the nominal requirements of §229.129 may be as little as 90.2 dB at 100 feet. According to Lipscomb (2001), the mean A-weighted sound level in 71 measurements of installed train horns at a distance of 100 feet in front of locomotives was 100 dB.

In reality, compliance with the requirement of 49 CFR Ch. II §229.129 guarantees nothing about the actual warning effectiveness (or even the audibility) of a train horn, because the audibility of a warning signal is determined by its frequency content relative to that of the masking (outdoor ambient or vehicle interior) noise in which it occurs.

49 CFR Ch. II §229.129 is also silent on the mounting position for warning devices on the locomotive, the manner of activation of the locomotive warning signal, and on the matter of adverse community reaction to frequent warning signals. The terrain, geometry, and land uses along the approach to a grade level crossing, the speed of a train at the crossing, the composition and volume of the cross traffic, the ambient noise environment in the vicinity of the crossing, and even the frequency of use of the rail crossing can all affect the effectiveness and community annoyance of train-mounted audible warning signals.

Thus, the same audible warning signal that is adequate to alert a few pedestrians to the hazards of slow-moving trains at crossings with unobstructed visibility and low ambient noise levels may be ineffective in alerting truck traffic to the hazards of collisions at grade level crossings in busy intersections in noisy, built-up industrial areas with short lines of sight along rail rights of way. By the same token, audible warning signals that annoy few people when sounded once or twice a day in low population density areas may be major irritants when sounded many times an hour in high population density neighborhoods.

Other Standards for Warning Signal Effectiveness

Audible warnings are commonplace in industrial, occupational, recreational, residential, military and other applications as diverse as back-up alarms for construction equipment; low vision street crossing aids; automotive signaling; maritime navigation; aviation, nuclear power plant and other critical operational settings (as varied as mining, quarrying, blasting, electrical distribution, radiological, overhead crane and elevator operation, and motor sports applications); indoor and outdoor emergency evacuation, public safety, and civil defense signals; medical electronics; fire and burglar alarms, and so forth. However, no industrial or statutory standards for warning signal effectiveness of transportation sources (including 49 CFR Ch. II §229.129) are directly applicable to alerting pedestrians to the hazards of light rail grade level crossings.

Furthermore, statutory requirements and other standards for audible warning signals typically offer only little or no quantitative guidance about their design and operation. The provisions of Chapter 5 ("Horns and Emergency Warning Signals") of the Indiana state code (IC 9-19-5-1) are typical, in that they simultaneously require that warning signals for motor vehicles be "capable of emitting sound audible under normal conditions from a distance of not less than two hundred (200) feet", and that such a "horn or other warning device may not emit an unreasonably loud or harsh sound or whistle." Similarly, a proposed national fire alarm standard (Swets and Green, 1975) suggests only that a two tone (high-low, or "continental") alarm is appropriate for outdoor signaling by *all* moving vehicles. No standard explicitly describes a quantitative criterion of warning signal effectiveness, nor provides a systematic rationale for prediction of community reaction to such signals.

Primary Empirical Research on the Effectiveness of Transportation-Related Audible Warnings

Surprisingly few controlled tests of the effectiveness of vehicular warning signals have been published in peer-reviewed journals. This dearth of original research is probably due in part to the number and complexity of factors that affect warning signal effectiveness in real-world settings. Although a large part of the problem of assessing warning signal effectiveness is acoustic in nature, another part, at least as important, is the phenomenon of divided attention. A great deal is understood about the ability of attentive observers to correctly report the presence of acoustic signals heard in broadband noise (*cf.* Green and Swets, 1966). Much less is understood about the ability of acoustic signals to distract attention from ongoing foreground tasks.

Little useful quantitative guidance about human performance in divided attention situations is applicable to everyday performance of real-world tasks. On the one hand, it is well known that human hearing is closely coupled to attentional mechanisms. Meaningful sounds of very low signal-to-noise ratio (a footfall or a whisper in a bedroom at night, a key turning in a lock, and a snapping twig in a forest) can serve to alert or even startle people. On the other hand, people whose attention is closely focused elsewhere (*e.g.*, on a cell phone conversation or listening to a walkman), or who are otherwise engrossed in cognitive tasks other than listening for warning signals, may fail to heed repeated auditory and visual warnings, even at high signal-to-noise ratios. No purely acoustic analysis of warning signal effectiveness reflects the full range of variability in human performance in processing warning signals.

The following four papers illustrate the range and types of theoretical and empirical approaches most directly relevant to estimating acoustic warning signal effectiveness.

Corliss, E.,and Jones, F. (1976) "Method for estimating the audibility and effective loudness of sirens and speech in automobiles", J. Acoust. Soc. Am., Vol 60, No. 5, 1126-1131.

This theoretical paper estimates from first principles the signal-to-noise ratios necessary for a sinusoid in noise to command attention. Corliss and Jones assume that “a fair criterion for the ability of an emergency vehicle siren to attract attention might be the requirement that it should produce for the driver the loudness sensation equivalent to a signal of 65 dB presented in the quiet”. They continue from this assumption to reason that for an emergency vehicle’s warning signal to attain a speech-like level of about 72 dB inside a quiet car, its outside level must exceed 100 dB, considering the nominal 30 dB acoustic insertion loss of a car in the frequency range of typical interest. Corliss and Jones present no empirical tests or demonstrations of warning signal effectiveness to confirm their analysis, however.

Fidell, S., (1978) “Effectiveness of audible warning signals for emergency vehicles”, Human Factors, 20(1), 19-26.

Fidell (1978) is the most commonly cited controlled empirical study of the effectiveness of transportation-relevant audible warning signals.[3] Fidell exposed 24 drivers of an instrumented test car in a laboratory setting to six warning signals from a loudspeaker in the back seat that reproduced both the emergency vehicle signals and road noise. The presentation levels (and hence, signal-to-noise ratios) of the randomly-timed warning signals were increased until test subjects interrupted an ongoing, simulated driving task by taking their feet off the accelerator pedal and braking, as instructed upon notice of a warning signal. The <u>average</u> level of audibility at which warning signals distracted attention from the ongoing driving task was characterized by a d’ level of 37.

The quantity d’ is a scalar (dimensionless) unit of signal detectability that reflects the bandwidth-adjusted signal-to-noise ratio of a signal in the presence of background noise. Green and Swets (1966) derive and discuss the theoretical basis for quantifying human signal detection performance under conditions of uncertainty and risk. Detectability (d’) is the ability to detect a signal in the presence of noise, quantified by the bandwidth adjusted signal-to-noise ratio:

$$d' = \eta \sqrt{\sum_{i=1}^{N} \Delta f_i \left(\frac{s_i}{n_i} \right)^4}$$

where

η is the efficiency of a human detector relative to an ideal energy detector (assumed to be 0.4 for a reasonably attentive human observer);
Δf_i is the bandwidth of the i^{th} one-third octave band;
s_i is the sound pressure of the signal in the i^{th} one-third octave band; and
n_i is the sound pressure of the noise in the i^{th} one-third octave band.

The quantity “Detectability Level”, or (D’*L*), is the decibel equivalent value of d’, or 10 log d’.

Figure 1 is a nomogram that may be used to determine from one-third octave band sound levels of both signal and noise when a signal attains a level of detectability characterized by a d’ value of 2.32[4]. The figure, a graphic representation of the terms of the above equation, is used by plotting the signal levels in one-third octave bands on the perpendicular axes, and the

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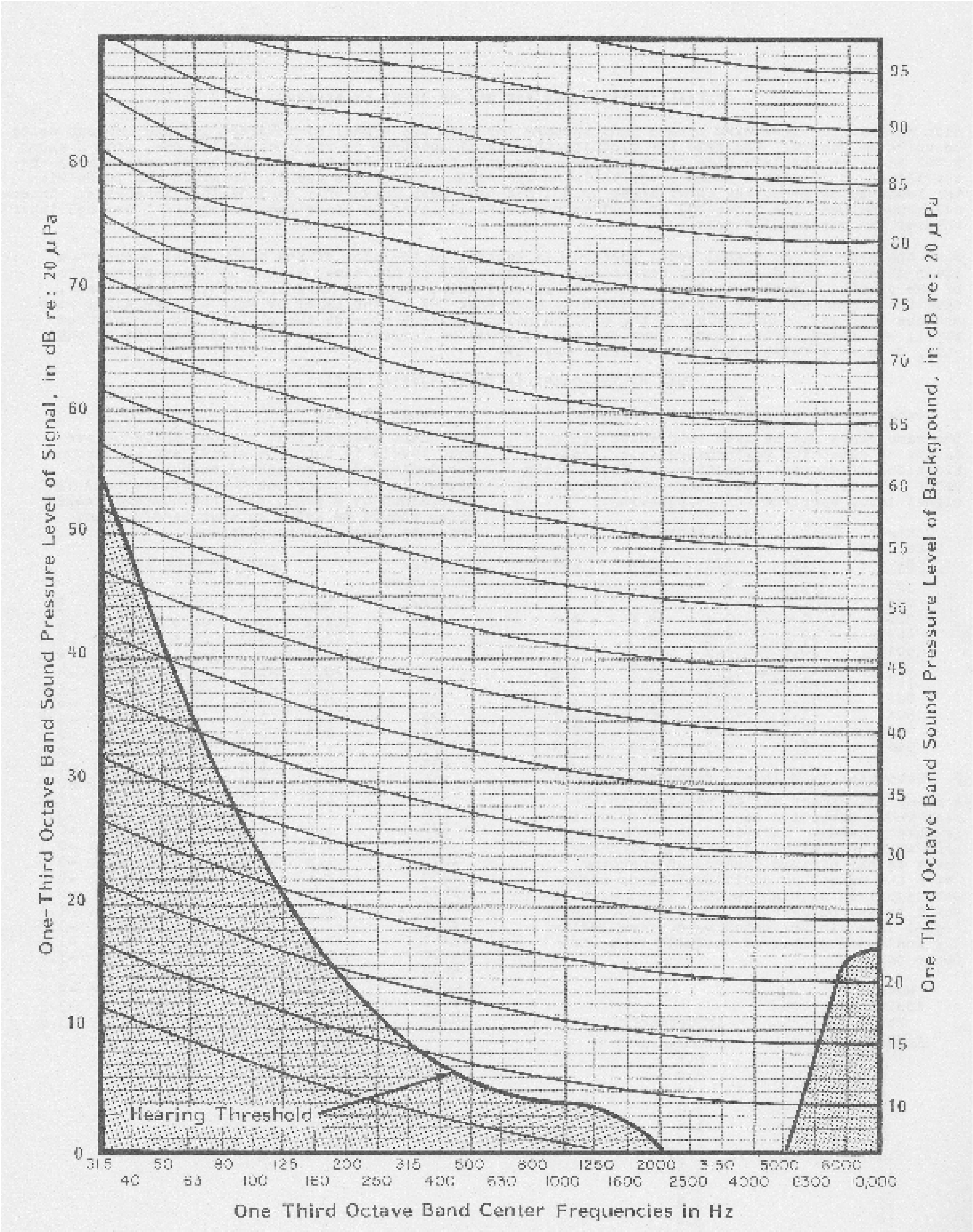
[3] This research, sponsored by the Society of Automotive Engineers, has also been reported in other technical documents (*e.g.*, Skeiber, Mason, and Potter, 1977) and in the trade press.

[4] A d’ level of 2.32 is sometimes considered a nominal threshold of audibility, since it represents a level of decision-making performance at which the presence of a signal is correctly reported 50% of the time at a 1% false alarm rate.



background noise levels with respect to the slanted lines. As plotted in Figure 1, a signal must attain a level equal to the noise in some frequency region for its audibility to reach a d' value of 2.32. Visual comparisons of signal-to-noise ratios in each one-third octave band can identify the frequency region(s) that contribute most strongly to overall signal detectability, as well as the magnitude of any changes necessary in signal (or noise) level to reach a d' value of 2.32.

Figure 1 Nomograph for determining when an acoustic signal is just audible [p(hit) = 0.5, p(false alarm) = .01] in broadband noise.

The average d’ value of 37 that was observed by Fidell (1978) is 12 dB greater than a nominal threshold of audibility (d’ =2.32), and approximately 10 dB greater than the d̃ value (4.0) at which people can correctly detect an acoustic signal 95% of the time with a 1% false alarm rate. In other words, the data of Fidell (1978) show that an effective warning signal — one noticeable enough to distract attention from an ongoing task other than attentive listening for warning signals—must on average attain a signal-to-noise ratio an order of magnitude (10 dB) greater than one which is merely reliably detectable (d’ = 4, or D’*L* = 6)) by an attentive listener. However, the level of audibility of a warning signal that would *invariably* come to the attention of all observers, regardless of attentional state, would obviously have to be higher yet.

Fidell, S. and Teffeteller, S., (1981) “Scaling the Annoyance of Intrusive Sounds,” J. Sound Vib., Vol. 78, No. 2, 291-298.

Fidell and Teffeteller conducted a controlled laboratory study under free-field listening conditions of the “intrusiveness” of noises to ten test subjects whose attention was absorbed in a video game. A computer varied the levels of a set of ten signals (household appliances and power tools) in a method of limits protocol, each sequence separated by unpredictable waiting periods of several minutes. Steps were presented in a staircase of 2 dB increments each 20 seconds long, and continued until they distracted attention from the video game sufficiently for a test subject to signify their notice by pressing a button. At the level at which test signals were sufficiently noticeable to be considered intrusive (not necessarily the same level at which they were first noticed), test subjects were also asked to judge whether they were “slightly”, “moderately”, “very”, or “extremely” annoying.

The average A-weighted level at which the test signals were noticed in a PNC-40 background noise environment was 48 dB. Their corresponding average detection level (D’*L*) was 14.2. Figure 2 shows the relationship between the audibility of intrusive signals (expressed in decibel-like D’*L* units) and mean annoyance ratings inferred from the data of this study. Very few sounds were judged highly (“very” or “extremely”) annoying at a level of audibility at which virtually everyone would be expected to notice them (d’ = 316, D’*L* = 25). Although this is an encouraging finding with respect to the potential community annoyance of auditory warning signals from light rail vehicles, it is based on a limited amount of information from a single laboratory study of modest size.

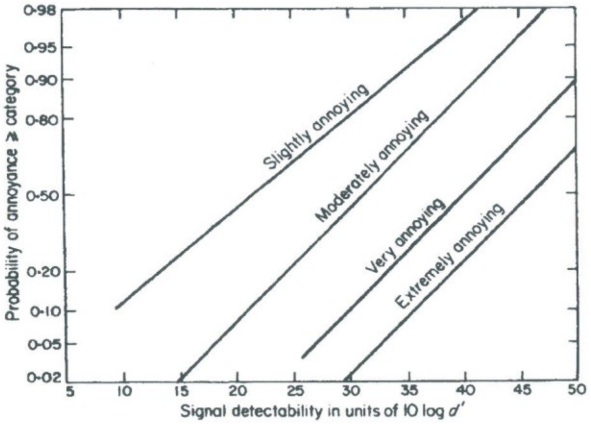


Figure 2 Least squares fits to cumulative distributions of the judge annoyance of intrusive sounds.

Sneddon, M., Pearsons, and Fidell, S., (in press) “Laboratory study of the noticeability and annoyance of sounds of low signal-to-noise ratio”, Noise Control Engineering Journal.

Sneddon *et al.* measured the levels of detectability at which fifteen acoustic signals (two aircraft flyovers, and car, truck and commuter rail vehicle passbys, as heard at four distances) reliably attracted the attention of ten test subjects engaged in an activity other than specifically listening for such a sound. The subjects, who were seated in an anechoic chamber while reading materials of their own choosing were asked in a free-response protocol to note the occurrence of sounds presented at relatively low signal-to-noise-ratios in natural-sounding but highly constrained background noise environments. A logistic fit to the findings (shown in Figure 3) indicated that a detectability level considerably greater than that needed for essentially perfect attentive detection (D’*L* = 6) was required if substantially all signal presentations are to be noticed.

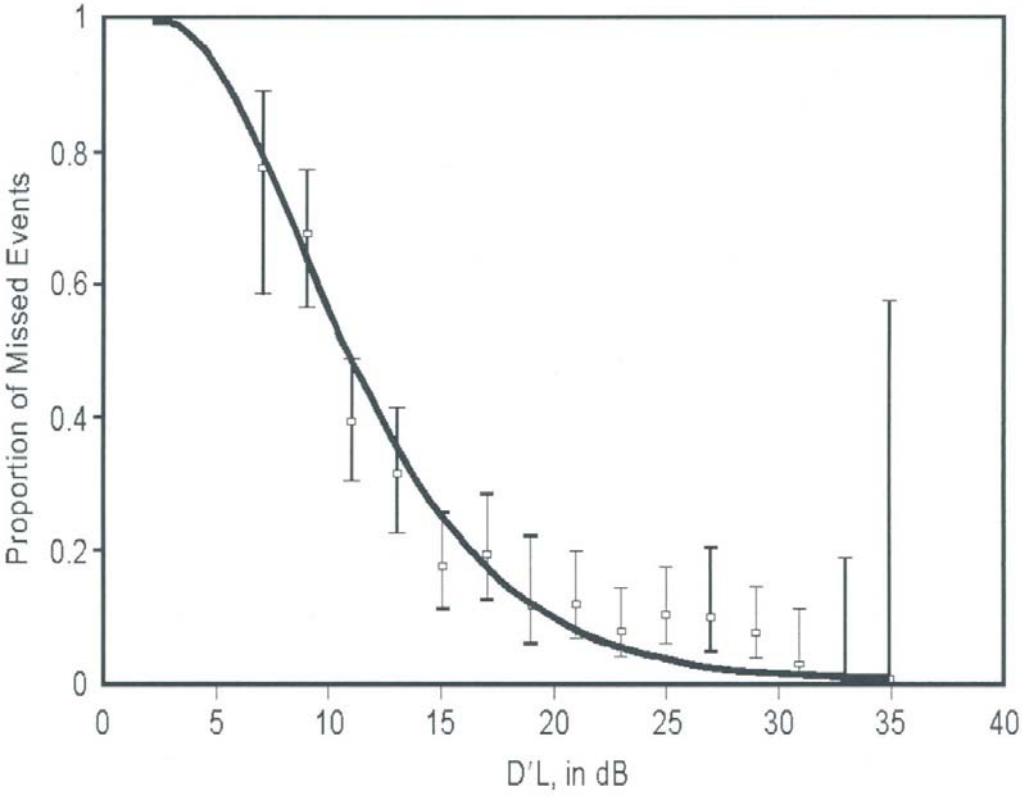


Figure 3 Detection levels of sounds at which test subjects failed to notice various proportions of signal presentations.

Secondary Literature On Audible Warnings in Grade Level Rail/Street Traffic Accidents

No primary research on the noticeability of transportation-related warning and other sounds apart from that described above was found in English-language, peer-reviewed journals. A modicum of analytic and case-study work has, however, been undertaken in occupational settings (*e.g.*, Patterson, 1982; Sorkin, 1987). Much of the rest of the oral presentations, symposium proceedings, handbook chapters, and technical reports germane to the present concern is comprised of non-empirical studies, anecdotal discussions, and oft-repeated cautions about the inability of locomotive-mounted horns to prevent automotive collisions with trains at grade level rail crossings. A number of typical references of this sort are summarized in the following sub-sections.

Abrams, B.S., and Lipscomb, D.M. (1996) “Visual and auditory correlates in rail crossing safety”, Presented at Fourth International Symposium on Railroad-Highway Grade Crossing Research and Safety, 8-10 October, 1996, Knovxville, TN.

The bulk of this three part presentation is an academic discussion of basic human sensory and perceptual capability, with only tenuous linkages drawn to specifics of sensory function or signal requirements in actual grade crossing settings. The authors conclude that better understanding of human perceptual capabilities can “contribute to better safety policies and equipment”.

The presentation makes a number of points about the audibility and noticeability of warning signals that are not directly relevant to issues of warning signal effectiveness. It notes, for example, on page 20 that “Most young, non-pathological ears can detect a 6.5 dB sound pressure level (SPL) at frequencies in the range of greatest sensitivity...(in the range of 2.5 kHz to 3 kHz)”. This information is tangential at best to present concerns, because it has little to do with the practical audibility of train horns. Train horns, which may not radiate strongly in the frequency range of greatest human sensitivity in any event, are typically produced and must be detected in background noise at levels many orders of magnitude higher.

Further, the relevant issue for audibility and effectiveness of warning signals is not the absolute sensitivity of human hearing, but the frequency region of the greatest effective signal-to-noise ratio at a listener’s ear. The concept of a unique, fixed auditory detection threshold (“now you hear it/now you don’t”) has also been outmoded since the 1960s, as recognition of the probabilistic nature of acoustic signal detection under real-world conditions of uncertainty and risk has become universal.

The authors do not distinguish carefully between an absolute sound pressure level and what they term an “alerting threshold” of 9 to 10 dB above the background or ambient sound level. The figure of “9 to 10 dB” that Abrams and Lipscomb cite is an *increase* in audibility above a detection level of d' = 4, not an A-weighted or an octave band differential in absolute signal level. The detection index d' is a measure of bandwidth-corrected signal to noise ratio, customarily calculated for warning signal analyses in one-third octave bands. An effective warning signal — that is, one noticeable enough to distract attention from an ongoing task — is not necessarily “twice as loud as competing sounds”, as Abrams and Lipscomb assert.

The Appendix to the document mis-states the requirement of 49 CFR 229.129 for a minimum A-weighted sound level of a locomotive-mounted warning device as 95 decibels.

Lipscomb, D.L. (1993). “Audibility of train horns and crossing accident investigation techniques.” Proceedings of Second International Symposium on Railroad-Highway Grade Crossing Research and Safety, Transportation Center, The University of Tennessee, Knoxville, TN.

This introductory-level presentation notes the deleterious effects of the acoustic insertion loss of automobiles on the audibility of locomotive warning horns, and concludes with an appeal for a non-acoustic alternative form of warning signal. The presentation does not develop the recommendation for such a device beyond a conceptual level.

Lipscomb, D.M., (1996) “Train horns seem so loud: So why don’t motorists hear them sometimes?”, Presentation made at Fourth International Symposium on Railroad-Highway Grade Crossing Research and Safety, 8-10 October, 1996, Knoxville, TN.

This oral presentation reiterates familiar aspects of the conventional source-path-receiver approach to analysis of the audibility of acoustic signals. The author cites common factors that can affect warning signal source levels (including make, model, age, maintenance, placement, orientation and activation of the train horn); factors that can affect propagation of sound from a locomotive horn to a driver approaching a grade level crossing (such as terrain, atmospheric conditions, barriers, and vehicle insertion loss); and masking noise levels. No mention is made of the attentional state of the listener.

The discussion presents no new research findings, and is general and largely non-quantitative in nature. It lacks specifics that would assist in prioritizing the importance of the various factors mentioned in passing, and criteria for warning signal effectiveness. The author concludes only that "myriad combinations" of factors influence audibility of train locomotive horns, and that their audibility in some circumstances does not imply their audibility in others.

Lipscomb D.M. (2001) "Measured sound output of locomotive horns", Presentation made at Sixth International Symposium on Railroad-Highway Grade Crossing Research and Safety, October 17-19, Knoxville, TN.

This oral presentation repeats many of the points made by the author in his 1996 presentation at the same symposium, while presenting summary information about 71 measurements of A-weighted sound levels produced by train horns 100 feet in front of the locomotive. The mean measured sound level rounds to 100 dB, with a standard deviation of 6.8 dB. The author notes that the median measured level (99 dB) is about 14 dB lower than the manufacturers' advertised specifications, but still 3 dB greater than the Federal Railroad Administration's regulatory requirement of 96 dB (49 CFR 229.129). The author notes that some percentage of the measured levels fall below the regulatory minimum, but fails to acknowledge the 4 dB testing tolerance allowed in CFR 49 229.129.

The conclusions suggest attention to installation-specific factors (placement, orientation) of train horns and confirmation of as-installed sound levels, rather than increased source levels, as a preferred compliance measure.

CONSIDERATIONS FOR PERSONS WITH DISABILITIES

The use of auditory directional icons may be particularly useful assisting visually impaired pedestrians locate potential threats at level grade crossings. The use of a visual iconic direction LED sign may be particularly helpful in assisting hearing-impaired pedestrians locate the direction of potential threats at grade crossings. The use of both directional warnings may reinforce each other in persons with some vision or hearing loss. Traditional bells and horns may not effectively meet the requirements of either population. A system to meet the needs of the impaired may also indicate when it is clear to cross. In order to address the needs of an impaired traveler, it may be more cost effective to adopt a new system, which meets their needs, while at the same time improving the safety of the non-impaired traveler. Optimizing the efficacy of non-directional bells and beacons may not meet either goal.

Legal blindness is defined as best corrected acuity (central vision) in the better eye of 20/200 or worse, and/or a visual field (peripheral vision) of 20 degrees or less. In actual fact, the definition of severe visual impairment as used by the National Center for Health Statistics is inability to read newsprint even with normal correction; a definition that suggests that severe visual impairment corresponds to a best corrected visual acuity of 20/50. To place this in some context, a visual acuity of 20/50 would, in addition to severely limiting reading and many activities of daily living, prevent an individual from obtaining a driver's license in most states (Goodrich, 1995). Many large, population-based, cross-sectional studies have documented the increase in prevalence of eye disease and visual impairment with increasing age, particularly in persons over the age of 75 (Haegersrtrom-Portnoy, Schneck and Brabyn, 1999). It is estimated that in the U.S. more than 26 million people over the age of 40 are affected with some type of visual disorder and that more than 4 million individuals in the U.S. aged 55 or older are currently experiencing severe vision loss (U.S. Department of Veterans Affairs, 1999). Moreover, The National Eye Institute (2001) recently estimated that in the U.S. over 1.1 million people are legally blind. Prevalence rate estimations of visual impairment per 1,000 persons in the U.S. clearly demonstrate the significant increase in vision problems with age.

Because vision impairment touches the lives of the majority of middle-aged and older adults either through personal experience, that of a family member, or of someone else in their social network, it represents a major health issue for Americans (Watson, 2001). Moreover, the economic implications surrounding this disability are considerable. A recent study has suggested that direct and indirect costs related to blindness and visual impairment total approximately $38.4 billion annually (NEI, 2001). Perhaps the most significant cost of visual impairment is the personal reduction in independence and diminished functional ability that often arises as a result of vision loss. The effects of visual impairment in reducing an individual's ability to drive and travel independently are often pointed to as expected outcomes following severe vision loss, yet other issues such as management of personal finances, correspondence, and other important daily activities also may prove extremely problematic because of visual impairment (Goodrich, 1995).

In order for visually impaired individuals to cross streets independently, they must be able to recognize that they have arrived at an intersecting street; determine the configuration of the intersection so that they can establish an optimal location, heading, and procedure for crossing. It is also helpful to be able to determine or confirm the name of the intersecting street. When intersections are familiar, some of this information may already be known. Much of this information is typically obtained by listening to traffic patterns and sounds of individual vehicles (Jacobson, 1993; LaGrow & Weessies, 1994; Blasch, Wiener & Welsh, 1997).

Techniques and cues used in crossing streets are diverse and vary by location and individual. Many visually impaired pedestrians have received mobility instruction from an orientation and mobility specialist to use a cane and/or dog guide to travel independently. In the most common technique utilized for crossing at signalized intersections, pedestrians who are blind begin to cross the street when there is a surge of traffic parallel to their direction of travel. Vehicular sounds are often sufficient to determine the onset of the WALK interval and the direction to the crosswalk on the opposite side of the street. However due to some intersection geometry, acoustic conditions, and traffic control systems it is very difficult if not prohibitive for persons who are visually impaired to determine the cues necessary to cross streets independently and safely. These problems of safe street crossing are generally made even more difficult for elderly visually impaired individuals with the additional functional limitations of reduced hearing, slower and in some cases an unsteady gait, ability to process information and response time to mention a few.

Despite the difficulties presented above, a large number of travelers who are blind cross streets safely and independently. This attests to their ability to apply principles and skills for street crossing which have continued to evolve with the growth of the field of Orientation and Mobility. These principles and skills are based on acquiring the necessary information through limited vision or other sensory modalities. Nonetheless, there are many intersections that blind individuals consider to be unsafe for crossing without the assistance of a human guide. Individual differences in impairments, skills, abilities, and personality as well as the environmental situation determine which streets any individual will choose to cross independently.

Since the 1940s, when organized instruction in independent travel for individuals who are blind began, there have been many changes to intersection configurations, traffic control systems and technology, and in vehicular traffic in general. Many of these changes have made crossing streets much more difficult if not prohibitive for persons with visual impairments. Where traffic is abundant on all streets at an intersection, it is usually possible for travelers who are blind to determine whether vehicular traffic on streets is controlled by stop signs or traffic signals. Further, where intersections are traffic signal controlled, it is often easy to determine which street has the right of way. Nonetheless, delayed or prolonged green lights, separate turning signals, and permitted right turns on red lights after stopping make it difficult to determine traffic control patterns at many intersections. Even if one understands the traffic control at an intersection, it may still be difficult to determine a safe time to initiate a crossing. Particularly difficult and hazardous are intersections with fast but intermittent traffic, in which it is difficult to determine the onset of parallel traffic.

Intersections in which there is a designated pedestrian crossing cycle present particular challenges, especially if all traffic is stopped during that cycle. While such signals often provide the only safe time for any pedestrian to cross, any situation in which there is not audibly idling traffic on all streets at an intersection there is insufficient auditory information for blind travelers. In this instance, the individual may not know whether there is simply no traffic on one street (for what could be a very short moment), or whether the pedestrian cycle has begun. Where pedestrian crossing cycles are pedestrian activated, it may be difficult for persons who are visually impaired to locate the activating button (Peck & Uslan, 1990; Bentzen, Barlow & Franck, 2000). Where all traffic is stopped during a pedestrian crossing cycle (scatter light), it may not only be difficult to determine the onset of the pedestrian cycle, but also to maintain a straight line of travel toward an opposite up curb because of the unpredictability of pedestrian travel directions. Traffic signals that are dynamically adjusted by volume of traffic flow (actuated) are particularly difficult for blind travelers because it is not possible to determine with any certainty when and for how long pedestrian cycles or parallel traffic cycles will occur.

Accessible Pedestrian Signals are classified into three types. The first type of signal uses mounted speakers that sound like some kind of bell, buzz, birdcall or melody, and most can be heard by anyone in the vicinity. A second type of Accessible Pedestrian Signal uses a transmitter or as an example, a remote infrared signage technology as used by Talking Signs™ and Relume™. This approach, as used at a number of intersections in San Francisco, uses recorded speech to tell users “Walk” or “Wait.” Messages which are audible only to users, and only when users are standing at a crosswalk, are heard by means of small receivers when the receivers are activated by users. As users approach corners, they can also receive messages telling them the name of the intersecting street, the parallel street, which block they are on (for example, 100 block), and which direction they are traveling. This type of device also has the capacity to provide messages that could also be used to describe intersection configuration and/or the traffic control system. The third type of Accessible Pedestrian Signal is a sound generator and vibrating hardware which are integrated into the pedestrian push button. Audible push button locating signals are heard from the near vicinity of the push button, and a different message or repetition rate is used to indicate the WALK interval.

Research on auditory pedestrian signals has yielded a number of significant findings indicating the advantages to visually impaired pedestrians, along with the drawbacks resulting from the use of these signals. Some of the advantages include, improved discrimination between the WALK and DON'T WALK indications, and a decrease in the time to align and complete the crossing (Stevens, 1993; Oliver, 1989). Stevens found that alternating audible pedestrian signals proved to be superior to non-alternating signals in helping blind pedestrians remain within the crosswalk. Although such signals provide notable advantages, problems exist such as difficulties localizing the sounds emitted, and the masking of the signal under noisy or high traffic conditions (Stevens1993; Oliver, 1989). Furthermore, these problems are exacerbated for seniors because hearing declines markedly as people age. Such difficulties may cause pedestrians to be unclear which leg of the intersection is safe to cross, and where exactly the opposite end of the crosswalk is located. Such shortcomings may lead to a false sense of security, which could lead to serious consequences.

Although little research has compared the relatively effectiveness of different commercially available accessible signals produced for persons with no vision, limited research has examined ways of assisting the larger portion of the blind community with some usable vision. One study by Van Houten, Blasch, and Malenfant, examined whether the addition of the animated eyes display used to remind sighted pedestrians to watch for turning vehicles helped blind persons with low vision to discriminate the WALK sign. The results of this study showed that low vision blind persons could identify the WALK signal 50% further when the eyes were included. This study was conducted under laboratory conditions and should be replicated under field conditions.

It is essential to compare the efficacy of these new emerging technologies in order to determine which ones best meet the needs of the elderly population with visual impairment. None of the research to date addresses this question.

As stated above, the number of older individuals experiencing vision loss and other disabilities is expected to grow in the coming decades (Crews, 1991; Pope & Tarlov, 1991; Manton, Corder & Stallard, 1993). Gerontological research has focused on identifying risk factors for the development of disability in terms of personal care tasks, (ADLs), and tasks considered essential for social independence, (IADLs) (Kovar & Lawton, 1994). This research has led to the recognition that successful performance of ADLs and IADLs involves multiple domains, of which mobility may be the single most important (Verbrugge, Gruber-Baldini & Fozard, 1996). Related measures, such as assessments of whether persons can independently leave their homes, go outdoors, and use transportation, have identified persons in need of assistance with ADLs (Clark & Maddox, 1992) suggesting that mobility limitation may, in fact, *precede* the development of difficulties in specific ADL and IADL tasks.

For the visually impaired traveler, the already difficult and dangerous task of safely traveling in cities is becoming even more complicated and hazardous. The right-turn on red law, as well as the increasing production of quieter running cars have made the use of traffic sounds more difficult, particularly for the visually impaired pedestrian. A major impediment to effective and safe street crossing for visually impaired travelers is the increasing use of traffic signals that are dynamically adjusted (actuated) by the volume of traffic flow. Because of these actuated traffic signals, the visually impaired traveler is not able to determine with any certainty when and for how long the 'WALK' signal will occur.

In response to this problem, the Transportation Equity Act for the 21st Century was passed in January of 1998 (H.R.2400). This Act specifies that safety considerations shall include the installation, where appropriate, and maintenance of audible traffic signals and audible signs at street crossings. However, there has been only limited evaluation of these different signals, and to date only one study has attempted to compare their effectiveness (Blasch, 1999). Although efforts have been made to develop

Accessible Pedestrian Signals for the totally blind traveler, little attention has been paid to the problem of developing more effective visual signals for the partially sighted individual. The paucity of research in the area of visual signals for individuals with low vision is particularly problematic considering that over 80 percent of the legally blind veteran population has some remaining vision (De l'Aune, Williams & Welsh, 2000).

There has been limited research testing Accessible Pedestrian Devices (Bentzen & Tabor, 1998; Bentzen, Crandall, Chigier, Warden & Carosella, 1995; Crandall, Brabyn, Bentzen & Myers, 1998; Crandall, Bentzen, Myers & Mitchell, 1995; Department of Transport, 1993; Hall, Rabelle & Zabihaylo, 1994; Huscher, 1976; and Van Houten, Malenfant & Van Houten, & Retting,1997). The studies that have been done compared a specific Accessible Pedestrian Device (e.g., Talking Signs) to no signal. In one case, Hall, Rabelle & Zabihaylo used one Accessible Pedestrian Device and tested a variety of presentations and locations of the sound sources. Unfortunately, there has been very limited research to evaluate Accessible Pedestrian Signals for individuals with low vision. Van Houten, Blasch, and Malenfant have evaluated a modification to the Relume™ Accessible Pedestrian signal that included animated eyes documented to improve the safety of sighted pedestrians by prompting them to look for turning vehicles (Van Houten, Retting, Van Houten, Farmer, & Malenfant, 1999). The study by Van Houten, Blasch, and Malenfant found that low vision blind pedestrians could identify the shape of the WALK indication from 50% further away when it included the animated eyes display. These results showed that the addition of an animated 'eyes' display to the WALK sign significantly improves recognition distance for a large segment of persons with visual impairment. It should also be noted that none of the participants miss-identified the WALK indication with the 'eyes' as the DON'T WALK indication or the DON'T WALK signal as the WALK with the 'eyes' display. However, many of the participants identified the 'WALK' symbol without the eyes as the 'DON'T WALK' indication, and the DON'T WALK signals as the standard WALK indication on some of the trials. These data suggest that using the WALK signal with the animated eyes could reduce the frequency of pedestrians with low vision inadvertently crossing against the signal. Although these findings are promising, they need to be replicated under field conditions with a larger pool of low vision participants, as proposed in this research study.

Preliminary research has shown that low vision pedestrians and totally blind pedestrians can be assisted by Accessible Pedestrian Signals. These data also show that although all currently produced Accessible Pedestrian Signals are useful to some degree to persons with a visual impairment, two of the signals (the ReLume™ and Talking Signs™) show particular promise in also providing a line of direction for street crossing. Blasch compared 8 different Accessible Pedestrian Signals installed along a major intersection located in the city of Decatur, Georgia during the meeting of the Southeastern Orientation and Mobility Association (SOMA) in March of 1999. Findings from this pilot study indicated that there were no significant differences between the different Accessible Pedestrian Signals regarding the confidence and comfort of the traveler between the 8 different devices. There was, however, a significant difference found between the eight Accessible Pedestrian Signals regarding their utility in providing a line of direction for the street crossing. The two pedestrian signals that were shown to significantly enhance traveler directional orientation were the ReLume™ and Talking Signs™ signals. This finding has practical significance, particularly in light of the fact that several studies have reported that individuals who are blind have difficulty staying within the crosswalk lines, as no non-visual cues are ordinarily present to provide assistance (Bentzen, Barlow, & Franck, 2000). Veering out of the crosswalk into the intersection is a particularly dangerous pedestrian travel event to which the ReLume™ and Talking Signs™ signals attempt to address.

Finally, the authors have been unable to find any study that directly compared the effectiveness of the different Accessible Pedestrian Signals in normal traffic conditions other than the 1999 pilot study conducted by Blasch. The paucity of scientifically rigorous research which evaluates the efficacy of various Accessible Pedestrian Signal devices is a serious limitation to extend knowledge on this critical area of visual impairment rehabilitation and policy.

Far more neglected is the research in the area of deaf and hearing impaired related to Pedestrian Signals. Because of the lack of research in the Light Rail Transit Environments for the visually impaired and hearing impaired, information has been presented in a similar area involving Accessible Pedestrian Signals.

The following summary of selected studies provides background on additional studies conducted on accessible design:

Accessible Pedestrian Signals: Synthesis and Guide to Best Practice (2003). NCHRP Research Results Digest, Transportation Research Board

This digest summarizes the publication "Accessible Pedestrian Signals: Synthesis and Guide to Best Practice," by J.M. Barlow, B.L. Bentzen and L. Tabor of Accessible Design for the Blind. Following an introduction and background information on accessible pedestrian signals (APS), the digest covers the following topics: U.S. rules and regulations related to APS; international practice; APS technologies and features; where to install APS; designing installations; new construction or reconstruction installation; retrofitting an intersection with an APS; and specifications for installation of APS components.

Arnold, ED, Jr; Dougald, LE. (2003). *Guidelines For The Retrofit Installation Of Accessible Pedestrian Signals By The Virginia Department Of Transportation: Phase I Report.* Virginia Transportation Research Council, Virginia Department of Transportation.

In late 2000, the Northern Virginia District of the Virginia Department of Transportation (VDOT) received a request from a visually impaired citizen to install accessible pedestrian signals (APS) at an intersection in Falls Church. Since there were no national or state guidelines for this type of installation, the district was requested to install APS at an intersection as a pilot and develop appropriate guidelines that could be used statewide by VDOT for future installations. The Virginia Transportation Research Council was asked to assist in developing the guidelines. Further, a committee composed of representatives from VDOT, the Federal Highway Administration, the Virginia Department for the Blind and Visually Impaired, and the blind/visually impaired community (both formal organizations and individual citizen activists) was established to provide overall guidance and advice.

The guidelines will be applicable to retrofit installations and will ultimately include the following sections: (1) a procedure for requesting APS, (2) the basic requirements for retrofit, (3) an intersection evaluation methodology, (4) a funding process, (5) the basic specifications for APS equipment to be used statewide, and (6) installation guidance. As of April 2003, the first four of these sections were finalized. The aforementioned committee recommended that VDOT undertake a 2-year pilot to field test the application of these four sections while the evaluation of the piloted equipment was being completed and the final two sections were being developed. This Phase I report describes the background for the pilot project, its purpose and scope, the methods undertaken, and the results to date that led to the recommendation for the 2-year pilot. Specifically, the report includes details on the following: (1) Results of a survey of VDOT's district traffic engineers. No APS have been installed at VDOT-maintained intersections and only a handful of cities have installed them. (2) Results of a review of the literature. The APS guidelines from the Committee for the Removal of Architectural Barriers; the Los Angeles Department of Transportation; Fountain Valley, California; and Portland, Oregon, are described. (3) Timeline of key events in the development of the guidelines. The timeline focuses on the committee's review and role and traces the drafting of the 10 iterations before the final guidelines were accepted and approved. (4) Outline of the guidelines. A final outline of the guidelines is provided, and Sections I through IV are presented in an appendix. Forms for requesting an APS retrofit and for evaluating intersections are also included in appendices. The report concludes with a discussion of the next steps, or tasks, that are required to complete the guidelines.

Bentzen, BL; Barlow, JM; Tabor, LS, (2000). *Detectable Warnings: Synthesis of U.S. and International Practice*. U.S. Access Board

This synthesis summarizes the state-of-the-art regarding the design, installation and effectiveness of detectable warning surfaces used in the U.S. and abroad. The need for a warning surface is documented. U.S. and international research on detectable warnings is reviewed. U.S. and international standards and guidelines for detectable warnings are presented. Use of detectable warnings in the U.S. and abroad is described, with illustrative case studies. Information is provided on U.S. detectable warning products and manufacturers. Jurisdictional recommendations for the use of truncated dome detectable warnings are summarized and illustrated. The synthesis will be helpful to transportation engineers, planners, and other interested persons working to make public rights-of-way more accessible to people who have visual impairments.

Bentzen, BL; Crandall, WF; Myers, L. (1999). *Wayfinding System for Transportation Services: Remote Infrared Audible Signage For Transit Stations, Surface Transit, and Intersections*. Transportation Research Record, Issue1671.

People who are print-disabled, who are blind, or who have other visual impairments are restricted in their ability to participate in public life because of lack of labels and signs in the environment. Currently, persons with severe visual impairments often require extensive assistance from strangers to travel in unfamiliar areas. Many other types of disabilities can prevent people from reading print. In addition to people who are blind or who have low vision, there are many head-injured, autistic, and dyslexic (or even just educationally impaired) people, along with persons who have had a stroke, who are not able to assimilate printed language even though they can see the page. Many people can accept the information through speech--that is, having print read aloud to them. Some human factors evaluations of a signage system specifically developed to aid people who have visual impairments or a print-reading disability gain information that is available to sighted people through print are described in this paper. This remote, infrared audible signage system--Talking Signs--is composed of a small infrared transmitter that emits a repeating voice message over a directional light beam to a handheld receiver carried by the blind pedestrian. The infrared system greatly reduces the need for travelers to remember distances, directions, and turns, thereby enhancing independence and efficiency in travel. Results show that remote infrared audible signage provides effective wayfinding information for using transit stations, surface transit, and intersections, thereby enhancing independent use of public transit by people who have visual impairments or cognitive disabilities.

Bentzen, BL; Tabor, LS. (1998). *Accessible Pedestrian Signals*. Accessible Designs for the Blind. Architectural and Transportation Barriers Compliance Board

The Transportation Equity Act for the 21st Century - TEA-21, the successor to ISTEA - directs the pedestrian safety considerations, including the installation of audible traffic signals, where appropriate, be included in new transportation plans and projects. The bill was signed into law on June 9, 1998.

Blasch, B., Templer, J., and Zimring, C. (1989). Visually *Impaired People - Design for Safety, Information and Orientation.* Encyclopedia of Architecture.

This article deals with design of the built environment to facilitate the accessibility and travel for individuals with a visual impairment. The use of design features to serve as landmarks for individuals with a visual impairment was also discussed. The intent of this article was to suggest the consideration of designing to facilitate wayfinding for individuals with a visual impairment up front rather than trying to retrofit after the environment has been built. Specific design considerations were suggested.

Blasch, B., Wiener, W. & Welsh, R. (Eds.) 1997. *Foundations of Orientation and Mobility, Second Edition,* New York: American Foundation for the Blind Press, Inc.

This textbook is used in the training of Orientation and Mobility Specialists through out the US and other English speaking countries. It contains 24 Chapters including chapters on Orientation Aids and Environmental Accessibility.

Crandall, W; Brabyn, J; Bentzen, BL; Myers, L. (1999). *Remote Infrared Signage Evaluation for Transit Stations and Intersections*. Journal of Rehabilitation Research and Development, Vol. 36. 4.

This paper focuses on 2 problems that are among the most challenging and dangerous faced by blind travelers: negotiating complex transit stations and controlled intersections. The authors report on human factors studies of the Talking Signs remote infrared signage system in these critical tasks, examining such issues as how much training is needed to use the system, its impact on performance and safety, benefits for different population subgroups, and user opinions of its value. Results indicate that blind people can quickly and easily learn to use remote infrared signage effectively, and that its use improves travel safety, efficiency, and independence.

Flemming, J. (1998) *A Simple Act, Often Forgotten*. Community Transportation. Community Transportation Association of America. Vol 16, Issue 4.

Close to eight years have elapsed since the signing of the Americans with Disabilities Act (ADA). Before the celebration of the 10th anniversary, some members of the disability community are beginning to identify the areas where real progress has been made and those where substantial work remains. FTA reports that 68% of the approximately 50,000 fixed route buses are lift equipped today, a far cry from 1990. However, the act of putting a lift on a bus does not by itself make that bus accessible. The information in this article is based on information provided by the American Council of the Blind (ACB) - a national advocacy organization for people with visual disabilities - which has assumed a proactive role in making fixed route public transit services fully accessible to the blind community. ACB's efforts have been directed at overcoming an important barrier experienced by blind and visually impaired persons in using fixed route bus and many rail services - compliance with the ADA mandate of calling out stops and making other related announcements. Announcing stops, routes and destinations is the accessibility equivalent to people with visual disabilities and those who cannot read of the lift for people with mobility impairments.

Glick, PB., (1998). *The ADA and Technological Solutions for Achieving Effective Communication With Hard of Hearing and Deaf People.* Journal of Urban Technology. Vol 5, Issue 1.

This article examines the various technologies being employed to enhance communication for hearing impaired people. Crowded and noisy sites are characteristic of urban life, and the barriers these pose to communication for citizens who are deaf or hard of hearing (DHH) can be partly overcome by technology. The public address systems in most theaters, concert halls, movie houses, exhibition spaces, lecture halls, and conference rooms are not effective in communicating speech to people who are DHH. The author discusses various technological approaches to overcoming communication barriers in public meeting places as part of her description of the comprehensive efforts being made by cities in the U.S. to comply with the accessibility standards for the deaf and hard of hearing.

Goto, K; Matsubara, H; Myojo, S. (1998). *A New Passenger Guide System for Visually Disabled Persons*. Railway Technical Research Inst, Quarterly Reports, Railway Technical Research Institute, Vol 39, Issue 4.

This paper presents a new passenger guide system for visually disabled persons. The system uses the latest technologies such as data carriers, mobile communication and portable computers. Data carriers are embedded at many places in the station such as floors, platforms, and walls. Coded data recorded in data-carriers are transferred to users via a reader installed in the cane of the user. The data are interpreted by a portable computer, which generates appropriate guide messages utilizing geographical information and user's personal data stored in it beforehand. Guide messages are finally conveyed orally to the user via a portable speaker.

Grubb, D. (2000). *Pedestrian Safety Handbook: A Handbook for Advocates Dedicated to Improving the Pedestrian Environment Guaranteeing People Who Are Blind or Visually Impaired Access to Intersection Identification and Traffic Control Information*. Second Edition. The American Council of the Blind

Pedestrians, especially blind pedestrians, are at risk of injury or death every time they attempt to cross a street. Major impediments are multiple street intersections with complex pedestrian island configurations; traffic patterns controlled by underground sensors that change the signaling at intersections to accommodate heavier traffic flow resulting in a lack of predictability of the time available to cross the street; traffic circles without traffic signals; turning signal arrows that allow vehicles to cross in front or in back of moving pedestrians; signaling devices that are difficult to locate and understand; and blended or level curbs that are not always detectable at the entrance to the street. This handbook provides information for blind pedestrians in order to help them navigate through, and advocate for, safer streets.

Hughes, RG; Turner, S; Landphair, H, (2002). *On The Integrated Application of Modeling, Simulation, and 3d/4d Visualization: The Concept of a 'Laboratory' For Non-Motorized Travel Research*. 9th World Congress on Intelligent Transport Systems. ITS America.

The UNC Highway Safety Research Center (HSRC) and the Texas Transportation Institute (TTI) are jointly pursuing the development of a 'laboratory' capability for the integrated application of modeling, simulation, and visualization technologies to non-motorized (ped/bike) research. The simulator component is to be developed in conjunction with the existing TTI driving simulator built by Hyperion/KQ Corporation (now Global Sim) and housed on the Texas A&M campus. HSRC is currently using the VISSIM model in a stand-alone (i.e., non-integrated) mode on NIH-sponsored research addressing the problems of blind and visually impaired pedestrians at complex intersections (e.g., roundabouts).

An expansion of the NIH work is anticipated that will permit the integrated application of modeling and simulation over the next year. The work with NIH will also permit exploration of the possibility of a high fidelity 'aural' simulation of the operational traffic environment (important to the blindness community). Such a simulation would be possible with the integration of the real time traffic modeling capabilities of VISSIM (or other similar model) and auditory psychophysics capabilities of the Vanderbilt partner of the NIH bioengineering research partnership (BRP). Such an application would also present new opportunities for the system development and evaluation of 'accessible pedestrian signal' (APS) concepts. A major goal is to be able to fully integrate the constructive simulation capabilities of a model such as VISSIM with the real time multi-modal capability of the TTI driving simulator. The ability to integrate real time and constructive simulation capabilities (and in turn the derivative capabilities for 3D/4D visualization) will represent a major step toward being able to utilize these technologies to convincingly demonstrate the 'operational' benefits of advanced Intelligent Transportation System (ITS) concepts prior to their actual implementation. It will have the effect of being able to move beyond the use of 3D/4D visualization technologies to simply show how advanced system concepts will 'look' to where we will be able to demonstrate (with the confidence of underlying micro-simulation models) how they will 'operate' as well. Being able to provide an operationally realistic (traffic) environment in the simulator will significantly increase the utility of the simulator as a research tool for the analysis of driver, vehicle, and system variables involved in advanced transportation system concepts.

Hunter-Zaworski, K; Hron, ML. (1999). *Bus Accessibility for People With Sensory Disabilities*. Transportation Research Record. Issue 1671.

With the passage of the Americans with Disabilities Act (ADA) it has become a civil rights violation to deny access to public transportation to people with disabilities. ADA requires transit agencies to provide accessible buses or equivalent services to people with mobility, sensory, or cognitive impairments. Issues concerning people with sensory impairments, and their access to fixed-route transit services, are examined in this study. The literature concerning access to public transit by people with sensory disabilities is summarized in this paper, along with exemplary training programs and technologies that have improved transit accessibility for people with sensory disabilities. A major conclusion of this study is that technological solutions may not increase bus accessibility for people with sensory impairments. One-on-one interaction is needed to solve many individual access problems of the transit users. Training for transit personnel is needed so personnel become aware of, and more sensitive to, the needs of all transit users. Training for the transit user is necessary so that use of the transit system is accomplished with grace, speed, efficiency, and dignity. Training for those who train people with disabilities is necessary so that transit travelers will be informed about all the available services offered by transit agencies. Visual signage must be consistent and highly legible to be effective and includes sign and information location, lighting, contrast, and content.

Kelleher, DG (2002) *Wayfinding Devices Designed and Installed For the Visually Impaired Community*. Bus and Paratransit Conference, Proceedings American Public Transportation Association

The Americans with Disabilities Act (ADA) has successfully addressed many of the needs of disabled people who had restricted mobility, and new technology becomes available every day to make things easier for the disabled community. This paper focuses on the use of The Talking Sign System, a wayfinding device that can reduce the barriers that blind and visually impaired people encounter when they are out in a built environment dominated by people who can see.

Kuemmel, DA (2000). *Accessible Pedestrian Signals*. Institute of Transportation Engineers. Vol. 70,3
Over the past 20 years, the Signals Technical Committee of the National Committee on Uniform Traffic Control Devices has discussed the topic of audible pedestrian signals and always failed to reach a consensus on the addition of any language in the Manual on Uniform Traffic Control Devices regarding this. The Americans with Disabilities Act requires access to public right-of-way for people with disabilities. In 1997, the issue was given to the Pedestrian Task Force to explore and provide recommendations on proposed language on a much broader issue than just audible pedestrian signals. The Traffic Engineering Council Accessible Intersection Committee is working to develop tools that will help traffic engineers make intersections more accessible for the blind and visually impaired. Proposed standards for accessible pedestrian signals are included.

La Grow, S., and Blasch, B. (1992). Orientation and Mobility for Older Adults with Impaired Vision. In Alberta Orr (Ed) *Aging and Vision Loss in the United States*. New York: American Foundation for the Blind, Inc.

This Chapter deals with the unique travel considerations for the mobility of older adults with impaired vision. Included are some of the common functional mobility limitations experienced by the older adult with impaired vision and some suggested solutions.

Loane, Gregg; Greenough, John C., (1998). *Audible Pedestrian Signals in the City of Toronto: A Municipal and Corporate Partnership with the Blind and Visually Impaired Communities*. 68th Annual Meeting of the Institute of Transportation Engineers. Institute of Transportation Engineers.

The use of Audible Pedestrian Signals (APS) is not new to North America. APS have been in operation from coast to coast, in one form or another, for decades. While a newcomer to this technology, the City of Toronto Transportation Department (Toronto Transportation) has developed a means of community consultation that may be of benefit to other municipalities in their attempts to provide for the best possible APS program. This paper describes how APS operate in the City of Toronto, functions of the APS Advisory Group, and reactions to the APS program.

Marin-Lamellet, C; Pachiaudi, G; Le Breton-Gadegbeku, B, (2001). *Information And Orientation Needs of Blind And Partially Sighted People in Public Transportation: Biovam Project*. Transportation Research Record, 1779

Presented are results of the BIOVAM project in France concerning the problems experienced by the visually impaired who use public transportation, such as buses, subways, and trains. The project focused on information gathering and orientation processes in the public transportation context. The BIOVAM approach uses a questionnaire survey to identify the main difficulties that public transportation users with visual impairment must manage. The approach includes a review of promising devices that could reduce these difficulties, such as personal information systems and tactile pavements. An overview of the results obtained from the survey is presented, addressing the use of buses and subways. The main technical solutions considered by the project are described, and the research protocols that are to be used in the field experiments are presented. The results of the BIOVAM project could be used to make concrete recommendations to include the specific needs of travelers with visual impairment in the design of a public transport infrastructure.

Norio N, (2002). *Development of a Traffic Signal System to Improve Mobility of The Visually Impaired*. 9th World Congress on Intelligent Transport Systems, ITS America.

Recently, safe walking by the visually impaired has become a socially important issue. It is especially dangerous when a totally blind person crosses an intersection, so some safety measures must be taken. Installation of an audible signal is fundamentally a top priority and it's desirable to increase the amount of information with an additional device. Some trial equipment was made with consideration for the advice from the users, with which verification tests were made. The paper discusses how the trial equipment could easily be used in the field after some modifications. About 3 million Japanese struggle with disabilities, 300,000 of which are visually impaired, as reported by the Ministry. In 1990 "the Barrier-free Law" was established by the related Ministry, with which much planning is being promoted in various circles to assist the handicapped in supporting themselves and participating freely in society. This project, which aims to enhance the mobility of the visually impaired, conducted a study on measures to eliminate difficulties associated with crossing intersections. One of the main problems is that there is no uniformity between audible signals at intersections among the different prefectures. With consideration for user-friendliness, safety and amenity, a new system of audible signals, which enable navigational guidance to the handicapped with uniformed sounds in Japan needs to be developed.

Ross, David & Blasch, B., (2002) Development and Evaluation of three Way-Finding Interfaces for People with Severe visual Impairment. IEEE Transactions on Rehabilitation Engineering.

This research study compared three methods of providing an individual with a visual impairment feedback to make a straight street crossing. The methods included a speech interface, a virtual 3D Sonic beacon and a “tapping” tactile interface. Based on the data, the recommended interface was the tapping tactile interface. It was noted that the speech and 3D beacon had some limitations due to the traffic sounds masking the feedback and also several of the subjects had hearing losses.

Williams, M. & Blasch, B. (2003) “Field Comparison of Accessible Pedestrian Devices,” International Mobility Conference (IMC), Stellenbosch, South Africa. April 5, 2003.

This study compared two Accessible Pedestrian Signals (APS) to the existing pedestrian crossing signal. The research was conducted in two parts. Experiment 1 will provide a field replication of a study conducted by Van Houten, Blasch, and Malenfant that compared the relative conspicuity of the Relume™ signal by comparing three different symbols (hand, person, and animated eyes) for low vision individuals. Experiment 2 will compare the effectiveness of two accessible pedestrian signals compared to a typical pedestrian traffic light signal as a control. The Relume™ and Polaria signals will be installed at two intersections along the same street. The dependent variable, amount of veering (deviation veer and signed veer) will be measured at each crossing. Whether deviations are toward or away from the intersection (signed veer) will also be recorded with measures of crossing alignment. At the time of this presentation, all of the data had not been collected

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Appendix B

Summary of Transit System Survey

Annex 1 Transit System Questionnaire
Annex 2 Summary of Completed Transit System Surveys

SUMMARY OF TRANSIT SYSTEM SURVEY (PREPARED JULY 2004)

INTRODUCTION AND SUMMARY

This report summarizes the results of the survey of transit systems (Task 2) conducted by the KORVE Team for TCRP Project D-10, *Audible Signals for Pedestrian Safety in LRT Environments*. The purpose of this survey is to gather information regarding operating procedures relating to pedestrian safety and audible warning devices on LRT systems across North America. This information will be incorporated into the upcoming State of the Practice Report. In addition, the accident data collected as part of this survey will be used for Task 3, Evaluation of the Effectiveness of Audible Warning Devices Based on Historical Data.

The survey was generated by the KORVE Team with feedback from the TCRP panel. The survey included questions relating to:

- Alignment type and route miles,
- Operating procedures (headways, frequency, consist, etc),
- Types, sound level, and use of audible warnings,
- Grade crossings design,
- Community noise impacts,
- New or innovative approaches to audible warnings and pedestrian safety, and
- Pedestrian accident data.

Surveys were sent to 17 transit agencies, including 15 in the United States and 2 in Canada. A total of 11 agencies responded. A list of agencies receiving and responding to the survey is included in Table 1.

After reviewing the surveys, the KORVE Team contacted agencies to ask follow-up questions and get more detailed information about operating conditions, grade crossing equipment, and procedures for using audible warnings. Agencies were contacted when there were unclear or incomplete responses to questions and when the agency indicated that they have considered or implemented some unique means of improving pedestrian safety and/or minimizing community noise impacts through audible warning devices. Some of the most useful information was obtained during these telephone conversations.

Key findings from the transit agency surveys and follow-up discussions include:

1. Agencies need flexibility in order to adjust standard procedures to fit local conditions.
2. Operating procedures and equipment are fairly consistent between agencies in the U.S. and Canada.
3. There are only a few LRT-specific standards that address pedestrian safety using audible warnings.
4. The steps that have been taken by agencies to address community complaints associated with audible warnings are not ground-breaking; however, these steps illustrate that relatively minor modifications can be very effective at reducing community annoyance from audible warnings without compromising pedestrian safety.

The remainder of this report includes: (1) an overview of conclusions from the system surveys, (2) discussions of some innovative approaches to address pedestrian safety and community noise issues, and (3) tables summarizing key data from the surveys. A copy of the survey is included as Annex 1 to this appendix. Detailed agency responses are included as Annex 2.

Table 1. Summary of Transit Agency Surveys

Transit Agency	Location	Response	
		Yes	No
Los Angeles County Metropolitan Transportation Authority (Metro)	Los Angeles, CA	✓	
Sacramento Regional Transit District (Sac RT)	Sacramento, CA	✓	
San Diego Trolley, Inc.	San Diego, CA	✓	
San Francisco Municipal Railway (MUNI)	San Francisco, CA		✓
Santa Clara Valley Transportation Authority (VTA)	San Jose, CA	✓	
TRIMET	Portland, OR		✓
Maryland Mass Transit Administration (MD MTA)	Baltimore, MD	✓	
Massachusetts Bay Transportation Authority (MBTA)	Boston, MA		✓
Houston Metro	Houston, TX		✓
Niagara Frontier Transportation Authority	Buffalo, NY		✓
Calgary Transit (Calgary)	Calgary, Alberta, Canada	✓	
Denver Regional Transit District (RTD)	Denver, CO	✓	
Edmonton Transit System (Edmonton)	Edmonton, Alberta, Canada	✓	
Dallas Area Rapid Transit (BART)	Dallas, TX	✓	
Bi-State Metro Development Agency (Bi-State)	St. Louis, MS	✓	
New Jersey Transit	Bloomfield, NJ		✓
Utah Transit Authority (UTA)	Salt Lake City, UT	✓	

CONCLUSIONS

Overall, there is a relatively common and straightforward approach to using audible warnings for pedestrian safety, with the use of crossing bells and on-vehicle warnings being fairly standard among transit agencies. Somewhat surprisingly, there are very few state-imposed regulations and industry standards that address the design or use of audible warnings for pedestrian safety. Much of existing guidance comes from freight railroad system standard practices, which are based on AREMA standards and FRA requirements.

Some agencies have modified their audible warning procedures or equipment in response to community complaints over grade crossing noise. These changes, while relatively minor, have the potential to significantly reduce community noise impacts. The general perception is that these changes have not compromised pedestrian safety.

Following are more detailed conclusions regarding the type and use of wayside and on-vehicle audible warning devices, operating rules and procedures governing the use of audible warnings, and other information relevant to pedestrian safety in LRT environments. Additional summary tables are included at the end of this report.

Crossing Bells

The use of crossing bells by the type of crossing is listed in Table 2. Specific conclusions are:

- Passive crossings are often found in pedestrian malls, other low-speed environments, or at pedestrian-only crossings with low pedestrian volumes. These crossings do not have any physical barriers or active visual warnings (i.e. flashing lights). Crossing bells are not used at these locations.
- Active, gated crossings are usually found along semi-exclusive rights-of-way where LRT speeds are in excess of 35 mph. Mechanical or electronic bells are used always used at these types of crossings in conjunction with conventional railroad-type flashing lights.
- Active, non-gated crossings include some traffic signal controlled intersections, pedestrian malls, and similar environments. Active non-gated crossings differ from passive crossings in that they have a visual warning (i.e. flashing lights). Active, non-gated crossings use either crossing bells or non-standard audible warnings. Examples of non-standard treatments include verbal announcements of “train approaching.”

Table 2. Summary of Crossing Bell Use by Type of Crossings

Crossing	Audible Devices at Crossing	
Passive	None	--
Active, Gated	Standard	Crossing Bells
Active, Non-Gated	Standard	Crossing Bells
	Non Standard	Other

- Grade crossing bells are sounded the entire time the crossing is active at most locations. In response to community complaints, some agencies have limited the duration of the crossing bells so that they are sounded only until the gates reach the horizontal (closed) position. This can reduce the total duration of the bell from one minute or more to approximately 10-15 seconds per pass-by.
- The operation of crossing bells at pedestrian-only crossings is similar to gated crossing except that typically the bells sound continuously from the time they are activated until the train has passed.
- The sound level of crossing bells are generally based on American Railway and Maintenance-of-Way Association (AREMA) standards and come pre-set from the supplier.
- Mechanical bells have been replaced by electronic bells in noise-sensitive communities (it is inferred that the electronic bells are preferred because the sound level can adjusted).
- Crossing bells seem to be a bigger source of community noise complaints than the on-vehicle audible warning.
- In response to these complaints, the loudness and annoyance of the crossing bells have been reduced in several communities by:
    - Adjusting the sound level of the device,
    - Covering the device with a shroud to “focus” the sound towards the crossing, or
    - By installing soft clappers on mechanical bells.
- It has been reported that, in place of a crossing bell, installations in Japan and Germany use a loudspeaker mounted on top of a pole at the crossing. The loudspeaker is pointed down to direct the sound towards the pedestrian walkway.[1]

On-Vehicle Audible Warnings

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[1] Telephone conversation with Mr. Richard A. Mather, Railroad Grade Crossing Signal Consultants, June 6, 2004.

Different types of audible warnings used in LRT environments, their relative sound level, and the locations where they are sounded are summarized in Table 3. In general, on-vehicle warnings are sounded at grade crossings, at stations, and in emergency situations.

Table 3. Summary of Type and Use of On-Vehicle Audible Warnings

Alignment & Crossing Type	Sound Level [1]	Audible Warning Description [2]
Street running, traffic signal controlled crossings and arriving/departing at stations	Low (≤ 75 dBA)	Bell/Gong
Semi-exclusive gated and pedestrian crossings	Medium (75 – 85 dBA)	Whistle/Quacker/Clacker/ Low Horn
High noise and hazard environments, joint use corridors, and emergency situations	High (≥ 85 dBA)	Horn

Notes:

[1] Approximate sound level of audible warning as measured at 100 feet from vehicle.

[2] The names used for different audible warnings vary between systems. For example, in many rail environments, the terms whistle and horn are synonymous. In Dallas, the "whistle" has a 10 dBA lower sound level than the "horn."

- On-vehicle audible warnings are sounded in advance of all gate-protected grade crossings. The medium to high sound level device is typically used at these locations.
- At traffic-signal controlled grade crossings, the use of on-vehicle warnings is less consistent among transit systems. At those locations where a warning is sounded, the low to medium sound level device is typically used.
- In pedestrian malls, mid-block locations, and along exclusive rights-of-way away from grade crossings, the on-vehicle audible warnings are used prophylactically (i.e. to keep pedestrians near the tracks off the tracks) and in emergency situations (i.e. potential incidents). In these cases, the medium to high sound level devices are commonly used.
- The lower sound level on-vehicle audible warnings are sometimes sounded to signal the arrival or departure from a station.
- A few transit agencies give the LRT operator complete discretion as to whether or not to sound an audible warning and, if so, what type should be sounded. All agencies give LRT operators discretion in emergency situations.
- Most systems do not test or calibrate the on-vehicle audible warning devices but rather rely on information provided by LRV manufacturer.
- Systems with more than one type of on-vehicle audible warning typically sound the mid-range sound level device at gate-protected grade crossings unless it is located in a high noise environment, is a "high-risk" crossing, or if emergency conditions warrant the use of the louder device. These procedures are in large part designed to minimize community complaints over grade crossing noise.
- In joint-use corridors, LRT horns are often specified to meet the Federal Railroad Administration's minimum requirement of 96 dBA at 100 feet.

Operating Rules

The following reference manuals were cited as dictating the sound level or use of audible warnings:

- American Railway and Maintenance-of-Way Association (AREMA)

Sound level for electronic crossing bells are recommended in Section 3.2.61.G.5 of the AREMA Communication & Signals Manual, which states that, "In a 360° plane the peak sound reading in decibels (A scale) measured in an anechoic test chamber at a point 10 feet from the face of the sound horn and in increments of 20° should not be more than 105 dBA or less than 75 dBA."

- California Public Utilities Commission (CPUC)

  The CPUC General Orders regulate the sound level and use of audible warning devices in California. These standards are also often adopted by other transit agencies outside California, particularly where there is no state PUC.[2]

  CPUC General Order 143-B, Section 3.04 requires that, "[E]very LRV shall be quipped with a bell or horn capable of producing a clearly audible warning measuring at least 75 dBA at a distance of 100 feet from the vehicle. In addition, every LRV operating on separate right-of-way over motor vehicle grade crossings shall be equipped with a horn or whistle capable of producing a clearly audible warning measuring at least 85 dBA at a distance of 100 feet from the LRV." This General Order does not specify which audible warning must be sounded at grade crossings.

  As for crossing bells, Section 7.8 of General Order 75-C requires that all warning aspects "be accompanied by the sounding of a bell." However, the General Order does not specify the sound level of the bell or provide any other specifications as to its use.

- Federal Railroad Administration (FRA)

  The FRA requires that trains sound their horns starting a quarter mile or 20 seconds from a highway-railroad grade crossing. These horns must measure at least 96 dBA at 100 feet. Experience tells us that they typically measure up to 105 dBA. LRTs traveling on joint use corridors (especially those where light rail vehicles and freight trains are not time-separated) are sometimes required to sound an FRA-compliant audible warning.

  The FRA recently announced the "Interim Final Rule" regarding the use of audible warnings at highway-railroad crossings. Although this rule does not directly apply to LRT systems, some of the supplementary safety measures approved in the rule are being tested on joint-use corridors (see discussion of the DART system). Also, the issue regarding its applicability is often raised by community groups trying to reduce noise levels from LRT operations.

  The rule includes, "specific standards local decision-makers can use to silence locomotive horns, while improving safety at public highway rail grade crossings."[3] Under the rule, local jurisdictions can establish quiet zones at crossings (1) with either a low risk of collision or (2) through the use of supplemental safety measures, such as four quadrant gates or other type of median divider, temporary crossing closures, or an automated wayside horn system.

Operating Procedures

- Agencies generally have the same daytime and nighttime operating rules even though traffic and pedestrian volumes and background noise levels are lower during the night.
- At least four of the agencies operate on joint-use freight corridors. Some use the same tracks but are time-separated from LRT operations (i.e. freight traffic running during the nighttime hours) and others, like Denver RT, DART, Metro's Blue Line and Edmonton, share the same crossing protections but have different tracks. For the most part, LRT operating procedures are different from those of freight trains on the same corridor.

Other Pedestrian Protections

- Pedestrian gates and Z crossings are the two most common types of pedestrian safety improvement measures tested and implemented by transit agencies.

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[2] One respondent indicated that the CPUC General Order 75-C and 143-B are the only LRT-specific design/operating guidance documents widely available to transit agencies.

[3] U.S. Department of Transportation, Office of Public Affairs, "FRA Issues Rule Providing Local Communities the Opportunity to Silence Train Horns at Railroad Crossings," December 17, 2003.

- Some systems have audible announcements on the station platforms, such as "train approaching, stand back."

OTHER ISSUES TO BE CONSIDERED

Based on these surveys, we have identified a few innovative approaches used by transit agencies to address community noise impacts while protecting pedestrian safety. Following is a discussion of the approaches or issues that could be applied in Phase II of the D-10 study or the guidebook.

Los Angeles County Metropolitan Transportation Authority (Metro)

Metro, the Los Angeles to Pasadena Metro Blue Line Construction Authority (Authority), and the City of South Pasadena (South Pasadena) recently entered into a proposed settlement regarding the construction and operation of the new Metro Gold Line light rail transit system. Many of the issues in the proposed settlement address grade crossing audible warnings. The proposed settlement is currently being considered by the California Public Utilities Commission (CPUC), which has safety oversight responsibilities for LRT systems in California.

The Gold Line is a new 14-mile LRT system extending from Downtown Los Angeles east to Pasadena, connecting many eastern communities in Los Angeles (Chinatown, Mt. Washington, and Highland Park), and the cities of South Pasadena and Pasadena. The system was constructed under the direction of the Authority, which is a Joint Powers Authority established by the state legislature for the express purpose of constructing the Gold Line, and opened for revenue service in July 2003. Metro is responsible for system operation and maintenance.

South Pasadena is primarily a residential community. Even though the Gold Line is a former freight railroad corridor that had regularly scheduled service up until the early 1990s, many single- and multi-family residences are right next to the tracks. In some cases the building setback is within 10 feet of the right-of-way. As a result, noise has been a major concern for residents and city officials. During the later stages of construction, through system testing and acceptance, and continuing on during operations, South Pasadena has raised issues regarding both the on-vehicle and wayside (crossing bells) audible warnings. In order to seek relief, South Pasadena and an interested third party (Pasadena Avenue-Monterey Road Committee, PAMRC) filed several actions with the CPUC. In particular, South Pasadena was requesting changes to the sound level and operating procedures for the audible warning devices along with other matters unrelated to grade crossing noise.

The terms agreed to by the three parties in the proposed settlement are summarized below. Individually, each term has the potential to reduce community annoyance and, collectively, represent a significant change the standard LRT operating procedures in California.

1. **On-Vehicle Audible Warnings**. The Gold Line vehicles are equipped with three audible warnings, a horn, a lower sound level "quacker," and a gong. The gong is not routinely used, although it is sometimes sounded when entering or exiting a station. The quacker measures 75 dBA at 100 feet and the horn measures 85 dBA at 100 feet.
   a. Sound Level: This term requires that Metro sound the quacker twice as trains approach the crossing. As noted above, the sound level of the quacker is 10 dBA lower than the horn.
   b. Hours of Use: The Gold Line operates between 20 and 21 hours per day. As agreed to in the settlement, Metro will participate in a CPUC directed safety study to silence the quacker between 10 p.m. and 6 a.m. It should be noted that the CPUC has not yet agreed to sponsor this study.
2. **Crossing Bells**: South Pasadena is proposing a number of modifications to the crossing bells. Generally speaking, as part of the settlement, Metro and Authority agree not to oppose any action taken by South Pasadena to modify the crossing bells as long as they demonstrate that these changes will not compromise public or operator safety. Possible changes include:
   a. Duration: When the Gold Line opened for revenue service, the grade crossing bells were active the entire time the crossing was occupied. As a result, the crossing bells rang for up to a minute per train pass-by. In fact, at a crossing near the South Pasadena station, the bells would often ring for up to two minutes. With a train in each direction every 5 to 6 minutes, this represents a significant source of

annoyance to the local community. In response to a previous application filed by South Pasadena in 2003, the CPUC permitted the Authority to modify five of the eight crossing bells in South Pasadena so that they stopped ringing once the gates reached the horizontal position. This change reduced the total ring time to approximately 10-12 seconds. South Pasadena proposes modifying the remaining bells to the same standard.

b. Sound Level: The sound level from the existing crossing bells measures between 80 and 90 dBA at 10 feet. Although this conforms to the AREMA specification, it is in the mid- to upper-end of the allowable range. The Authority has agreed to either adjust or install new bells that have sound levels near the lower end of the range (75-80 dBA).

c. Hours of Use: The safety study to silence the on-vehicle audible warnings during nighttime and early morning hours will also include the crossing bells.

d. Directional Bells: Bell “shrouds” are to be provided at all crossings as part of the settlement. The bells are placed on top of the crossing posts (12-16 feet above the ground) and generally radiate sound in a 360° plane. The purpose of the shroud is to focus the noise towards the crossing where it is needed and to limit the noise that is unnecessarily radiated out into the community.

There are some important conditions relative to Gold Line operations through South Pasadena that facilitate the adoption of the proposed settlement terms. These conditions should be considered when assessing the applicability of the terms to other LRT environments:

- **Existing Noise Level**. South Pasadena is characterized by relatively low ambient noise levels. As a result, lower sound level audible warnings are sufficient to alert pedestrians to on-coming trains.
- **Alignment Type**: The Gold Line operates on a semi-exclusive right-of-way through South Pasadena. Therefore, access to the right-of-way is limited to the grade crossings.
- **Operating Speeds**. LRT speeds are generally between 25 and 35 mph in the more noise-sensitive areas.
- **Crossing Protections**: All grade crossings in South Pasadena are equipped with pedestrian crossing arms and swing gates.

Most of the proposed settlement terms relating to audible warning devices are subject to detailed field safety studies and CPUC and Metro approval. Therefore, if the CPUC agrees with the terms of the settlement, some useful information regarding the ability of the proposed measures to maintain adequate levels of pedestrian and operator safety while minimizing community noise impacts may be available to the D-10 Project and will be considered for the Phase II study.

Santa Clara Valley Transportation Authority (VTA)

The VTA vehicles have four different audible warnings: an electro-mechanical bell (gong), an electronic “church” bell, a low horn, and a high horn. The sound level of these audible warnings ranges from approximately 60 dBA at 100 feet for the gong up to 85 dBA for the louder horn. Different warnings are used based on alignment type, speed, and the noise-sensitivity of the adjacent land uses.

Following complaints from local property owners, VTA was granted a “Low Noise Zone” by the CPUC at Whisman Road. The operating conditions at this crossing are:

- The crossing bells are turned down to the lowest acceptable level (audible to pedestrians and to motorists with the windows rolled down).
- The crossing bells stop ringing once the gates have reached the horizontal (closed) position.
- The gong is sounded in advance of the crossing.

The approval of these measures was, in part, due to the low operating speed. Nonetheless, they have been very successful in limiting community noise complaints with no accidents being reported since the changes were implemented.

Calgary Transit

Numerous changes to crossing bells have been made by Calgary Transit. Specifically, softer tone electronic bells are used at pedestrian crossings that are close to residential areas. Also, a “shield” with opening slots is used to “direct” sound towards the crossing. Photographs of a normal bell and one with a shield are included as Figure 1 and Figure 2, respectively.

Dallas Area Rapid Transit (DART)

Outside of the Central Business District (CBD), some of the DART system is on shared-use freight corridor. DART uses an FRA-compliant horn along this section. FRA regulations state that these horns must measure at least 96 dBA at 100 feet, which is substantially louder than typical LRT on-vehicle audible warnings. DART vehicles also have a gong and a whistle, both of which are specified to be 75 dBA at 100 feet in front of the vehicle. Although the use of the whistle is not required, it is sounded at most grade crossings except those in “high hazard” and “high noise” areas where the horn is used. The gong is used when leaving stations in the CBD.

The City of Richardson, TX is testing a wayside horn system at one of the joint freight/DART crossings. The wayside horn is only being used for freight trains. DART vehicles continue to sound their horn in advance of the crossing.

Table 4. Summary of Alignment Type

Alignment Type	Metro	Sac RT	San Diego	VTA	MD MTA	Cal-gary	RTD	Edmon-ton	DART	Bi-State	UTA
Exclusive	25.5	3.7	55.5	11.1		21.1	10.7				
Semi-Exclusive/ Fenced	23.2	20.2		5.7			1.7	x	44.0	37.0	11.5
Street Median/ Fence & Curb											
Side Alignment/ Fence & Curb											
Street Median/ Curb (No Fence)	5.5		4.5	18.2				x	3.0		1.5
Side Alignment/ Curb (No Fence)	0.6						3.4				2.0
Street Median/ Transit Lane								x			2.5
Side Alignment/ Transit Lane		2.7									
Non-Exclusive/ Mixed Traffic		2.7		0.1	x	1.3					
Non-Exclusive/ Pedestrian Mall		0.4		1.3							
Total Miles	54.7	29.7	60.0	36.4		22.3	15.8	8.1	47.0	37.0	17.5
No. of Lines	3	2	3	3	2	4	3	1	2	2	3

Table 5. Summary of Crossing Bells

Xing Bells	Metro	Sac RT	San Diego	VTA	MD MTA	Cal-gary	RTD	Edmon-ton	DART	Bi-State	UTA
Type of Bell											
Mechanical	x	x	x	x	x	x	x	x	x	x	x
Electronic	x	x		x		x		x			
Wayside											
Special											
Other											
Xing Type											
Gated	x	x	x	x	x	x	x	x	x		x
Traffic Signal		x	x					x			
Pedestrian	x	x	x			x		x	x		
Use											
Approach	x	x		x	x				x	x	x
Occupied	x	x	x	x		x	x	x			
Other											
Complaints	x	x		x		x		x	x		X

Notes:
Approach = Crossing bell sounds until gates reach horizontal position.
Occupied = Crossing bell sounds entire time gates are active.
Complaints = Agency has received complaints from local community about sound level or general annoyance from bell.

Table 6. Summary of On-Vehicle Audible Warnings

Warning	Metro	Sac RT	San Diego	VTA	MD MTA	Cal-gary	RTD	Edmon-ton	DART	Bi-State	UTA
Type of Device											
Horn	x	x	x	x	x	x	x	x	x	x	x
Bell Type	x	x		x	x	x	x	x	x	x	x
Other	x		x	x					x		
Use											
Gated											
High	x	x	x	x			x		x	x	
Low	x	x	x	x					x		
Non Gated											
High							x				
Low	x	x		x	x		x		x		
Sound Level											
dBA	75-85			60-85				80-90	75-95		
Calibrated	Y	Y		Y	N	N	N	Y	N	N	N
Special Procedures	Y	N	Y	Y	Y	N	N	Y	Y	N	N

Notes:

Metro	Different devices are used based on alignment.
	Higher sound level horn used on Blue Line shared-use corridor.
	"Quacker" or lower sound level bell type device used at all other crossings (gated and non-gated).
Sac RT	Lower sound level bell in residential areas and horn only in emergencies.
San Diego	Lower sound level clacker used in noise-sensitive communities.
VTA	4 types of devices: gong, "church" bell, low horn, high horn.
MD MTA	Change during nighttime operation.

Calgary	"Use bell/horn as need - no special instructions."
RTD	Horn used at gated crossings, horn or bell used at non-gated based on operator's discretion.
Edmonton	Change during nighttime operation.
DART	Horn used in “high noise” and “high hazard” areas, lower sound level whistle used outside the CBD.
Bi-State	Similar procedures in Illinois and Missouri.

Figure 1. Example of a Typical Electronic Crossing Bell (Calgary)

Figure 2. Example of an Electronic Crossing Bell with a Shield (Calgary)

Annex 1 Transit System Questionnaire

QUESTIONNAIRE

TRANSPORTATION RESEARCH BOARD
TRANSIT COOPERATIVE RESEARCH PROGRAM (TCRP)

PROJECT D - 10
AUDIBLE SIGNALS FOR PEDESTRIAN SAFETY IN LIGHT RAIL TRANSIT ENVIRONMENTS

Transit Agency ____________________________________
Attn: TCRP Project D-10 Contact
Address __________________________
Address __________________________
City, State Zip Code ____________________

Name of person(s) completing this Interview Guide:___________________________________

Title:___________________________________

Phone:___________________________________

Email:___________________________________

RESEARCH PURPOSE

The overall goal of this research is to develop guidelines for LRT systems on the use of audible warnings to reduce risky behavior by pedestrians while simultaneously minimizing adverse noise impacts on adjacent communities. Specifically, the objective of this research is to develop a guidebook on the use of audible signals and related operating procedures for pedestrian-crossing safety in a light rail transit environment. The areas to be addressed in order to achieve the research objective are described below.

- Integration of these audible devices with other crossing measures (e.g., signage, channelization, warning and control devices) to maximize safety.
- Types of on-vehicle and wayside audible signals. The types of audible warning devices currently in use, or available for use, vary widely, even among similar devices. General categories include:
  - On-vehicle horns and bells
  - Crossing gate bells
  - Wayside horns
  - Other Wayside Audible Devices
- Needs of disabled individuals.

- Operating procedures used for the audible warnings. This includes:
  - Transit system operating procedures vary for the use of audible devices.
  - Distance the train is from the crossing when the warning sounds are initiated
  - Patterns of sounds
  - Special procedures for particular areas.
- Safety levels associated with pedestrian crossings with alternative audible treatments in distinctively different environments (e.g., low-speed street running, stations, and highway-rail at-grade crossings in semi-exclusive rights-of-way).
- Identify practical solutions and recommendations in a final guidebook for implementation on existing and future light rail systems. Some key factors that will be considered in developing the guidebook are:
  - Cost
  - Best practices for use of existing devices
  - Potential for new or modified devices
  - Legal challenges and existing legislation
  - Other Implementation issues

STRUCTURED INTERVIEW

A. General Characteristics of the LRT System

Please provide the following general LRT system information:

1) *Number of route-miles in the following types of right-of-way (include line name/number, segment and year opened):*

	Line ____________	Line ____________	Line ____________
	Segment _________	Segment _________	Segment ________
	Year Opened _____	Year Opened _____	Year Opened ____
Exclusive			
Semi-Exclusive/Fenced			
Street Median/Fence & Curb			
Side Alignment/Fence & Curb			
Street Median/Curb (No Fence)			
Side Alignment/Curb (No Fence)			
Street Median/Transit Lane			
Side Alignment/Transit Lane			
Non-Exclusive/Mixed Traffic			

QUESTIONNAIRE

Non-Exclusive/Pedestrian Mall			

2) *Principle Types of LRVs in use (please check and list by line where applicable):*

LRV Manufacturer/Model/Year:
LRV Articulated: ☐ Yes ☐ No
Floor: ☐ Low Floor ☐ High Floor
Stations: ☐ high platform ☐ low platform ☐ low platform with high block
Audible Warning Device on LRV: ☐ LRV Horn ☐ Bell Type

(Please list audible warning messages also):

3) *Typical train consist length by line (include time of operation if appropriate, i.e., rush hour, off-peak, weekend, summer/winter):*

Line____:______________________________

Line____:______________________________

Line____:______________________________

4) *Service frequency/headway by line (include time of operation if appropriate):*

Line____:______________________________

Line____:______________________________

Line____:______________________________

For the remainder of this survey, it would be beneficial to consider the following factors when answering the questions:

- ***Alignment type***
- ***Pedestrian crossing type:***
  - ***With traffic – gated crossings***
  - ***With traffic – traffic signal controlled***
  - ***Pedestrian only***

5) *Operating speeds, policies, and instructions (e.g., use of horns, chimes, other on vehicle warning devices) for the various lines (Is a copy of an operator's rule book available?)*:

QUESTIONNAIRE

6) *Types of wayside audible devices used (please check where applicable):*

	Pedestrian Crossing Type		
Device	*With Traffic, Gated*	*With Traffic, TS Controlled*	*Ped. Only*
1. Mechanical bells	☐	☐	☐
2. Electronic bells	☐	☐	☐
3. Wayside horn	☐	☐	☐
4. Special wayside ped. audible device	☐	☐	☐
5. Other	☐	☐	☐

(Please describe if special wayside pedestrian audible device or other device is used):

7) *Operating characteristics of grade crossing bells and other wayside audible devices (please check where applicable):*

	Pedestrian Crossing Type		
Device	*With Traffic, Gated*	*With Traffic, TS Controlled*	*Ped. Only*
1. Active only on train approach, until gates are in horizontal position.	☐	☐	☐
2. Active during approach and entire time crossing is occupied.	☐	☐	☐
3. Other	☐	☐	☐

(Please describe if other operating characteristics is used):

8) *Operating speeds, polices, and instructions <u>for night</u> operations (e.g., use of headlights, strobe lights, audible devices) for the various lines:*

9) *Do any of your LRT lines intersect with designated bicycling/walking facilities, such as Class I off-road paths, Class II bike lanes, or Class III marked bike routes?*

☐ Yes ☐ No

If yes, please identify:

B. Highway-light Rail Grade Crossing Operations

<u>General</u>

QUESTIONNAIRE

1) *Have any changes been made to the grade crossing audible devices (either on the LRV or wayside) since the LRT started operations, or are there any changes planned in the near future?*

☐ Yes ☐ No

If yes, please identify:

2) *If devices have changed since opening of service or from line to line, describe rational and noted effects:*

3) *Please provide your experience, ideas, and/or comments in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire:*

4) *Please provide comments on the results of any demonstration projects related to grade crossing safety improvements involving audible devices:*

5) *Does your LRT system have at-grade shared crossings with freight railroad in an immediately adjacent right-of-way to your LRT right-of-way or shared crossings where freight trains use the same set of tracks as LRT (but at a different time of the day)?*

☐ Yes ☐ No

If yes, please identify and provide operations details (or operating agreements) and any special traffic control devices that indicate an LRV or train is about to pass through the crossing:

How does audible device use vary between LRV and freight operations at the crossing?

Background

1) *Are there any crossings with special or unique operating characteristics with regard to audible device use that are described In the Operating Rule Book or other Special Instructions?*

☐ Yes ☐ No

If yes, please explain:

2) *Does your agency have a written policy for the selection of highway-rail grade crossing safety improvements?*

☐ Yes ☐ No

If yes, please provide:

3) *To what extent do you rely on the supplier of the audible equipment for the development of plans and specifications for audible improvements?*

4) *How do you determine what the noise level (loudness) of the audible devices will be?*

5) *Do you test the noise levels of the audible devices after the installation (i.e. take measurements of decibels)?*

☐ Yes ☐ No

If yes, how?

6) *Are noise levels of audible warning devices calibrated?*

☐ Yes ☐ No

If yes, how often?

7) *Are there any guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings?*

☐ Yes ☐ No

If yes, please identify:

8) *Which of the following procedures does the agency use in the evaluation of safety at highway-rail crossings (please check where appropriate)?*

☐ Engineering study as defined in the MUTCD
☐ Diagnostic team study as defined in the Rail-Highway Grade Crossing Handbook
☐ Others

If others, please describe:

9) *Do you have an inventory of all highway-rail grade crossings?*

☐ Yes ☐ No

10) *Is this inventory consistent with the U.S. DOT/AAR national inventory?*

☐ Yes ☐ No

11) *From what source(s) do you obtain motor vehicle/train accident reports and statistics?*

12) *Is the disabled community involved in the selection of audible devices (i.e. through task forces or other means)?*

☐ Yes ☐ No

If yes, how?

13) *Can you provide a contact person (or persons) for the disabled community task force that we could contact?*

14) *From what source(s) do you obtain pedestrian/train collision reports and statistics?*

15) *Has your agency investigated the possible application of new technology listed below (please check where applicable)?*

☐ Automated train horn at the crossing.
☐ Special pedestrian crossing control devices

☐ Audible Devices
☐ Z Crossings
☐ Pedestrian Automatic Gates

16) *Have any community noise concerns caused a change in the type of audible device used or the way it is operated?*

☐ Yes ☐ No

If yes, please explain:

17) *Have there been any changes to audible devices use resulting from legal challenges?*

☐ Yes ☐ No

If yes, please explain:

18) *Have there been any legal challenges resulting from changes in audible device use?*

☐ Yes ☐ No

If yes, please explain:

D. Collision Data

Note: This information will be used for research purposes only.

1) *Please provide pedestrian collision experience summary of your system by type, locations, and severity:*

2) *For two to three high accident crossing locations, please provide the following data (where available):*

- Detailed accident records (collision diagrams if available)
- Type of warning devices in place, including audible devices
- Information on site specific conditions
- Ambient noise level

- Train speed and direction
- Traffic volume
- Pedestrian volume
- Information on contributing factors
- Steps taken after collision to address causal factors

3) *Have any safety studies been conducted by your agency to determine factors contributing to pedestrian collisions?*

☐ Yes ☐ No

If yes, can they be provided to us?

E. Conclusion

1) *Would your light rail system be interested in participating further in Phase II of TCRP Project D-10? Phase II of this project will test (either via focus groups, laboratory tests, field tests, etc.) audible devices that warrant further evaluation before being recommended for inclusion in Part X of the MUTCD.*

☐ Yes ☐ No

2) *We may be conducting field survey and video taping at four to five of your at-grade LRT crossings. Which crossings would you recommend visiting (crossings with unique audible devices, high number of pedestrian collisions, etc.)?*

For any questions or concerns, please contact:
Korve Engineering, Inc.
Jay Nelson, PE, PTOE or Travis Jensen
935 E. South Union Avenue D-203
Midvale, UT 84047
Phone: (801) 569 – 2131
Fax: (801) 569 – 2149
jnelson@korve.com or tjensen@korve.com

Annex 2

Summary of Completed Transit System Surveys

QUESTIONNAIRE
Transportation Research Board
Transit Cooperative Research Program (TCRP)
PROJECT D - 10
Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Bi-State Metro St. Louis, MO		
A. General Characteristics of the LRT System				
1)	*LRT System in use*			
	A. Line	Phase 1	St. Clair	
	B. Right of Way Type			
	C. Segment	17 Miles	20 Miles	
	D. Length			
	E. Year Opened	1993	2001	
2)	*LRVs Type in use*			
	A. Manufacturer/Model/Year	1992, 2000		
	B. Articulated	Yes		
	C. Floor	High floor		
	D. Stations			
	E. Audible Warning Device on LRV	LRV Horn		
	F. Audible warning messages			
3)	*Typical train consist length*			
	A. Line	1	St. Clair	
	B. Length	Two Car Consist 188'	Two Car Consist 188'	
	C. Time of Operation			
4)	*Service frequency/headway by line (include time of operation if appropriate):*			
	A. Line	1	St. Clair	
	B. Frequency/Headway	7.5 Headways	7.5 Headways	
	C. Time of Operation			
5)	*Operating speeds, policies, and instructions*	Yes		
6)	*Types of wayside audible devices*			
	A. Mechanical bells	Gated		
	B. Electronic bells			
	C. Wayside horn			
	D. Special wayside ped. audible device			
	E. Other (describe)			
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*			
	A. Active only on trainap proach, until gatesare in horizontal position.	Gated		
	B. Active during approach and entire time crossing is occupied.			
	C. Other (describe)			
8)	*Operating speeds, polices, and instructions for night operations*	Yes		
9)	*LRT lines intersect with designated bicycling/walking facilities*	No		
B. Highway-Light Rail Grade Crossing Operations				
General				
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	No		
2)	*Describe rational and noted effects of the changes made and.or planned*	N/A		
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*	N/A		
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*	N/A		
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	No		
Background				
1)	*Crossings with special or unique operating characteristics*	No		
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	No		
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*	100%		
4)	*Determination of audible device noise level (loudness)*	N/A		
5)	*Testing noise levels after audible device installation*	No		
6)	*Calibration audible device noise levels*	No		
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	No		
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Engineering Study as defined in the MUTCD		
9)	*Available inventory of all highway-rail grade crossings*	Yes		
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	Yes		
11)	*Source motor vehicle/train accident reports and statistics*	N/A		
12)	*Involvement of the disabled community selection of audible devices*	No		
13)	*Contact person (or persons) for the disabled community task force*	No		
14)	*Source(s) for pedestrian/train collision reports and statistics*	N/A		
15)	*Investigation/consideration of possible application of new technology as follow:*			
	A. Automated train horn at the crossing.	No		
	B. Special pedestrian crossing control devices	No		
	C. Audible Devices	No		
	D. Z Crossings	No		
	E. Pedestrian Automatic Gates	No		
16)	*Change in type of audible device used caused by community noise*	No		
17)	*Changes to audible devices use resulting from legal challenges*	No		
18)	*Legal challenges resulting from changes in audible device use*	No		

QUESTIONNAIRE

Transportation Research Board

Transit Cooperative Research Program (TCRP)

PROJECT D - 10

Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Edmonton Transit System		
A. General Characteristics of the LRT System				
1)	*LRT System in use*			
	A. Line	North-South		
	B. Right of Way Type			
	C. Segment	13 km		
	D. Length			
	E. Year Opened	1977		
2)	*LRVs Type in use*			
	A. Manufacturer/Model/Year			
	B. Articulated	Yes		
	C. Floor	High Floor		
	D. Stations			
	E. Audible Warning Device on LRV	LRV Horn		
	F. Audible warning messages			
3)	*Typical train consist length*			
	A. Line	North-South		
	B. Length	1-4 car trains		
	C. Time of Operation			
4)	*Service frequency/headway by line (include time of operation if appropriate):*			
	A. Line	North-South		
	B. Frequency/Headway	5 Minutes, 10 Minutes & 15 Minutes		
	C. Time of Operation			
5)	*Operating speeds, policies, and instructions*	Operator's rule book is available		
6)	*Types of wayside audible devices*			
	A. Mechanical bells	Gated, TS Controlled, Ped. Only		
	B. Electronic bells	Gated, TS Controlled, Ped. Only		
	C. Wayside horn			
	D. Special wayside ped. audible device			
	E. Other (describe)			
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*			
	A. Active only on trainap proach, until gatesare in horizontal position.			
	B. Active during approach and entire time crossing is occupied.	Gated, TS Controlled, Ped. Only		
	C. Other (describe)			
8)	*Operating speeds, polices, and instructions for night operations*	Headlights, horns or bells by the operator		
9)	*LRT lines intersect with designated bicycling/walking facilities*	Yes, class 3		
B. Highway-Light Rail Grade Crossing Operations				
General				
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	No		
2)	*Describe rational and noted effects of the changes made and.or planned*	Instead of mechanical bells, electronic bells were used in residential area as a trial at grade crossing with flashing red lights and gates		
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*	Electric bells do not work well in -30 degree temperature which is quite common in Edmonton, Alberta, Canada		
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*	Electromechanical bells with flashing red lights and gate crossings provide to highest safety for ped. Traffics and LRT system.		
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	Yes, at certain segments of the line, we have the LRT and freight trains sharing the same grade crossing protection but on separate tracks.		
Background				
1)	*Crossings with special or unique operating characteristics*	No		
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	No		
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*	We buy whatever the supplier provide audible devices, namely the electromechanical bells.		
4)	*Determination of audible device noise level (loudness)*	As per AREMA standard, about 80 to 90db		
5)	*Testing noise levels after audible device installation*	Yes		
6)	*Calibration audible device noise levels*	No		
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	No		
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Other, we do not have highway-rail crossings in our system		
9)	*Available inventory of all highway-rail grade crossings*	No		
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	N/A		
11)	*Source motor vehicle/train accident reports and statistics*	We write our own motor vehicle/train accident reports and have our own statistics.		
12)	*Involvement of the disabled community selection of audible devices*	Yes, we have regular meetings with the disabled community to discuss on items that they have concern		
13)	*Contact person (or persons) for the disabled community task force*	Diane Bergeron (780) 496-5822,City of Edmonton, Community Services Department		
14)	*Source(s) for pedestrian/train collision reports and statistics*	We write our own pedestrian/train incident report and have our own statistics.		
15)	*Investigation/consideration of possible application of new technology as follow:*			
	A. Automated train horn at the crossing.	No		
	B. Special pedestrian crossing control devices	Yes		
	C. Audible Devices	Yes		
	D. Z Crossings	Yes		
	E. Pedestrian Automatic Gates	Yes		
16)	*Change in type of audible device used caused by community noise*	Not at present, however, when we extend our line further south, we will run into some residential area, directional electronic bells are in consideration at the moment.		
17)	*Changes to audible devices use resulting from legal challenges*	No		
18)	*Legal challenges resulting from changes in audible device use*	No		

QUESTIONNAIRE

Transportation Research Board

Transit Cooperative Research Program (TCRP)

PROJECT D - 10

Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Calgary Transit		
A. General Characteristics of the LRT System				
1)	*LRT System in use*			
	A. Line	South	Northeast	Northwest
	B. Right of Way Type	Exclusive	Exclusive	Exclusive
	C. Segment	14.3	9.8	9.6
	D. Length			
	E. Year Opened	1981/2001	1985	1987/91/03
2)	*LRVs Type in use*			
	A. Manufacturer/Model/Year			
	B. Articulated	LRV articulated		
	C. Floor	High Floor		
	D. Stations	High Platform		
	E. Audible Warning Device on LRV	LRV Horn, Bell Type		
	F. Audible warning messages			
3)	*Typical train consist length*			
	A. Line	South	Northeast	Northwest
	B. Length	3 Car Trains/ 2 Cars	3 Car Trains/ 2 Cars	3 Car Trains/ 2 Cars
	C. Time of Operation	During Most times/ Late Evening, Weekend, Evening	During Most times/ Late Evening, Weekend, Evening	During Most times/ Late Evening, Weekend, Evening
4)	*Service frequency/headway by line (include time of operation if appropriate):*			
	A. Line	South	Northeast	Northwest
	B. Frequency/Headway	Peak (0600-0900), (1500-1800) Every 5 Minutes/ Off Peak- Every 15 Minutes Downtown 7 Avenue Transit mall- 2 min Downtown 7th Avenue Transit mall 2 min.	Peak (0600-0900), (1500-1800) Every 5 Minutes/ Off Peak- Every 15 Minutes Downtown 7 Avenue Transit mall- 2 min	Peak (0600-0900), (1500-1800) Every 5 Minutes/ Off Peak- Every 15 Minutes Downtown 7 Avenue Transit mall- 2 min Downtown 7th Avenue Transit mall 2 min.
	C. Time of Operation			
5)	*Operating speeds, policies, and instructions*	Use bell/horn as needed- no special instructions at intersections		
6)	*Types of wayside audible devices*			
	A. Mechanical bells	Gated, Ped. Only		
	B. Electronic bells	Gated, Ped. Only		
	C. Wayside horn			
	D. Special wayside ped. audible device			
	E. Other (describe)			
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*			
	A. Active only on trainap proach, until gatesare in horizontal position			
	B. Active during approach and entire time crossing is occupied.	Gated, Ped. Only		
	C. Other (describe)			
8)	*Operating speeds, polices, and instructions <u>for night</u> operations*	No special instructions		
9)	*LRT lines intersect with designated bicycling/walking facilities*	Yes, one Ped. Pathway through college SAIT campus ground crosses LRT line-with protection signalized.		
B. Highway-Light Rail Grade Crossing Operations				
<u>General</u>				
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	Yes,after complaints about noise from residents,.some bells have been muted, and made directional. Some bells have also been filled with soft clappers.		
2)	*Describe rational and noted effects of the changes made and.or planned*	Noise complaints from residents. Residents satisfied with resulting noise levels after change.		
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*			
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*			
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	Yes, shared R-O-W only, we do not share tracks at intersections, Standard Crossing Protection equipment at crossing and is "called on" by either LRT or freight train movement.		
<u>Background</u>				
1)	*Crossings with special or unique operating characteristics*	No		
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	Yes, Calgart Transit has a Crossing Protection Committee to review safety issues and improvement.		
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*	Improvement specifications left to supplier. Only modifications made by Calgary Transit and muting of bells and creating directional bells.		
4)	*Determination of audible device noise level (loudness)*	As supplied by supplier provided they comply to AREMA/AAR standard.		
5)	*Testing noise levels after audible device installation*	Yes, use of DB meter after installation. Monthly inspections done by ear. Will measure noise level ir special circumstances or if bell is suspected.		
6)	*Calibration audible device noise levels*	No, only when muted to satisfy residential concerns.		
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control*	No		
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Others LRT Crossing Protection Committee evaluates safety at crossing.		
9)	*Available inventory of all highway-rail grade crossings*	Yes .		
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	No, don't know, list kept is an "in house" list.		
11)	*Source motor vehicle/train accident reports and statistics*	In house records?		
12)	*Involvement of the disabled community selection of audible devices*	No		
13)	*Contact person (or persons) for the disabled community task force*			
14)	*Source(s) for pedestrian/train collision reports and statistics*	In house records		
15)	*Investigation/consideration of possible application of new technology as follow:*			
	A. Automated train horn at the crossing.			
	B. Special pedestrian crossing control devices			
	C. Audible Devices			
	D. Z Crossings			
	E. Pedestrian Automatic Gates			
16)	*Change in type of audible device used caused by community noise*	Yes, residents adjacent to Ped. Crossing have complaine of noise levels. These complaints were solved by muting bells and creating directional bell ringing.		
17)	*Changes to audible devices use resulting from legal challenges*	No		
18)	*Legal challenges resulting from changes in audible device use*	No		

QUESTIONNAIRE

Transportation Research Board
Transit Cooperative Research Program (TCRP)
PROJECT D - 10
Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Los Angeles County MTA		
A. General Characteristics of the LRT System				
1)	*LRT System in use*			
	A. Line	Line_Metro Blue_	Line_Metro Green__	Line_Metro Gold_
	B. Right of Way Type	Exclusive, Semi-Exclusive/Fenced, Street Median/Curb(No fence), Side Alignment/Curb (No fence)	Exclusive	Exclusive, Semi-Exclusive/Fenced, Street Median/Curb(No fence)
	C. Segment	21.35	19.7	13.8
	D. Length			
	E. Year Opened	1990	1995	2003
2)	*LRVs Type in use*			
	A. Manufacturer/Model/Year			
	B. Articulated	LRV Articulated		
	C. Floor	High Floor		
	D. Stations	High Platform		
	E. Audible Warning Device on LRV	LRV Horn, Bell Type		
	F. Audible warning messages			
3)	*Typical train consist length*			
	A. Line	Blue_	Green_	Gold_
	B. Length	Rush Hour- 2 & 3 car trains, Off peak- 3 car trains, Evening-2 car trains	Rush hour- 2 car trains, off peak- 2 car trains, Evening-1 car trains	Rush hour- 2 car trains, off peak- 2 car trains, Evening-1 car trains
	C. Time of Operation	During Most times/ Late Evening, Weekend, Evening	During Most times/ Late Evening, Weekend, Evening	During Most times/ Late Evening, Weekend, Evening
4)	*Service frequency/headway by line (include time of operation if appropriate):*			
	A. Line	Blue_	Green_	Gold_
	B. Frequency/Headway	07:00-09:00 & 15:30- 19:30 Peak Service @ 5-6 min. headways, @ 10-12 south of Willow 09:00-15:30 & 19:30-20:00 Off Peak Service @ 10 min. headways 04:30- 07:00 & 20:00-01:40 Evening Service @ 20 min.headways Weekend service: A.M., @ 15 min., mid-day & P.M. @ 12 min., night @ 20 min.	07:00-09:00 & 15:30- 19:30 Peak Service @ 7-8 min. headways, 09:00-15:30 & 19:30-20:00 Off Peak Service @ 15 min. headways 03:40- 07:00 & 20:00-02:10Evening Service @ 20 min.headways Weekend service: A.M.,mid-day & P.M. @ 15 min., night @ 20 min.	07:00-09:00 & 15:30- 19:30 Peak Service @ 10 min. headways, 09:00-15:30 & 19:30-20:00 Off Peak Service @ 12 min. headways 03:50- 07:00 & 20:00-02:10Evening Service @ 20 min.headways Weekend service: A.M., mid-day & P.M. @ 15 min., night @ 20 min.
	C. Time of Operation			
5)	*Operating speeds, policies, and instructions*	This Line semi exclusive ROW operates at 55 MPH in a shared corridor with Union Pacific (UP) and has standard highway rail grade crossing warning gatees, lights, and bells; as such the trains us the electronic horn set at 85 db and sound the conventional 2 long, short, long signal. In the Street Running ROW the Metro Blue Line operates at 35 MPH with an Electronic Bell set at 75 db and sounds on approach until the crossing is occupied	This line has no At Grade Highway Rail Grade Crossings and travels up to 65 MPH.	This line semi exclusive ROW has all Highway Rail Grade Crossing supported by 4 quad Crossing Warning Devices (gates, lights, & bells) and operates up to 55 MPH; as such the Trains use an Electronic "Quaker" set at 75 db and sound two long signals on approach. In the Street Running ROW this line operates at 20MPH with the Electronic "Quaker" set at 75 db and sounds on approach until the crossing is occupied.
6)	*Types of wayside audible devices*			
	A. Mechanical bells	Gated		
	B. Electronic bells	Gated, Ped only		
	C. Wayside horn			
	D. Special wayside ped. audible device			
	E. Other (describe)			
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*			
	A. Active only on trainap proach, until gatesare in horizontal position.			Cerain Crossings only
	B. Active during approach and entire time crossing is occupied.	Gated, Ped only	Gated, Ped only	Gated, Ped only
	C. Other (describe)	Station entrances on this line have been constructed with ped. Swing Gates as well as the tradtional Flashing Lights and Bells. (Installed "second train coming" sign at the Verno Ave. Station Entrance to enhance the ped. Warning on this line) Installed "No left Turn" sings that acitvat when a train approaches at driveways and "Train" signs above left turn pockets on the streets in Street Running Territory in LA. Installed "Train Coming" signs that activate when a train apporaches Marmion Way and the street running portion of LA	Installed "No left Turn" sings that acitvat when a train approaches at driveways and "Train" signs above left turn pockets on the streets in Street Running Territory i LA. Installed "Train Coming" signs that activate when a train apporaches Marmion Way and the street running portion of LA	Installed "No left Turn" sings that acitvat when a trai approaches at driveways and "Train" signs above left turn pockets on the streets in Street Running Territory in LA. Installed "Train Coming" signs that activate when a train apporaches Marmion Way and the street running portion of LA
8)	*Operating speeds, polices, and instructions <u>for night</u> operations*	Train operations is same day or night and the trains have all been configured with the FRA traingle of light (two headlights "ditch lights" that flash alternateively and have added a Cyclops light on the roof of the LRT's to indicate the triangle of light similar to the FRA		
9)	*LRT lines intersect with designated bicycling/walking facilities*	No		
B. Highway-Light Rail Grade Crossing Operations				
<u>General</u>				
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	Yes, on Metro GOLD Line, Installed a 75 db "quaker" horn, turn off bells after gates lower, changed pattern of sounding warning, and plan to consider reducing warning bells to approximately 785 db		
2)	*Describe rational and noted effects of the changes made and.or planned*	Mechanical Bells--non-adjustable		Electronic Bells--can be adjested to mitigat noise fo residents
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*	N/A		
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*	Wayside horn demo conducted on Metro Blue Line--results were not favorable-problem of 2nd train approaching crossing at same time (simultaneous), and increased n for residents at the crossing.		
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	Yes, the Metro Blue Line shares grade crossings with the adjacent Union Pacific Railroad and when paralleling a UP Train or overtaing a UP Train at a highway rail grade crossing, the LRT Trains slow until they (UP) actually occupy the crossing due to the possible anxious person or motorist not waiting for the gates and bells to de-activate.		
<u>Background</u>				
1)	*Crossings with special or unique operating characteristics*	Yes, we have some Highway Rail Grade Crossings adjacent to senior nursing homes at those locations, we have silenced the bells once the gates have reached the horizontal position. Also, a reduction pattern is usedc at these crossings.		
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	No		
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*	Have not relied on supplier since the start of LRT in Los Angeles as we approached various industries and suppliers to try and service our special needs with horn modifications, etc.		
4)	*Determination of audible device noise level (loudness)*	Have to comply with the minimum requirements established by the State Oversight--CPUC.		
5)	*Testing noise levels after audible device installation*	Yes, we use calibrated equipment and measured distances to ensure that the audible devices both on the trains at the yards and at wayside locations where the crossing bells have been lowered comply with state requirements.		
6)	*Calibration audible device noise levels*	Yes, the validation of the audible warning devices on the train are checked daily to ensure they work and the calibrated evaluation is done as part of the routine maintenance associated with the manufacturer's recommended practices.		
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	No		
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Diagnostic team study as defined in the Rail-Highway Grade Crossing Handbook		
9)	*Available inventory of all highway-rail grade crossings*	Yes,		
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	No		
11)	*Source motor vehicle/train accident reports and statistics*	We monitor and maintain our own records for accident based on initial reports generated by the Rail Operations Control Center. Thus we have a comprehensive list of accident statistics for all crossings associated with the Light Rail Lines.		
12)	*Involvement of the disabled community selection of audible devices*	No		
13)	*Contact person (or persons) for the disabled community task force*			
14)	*Source(s) for pedestrian/train collision reports and statistics*	Same as #11		
15)	*Investigation/consideration of possible application of new technology as follow:*			
	A. Automated train horn at the crossing.	Yes		
	B. Special pedestrian crossing control devices	Yes		
	C. Audible Devices	Yes		
	D. Z Crossings	Yes		
	E. Pedestrian Automatic Gates	Yes		
16)	*Change in type of audible device used caused by community noise*	Yes, see details listed previously		
17)	*Changes to audible devices use resulting from legal challenges*	No		
18)	*Legal challenges resulting from changes in audible device use*	No		

QUESTIONNAIRE

Transportation Research Board

Transit Cooperative Research Program (TCRP)

PROJECT D - 10

Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Maryland Mass Transit Administration	
1)	*LRT System in use*		
	A. Line	CLRL, I	CLRL, II
	B. Right of Way Type	Non-exclusive/ mixed traffic	Non-exclusive/ mixed traffic
	C. Segment		
	D. Length		
	D. Year Opened	1992	1997
2)	*LRVs Type in use*		
	A. Manufacturer/Model/Year	ADRANZ 1	
	B. Articulated	Yes	
	C. Floor	High Floor	
	D. Stations	How platform with high block	
	E. Audible Warning Device on LRV	Bell Type	
	F. Audible warning messages		
3)	*Typical train consist length*		
	A. Line	CLRL, I	CLRL, II
	B. Length	2 Car trains- normal service, 3 Car trains- stadium events	
	C. Time of Operation		
4)	*Service frequency/headway by line (include time of operation if appropriate):*		
	A. Line		
	B. Frequency/Headway	20 minutes Peak (with overlap) 30 minutes off peak.	
	C. Time of Operation		
5)	*Operating speeds, policies, and instructions*	Being Re-written for ATP/Double Track	
6)	*Types of wayside audible devices*		
	A. Mechanical bells	Gated	
	B. Electronic bells		
	C. Wayside horn		
	D. Special wayside ped. audible device		
	E. Other (describe)		
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*		
	A. Active only on trainap proach, until gatesare in horizontal position.	Gated	
	B. Active during approach and entire time crossing is occupied.		
	C. Other (describe)		
8)	*Operating speeds, polices, and instructions for night operations*	Yes, Lake Roland	
9)	*LRT lines intersect with designated bicycling/walking facilities*		
B. Highway-Light Rail Grade Crossing Operations			
General			
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	No	
2)	*Describe rational and noted effects of the changes made and.or planned*		
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*		
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*	Only in second train coming Project	
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	No	
Background			
1)	*Crossings with special or unique operating characteristics*	No	
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	No	
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*	For recommendations	
4)	*Determination of audible device noise level (loudness)*	MUTCD	
5)	*Testing noise levels after audible device installation*	No	
6)	*Calibration audible device noise levels*	No	
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	No	
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Engineering Study as defined in the MUTCD	
9)	*Available inventory of all highway-rail grade crossings*	Yes	
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	Yes	
11)	*Source motor vehicle/train accident reports and statistics*	Safety and Risk Management Department	
12)	*Involvement of the disabled community selection of audible devices*	No	
13)	*Contact person (or persons) for the disabled community task force*	N.A.	
14)	*Source(s) for pedestrian/train collision reports and statistics*	Safety and Risk Management Department	
15)	*Investigation/consideration of possible application of new technology as follow:*		
	A. Automated train horn at the crossing.	Yes	
	B. Special pedestrian crossing control devices		
	C. Audible Devices		
	D. Z Crossings		
	E. Pedestrian Automatic Gates		
16)	*Change in type of audible device used caused by community noise*	Yes, vehicle horn for night time operation	
17)	*Changes to audible devices use resulting from legal challenges*	No	
18)	*Legal challenges resulting from changes in audible device use*	No	

QUESTIONNAIRE
Transportation Research Board
Transit Cooperative Research Program (TCRP)
PROJECT D - 10
Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Sacramento Regional Transit District	
1)	*LRT System in use*		
	A. Line	Main Line	South Line
	B. Right of Way Type	Exclusive, Semi-exclusive, Side alignment/ Transit Line, Non-exclusive/ Mixed Traffic, Non-exclusive/ ped. mall	Semi-exclusive/ fenced
	C. Segment	Watt/Mather	Meadowview
	D. Length	20.7	6.3
	D. Year Opened	1987	2003
2)	*LRVs Type in use*		
	A. Manufacturer/Model/Year		
	B. Articulated	Yes	
	C. Floor	High Floor	
	D. Stations	Low Platform	
	E. Audible Warning Device on LRV	LRV Horn, Bell Type	
	F. Audible warning messages	"This train is out of service","The train is departing, please stand clear."	
3)	*Typical train consist length*		
	A. Line	Main Line	South Line
	B. Length	4 car trains during peak (M-F 6 am-9 am & 3:30 pm- 6 pm 2 car trains during off peak hours, single car trains late evening (after 6 pm) and Sundays	
	C. Time of Operation		
4)	*Service frequency/headway by line (include time of operation if appropriate):*		
	A. Line	Main Line	South Line
	B. Frequency/Headway	8 trains running at 15 min. intervals during day,4 trains running at 30 min intervals during evening and early weekend	4 trains running at 15 min intervals during the day, 4 trains running at 30 min intervals during evening and early weekend
	C. Time of Operation		
5)	*Operating speeds, policies, and instructions*	Yes, copies are available for operators	
6)	*Types of wayside audible devices*		
	A. Mechanical bells	Gated,	
	B. Electronic bells	Gated, Ped only	
	C. Wayside horn		
	D. Special wayside ped. audible device		
	E. Other (describe)	TS controlled	
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*		
	A. Active only on trainap proach, until gatesare in horizontal position.	Gated	
	B. Active during approach and entire time crossing is occupied.	Ped only	
	C. Other (describe)		
8)	*Operating speeds, polices, and instructions for night operations*	RR headlights on at all times, different speed limits at different segments of the track	
9)	*LRT lines intersect with designated bicycling/walking facilities*	Yes, train crosses over American River bike trail on bridge	
B. Highway-Light Rail Grade Crossing Operations			
General			
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	Yes, there are currently some changes in the works	
2)	*Describe rational and noted effects of the changes made and.or planned*	N/A	
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*	N/A	
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*	N/A	
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	Yes, the South line runs adjacent to the UP tracks	
Background			
1)	*Crossings with special or unique operating characteristics*	No	
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	No	
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*	N/A	
4)	*Determination of audible device noise level (loudness)*	Try to keep noise level below 80 db and they are dtermined by Civil and System Engineering	
5)	*Testing noise levels after audible device installation*	Yes, Construction and RT personnel	
6)	*Calibration audible device noise levels*	Yes, every year	
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	No	
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Engineering Study as defined in the MUTCD	
9)	*Available inventory of all highway-rail grade crossings*	Yes	
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	Yes	
11)	*Source motor vehicle/train accident reports and statistics*	Safety department and NSTB	
12)	*Involvement of the disabled community selection of audible devices*	Yes, RT has a group dedicated to this, Accessible Services	
13)	*Contact person (or persons) for the disabled community task force*	Laura Forester (916) 321-3871	
14)	*Source(s) for pedestrian/train collision reports and statistics*	Safety department	
15)	*Investigation/consideration of possible application of new technology as follow:*		
	A. Automated train horn at the crossing.		
	B. Special pedestrian crossing control devices		
	C. Audible Devices		
	D. Z Crossings		
	E. Pedestrian Automatic Gates		
16)	*Change in type of audible device used caused by community noise*	Yes, try to keep noise level below 80 db	
17)	*Changes to audible devices use resulting from legal challenges*	No	
18)	*Legal challenges resulting from changes in audible device use*	No	

QUESTIONNAIRE
Transportation Research Board
Transit Cooperative Research Program (TCRP)
PROJECT D - 10
Audible Signals for pedestrian Safety in Light Rail Transit Environments

		San Diego Trolley, Inc.	
A. General Characteristics of the LRT System			
1)	*LRT System in use*		
	A. Line	Estimate Blue	Estimate Orange
	B. Right of Way Type	Exclusive, Street Median/ Curb (no fence)	Exclusive, Street Median/ Curb (no fence)
	C. Segment		
	D. Length	16	22
	E. Year Opened	1981	1995
2)	*LRVs Type in use*		
	A. Manufacturer/Model/Year	Siemens Dunwag 1980-1988	
	B. Articulated	No	
	C. Floor	High Floor	
	D. Stations	Low Platform	
	E. Audible Warning Device on LRV	LRV Horn	
	F. Audible warning messages		
3)	*Typical train consist length*		
	A. Line	Blue	Orange
	B. Length	3 car trains, 15 min/7.5 peak periods, 21 hour operations	2 cars (3 rush hour), 15 min all day, 21 hour operations
	C. Time of Operation	15 to 7.5 during rush (4:30 pm- 1:30 am)	15 all day (4:30 am-1 am)
4)	*Service frequency/headway by line (include time of operation if appropriate):*		
	A. Line	Blue	Orange
	B. Frequency/Headway	15 to 7.5 during rush (4:30 pm- 1:30 am)	15 all day (4:30 am-1 am)
	C. Time of Operation		
5)	*Operating speeds, policies, and instructions*	Max speed 55 MPH, city streets 25-30 MPH -regular horn- & clacker type horn (no bell) rule book available.	
6)	*Types of wayside audible devices*		
	A. Mechanical bells	Grated, Ped only	
	B. Electronic bells		
	C. Wayside horn	TS Controlled	
	D. Special wayside ped. audible device		
	E. Other (describe)		
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*		
	A. Active only on trainap proach, until gatesare in horizontal position.		
	B. Active during approach and entire time crossing is occupied.	Grated	
	C. Other (describe)	(Horn, clacker) TS Controlled, Ped only	
8)	*Operating speeds, polices, and instructions <u>for night</u> operations*	Same as day	
9)	*LRT lines intersect with designated bicycling/walking facilities*	No	
B. Highway-Light Rail Grade Crossing Operations			
<u>General</u>			
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	No	
2)	*Describe rational and noted effects of the changes made and.or planned*		
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*	None, we have been very sucessful with the warning equipment we have currently	
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*	N/A	
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	Yes, San Diego Imperial Valley Railroad--Same as LRT--speeds lower however. (Freights use standard heavy rail horns, far above levels of LRT operations.)	
<u>Background</u>			
1)	*Crossings with special or unique operating characteristics*	No	
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	No	
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*	None at this time	
4)	*Determination of audible device noise level (loudness)*	California Public Utilities (CPVE) regulates	
5)	*Testing noise levels after audible device installation*	No	
6)	*Calibration audible device noise levels*	No	
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	No	
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Engineering study as defined in the MUTCD	
9)	*Available inventory of all highway-rail grade crossings*	Yes, San Diego Imperial Valley Railroad--Same as LRT--speeds lower however. (Freights use standard heavy rail horns, far above levels of LRT operations.)	
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	Yes	
11)	*Source motor vehicle/train accident reports and statistics*	Maintained in our safety department from 1981--Listing of all crossings, types of accidents, etc.	
12)	*Involvement of the disabled community selection of audible devices*	No	
13)	*Contact person (or persons) for the disabled community task force*	No	
14)	*Source(s) for pedestrian/train collision reports and statistics*	Safety Department	
15)	*Investigation/consideration of possible application of new technology as follow:*		
	A. Automated train horn at the crossing.		
	B. Special pedestrian crossing control devices	Yes	
	C. Audible Devices		
	D. Z Crossings	80	
	E. Pedestrian Automatic Gates		
16)	*Change in type of audible device used caused by community noise*	Yes, some communities we use the quieter clacker type horn, The louder horn is used only when a potential sutation could occur.	
17)	*Changes to audible devices use resulting from legal challenges*	No	
18)	*Legal challenges resulting from changes in audible device use*	No	

QUESTIONNAIRE
Transportation Research Board
Transit Cooperative Research Program (TCRP)
PROJECT D - 10
Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Santa Clara Valley Transportation Authority (VTA)		
A. General Characteristics of the LRT System				
1)	*LRT System in use*			
	A. Line	Guadalupe	Tasman	Almaden
	B. Right of Way Type	Exclusive, Street Median/ Curb (no fence), Non-exclusive/ mixed traffic, non-exclusive/ ped. Mall	Exclusive, Semi-exclusive/ fenced Street Median/ Curb (no fence)	Semi-exclusive
	C. Segment	All	All	All
	D. Length	19.8	15.94	1.18
	E. Year Opened	1987-1991	1999-2004	1993
2)	*LRVs Type in use*			
	A. Manufacturer/Model/Year	Kinkisharyo		
	B. Articulated	Yes		
	C. Floor	Low Floor		
	D. Stations	How platform		
	E. Audible Warning Device on LRV	LRV Horn		
	F. Audible warning messages	Please stand clear of track, train out of service		
3)	*Typical train consist length*			
	A. Line	Guadalupe	Tasman	Almaden
	B. Length	2 to 3 cars rush and mid-day, 1 car night and weekends	1 car	1 car
	C. Time of Operation			
4)	*Service frequency/headway by line (include time of operation if appropriate):*			
	A. Line	Guadalupe	Tasman	Almaden
	B. Frequency/Headway	15" 4:15 am- 8 pm, 30" to 11:30 pm, 60" to 2 am	15" 6 am - 9:30 am and 2:30 pm to 7 pm, 30" sll others to 11 pm, 60" to 12 am	15" all day (5:30 am-11 pm)
	C. Time of Operation			
5)	*Operating speeds, policies, and instructions*	Ped mall speed = 10 MPH, Median operation = 30 or 35 MPH, Exclusive = 55 MPH maximum		
6)	*Types of wayside audible devices*			
	A. Mechanical bells	Gated, Ped only		
	B. Electronic bells	Gated, Ped only		
	C. Wayside horn			
	D. Special wayside ped. audible device			
	E. Other (describe)	None, none in mal		
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*			
	A. Active only on trainap proach, until gatesare in horizontal position.	80% Gated, Ped only		
	B. Active during approach and entire time crossing is occupied.	20% Gated (none in mall)		
	C. Other (describe)			
8)	*Operating speeds, polices, and instructions <u>for night</u> operations*	High beam and railroad light not to be used where it will blind motorists. No "night only" speed restrictions. We encourage "reasonable" use of audible devices.		
9)	*LRT lines intersect with designated bicycling/walking facilities*	Yes, no special measure at these facilities		
B. Highway-Light Rail Grade Crossing Operations				
<u>General</u>				
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	Yes, LRV has electronic horn and bell. Plus an electromechanical bell similar to P.C.C streetcar. Elec tornic sounds are source of complaints, new sounds being programmed at same db level, but less obnoxious. Crossing bells now silent when gates are down. P.U.C has permitted use to enact "low noise zones" in some neighborhoods.		
2)	*Describe rational and noted effects of the changes made and.or planned*	Air horn replaced by electronic horns in 1991. Air horn sounded too much like automotive horn. This was one of several steps taken to reduce accidents.		
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*	Inour environment we have few exclusively ped only warnings.		
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*	Low noise zones approved by C.P.U.C after six-month demonstration at one critical crossing.		
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	No, (line opening late 2005= yes)		
<u>Background</u>				
1)	*Crossings with special or unique operating characteristics*	Yes, P.U.C. approved "low noise zone" at Whisman Rd.		
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	Yes		
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*	nil		
4)	*Determination of audible device noise level (loudness)*	It is stated in C.P.U.C General Order 143-B		
5)	*Testing noise levels after audible device installation*	Yes		
6)	*Calibration audible device noise levels*	Yes, at vehicle delivery and when changes made to audible warnings (rare)		
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	Yes, see C.P.U.C General Orders 72, 75, and 88		
8)	*Procedures use in the evaluation of safety at highway-rail crossings*			
9)	*Available inventory of all highway-rail grade crossings*	Yes		
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	California P.U.C. list		
11)	*Source motor vehicle/train accident reports and statistics*	Our records based on Operator and Supervisor accident reports, Safety Dept. analysis, etc.		
12)	*Involvement of the disabled community selection of audible devices*	No		
13)	*Contact person (or persons) for the disabled community task force*	George Tacke: (408) 321-7040; george.tacke@vta.org		
14)	*Source(s) for pedestrian/train collision reports and statistics*	Same as # 11 above		
15)	*Investigation/consideration of possible application of new technology as follow:*			
	A. Automated train horn at the crossing.	Yes		
	B. Special pedestrian crossing control devices	Yes		
	C. Audible Devices	Yes		
	D. Z Crossings	Yes		
	E. Pedestrian Automatic Gates			
16)	*Change in type of audible device used caused by community noise*	Yes		
17)	*Changes to audible devices use resulting from legal challenges*	No		
18)	*Legal challenges resulting from changes in audible device use*	No		

QUESTIONNAIRE
Transportation Research Board
Transit Cooperative Research Program (TCRP)
PROJECT D - 10
Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Denver Regional Transit District		
A. General Characteristics of the LRT System				
1)	*LRT System in use*			
	A. Line	Central Corridor	Southwest	Central Platte
	B. Right of Way Type	Exclusive, Side alignment/Curb (no fence)	Exclusive	Exclusive, Side alignment/Curb (no fence)
	C. Segment			
	D. Length	5.3	8.7	1.8
	E. Year Opened	1994	2000	2002
2)	*LRVs Type in use*			
	A. Manufacturer/Model/Year	Siemens Duewag/SD100		
	B. Articulated	Yes		
	C. Floor	High Floor		
	D. Stations	Low platform with high block		
	E. Audible Warning Device on LRV	LRV Horn, Bell Type		
	F. Audible warning messages	Operator may make external and internal PA announcements. Internal passages and also automated		
3)	*Typical train consist length*			
	A. Line	Central Corridor	Southwest	Central Platte
	B. Length	Typical consist is 2 to 3 car with 3 car common during peak periods and for special events.	Typical consist is 2 to 3 car with 3 car common during peak periods and for special events.	Typical consist is 2 to 3 car with 3 car common during peak periods and for special events.
	C. Time of Operation			
4)	*Service frequency/headway by line (include time of operation if appropriate):*			
	A. Line	Central Corridor	Southwest	Central Platte
	B. Frequency/Headway	5 minutes to 30 minutes (peak to non-peak)		
	C. Time of Operation			
5)	*Operating speeds, policies, and instructions*	Gated crossings- speed varies from 55 MPH to 25 MPH depending upon type of row, exclusive vs. semi-exclusive. Operators use horns. Traffic controlled by traffic signal- approximate speed of 25 MPH may use horn and/or bells depending on circumstances at time of crossing		
6)	*Types of wayside audible devices*			
	A. Mechanical bells	With traffic, Gated		
	B. Electronic bells			
	C. Wayside horn			
	D. Special wayside ped. audible device			
	E. Other (describe)			
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*			
	A. Active only on trainap proach, until gatesare in horizontal position.			
	B. Active during approach and entire time crossing is occupied.	Gated		
	C. Other (describe)			
8)	*Operating speeds, polices, and instructions for night operations*	Night time operating speeds same as daytime. In street running sections, headlights are used in a wig wag fashion day and night. No streets. Audible services same as daytime		
9)	*LRT lines intersect with designated bicycling/walking facilities*	No		
B. Highway-Light Rail Grade Crossing Operations				
General				
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	No		
2)	*Describe rational and noted effects of the changes made and.or planned*			
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*			
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*			
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	Yes, transit maintains transit side of crossing, RR maintains railroad side of crossing. Transit may provide quick repair (broken gate) to railroad side. No special devices to distinguish between LRV and RR. Operating agreement is maintained. LRV follows transit rules--2 long, short, long. RR follows railroa rules		
Background				
1)	*Crossings with special or unique operating characteristics*	No		
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	No, however, grade crossings are addressed within light rail design criteria		
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*			
4)	*Determination of audible device noise level (loudness)*	FRA & AREMA guidelines.		
5)	*Testing noise levels after audible device installation*	Yes, during acceptance testing. Regular inspections verify that mechanical bells are functioning.		
6)	*Calibration audible device noise levels*	No		
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	No		
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Engineering study as defined in the MUTCD, diagnostic team study as defined in the Rail-Highway Grad Crossing Handbook		
9)	*Available inventory of all highway-rail grade crossings*	Yes		
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*			
11)	*Source motor vehicle/train accident reports and statistics*	NTSB, USDOT, FTA		
12)	*Involvement of the disabled community selection of audible devices*	No, not currently, but may be in future		
13)	*Contact person (or persons) for the disabled community task force*			
14)	*Source(s) for pedestrian/train collision reports and statistics*	NTSB, USDOT, FTA		
15)	*Investigation/consideration of possible application of new technology as follow:*			
	A. Automated train horn at the crossing.	All of these may be investigated for future corridor.		
	B. Special pedestrian crossing control devices			
	C. Audible Devices			
	D. Z Crossings			
	E. Pedestrian Automatic Gates			
16)	*Change in type of audible device used caused by community noise*	No, not currently, but may be in future		
17)	*Changes to audible devices use resulting from legal challenges*	No		
18)	*Legal challenges resulting from changes in audible device use*	No		

QUESTIONNAIRE

Transportation Research Board

Transit Cooperative Research Program (TCRP)

PROJECT D - 10

Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Utah Transit Authority		
A. General Characteristics of the LRT System				
1)	*LRT System in use*			
	A. Line	North/ South	University	Medical
	B. Right of Way Type	Exclusive, Street Median/ Transit Line	Side Alignment/Curb (No fence)	Street Median/Curb (No fence)
	C. Segment			
	D. Length	14	2	1.5 (fence @ 1 Station
	E. Year Opened	1999	2001	2003
2)	*LRVs Type in use*			
	A. Manufacturer/Model/Year	Siemens, Model 100/1998-1999. Siemens model 160. 2001-2002		
	B. Articulated	Yes		
	C. Floor	High Floor		
	D. Stations	Low platform with high blocks		
	E. Audible Warning Device on LRV	LRV Horn, Bell Type		
	F. Audible warning messages	There are audible warning messages on the platforms such as train approaching, stand back		
3)	*Typical train consist length*			
	A. Line	North/ South	University	Medical
	B. Length	Peak 3-4 car trains, non peak 2 car trains, Friday Saturday-single car trains after 23:00	Peak AM, PM-one special trip directly to & from Medical Center to far south Station-normally passengers have to transfer to go directly south. 5- 2 car trains, non peak 4-1 car trains, 1-2 car train	Peak AM, PM-one special trip directly to & from Medical Center to far south Station-normally passengers have to transfer to go directly south. 5- 2 car trains, non peak 4-1 car trains, 1-2 car train
	C. Time of Operation			
4)	*Service frequency/headway by line (include time of operation if appropriate):*			
	A. Line			
	B. Frequency/Headway	15 minutes- Mon-Thurs, Fri-Sat after 23:17- 30 minute headways until 1:02	15 minutes- Mon-Thurs, Fri-Sat after22:41-30 minute headways until 1:00	15 minutes- Mon-Thurs, Fri-Sat after22:41-30 minute headways until 1:00
	C. Time of Operation			
5)	*Operating speeds, policies, and instructions*	Will be sending copy of rules pertaining to the above. 4.24, 4.27, 4.29, 11.15 operating speed in ABS territory 55 MPH unless otherwise posted. Street running 25-40 MPH depending on location		
6)	*Types of wayside audible devices*			
	A. Mechanical bells	With traffic, Gated		
	B. Electronic bells			
	C. Wayside horn			
	D. Special wayside ped. audible device	With Traffic, Gated- TS Controlled		
	E. Other (describe)	The only audible ped device which is used is for people on the platform. This can be heard while entering platforms (Ex- "Please stand behind the yellow line." At all stations in ABS territory at areas where pedestrians cross track to get to the platform there is a yellow information sight to watch for trains.		
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*			
	A. Active only on trainap proach, until gatesare in horizontal position.	With traffic, Gated		
	B. Active during approach and entire time crossing is occupied.			
	C. Other (describe)			
8)	*Operating speeds, polices, and instructions <u>for night</u> operations*	Same as day		
9)	*LRT lines intersect with designated bicycling/walking facilities*	No		
B. Highway-Light Rail Grade Crossing Operations				
<u>General</u>				
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	Yes, once gates are locked in a horzontal position mechanical bells on gate mechanism stop.		
2)	*Describe rational and noted effects of the changes made and.or planned*	Complaints about noise from the community		
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*	I think that no matter what you do, a small group of people will always disobey. However, it would be nice to have some sort of audible further away so people don't run in front of the train…. (continued)		
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*	I am not aware of any in our area		
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	Yes, Freight has a window of operation from midnight to 5:00 AM. They do not run Friday & Saturday nights, See SOP on Freight operations		
<u>Background</u>				
1)	*Crossings with special or unique operating characteristics*	Yes, audible devices sound only when gate is going down once it is locked in horizontal position, the bells stop		
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	No		
3)	*The audible device supplier involvement development of plans and specifications for*	Supplier resposibility		
4)	*Determination of audible device noise level (loudness)*	As loud as the neighbors will allow		
5)	*Testing noise levels after audible device installation*	No		
6)	*Calibration audible device noise levels*	No		
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	No		
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Engineering study as defined in the MUTCD, diagnostic team study as defined in the Rail-Highway Grade Crossing Handbook		
9)	*Available inventory of all highway-rail grade crossings*	Yes		
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	Yes		
11)	*Source motor vehicle/train accident reports and statistics*	We have a safety administrator who compiles these and we keep our report (a copy of) in our files & safety administrator- Ed Buchanon		
12)	*Involvement of the disabled community selection of audible devices*	No		
13)	*Contact person (or persons) for the disabled community task force*	262-5626, Sherry Repsher- ex. 3436, she is in our Civil Rights department and works closely with the disabled community		
14)	*Source(s) for pedestrian/train collision reports and statistics*	Again that would be our Safety Administrator Ed Buchanon who can be contacted @ 352-6603		
15)	*Investigation/consideration of possible application of new technology as follow:*			
	A. Automated train horn at the crossing.			
	B. Special pedestrian crossing control devices			
	C. Audible Devices			
	D. Z Crossings			
	E. Pedestrian Automatic Gates			
16)	*Change in type of audible device used caused by community noise*	Yes, afain as the gates go down the bells ring, once the gates are locked the lights still flash but the bells stop		
17)	*Changes to audible devices use resulting from legal challenges*	No		
18)	*Legal challenges resulting from changes in audible device use*	No		

QUESTIONNAIRE
Transportation Research Board
Transit Cooperative Research Program (TCRP)
PROJECT D - 10
Audible Signals for pedestrian Safety in Light Rail Transit Environments

		Dart	
A. General Characteristics of the LRT System			
1)	*LRT System in use*		
	A. Line	Red	Blue
	B. Right of Way Type		
	C. Segment	WOC/NC	SOC/NE
	D. Length	~25 Miles	~22 Miles
	E. Year Opened	1997/2002	1996/20002
2)	*LRVs Type in use*		
	A. Manufacturer/Model/Year	Kinkisharyo/Dart/1995-96 & 1999 & 2000	
	B. Articulated	Yes	
	C. Floor	High Floor	
	D. Stations	Low platform with high block	
	E. Audible Warning Device on LRV	LRV Horn, Bell Type Gong, Whistle	
	F. Audible warning messages		
3)	*Typical train consist length*		
	A. Line	Red	Blue
	B. Length	3-car Consist; Operation 4:00am-1:00 am; Peak Time 6am-9am & 3pm-6pm	2-car Consist; Operation 4:00am-1:00 am; Peak Time 6am-9am & 3pm-6pm
	C. Time of Operation		
4)	*Service frequency/headway by line (include time of operation if appropriate):*		
	A. Line	Red	Blue
	B. Frequency/Headway	5 minutes for peak hour/peak direction, 10 minute for remainder of the peak, 20 minutes for base	10 minutes for peak period, 20 minutes for base
	C. Time of Operation		
5)	*Operating speeds, policies, and instructions*		
6)	*Types of wayside audible devices*		
	A. Mechanical bells	With Traffic, Gated, Ped Only (off quadrant)	
	B. Electronic bells		
	C. Wayside horn		
	D. Special wayside ped. audible device		
	E. Other (describe)	12 gongs used	
7)	*Operating characteristics of grade crossing bells and other wayside audible devices*		
	A. Active only on trainap proach, until gatesare in horizontal position.	With Traffic, Gated, Ped Only (off quadrant)	
	B. Active during approach and entire time crossing is occupied.		
	C. Other (describe)		
8)	*Operating speeds, polices, and instructions for night operations*	Same as daytime operation	
9)	*LRT lines intersect with designated bicycling/walking facilities*	Yes, G-1 Fisher Road adjacent to a park. NC-4/5 have adjacent, non-crossing path separated by chain link fence.	
B. Highway-Light Rail Grade Crossing Operations			
General			
1)	*Changes made and/or planned to the grade crossing audible devices since the LRT started operations*	Yes, use of whistle is standard outside CBD except in known high hazard (Lancaster Rd) or high noise (NC-4) areas where horn is used. Change of horn to whistle @ NC-4 Jackson Street @ City request.	
2)	*Describe rational and noted effects of the changes made and.or planned*	Higher hazard (non-gated) on Lanchester Road, High Ambient noise- Hwy 75 adjacency in NC-4, City request	
3)	*Agency inputs in relation to the various types of problems/techniques identified in the Research Purpose of this questionnaire*	Audible devices should be one of many techniques used to warn at crossings. Agencies need flexibility to customize on a case by case basis for mitigation of identified hazards.	
4)	*Results of any demonstration projects related to grade crossing safety improvements involving audible devices*		
5)	*At-grade shared crossings with freight railroad (adjacent to LRT r-o-w to or using the same set of tracks), operation details/traffic control device and variation between LRV and Freight operations.*	Yes, MOU in place for shared corridor operations. LRT maintains devices. No special indication of LRV vs train. (*LRV sound per attached rule. Freight sounds per FRA)*	
Background			
1)	*Crossings with special or unique operating characteristics*	Yes, Median running on Lancaster Road requires use of horn. When safety concerns/ hazardous conditions identified, use horn.	
2)	*Available written policy for the selection of highway-rail grade crossing safety improvements*	Yes, Traffic control signals in street or median running operations only. Warning gates, medians, signage typical for other ROW. Part of agency Design Criteria. Also, follow TX MUTCD.	
3)	*The audible device supplier involvement development of plans and specifications for audible improvements*	Specifications provided to installer/supplier by agency for grade crossing & LRV equipment.	
4)	*Determination of audible device noise level (loudness)*	Specifications & acceptance testing	
5)	*Testing noise levels after audible device installation*	Yes, Was conducted for LRV mounted horn, gong & whistle	
6)	*Calibration audible device noise levels*	No, adjusted initially	
7)	*Guidelines or warrants for the use of special audible pedestrian/bicycle control devices at LRT (or rail) crossings*	Yes, Design Criteria provides provisions for pedestrian warning gates (including bells) for special circumstances (schools, parks, etc) on a case-by-case basis.	
8)	*Procedures use in the evaluation of safety at highway-rail crossings*	Engineering study as defined in the MUTCD, diagnostic team study as defined in the Rail-Highway Grade Crossing Handbook, other (Independent safety review and Agency Systems Safety & Security Certification Plan.	
9)	*Available inventory of all highway-rail grade crossings*	Yes	
10)	*Inventory consistent with the U.S. DOT/AAR national inventory*	No	
11)	*Source motor vehicle/train accident reports and statistics*	In house claims data	
12)	*Involvement of the disabled community selection of audible devices*	No	
13)	*Contact person (or persons) for the disabled community task force*	David Ehrlicher, Marcus Moore	
14)	*Source(s) for pedestrian/train collision reports and statistics*	In house claims data	
15)	*Investigation/consideration of possible application of new technology as follow:*		
	A. Automated train horn at the crossing.	Automated train horn at the crossing (*reviewed technology-local freight has demonstration project w/City of Richardson),* Special pedestrian crossing control devices, Z Crossings, Pedestrian Automatic Gates.	
	B. Special pedestrian crossing control devices		
	C. Audible Devices		
	D. Z Crossings		
	E. Pedestrian Automatic Gates		
16)	*Change in type of audible device used caused by community noise*	No	
17)	*Changes to audible devices use resulting from legal challenges*	No	
18)	*Legal challenges resulting from changes in audible device use*	No	

Appendix C

C-1 Analysis of Pedestrian/LRV Collision Data (Prepared February 2005)
C-2 Review of Accident Data (Prepared September 2004)

APPENDIX C-1

ANALYSIS OF PEDESTRIAN/LRV COLLISION DATA (Prepared February 2005)

INTRODUCTION AND SUMMARY

This report summarizes the results of our analysis of pedestrian/LRT accident data for Task 3: Evaluation of the Effectiveness of Audible Devices Based on Historical Data for TCRP Project D-10: Audible Signals for Pedestrian Safety in LRT Environments. Specifically, the KORVE Team gathered accident data from both transit agencies and the National Transit Database, analyzed this data, and identified trends regarding the number, location, severity, and potential cause of pedestrian/LRT accidents. The preliminary conclusions are:

- The annual number of pedestrian/LRT accidents is very low relative to the number of vehicle/LRT accidents.
- There is substantial variability in accident rates among transit agencies.
- Pedestrian/LRT accidents are much more likely to result in fatalities than vehicle/LRT accidents.
- About half of pedestrian/LRT accidents occur at grade crossings.
- Most of the at grade crossings where collisions occur have active crossing control devices.
- Of the accidents at grade crossings with active crossing control devices, traffic signals and a combination of gates, flashing lights, and bells are the most common active devices.
- Risky or inattentive behavior appears to be a frequent factor in pedestrian/LRT accidents.
- Annual revenue service miles and directional route miles are good predictors of the number of pedestrian/LRT accidents.
- Site- or alignment-specific factors that are unique to a particular transit agency may be significant contributors to pedestrian/LRT accidents.
- It is not possible to directly evaluate the effectiveness of audible warnings in preventing pedestrian/LRT accidents based on the available data.

This report is organized into three sections. The first section summarizes our analysis of the National Transit Database for the years 2002 and 2003. The second section includes detailed analyses of more historical data obtained from three transit agencies: (1) Los Angeles County Metropolitan Transportation Authority; (2) the Santa Clara Valley Transportation Authority; and (3) San Diego Trolley, Inc. The final section includes general conclusions regarding the effectiveness of audible devices based on all the data sources.

NATIONAL TRANSIT DATABASE

Transit agencies receiving Federal Transit Administration (FTA) Urbanized Area Formula Program grants are required to submit data to the FTA regarding transit service and safety. The FTA maintains this data in the National Transit Database (NTD). The Volpe National Transportations System Center (Volpe Center) is responsible for maintaining this database.

The KORVE Team contacted the Volpe Center and requested pedestrian/LRT accident data for the past several years. Due to a significant change in reporting requirements, year 2002 and 2003 data is far more detailed than in previous years. Although this is helpful in evaluating the locations and causes of pedestrian/LRT accidents, it does prevent us from drawing conclusions based on accident trends over longer periods of time. As a result, most of the analysis reported herein is based on data over the past two years.

In order to qualify for reporting, the current standard is that a pedestrian/LRT collision must result in "injuries requiring medical attention away from the scene for one or more persons." Prior to 2002, the threshold for reporting was lower, resulting in a higher number of accidents.

In terms of the pedestrian/LRT accident data collected, some of the key parameters related to the study are[1]:

- Agency. In 2003, there were 22 transit agencies operating LRT systems that reported to the NTD.
- Alignment Type. Possible alignment types include:
  - Exclusive right-of-way (tunnel, elevated structure, at-grade).
  - Semi-exclusive right-of-way.
  - Non-exclusive right-of-way (mixed traffic/LRT, transit mall, and LRT/pedestrian mall).
  - Shared track/corridor (temporal separation, non-temporal separation).
  - Other non-exclusive.
- Collision Location. Possible locations include:
  - Revenue facility (transit center, platform, other revenue facility).
  - Non-revenue facility.
  - Right-of-way/roadway (grade crossing, intersection, other).
  - Private property (shopping center, residential, commercial, nonprofit facility).
  - Other.
- Grade-Crossing Controls. Possible control options include:
  - Active devices (two quadrant gates [median barrier, no median barrier], four quadrant gates, flashing lights, traffic signal, and train approaching sign).
  - Passive devices (stop sign, cross bucks).
  - No control device.
- Event Description. This includes narrative summaries of the event.
- Injury Severity. Generally classified as fatal or non-fatal.
- Action Description. Although not provided for all events, this identifies possible causes for the accident.
- Party Involved. Collisions occurred with trespassers, employees, revenue facility occupants, and others.

Following are findings from the NTD data with respect to the number of accidents, fatality rates, accident locations, types of crossing control, possible accident causes, and potential predictor variables for pedestrian/LRT accidents.

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[1] Data categories are from the NTD *Safety and Security Manual, Major Incident Reporting form (S&S-40)*, 2004.

Number of Accidents

- ***There are relatively few annual pedestrian/LRT accidents***

The total number of pedestrian/LRT incidents by transit agency, including both fatal and non-fatal incidents, in the years 2002 and 2003 are presented in Table 1 below (detailed incident statistics from 2002 and 2003 can be found in Appendix A). There were relatively few pedestrian/LRT incidents over this two year period, particularly with respect to fatalities. Of the 56 total incidents, 55 resulted in 1 injury and 1 incident had 2 reported injuries, for a total of 57 injuries.

Table 1. Summary of Pedestrian/LRT Incidents by Transit Agency (2002 and 2003)

		2002			2003	
Transit Agency	**Fatal**	**Non-Fatal**	**Total**	**Fatal**	**Non-Fatal**	**Total**
City of Detroit DOT	0	0	0	0	0	0
Cleveland-RTA	0	0	0	0	0	0
Dallas Area Rapid Transit	0	1	1	0	0	0
Denver-RTD	0	0	0	0	0	0
Kenosha Transit	0	0	0	0	0	0
King County DOT	0	1	1	0	0	0
Los Angeles County MTA	1	8	9	1	4	5
Maryland MTA	2	1	3	0	0	0
Mass. Bay Transp. Auth.	0	1	1	0	0	0
Memphis Area TA	0	0	0	0	0	0
New Jersey Transit	0	0	0	0	0	0
New Orleans-RTA	0	0	0	0	0	0
Niagara Frontier Transp. Auth.	0	0	0	0	1	1
Pittsburgh Transit	0	0	0	0	0	0
Portland Tri-Met	0	2	2	2	5	7
Sacramento RT	0	0	0	1	0	1
San Diego	0	2	2	2	0	2
San Francisco MUNI	1	4	5	0	8	8
Santa Clara VTA	1	0	1	0	0	0
SE Pennsylvania Trans. Auth.	0	3	3	0	2	2
St. Louis Bi-State Dev.	0	0	0	0	0	0
Utah Transit Authority	2	0	2	0	0	0
Total	**7**	**23**	**30**	**6**	**20**	**26**

Source: National Transit Database

The 22 transit agencies listed in Table 1 with qualifying LRT systems included in the NTD operated a total of 38.7 million annual revenue service miles in 2002. Table 2 lists accident rates by transit agency in both accidents per thousand revenue service miles and number of revenue service miles per accident. The accident rates are based on the average yearly accidents in 2002 and 2003.

Table 2. Accident Rates by Transit Agency 2002 & 2003

Transit Agency	Annual Revenue Service Miles (million) [1]	Average Accidents (per year) [1]	Accident Rates (million miles)	
			Per Mile	Miles between Accidents
City of Detroit DOT	0.01	0	0.00	0.00
Cleveland-RTA	0.94	0	0.00	0.00
Dallas Area Rapid Transit	2.64	0.5	0.19	5.28
Denver-RTD	1.56	0	0.00	0.00
Kenosha Transit	0.02	0	0.00	0.00
King County DOT	0.04	0.5	12.09	0.08
Los Angeles County MTA	3.07	7	2.28	0.44
Maryland MTA	1.66	1.5	0.90	1.11
Mass. Bay Transp. Auth.	4.26	0.5	0.12	8.52
Memphis Area TA	0.40	0	0.00	0.00
New Jersey Transit	1.24	0	0.00	0.00
New Orleans-RTA	0.69	0	0.00	0.00
Niagara Frontier Transp. Auth.	0.38	0.5	1.32	0.76
Pittsburgh Transit	1.33	0	0.00	0.00
Portland Tri-Met	3.27	4.5	1.38	0.73
Sacramento RT	0.95	0.5	0.52	1.91
San Diego	2.64	2	0.76	1.32
San Francisco MUNI	5.49	6.5	1.18	0.85
Santa Clara VTA	1.73	0.5	0.29	3.46
SE Pennsylvania Trans. Auth.	3.08	2.5	0.81	1.23
St. Louis-Bi-State Dev.	2.65	0	0.00	0.00
Utah Transit Authority	1.10	1	0.91	1.10
Total	**39.16**	**28**	**--**	**--**
Average	**1.78**	**1.27**	**1.03**	**1.22**

Notes: [1] Based on an average of 2002 and 2003 data.

- ***There is substantial variability in accident rates among transit agencies.***

As can be seen, there is significant variability in the accident rates. The agencies with the highest rates include the Los Angeles County MTA (highest), Portland Tri-Met, and San Francisco MUNI.[2] There are nine agencies that did not report any pedestrian/LRT accidents in either 2002 or 2003. Five of the nine agencies operate less than 1 million annual revenue service miles (Detroit, Cleveland, Kenosha, Memphis, and New Orleans). The four agencies with more than 1 million annual revenue service miles but no reported accidents are Denver, New Jersey, Pittsburgh, and St. Louis. One possible reason for the low accident rate with these four agencies is that they operate primarily on semi-exclusive rights-of-way with relatively few grade crossings. However, as explained later in the analysis of predictor variables, neither of these two factors are strongly correlated with accident rates.

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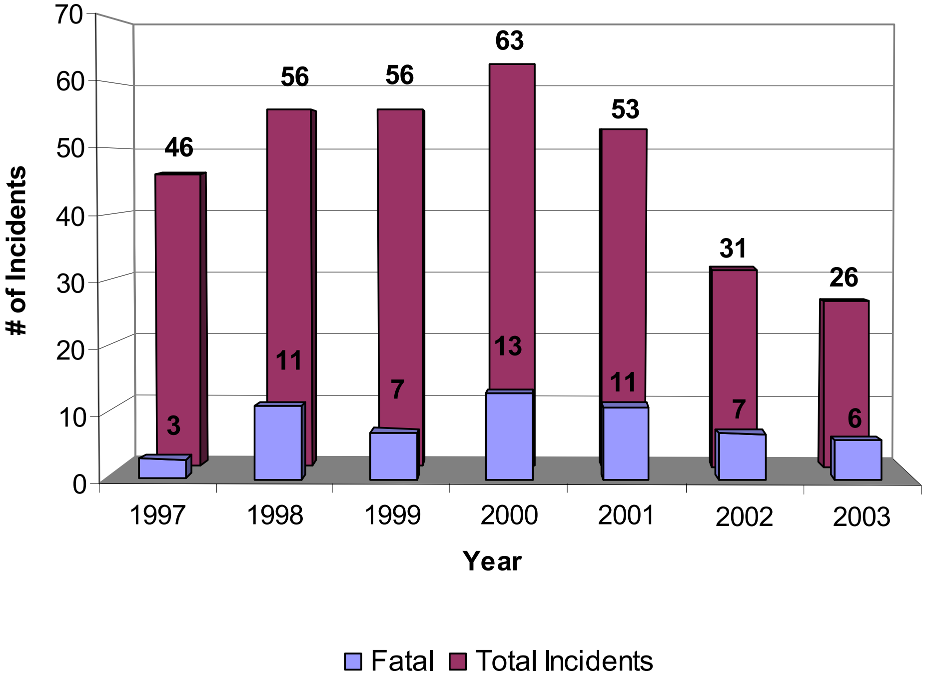
[2] This excludes King County DOT and Niagara Frontier Transportation Authority due to the low number of annual revenue service miles.

Fatalities

- ***Pedestrian/LRT incidents are much more likely to result in fatalities than vehicle/LRT incidents.***

An average of 23% of all pedestrian/LRT incidents in 2002 and 2003 resulted in fatalities. Figure 1 compares the total number of pedestrian/LRT fatalities to total number of pedestrian/LRT injuries over the past seven years. Note that the reporting requirements for accidents changed in 2002, likely resulting in a lower number of reported accidents in 2002 and 2003.

Figure 1. Fatal vs. Total Pedestrian/LRT Accidents (1997 to 2003)



As discussed in TCRP Report 69, relative to vehicle/LRT accidents, pedestrian/LRT accidents are much more likely to result in fatalities in both high-speed and low-speed settings.[3] For example, along alignments with speeds greater than 55 km/hour (35 mph), 29% of pedestrian/LRT accidents result in fatalities whereas only 19% of vehicle/LRT accidents result in fatalities. Where LRT speeds are less than 55 km/hour, the disparity is even more dramatic, with fatality rates of 18% and 1%, respectively.

Table 3 lists the total incidents, fatalities, and injuries for vehicle/LRT, object/LRT, and pedestrian/LRT collisions for the period between 1997 and 2001. As shown in the table and in Figure 2, most incidents were between vehicles and light rail vehicles. Although pedestrian/LRT accidents represent less than 20% of the total LRT incidents, they average 67% of the total LRT fatalities.

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[3] Transportation Research Board, Transit Cooperative Research Board, *TCRP Report #69 – Light Rail Service: Pedestrian and Vehicular Safety*, 2001.

Table 3. Summary of LRT Incidents (1997 to 2001)

Collisions	Year					Total	% of Total
	1997	1998	1999	2000	2001		
Total Incidents	352	297	276	333	301	1559	100%
w/ vehicles	281	223	206	260	234	1204	77%
w/ objects	25	18	14	10	14	81	5%
w/ people	46	56	56	63	53	274	18%
Fatalities	3	14	13	22	15	67	100%
w/ vehicles	0	2	6	9	4	21	31%
w/ objects	0	1	0	0	0	1	2%
w/ people	3	11	7	13	11	45	67%
Injuries	316	332	404	359	299	1710	100%
w/ vehicles	263	254	339	261	244	1361	79%
w/ objects	8	14	11	37	11	81	5%
w/ people	45	64	54	61	44	268	16%

Figure 2. LRT Incidents Involving Vehicles, Objects, and People (1997 to 2001)

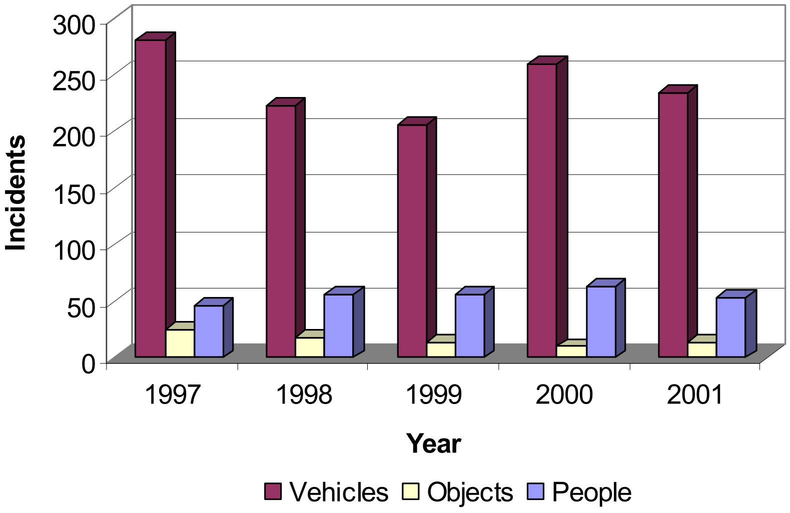
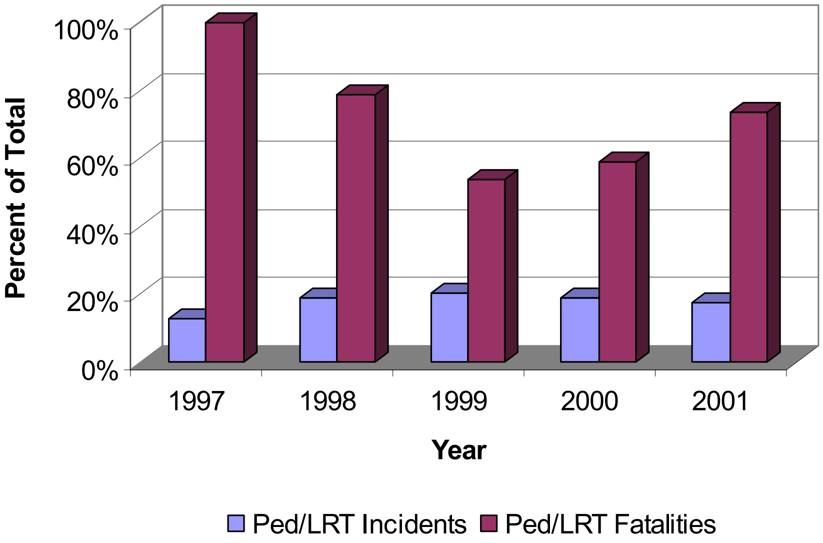


Figure 3. Percent Pedestrian/LRT Incidents vs. Total Incidents and Percent Pedestrian/LRT Fatalities vs. Total Fatalities



Location of Accidents

- ***Approximately half of pedestrian/LRT accidents occur at grade crossings.***

Table 4 below separates the total number of pedestrian/LRT injuries by crossings, stations, and other locations. As can be seen, 27 of the 57 total injuries resulting from pedestrian/LRT collisions in 2002 and 2003 occurred at crossings, including either vehicle grade crossings or pedestrian-only crossings. The 22 accidents occurring at “other” locations are typically associated with trespassers and occurred at mid-block locations or within exclusive rights-of-way.

Table 4. Fatal and Non-Fatal Pedestrian/LRT Injuries by Location (2002 & 2003)

Location	Fatal	Non-Fatal	Total
Crossing	5	22	27
Station	1	7	8
Other	7	15	22
Total Injuries	**13**	**44**	**57**

Note: Crossings include grade crossings & intersections. The incidents at stations include all the accidents in the NTD that occurred at revenue facilities.

Figure 4 and Figure 5 provide a percentage breakdown of the fatal and non-fatal pedestrian/LRT injuries by crossing, station, and other locations. As shown by the graphs, fatal injuries are most likely (54%) to occur at other locations whereas non-fatal injuries occur more commonly at crossings (49%) than at stations or other locations.

Figure 4. Percent of Fatal Pedestrian/LRT Injuries by Location

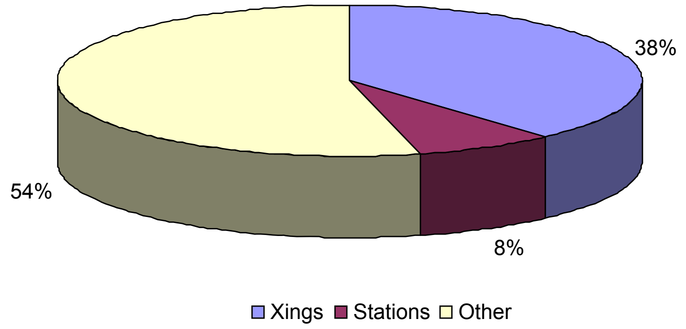
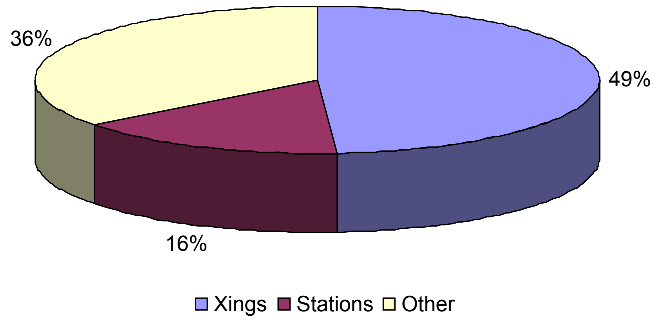


Figure 5. Percent of Non-Fatal Pedestrian/LRT Injuries by Location



Accidents occurring at “other” locations are generally beyond the scope of the D-10 study. When they are removed from the analysis, the difference between the percentage of pedestrian/LRT accidents occurring at grade crossings compared to stations is more pronounced, with 83% of fatalities occurring at grade crossings and 75% of non-fatal accidents occurring at grade crossings.

Crossing Controls

- ***Most pedestrian/LRT accidents at grade crossings occur at locations with active crossing control devices.***

As illustrated in Table 5, 42% of the pedestrian/LRT injuries in 2002 and 2003 (24 in total) occurred at locations with active crossing control devices. In addition, nine injuries occurred at grade crossings where the type of crossing control device was not listed. From the data collected as part of Task 2, we know that most grade crossings have some type of active device. Therefore, the number of injuries at locations with active devices is likely to be higher than listed in Table 5.

Table 5. Fatal and Non-Fatal Pedestrian/LRT Injuries by Crossing Control Type (2002 & 2003)

Protection Type	Fatal	Non-Fatal	Total
Active	5	19	24
Passive	1	1	2
Other	0	0	0
Not Listed	4	21	25
None	3	3	6
Total	**13**	**44**	**57**

Table 6 provides a breakdown of the aggregate injury data (fatal and non-fatal) by protection type and location. Once again, when accidents at “other” locations are removed, the percentage of pedestrian/LRT accidents at active crossing controls increases to 55%.

Table 6. Total Pedestrian/LRT Injuries by Protection Type and Crossing (2002 & 2003)

Protection Type	Crossings	Stations	Other	Total
Active	17	3	4	24
Passive	2	0	0	2
Other	0	0	0	0
Not Listed	8	5	12	25
None	0	0	6	6
Total	**27**	**8**	**22**	**57**

Active Crossing Control Devices

- ***At locations with active crossing control devices, most accidents occur where there are traffic signals or crossing gates.***

Table 7 is a breakdown of all the injuries (fatal and non-fatal) that occurred at locations with active crossing control devices. The major categories include crossing gates, traffic signals, flashers/lights/bells, and other. Gates and traffic signals comprise 83% of all the accidents at locations with active crossing control devices, with slightly more at the traffic-signal controlled crossings. It is assumed that there are no flashing lights or crossing bells at the traffic-signal controlled locations.

TCRP Report 17[4] found that LRV accidents in shared rights-of-way account for the largest proportion of accidents even though this alignment type constitutes the smallest proportion of route miles. Although the analysis in TRCP Report 17 included vehicle as well as pedestrian accidents, this supports the finding of this Task 3 report in that a greater number of

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[4] Transportation Research Board, Transit Cooperative Research Program, *TCRP Report 17: Integration of Light Rail Transit into City Streets*, 1996.

pedestrian/LRT accidents occur along shared rights-of-way where traffic signals are used to control pedestrian movement across the tracks.

Table 7. Total LRT/Pedestrian Injuries at Different Locations by Type of Active Crossing Control Device (2002 & 2003)

Type of Active Device	Crossings	Stations	Other	Total
Gates	7	2	0	9
Traffic Signals	9	0	2	11
Flashers/Lights/Bells	1	1	0	2
Other	0	0	2	2
Total	**17**	**3**	**4**	**24**

As can be seen in Figure 6 and Figure 7, there is a substantially larger percentage of fatal accidents (60%) occurring at traffic signal controlled crossings compared to non-fatal accidents (42%).

Figure 6. Percent Fatal Pedestrian/LRT Injuries by Active Device

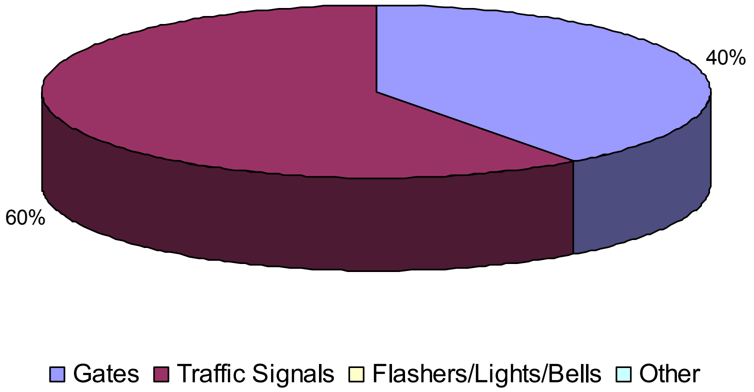
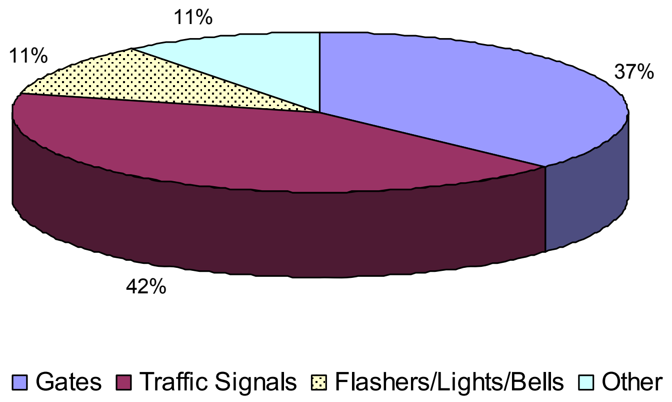


Figure 7. Percent Non-Fatal Pedestrian/LRT Injuries by Active Device



Cause of Accidents

- ***Risky or inattentive pedestrian behavior is a frequent factor in pedestrian/LRT accidents.***

The NTD does not provide a root-cause analysis for each accident. However, based on the available data, in many instances risky or inattentive pedestrian behavior appears to have contributed to the accident. The operator was at least partially at fault in only a few incidents. Observations from the NTD data are supplemented and supported by conversations with transit agency staff. In no particular order, many of the reasons for the 57 pedestrian/LRT injuries in 2002 and 2003 are:

1. Rushing to catch trains or get across intersections. This primarily includes accidents near stations or on station platforms. Coupler jumping also contributed to a few accidents.
2. Ignoring audible and/or visual warnings at grade crossings. In many instances, pedestrians purposefully walked around crossing gates or disregarded other active warnings. The reasons for this behavior are not known.
3. Distractions. The use of cells phones and headsets were contributing factors in four of the accidents.
4. Not paying attention in transit malls. Although most of these incidents do not result in serious injury and therefore were not reported in the NTD, several agencies indicated that this is their most common type of accident. For instance, people walk in front of trains as they leave the station – even after an audible warning is sounded.
5. Intoxication. At least five serious accidents were attributed to intoxicated pedestrians.
6. Trespassing. There were several accidents near tunnel portals or within exclusive rights-of-way. These locations are clearly off limits to pedestrians and are relatively inaccessible. Accidents due to trespassing are beyond the scope of the D-10 study.

Pedestrians with Disabilities

Although there was no specific category in the NTD identifying LRT collisions with persons with disabilities, there was no indication in either the Event Description or Action Description categories that any of the pedestrian/LRT accidents involved hearing impaired, visually impaired, or other disabled persons. Therefore, based on the available data, it can not be concluded that disability is a significant factor in pedestrian/LRT accidents.

Accident Predictors

- ***Annual revenue service miles and directional route miles are good predictors of the number of pedestrian/LRT accidents.***

In order to better predict where pedestrian/LRT accidents are likely to occur, a regression analysis was performed looking at a number of possible predictor variables. Specifically, single-variable regressions on the average total accidents in 2002 and 2003 (excluding the 22 total accidents occurring at "other" locations, which are not covered in this study) for each transit agency were run against:

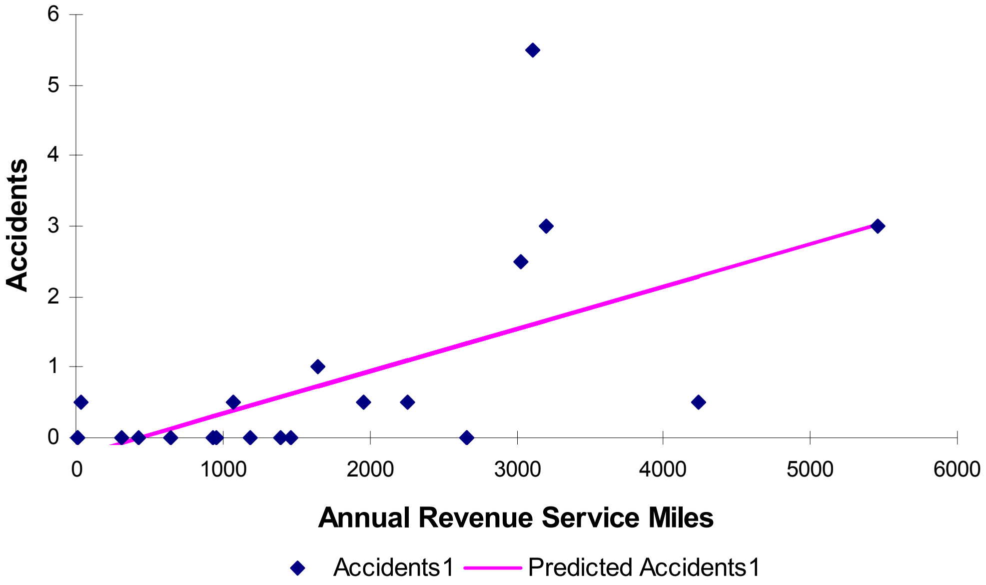
- Annual Revenue Service Miles
- Directional Route Miles
- Number of Stations
- Number of Grade Crossings
- At-Grade Track Miles

Table 8 gives the relevant regression statistics for each variable. The variables are organized by the degree of statistical significance with the number of accidents. Generally speaking, T-Statistics greater than 2 are considered statistically significant. The strongest relationships are annual revenue service miles and directional route miles. These two variables have the highest R squared values, F-statistics, and T-statistics. The usefulness of the statistical analysis is limited because of limited available data. However, including data prior to 2002 is problematic because of different reporting requirements. Figure 8 shows the linear regression of annual revenue service miles, which has the strongest relationship with pedestrian/LRT accidents. There also appears to be somewhat of a weak relationship between accidents and at-grade track miles and accidents and the number of grade crossings. However, it is clear that the number of stations is not a good predictor of pedestrian/LRT accidents.

Table 8. Summary of Regression Results

		F-Statistic		
	R Squared	**Value**	**Significance**	**T-Statistic**
Annual Revenue Service Miles	0.37	11.74	0.003	3.4
Directional Route Miles	0.32	9.51	0.006	3.1
At-Grade Track Miles	0.17	4.11	0.056	2.0
Number of Grade Crossings	0.14	3.24	0.087	1.8
Number of Stations	0.07	1.55	0.228	1.2

Figure 8. Linear Regression of Pedestrian LRT Accident Rate and Annual Revenue Service Miles



There also appear to be relationships between many of the variables. For example, systems with a greater number of annual revenue service miles are likely to have more grade crossings and systems with more grade crossings are likely to have a greater number of at-grade track miles. Table 9 is a correlation matrix of these variables. Generally, correlations above 0.6 can be considered "significant." Of the 10 co-variants, the correlation coefficient was above 0.6 for:

- Number of Grade Crossings and At-Grade Track Miles
- Annual Revenue Service Miles and Directional Route Miles

Table 9. Correlation Matrix for Regression Variables

	Annual Revenue Service Miles	**Directional Route Miles**	**No. of Stations**	**No. of Grade Crossings**	**At-Grade Track Miles**
Annual Revenue Service Miles	1.00				
Directional Route Miles	0.82	1.00			
Number of Stations	0.55	0.59	1.00		
Number of Grade Crossings	0.35	0.31	0.42	1.00	
At-Grade Track Miles	0.42	0.40	0.49	0.99	1.00

At-grade track miles and the number of grade crossings have the highest correlation among the predictor variables. Both of these variables were also found to have somewhat weak relationships with the number of pedestrian/LRT accidents. The correlation between annual revenue service miles and directional route miles was also relatively high (0.82). Therefore, either variable would be equally effective at predicting the number of pedestrian/LRT accidents.

TRANSIT AGENCIES

Accident data was also requested from the transit agencies surveyed as part of Task 2 of this project. Of the 11 agencies who responded to the survey, detailed accident data was obtained from:

- Los Angeles County Metropolitan Transportation Authority (LA Metro)
- Santa Clara Valley Transportation Authority (VTA)
- San Diego Trolley, Inc.

Other agencies did not have the information available or had too little data to provide a meaningful analysis. Follow-up phone calls with staff were also conducted to gather anecdotal information and ask questions regarding specific pedestrian safety issues facing each agency.

Table 10 presents the aggregated historical pedestrian/LRT data for the three agencies based on accident location. Similar to the NTD data, accidents are classified as occurring at crossings, stations, or other. Consistent with the national data, a majority (64%) of all accidents occurred at crossings. However, more accidents occurred at/near stations for VTA and San Diego than at grade crossings.[5] These and other trends are further analyzed in the following section. The information that is reported by the transit agencies is limited.

Table 10. Summary of Historical Pedestrian/LRT Accident Data for San Diego, VTA, and LA Metro

Location	San Diego	VTA	LA Metro	Total
Crossings	9	18	89	116
Station	12	22	17	51
Other	4	0	6	10
Total	**25**	**40**	**112**	**177**

Notes:
San Diego (August 1999 – May 2004)
VTA (September 1988 – March 2004)
LA Metro (July 1990 – March 2004)

Los Angeles County Metropolitan Transportation Authority (LA Metro)[6]

LA Metro operates approximately 55 route miles of light rail service on three lines, the Blue, Gold, and Green lines. Figure in Appendix B is a map of the Metro Rail system. The Green line is fully within an exclusive right-of-way and therefore is not included in this analysis. The 14-mile Gold Line opened for revenue service in July 2003. Historical accident data from this new system is not yet available.

The Long Beach Blue Line, which runs approximately 22 miles from downtown Los Angeles south to downtown Long Beach, has experienced a high level of vehicle/LRT and

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[5] It is important to note that the classifications for accidents at stations, grade crossings, etc. may not be the same between transit agencies or with the NTD.

[6] Accident data in this section comes from the Los Angeles County Metropolitan Transportation Authority, *Summary of Metro Blue Line Train/Vehicle and Train/Pedestrian Accidents (July 1990 – March 2004)*, April, 2004, and communications with Vijay Khawani, Metro Rail Operations Safety Department.

pedestrian/LRT accidents. The Blue Line opened for revenue service in July 1990. As of the end of the first quarter of 2004, there have been a total of 679 accidents on the Blue Line (excluding 12 suicides). Of these accidents, 112 have involved pedestrians. While pedestrian/LRT accidents represent only 16% of the total accidents, they account for slightly over half (51%) of the 55 total fatalities.

The Blue Line has three distinct route segments defined as the Los Angeles Street Running (LASR), Cab Signal (CS), and Long Beach Street Running (LBSR). A vast majority of the pedestrian/LRT accidents (91 of the 112, or 81%) have occurred along the Cab Signal segment, which extends from approximately the Washington Station in Los Angeles to past the Willow Station in Long Beach. The Blue Line generally operates on a semi-exclusive/fenced right-of-way along this 15-mile segment which has approximately 31 grade crossings (including pedestrian only crossings). A portion of the Cab Signal alignment is adjacent to a freight rail corridor, which means that there are up to four parallel tracks (1-2 freight, 2 LRT).

In terms of safety devices, all of the motor vehicle crossings along the Cab Signal segment have warning devices installed such as gates, flashing lights, and crossing bells. The vehicle crossing at 124th Street has four quadrant gates whereas all other crossings have two quadrant gates. LA Metro is currently expanding the four quadrant gate system to 11 additional crossings on the Blue Line, the design for which is currently in progress. There are also at least three pedestrian only crossings, which do not have flashing lights, or bells. In addition to these active warnings, LA Metro sounds a train horn in advance of each crossing (vehicle and pedestrian). The horns are set to meet the CPUC minimum sound level of 75 dBA at 100 feet. Although the exact sound level of the horn is not known, it is believed to be about 95 dBA at 100 feet.

In addition to the warning devices listed above, LA Metro has also installed supplementary safety devices at several of the crossings. Specifically, there are pedestrian swing gates at the Imperial Station, Artesia Station, and Willow Street Station. Also, a fiber-optic “2nd train coming” sign has been installed at the Vernon Avenue pedestrian grade crossing as part of a TCRP demonstration project.[7]

Table 11 summarizes the fatal and non-fatal accidents by location. The vast majority of accidents occurred at grade crossings (89 out of 112, or 79%). All of the accidents were at crossings with active visual and audible warnings, with 58 of the 89 accidents at crossings with gates.[8]

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[7] TCRP Project A-5A, “Active Train Coming/Second Train Coming Sign Demonstration Project.”

[8] Crossing accidents do not include those accidents identified as at stations or median barriers.

Table 11. Summary of LA Metro Blue Line Pedestrian/LRT Accident Data (July 1990 – March 2004)

Location	Fatal	Non-Fatal	Total
Stations	16	1	17
Gated Crossings	--	--	--
Gates, Flashing Lights, Bells/Traffic Signal	23	9	32
Gates, Flashing Lights, Bells	12	7	19
Double Gates, Flashing Lights, Bells/Traffic Signal	2	5	7
Signalized Crossings	--	--	--
Signal, No Left Turn	3	--	3
Walk/Don't Walk	2	--	2
Traffic Signal	10	2	12
Ped Crossings (Flashing Lights, Bells)	12	2	14
Other (Median Barrier)	4	2	6
Total	**84**	**28**	**112**

Note: Double gates = four quadrant gates

Figure 9 shows the frequency of accidents per crossings, including crossings at stations. It excludes the other (median barrier) pedestrian/LRT incidents. As can be seen, a disproportionately large number of accidents (37 accidents) have occurred at only 4 locations, all of which are along the Cab Signal segment. All four of these crossings are also at stations:

- Vernon Avenue (14 accidents). This grade crossing is protected by gates, flashing lights, bells, pedestrian gates, 2nd Train Coming sign, and traffic signals.
- Florence Avenue (8 accidents). This grade crossing is protected by gates, flashing lights, bells, and pedestrian gates.
- Artesia Pedestrian (8 accidents). This pedestrian crossing is protected by flashing lights, bells, and swing gates.
- 103rd Street (7 accidents). This grade crossing is protected by gates, flashing lights, bells, pedestrian gates, and traffic signals.

Figure 9. Histogram of LA Metro Blue Line Pedestrian/LRT Accidents per Crossing (July 1990 through March 2004)

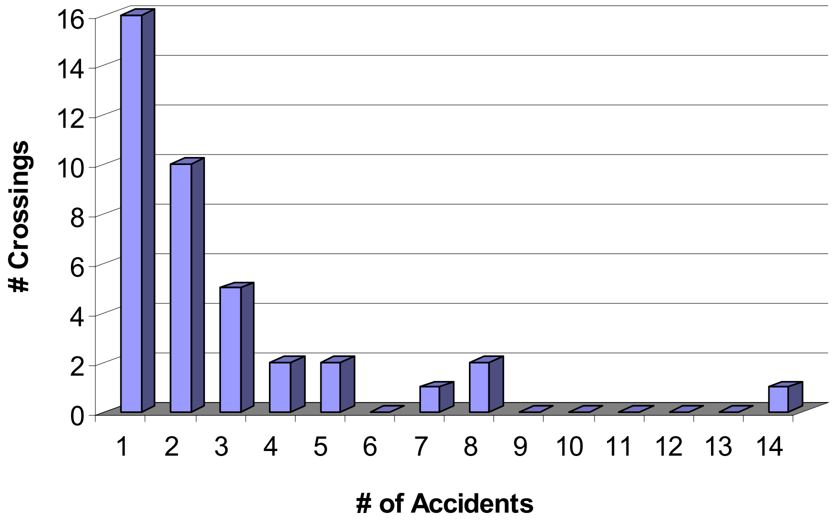


Figure 10 shows the number of accidents for both vehicle/LRT and pedestrian/LRT accidents by route segment. Vehicle and pedestrian accidents are occurring along different route segments. This difference becomes even more pronounced when comparing accidents by segment on a percentage basis, which is shown in Figure 11. We can not determine why there are so many accidents on the CS segment of the Blue Line, and without doing extensive research we can not derive any meaningful conclusions.

Figure 10. No. of Vehicle/LRT and Pedestrian/LRT Accidents by Route Segment (July 1990 through March 2004)

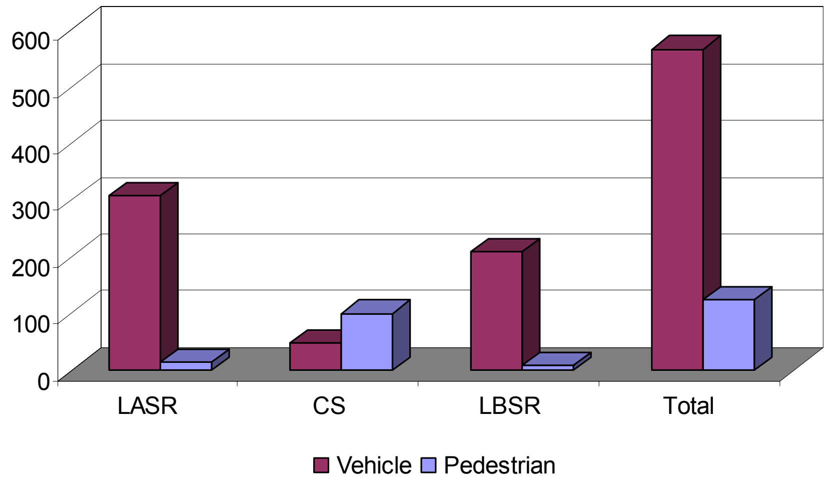


Figure 11. Percent Vehicle/LRT and Pedestrian/LRT Accidents by Route Segment (July 1990 through March 2004)

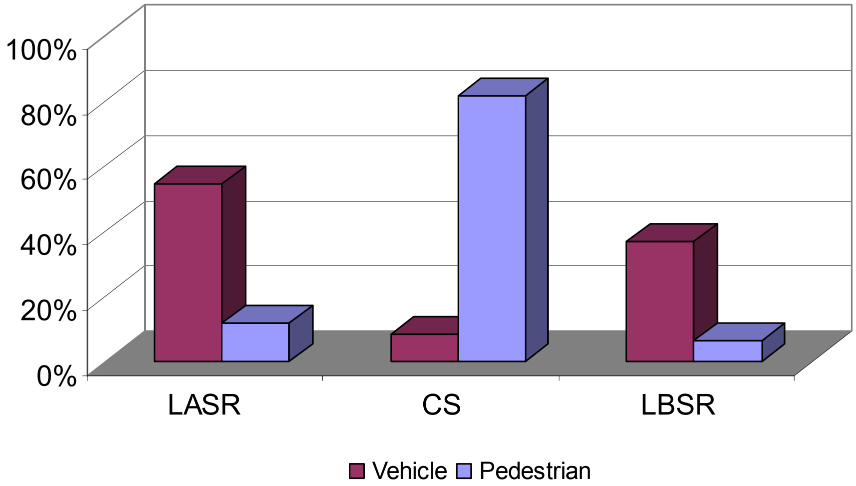
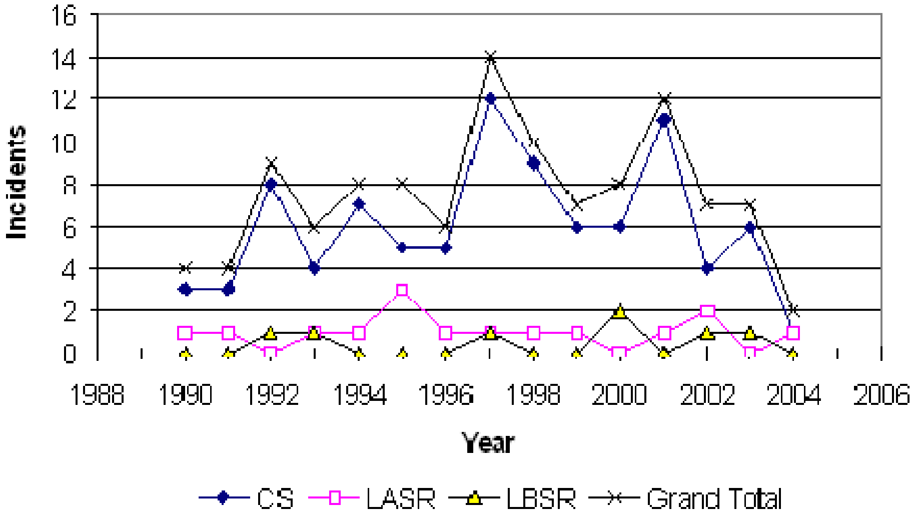


Figure 12 shows the accident rate by segment and in total on the Blue Line since just after it opened in July 1990. Although there is a spike in the Cab Signal segment and total accidents in 1998 and a dip in 1996, pedestrian/LRT accidents rates have been fairly steady over the past 13 years, averaging slightly over 7 per year on the Cab Signal segment. Although there may have been minor increases in total annual revenue service miles over the years (i.e. change from 1 to 2 and 2 to 3 car trains), the general operation of the Blue Line has remained consistent. To our knowledge LA Metro has not installed any innovative audible devices or wayside horns.

Figure 12. Pedestrian/LRT Accidents over Time



There are several factors that may be contributing to the high accident rate on the Blue Line. The first is speed. The Blue Line generally operates at speeds greater than 55 km/hour along the Cab Signal route segment. The second is the adjacent freight railroad (UPRR). These factors are discussed in more detail in section 2.3.6.3 of TRCP Report 69 and in the TCRP Research Results Digest (November 2002, Number 51).

As previously discussed, LA Metro has installed swing gates and fiber optic active warning signs to improve pedestrian safety at certain crossings. Other pedestrian safety measures include pedestrian gates, flashing train headlights, fencing, and delineated crosswalks. From an education standpoint, LA Metro has provided safety education seminars to all schools, and at events such as fairs, community meetings, church meetings and other social gatherings. LA Metro has also produced 9 PSAs and computer generated animation videos that are currently being shown on local cable and TV stations. LA Metro has also invested in a mobile safety education theatre called the Metro Experience that is used to spread the rail safety message. Despite all of LA Metro's efforts, accidents continue to occur. The data indicates that pedestrian/LRT accidents in the CS segment continue to be a challenge to mitigate.

Santa Clara Valley Transportation Authority (VTA)

The VTA operates three LRT lines: Guadalupe, Tasman, and Almaden. Figure in Appendix B is a map of the VTA rail system. A summary of the mileage by alignment type for all three lines is given in Table 12. A majority of the alignment is in a street median with no fence where the maximum speed is 55 km/hour (35 mph). The crossings in these locations are typically traffic signal controlled and do not have crossing bells. Also, consistent with California Public Utilities Commission requirements, on-vehicle audible warnings are not routinely sounded in advance of the crossings. The maximum speed is 15 km/hour (10 mph) in the pedestrian mall.

Table 12. VTA Mileage by Alignment and Line

Alignment	Guadalupe	Tasman	Almaden	Total
Exclusive	9.5	1.58	0	11.1
Semi-Exclusive	0	4.47	1.18	5.7
Street Median/Curb (no fence)	8.35	9.89	0	18.2
Non-Exclusive/Mixed Traffic	0.1	0	0	0.1
Non-Exclusive/Pedestrian Mall	1.33	0	0	1.3
Total	**19.3**	**15.9**	**1.2**	**36.4**

Note: The Guadalupe line opened in 1997, the Almaden extension in 1991, and the Tasman line in 1999.
Source: VTA, 2004.

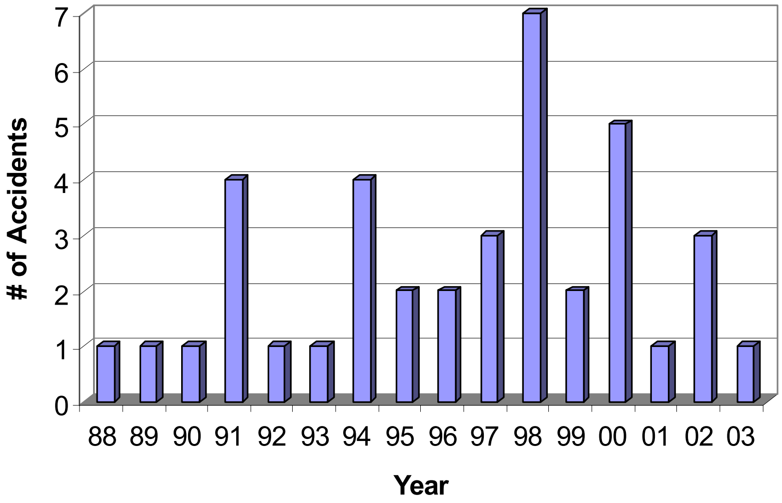
Table 13 is a breakdown of the fatal and non-fatal accidents by alignment type. All 40 of the pedestrian/LRT accidents that have occurred since revenue service began in 1987 have been on the Guadalupe Line. This is somewhat surprising since 12 of the 40 accidents have occurred since 1999 (when the Tasman line opened). Also, the Tasman line has nearly 10 miles of street median/curb (no fence) alignment. Crossing treatments are similar on all three lines and no unique audible devices have been installed. Figure 13 shows the yearly number of accidents since 1988. It should be noted that there is a discrepancy between the VTA data in Figure 13 and the NTD data in Table 1 for VTA. We believe the discrepancy exists because of differences in the reporting requirements.

Table 13. VTA Pedestrian/LRT Accidents by Alignment Type (September 1990 through March 2004)

Alignment	Fatal	Non-Fatal Major	Non-Fatal Minor	Total
Exclusive	0	0	0	0
Street Median/Curb (no fence)	3	9	7	19
Non-Exclusive/Mixed Traffic	0	0	0	0
Non-Exclusive/Pedestrian Mall	0	5	16	21
Total	**3**	**14**	**23**	**40**

Note: No information provided regarding difference between major and minor non-fatal injuries. This table includes one accident that occurred in 2004.

Figure 13. Number of VTA Pedestrian/LRT Accidents over Time (1988 to 2003)



In addition to the fact that all of the reported accidents have been on the Guadalupe line, all of the accidents have occurred along segments where the operational speed is less than 55 km/hour (35 mph), which represents only 50% of the total line miles. Table 14 includes the historical accident rate per mile for each alignment segment. In particular, the accident rate per mile for the downtown pedestrian mall is very high, but the severity of the accidents is low. One possible reason is the lower operating speed in this area. The pedestrian mall is effectively a continuous crossing in a busy/pedestrian heavy urban environment.

Table 14. VTA Pedestrian/LRT Accident Rate by Alignment Type (September 1990 through March 2004)

Alignment	Miles	Accidents	Accident Rate (#/ Route Mile)
Exclusive	9.5	0	0
Street Median/Curb (no fence)	8.35	19	2.3
Non-Exclusive/Mixed Traffic	0.1	0	0
Non-Exclusive/Pedestrian Mall	1.33	21	15.8
Total	**19.3**	**40**	**2.1**

Table 15 shows the number of pedestrian/LRT accidents at either traffic signal controlled grade crossings or at/near stations, with the majority (63%) of the accidents at/near stations.

Table 15. VTA Pedestrian/LRT Accidents by Location (September 1990 through March 2004)

Alignment	Traffic Signal	Station	Total
Street Median/Curb (no fence)	9	10	19
Non-Exclusive/Pedestrian Mall	9	12	21
Total	**18**	**20**	**40**

San Diego Trolley

The San Diego Trolley is comprised of two lines totaling approximately 60 route miles. Figure in Appendix B is a map of the San Diego Trolley System. The Blue Line runs north-south from Mission Valley to the U.S.-Mexico Border at San Ysidro. The northern portion of this line operates at speeds up to 90 km/hr (55 mph) along a semi-exclusive right-of-way. The downtown segment is approximately 2 miles long and is in a street median/curb (no fence) alignment. South of downtown, the line operates at speeds up to 55 km/hr (35 mph) on a semi-exclusive right-of-way shared with the San Diego and Imperial Valley Railway during non-revenue service hours. There are approximately 35 grade crossings along the southern portion of this route.

The Orange Line runs east-west from downtown San Diego to Santee. From downtown east to approximately 32nd Street, the Orange Line operates at speeds up to 55 km/hr (35 mph) on Street Median/Curb (no fence) alignment. To the east, the alignment is semi-exclusive right-of-way at speeds up to 90 km/hr (55 mph).

Between August 1999 and December 2003, there have been a total of 25 pedestrian/LRT accidents on the San Diego Trolley System. Only 2 of these 25 accidents have been fatalities. Table 16 lists the accidents by line and location. As can be seen, nearly 80% of all accidents have occurred on the Blue Line even though the Blue Line and Orange Line are similar in route length and have approximately the same number of grade crossings. In addition, nearly half of all the accidents have occurred at or near stations.

Table 16. Summary of San Diego Pedestrian/LRT Accidents by Location and Line (September 1990 through March 2004)

Location	Blue	Orange	Total
Gates, Flashing lights, Bells	4	1	5
Traffic Signal	2	2	4
Station	9	3	12
Exclusive Right-of-Way	4	0	4
Total	**19**	**6**	**25**

The highest number of reported accidents at any one location was at or near the Palm Avenue Station (4 accidents). According to TCRP Report 69, there is a tall wall separating the freight railroad tracks from the back side of the LRT platform, which limits the ability of pedestrians walking on the sidewalk just outside the LRT station to see an approaching LRV on the tracks on the other side of the wall. We are not aware of the installation of any innovative audible devices at this location.

According to the NTD, the San Diego Trolley system includes approximately 97 track miles, 88 of which are either on semi-exclusive or non-exclusive rights-of-way. By grouping incidents together either by using direct information regarding their location or by the types of crossing protections indicated, we were able to compare the incident rates by alignment type to the track miles by alignment type. As can be seen in Table 17, the percentage of track miles and % incidents by alignment are relatively uniform, with most occurring along the semi-exclusive track segments.

Table 17. Summary of San Diego Pedestrian/LRT Incidents by Alignment Type & Track Miles

Alignment	Track Miles	Incidents	% Track Miles	% Incidents
At-Grade				
Semi-Exclusive	80	20	82%	80%
Non-Exclusive, Mixed	8	5	8%	20%
Subtotal	88	25	90%	100%
Exclusive	9	NA	10%	NA
Total	**97**	**25**	**100%**	**100%**

Notes: August 1999 to May 2004

CONCLUSIONS

Based on the data collected, it is difficult to determine the effectiveness of audible warnings in preventing pedestrian/LRT accidents. First, it is not possible to know why the accident occurred. Neither the NTD nor the agency data provide definitive causes for each accident or include a first-hand account from the pedestrian's perspective. Second, the reporting does not always include the procedures for using audible warning devices prior to each accident. Some generalized information is available based on the information obtained from Task 2 of this project. Nonetheless, we cannot accurately determine what role, if any, the audible warnings played in the accident. Third, we do not have any data to determine whether, if sounded, an audible warning helped prevent an accident. Near misses are not recorded in the NTD or independently by most transit agencies. In addition, anecdotal information suggests that on a few occasions emergency horns actually contributed to an accident by startling and confusing pedestrians. In one instance, an elderly pedestrian outside the right-of-way was confused by the emergency horn and walked into the path of the train.

Following is a review of what we have found in analyzing the accident data.

- There are relatively few annual pedestrian/LRT accidents. We can generally conclude that existing grade crossing measures and LRT operating procedures are relatively effective at preventing pedestrian/LRT accidents.
- Pedestrian/LRT accidents are more likely to result in fatalities than vehicle/LRT collisions. This is not an unusual result considering the lack of physical crossing control for pedestrians.
- The majority of pedestrian/LRT accidents occur at grade crossings. Since most LRT systems operate along alignments with some sort of physical barrier between pedestrians and the train (curbs, fences, etc.), most pedestrians are channeled to designated crossings. As a result, this is where accidents are most likely to occur. The NTD appears to group all accidents together that occur at revenue facilities. This appears to include accidents at grade crossings near stations and on the platforms, therefore it is difficult to determine exactly where some accidents at revenue facilities occurred. Adding accidents at grade crossings near stations would increase the number and percentage of accidents that occur at grade crossings.
- Most accidents occur at locations with active protective devices. Based on information obtained in Task 2 of this project, most LRT crossings, including pedestrian-only crossings, have some type of active crossing control device.
- The higher number of accidents at traffic signal controlled crossings versus gated crossings appears to suggest that lack of visual, physical, and/or audible measures decreases pedestrian safety. This preliminary conclusion is supported by common sense and casual observation, given that beyond the sounding of an on-vehicle audible warning (which is not always sounded at traffic signal controlled crossings)[9], there are no standard visual or audible cues that a train is approaching.
- It may not be possible to use audible devices to protect against many causes of pedestrian/LRT accidents. In particular, accidents attributed to intoxication and trespassing are not a function of audible warnings or a lack thereof. Furthermore, distraction from cell phones and headsets may be difficult to overcome using audible devices.

  Many accidents occurred at locations with physical (gates), audible (bells and horns), and visual warnings (flashers and lights). These accidents are likely due to risky pedestrian behavior that is independent of the degree of crossing protection. However, there seem to be some exceptions to this trend that warrant further consideration. For example, there are

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[9] The California Public Utilities Commission General Orders, which regulate LRT systems in California and are often used as a model for transit agencies in other states, only require the sounding of an on-vehicle audible warning at gate-protected crossings.

situations where audible warnings are ignored not necessarily because of risky behavior but instead due to other factors such as:

  - Second train coming. This type of accident occurs when a pedestrian enters a crossing against the active crossing control devices after a train clears the crossing and the pedestrian is unaware of a train approaching from the opposite direction.
  - Active joint use corridors. In situations where both slower moving and louder freight trains share crossing control devices with faster and quieter LRT systems, some pedestrians enter a crossing against the active protection devices thinking that they are warning the approach of a freight train rather than the LRV.

- There is substantial variability in accident rates among transit agencies. Some of this variability is explained by the size of the LRT system (annual revenue service or directional route miles); however, much of it is not. Therefore, site- or alignment-specific factors that are unique to transit agencies may be significant contributors to pedestrian/LRT accidents. The variation in accident trends seems to indicate that nation wide statistics have limited usefulness when looking at individual transit agencies.

ANNEX A: TRANSIT AGENCY DATA

Table A-1. Summary of Transit Agency Alignment and Track Mileage

	Track Mileage								
	At Grade								
Agency	Exclusive Right-of-Way	with Cross Traffic	Mixed and Cross Traffic	Total	Elevated on Structure	Elevated on Fill	Open-cut	Subway	Total Miles
City of Detroit	0.0	0.0	1.3	1.3	0.0	0.0	0.0	0.0	1.3
Cleveland-RTA	12.5	14.5	0.0	27.0	0.9	2.0	3.1	0.0	33.0
Dallas Area Rapid Transit	9.0	54.0	3.0	66.0	9.0	0.0	2.0	6.0	83.0
Denver RTD	15.2	4.3	0.0	19.5	3.4	7.0	2.2	0.0	32.1
Kenosha Transit	0.0	0.5	1.4	1.9	0.0	0.0	0.0	0.0	1.9
King County DOT	0.0	2.1	0.0	2.1	0.0	0.0	0.0	0.0	2.1
Los Angeles County MTA	4.0	31.0	0.0	35.0	12.0	24.0	15.0	1.0	87.0
Maryland MTA	37.0	10.0	3.0	50.0	2.0	0.0	0.0	0.0	52.0
Mass Bay Transp. Auth.	29.0	29.0	2.0	60.0	4.0	0.0	0.0	14.0	78.0
Memphis	0.0	2.4	3.7	6.1	0.0	0.0	0.0	0.0	6.1
New Jersey Transit	17	7	2	26.0	0	0	3	0	29
New Orleans	16.0	0.0	0.0	16.0	0.0	0.0	0.0	0.0	16.0
Niagara Frontier	1.6	2.8	0.0	4.4	0.0	0.0	0.0	9.7	14.1
Pittsburg Transit	34.1	0.0	4.4	38.5	1.9	0.0	0.0	4.4	44.8
Portland Tri-Met	12.0	45.0	5.0	62.0	2.0	1.0	10.0	6.0	81.0
Sacramento RT	9.9	19.4	6.8	36.1	1.8	1.5	0.0	0.0	39.4
San Diego	0.0	80.2	8.0	88.2	6.0	1.8	0.6	0.0	96.6
San Francisco MUNI	5.0	6.0	48.0	59.0	0.0	0.0	0.0	15.0	74.0
Santa Clara VTA	12.0	37.0	0.0	49.0	1.0	7.0	1.0	0.0	58.0
SE Pennsylvania	1.0	21.0	145.0	167.0	0.0	0.0	0.0	4.0	171.0
St. Louis	44.0	1.0	0.0	45.0	5.0	10.0	11.0	3.0	74.0
Utah Transit Authority	0.0	30.2	4.0	34.2	0.0	0.0	0.0	0.0	34.2

Table A-2. Summary of NTD Transit Agency Alignment and Operating Data

Agency	Number of Crossings			Directional Route Miles	Stations	Transit Service Supplied				
	with Cross Traffic	Mixed and Cross Traffic	Total			Number of Trains in Operation (Average Weekday)	Annual Train Miles	Annual Train Revenue Miles	Annual Train Hours	Annual Train Revenue Hours
City of Detroit	0	8	8	1.3	8	0	13.0	11.2	3.1	1.9
Cleveland-RTA	22	0	22	30.4	34	15	951.3	938.3	62.6	61.2
Dallas Area Rapid Transit	70	13	83	71.9	22	24	2,279.3	2,260.2	124.8	122.6
Denver RTD	39	0	39	31.6	20	17	1,691.8	1,463.7	107.4	89.7
Kenosha Transit	7	12	19	1.9	1	1	16.8	16.5	2.6	2.4
King County DOT	14	0	14	3.7	9	3	39.9	39.8	11.6	11.5
Los Angeles County MTA	77	0	77	82.4	36	31	3,143.6	3,114.6	135.5	130.7
Maryland MTA	35	17	52	57.6	32	17	1,668.6	1,649.0	103.6	102.1
Mass Bay Transp. Auth.	56	0	56	51.0	78	80	4,246.7	4,238.2	283.1	282.5
Memphis	0	0	0	5.8	28	10	309.7	308.1	38.7	38.4
New Jersey Transit	16	11	27	25	26	24.0	1,183.8	1,183.8	118.5	118.516
New Orleans	124	0	124	16.0	9	20	681.2	648.2	93.7	77.2
Niagara Frontier	8	0	8	12.4	14	10	428.2	421.1	36.9	35.5
Pittsburg Transit	34	5	39	34.8	13	33	1,454.1	1,394.6	112.8	107.9
Portland Tri-Met	115	81	196	81.3	47	29	3,218.2	3,203.2	202.2	201.0
Sacramento RT	34	56	90	40.7	29	8	971.6	953.5	47.5	46.4
San Diego	70	26	96	96.6	49	27	2,687.7	2,661.3	141.6	138.8
San Francisco MUNI	27	324	351	72.9	11	126	5,458.9	5,458.9	571.3	571.3
Santa Clara VTA	97	0	97	58.4	49	23	2,031.4	1,960.8	137.0	131.9
SE Pennsylvania	43	1,659	1,702	69.3	64	110	3,135.9	3,027.9	320.1	310.3
St. Louis	23	0	23	68.8	26	21	2,679.2	2,658.8	106.0	91.1
Utah Transit Authority	33	32	65	34.2	20	12	1,080.5	1,075.1	95.9	95.4

Table A-3. Summary NTD Pedestrian/LRT Data for 2003

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
Portland Tri-Met			Right of way/roadway: Other	Pedestrian came down the steps and walked into side of train, making contact just behind operator's right side window. Man limped away. A MOW unit made him wait for a supervisor. Pedestrian was transported.	2-25-03	0	Trespasser
Portland Tri-Met	Exclusive right of way: At grade		Right of way/roadway: Other	Operator stated he made service stop 18 ties south of berthing marker which allows sound of bell to radiate from glass on shelter. Passenger detrained and was running on the platform same time train started to depart station. Operator made two bell warn	4-01-03	0	Other
Portland Tri-Met	Exclusive right of way: At grade	Passive Devices : Stop Sign	Other (specify in box below)	Bicyclist was traveling along side the train and cut in front of it. Bike was knocked clear and pedestrian went under the train.	6-23-03	1	Trespasser
Portland Tri-Met			Right of way/roadway: Other	A senior citizen walked out in front of the moving train.	6-03-03	0	Trespasser
Portland Tri-Met	Exclusive right of way: At grade		Revenue facility: Platform	Train was headed eastbound into the Rockwood platform. While dropping speed to enter the intersection, operator was scanning left, right, and forward for pedestrians, etc. Op was paying extra close attention to the west end of the platform because it was	10-10-03	1	Other
Portland Tri-Met			Right of way/roadway: Other	After servicing the Quatama (Hillsboro) platform westbound, operator proceeded on a green indication with two bell warnings. The pedestrian crosswalk was empty. After leaving, the operator heard a noise on the left hand side of the train and pulled the	11-12-03	0	Other

Table A-3. Summary NTD Pedestrian/LRT Data for 2003

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
Portland Tri-Met			Right of way/roadway: Other	Two girls were "horsing" around on the platform and one of them pushed the other between the coupled cars. Victim dragged perhaps 12 feet. Not life-threatening injuries - minor. Operator saw a hand between platform and side of rear car, towards the fro	11-17-03	0	Other
Niagara Frontier			Right of way/roadway: Other	Intoxicated pedestrian apparently walked 996 feet into train tunnel from portal gate, ignoring signs and flashing lights. Front of train struck pedestrian.	4-27-03	0	Passenger
SEPTA	Exclusive right of way: At grade	Active Devices: Traffic Signal	Right of way/roadway: Grade crossing	Trolley driver pulled away from stop, lady ran in front of trolley past #4 door, she yelled out a man just ran into trolley, man was laying on sidewalk..	5-29-03	0	
SEPTA	Exclusive right of way: At grade	Active Devices: Traffic Signal	Right of way/roadway: Grade crossing	Heading east on Island Road, driver pulled to end of stand, going by crowd, then slowed down and heard a thump. Driver went to see what happened, girl was sitting on the ground near pole. Kids said she was hit by trolley.	5-19-03	0	
SF MUNI	Non-Exclusive right of way: Mixed traffic/LRT		Other (specify in box below)	Pedestrian stepped in front of the streetcar.	1-22-03	0	Other
SF MUNI	Exclusive right of way: Tunnel		Right of way/roadway: Other	In the subway between Vanness and Civic Center. The pedestrian was walking in the subway and was unable to get fully out of the way of a train. The train sideswiped him twice causing minor injuries.	7-3-03	0	Trespasser

Table A-3. Summary NTD Pedestrian/LRT Data for 2003

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
SF MUNI			Non-revenue facility	The employee was standing near the track and was hit by the rear of the train as it turned.		0	Employees
SF MUNI	Non-Exclusive right of way: Transit mall	Active Devices: Train Approaching Sign	Revenue facility : Other revenue facility (specify below)	PCC streetcar traveling south struck a pedestrian that was inattentive while using a cell phone and stepped off the curb and into the approaching streetcar.	9-25-03	0	Revenue Facility Occupants
SF MUNI	Non-Exclusive right of way: Transit mall	Active Devices: Train Approaching Sign	Revenue facility: Other revenue facility (specify below)	PCC streetcar traveling south struck a pedestrian that was inattentive while using a cell phone and stepped off the curb and into the approaching streetcar.	9-25-03	0	Other
SF MUNI	Semi-exclusive right of way	Active Devices: Traffic Signal	Right of way/roadway: Grade crossing	Historic streetcar attempting to come to a stop at traffic stop light, made contact with a pedestrian that was crossing in the crosswalk	12-12-03	0	Other
SF MUNI	Non-Exclusive right of way: Mixed traffic/LRT	Passive Devices: Stop Sign	Right of way/roadway: Grade crossing	Male pedestrian ran into the left front side of the LRV that was moving through an intersection.	12-17-03	0	Other
SF MUNI			Right of way/roadway: Grade crossing	F Market going straight; pedestrian stepped from the curb in front of the streetcar. The traffic light was green for the streetcar, but the pedestrian stepped into the roadway outside the crosswalk.	10-22-03	0	Other

Table A-3. Summary NTD Pedestrian/LRT Data for 2003

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
Sac RT	Semi-exclusive right of way		Right of way/roadway: Other	Trespasser was between the rails as train approached. Trespasser made no attempt to clear the tracks and the train was unable to stop short of the impact.	3-21-03	1	Trespasser
San Diego	Exclusive right of way: At grade	No control device	Right of way/roadway: Other		3-13-03	1	Trespasser
San Diego	Semi-exclusive right of way	No control device	Right of way/roadway: Other	Eastbound Train #5 departed Harborside Station at 11:35PM on the Blue Line and reported observing an object between running rails. The T/O discovered blood and pieces of flesh. Trains emergency brakes were applied but the train was not able to stop short	8-02-03	1	Trespasser
LACMTA	Semi-exclusive right of way	Active Devices: Gates (no median barrier)	Right of way/roadway: Grade crossing	Northbound Train 12 was approaching 119th St grade crossing in coast mode, when an individual on a bicycle bolted past the flashing lights and bells on the grade crossing warning devices into the grade crossing.	01-08-03	0	Other
LACMTA	Semi-exclusive right of way	Active Devices: Gates (no median barrier)	Right of way/roadway: Grade crossing	Northbound Train 9 approaching Century Blvd. Crossing gates were down but a bicyclist went around them eastbound. Train Operator activated emergency braking and horn but unable to avoid contact.	2-12-03	1	Other
LACMTA	Semi-exclusive right of way	Active Devices: Traffic Signal	Right of way/roadway: Grade crossing	Northbound Train 8 gave audible warning prior to entering Long Beach Blvd intersection into Willow Station. Operator proceeded upon receipt of wayside "proceed" indication. Operator observed	3-14-03	0	Other

Table A-3. Summary NTD Pedestrian/LRT Data for 2003

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
				bicyclist moving across parking lot slowly, gave audible warning			
LACMTA	Semi-exclusive right of way		Revenue facility: Platform	Northbound train was approaching Firestone Station in full service braking when he noticed an individual lying between the running rails in a fetal position. Operator went into emergency braking but was unable to avoid contact.	4-15-03	0	Revenue Facility Occupants
LACMTA	Semi-exclusive right of way	Active Devices: Gates (median barrier)	Right of way/roadway: Grade crossing	Southbound Train 15 was approaching Imperial Pedestrian Crossing. Train Operator observed male pedestrian wearing headsets enter crossing. The pedestrian was not heeding or attentive to on-coming train. Train Operator applied emergency brakes and used both.	7-2-03	0	Revenue Facility Occupants

[1] The Event Descriptions were truncated in records obtained from the NTD.

Table A-4. Summary NTD Pedestrian/LRT Data for 2002

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
King County DOT	Non-Exclusive right of way: Mixed traffic/LRT	Active Devices: Traffic Signal	Right of way/roadway: Grade crossing	A pedestrian walked into the right front side of the passing streetcar proceeding through the intersection. The pedestrian sustained facial/head injures and was transported to the hospital.	5-9-02	0	Other
Tri-Met			Right of way/roadway: Grade crossing	As I approached SW 9th Avenue, I noticed a bicyclist on the sidewalk on the SE corner headed north. I started showing down as I was not sure if the bicyclist would stop. The bicyclist did stop. A second bicyclist coming from the same direction did not	6-16-02	0	Other
Tri-Met			Revenue facility : Platform	A person in a wheelchair made contact with the side of the train coming into platform WB. Witnesses said person was intoxicated. Was treated and released same day.	8-25-02	0	Other
MBTA			Right of way/roadway: Grade crossing	Bus diversion to allow maintenance crews to make track repairs. MOW crew on ROW as the KGT Boom Truck operator was attempting to place it on the track on a 5.7% grade level. As operator lowered the rear wheels the KGT started to free wheel down the gra	8-11-02	0	Employees
SEPTA			Right of way/roadway: Grade crossing	Trolley was traveling westbound when a pedestrian suddenly walked into path of trolley.	7-20-02	0	Trespassers

Table A-4. Summary NTD Pedestrian/LRT Data for 2002

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
SEPTA	Exclusive right of way: At grade	Active Devices: Traffic Signal	Right of way/roadway: Grade crossing	Discharged passenger claimed the operator brushed her arms when taking off. Mentor saw two ladies on the platform when operator pulled off, both ladies were standing..	9-23-02	0	
SEPTA	Exclusive right of way: At grade	Active Devices: Traffic Signal	Right of way/roadway: Grade crossing	Going through intersection, 3 people walking across not watching traffic. As I got close, I blew the horn, 3rd person never looked up and walked into the path of the trolley, trolley was put into emergency, stopped as contact was made.	10-17-02	0	
MD MTA	Non-Exclusive right of way: Mixed traffic/LRT	Active Devices: Traffic Signal	Right of way/roadway: Intersections	Pedestrian stepped of roadway median strip on MLK Blvd@Read street into a southbound train on ML1.	4-3-02	1	Other
MD MTA	Non-Exclusive right of way: Mixed traffic/LRT		Right of way/roadway: Intersections	Train 24 had lady walk into side of train	5-17-02	0	Other
MD MTA	Exclusive right of way: At grade		Right of way/roadway: Other	Dark area, trespasser	11-10-02	1	Trespassers
DART	Exclusive right of way: At grade	Active Devices: Gates (median	Right of way/roadway: Grade crossing	A pedestrian disregarded flashing light and bell at grade crossing.	1-23-02	0	Other

Table A-4. Summary NTD Pedestrian/LRT Data for 2002

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
		barrier)					
UTA	Shared track/corridor (LRT/FRA): Temporal separation	Active Devices: Gates (median barrier)	Right of way/roadway: Grade crossing	Northbound train (1005,1010,1007) struck a pedestrian walking Westbound across the main line tracks at 9400 South intersection (Grade Crossing) Gates, Lights, Bells were all operational at the time of incident.	1-4-02	1	Other
UTA	Non-Exclusive right of way: Mixed traffic/LRT	No control device	Right of way/roadway: Other	Train #1016B was arriving at the 900 East Station platform traveling at approximately 20 mph. An individual male (48 yr.) was walking across the street to get to the Light Rail station ("jay-walking). Operator observed the pedestrian walking in the far	11-3-02	1	Trespassers
VTA	Non-Exclusive right of way: Mixed traffic/LRT	Active Devices: Traffic Signal	Right of way/roadway: Intersections	Pedestrian was crossing against the red light and ran right in front of the train. He was struck by train at the right front corner at the right front headlight turn light/brake light assembly area of LRV. He received medical attention at the scene then w	8-20-02	1	Other
SF MUNI			Right of way/roadway: Grade crossing	Male walked in front of car and was struck as car started out.	2-9-02	0	
SF MUNI			Right of way/roadway: Intersections		3-9-02	0	
SF MUNI			Right of		4-1-02	0	

Table A-4. Summary NTD Pedestrian/LRT Data for 2002

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
			way/roadway: Grade crossing				
SF MUNI			Right of way/roadway: Other	alleged intoxicated pedestrian grabbed unto trunk of auto. As auto left scene, pedestrian fell from auto into path of the streetcar. Left front wheel of streetcar made contact with pedestrian resulting in severe injuries.	10-30-02	0	Other
SF MUNI	Non-Exclusive right of way: Mixed traffic/LRT		Other (specify in box below)	Pedestrian fell in the coupled area between the two cars of a two-car trains	11-16-02	1	Other
San Diego	Exclusive right of way: At grade	No control device	Right of way/roadway: Other	17 year old female jumped into the path of westbound Train #52 east of Amaya Station and the grade crossing. Trespasser sustained major injuries.	5-27-02	0	Trespassers
San Diego	Exclusive right of way: At grade	No control device	Right of way/roadway: Other	Approximately 182 feet west of the 47th Street Station, a white male adult walked out of the early morning darkness and into the path of the approaching eastbound train #51. The train operator applied the emergency brakes but was unable to stop before co	11-14-02	0	Trespassers
LACMTA	Semi-exclusive right of way	No control device	Other (specify in box below)	A Latin female patron walked into the side of moving northbound train. The operator was approaching Pico Station and passed the pedestrian crosswalk leading into the station. Witness statement indicates patron walked	2-11-02	0	Other

Table A-4. Summary NTD Pedestrian/LRT Data for 2002

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
				into the side of the train.			
LACMTA	Semi-exclusive right of way	Active Devices: Gates (no median barrier)	Right of way/roadway: Grade crossing	Train 9 was southbound and made contact with the head of a man who was bending over. The operator and the pedestrian were transported.	4-8-02	0	Employees
LACMTA	Semi-exclusive right of way	Active Devices: Gates (no median barrier)	Right of way/roadway: Grade crossing	Train 9 was southbound and made contact with the head of a man who was bending over. The operator and the pedestrian were transported.	4-8-02	0	Other
LACMTA	Semi-exclusive right of way	Active Devices: Gates (no median barrier)	Revenue facility: Platform	Northbound train departing Compton station sounding audible warning (gong) continuously. The train operator observed a previous passenger run in front of the train eastbound on the pedestrian crossing and then a female pedestrian looking northbound walk w	7-18-02	0	Other
LACMTA	Semi-exclusive right of way	Active Devices: Gates (no median barrier)	Revenue facility: Platform	Northbound train departing Compton station sounding audible warning (gong) continuously. The train operator observed a previous passenger run in front of the train eastbound on the pedestrian crossing and then a female pedestrian looking northbound walk w	7-18-02	0	Revenue Facility Occupants
LACMTA	Semi-exclusive	Active Devices:	Revenue facility: Other	Southbound Train 9 was approaching Artesia Station when two pedestrians enter	11-9-02	0	Revenue Facility

Table A-4. Summary NTD Pedestrian/LRT Data for 2002

Agency Name:	Alignment Type	Grade Crossing Control	Collision Location	Event Description [1]	Date	Fatality	Involved Party
	right of way	Flashing Lights	revenue facility (specify below)	the ped gates and went into braking. The male pedestrian ran across and the female pedestrian continued walking and her right calf was scraped by the train. She refused medical			Occupants
LACMTA	Semi-exclusive right of way	Active Devices: Traffic Signal	Right of way/roadway: Other	Southbound Train 17 on approach to berth at San Pedro Station hit a young female who ran in front of the train.	11-22-02	0	Trespassers
LACMTA	Semi-exclusive right of way	Active Devices: Traffic Signal	Right of way/roadway: Other	Southbound Train 17 on approach to berth at San Pedro Station hit a young female who ran in front of the train.	11-22-02	1	Other
LACMTA	Semi-exclusive right of way	Active Devices: Flashing Lights	Right of way/roadway: Grade crossing	Southbound Train 5 was braking as it approached Artesia Station and the Ped Crossing. A female pedestrian wearing headsets and reading a newspaper entered the pedestrian crossing. The train went into emergency braking, sounding the horn, pedestrian looked	12-23-02	0	Revenue Facility Occupants

[1] The Event Descriptions were truncated in records obtained from the NTD.

Table A-5. Summary of Pedestrian/LRT Accidents between 1997 and 2001

	1997		1998		1999		2000		2001	
Agency	**Accidents**	**Fatal**	**Accidents**	**Fatal**	**Accidents**	**Fatal**	**Accidents**	**Fatal**	**Accidents**	**Fatal**
City of Detroit DOT	--	--	--	--	--	--	--	--	0	0
Cleveland-RTA	0	0	1	0	1	0	1	0	0	0
Dallas Area Rapid Transit	2	0	2	0	1	0	0	0	1	0
Denver-RTD	5	0	2	0	0	0	5	3	0	0
Kenosha Transit	--	--	--	--	--	--	0	0	0	0
King County DOT	0	0	0	0	0	0	0	0	0	0
Los Angeles County MTA	8	2	3	4	4	2	9	1	7	1
Maryland MTA	5	0	10	0	8	0	5	2	4	4
Mass. Bay Transp. Auth.	7	0	7	0	8	0	10	0	10	0
Memphis Area TA	0	0	0	0	0	0	0	0	0	0
New Jersey Transit	1	0	0	0	0	0	1	0	0	0
New Orleans-RTA	0	0	0	0	0	0	0	0	NR	NR
Niagara Frontier Trans.	0	0	0	0	1	0	0	0	0	0
Pittsburg Transit	0	0	1	1	2	0	2	0	2	0
Portland Tri-Met	3	0	3	0	7	3	4	2	2	0
Sacramento RT	0	0	2	0	4	0	2	0	4	1
San Diego	NR	NR	4	4	4	1	1	0	3	1
San Francisco MUNI	6	0	9	1	7	0	12	1	6	2
Santa Clara VTA	1	0	4	0	3	0	2	1	3	1
SE Pennsylvania Trans.	8	1	7	1	4	0	7	2	10	1
St. Louis Bi-State Dev.	0	0	1	0	0	0	1	0	1	0
Utah Transit Authority	--	--	--	--	--	--	1	1	0	0
Sum	46	3	56	11	54	6	63	13	53	11

-- indicates the LRT system was not operating during this year and NR indicates the agency did Not Report any accident data

ANNEX B: MAPS OF THE LA METRO, VTA, AND SAN DIEGO SYSTEMS

Figure A-1. Map of the LA Metro Rail System

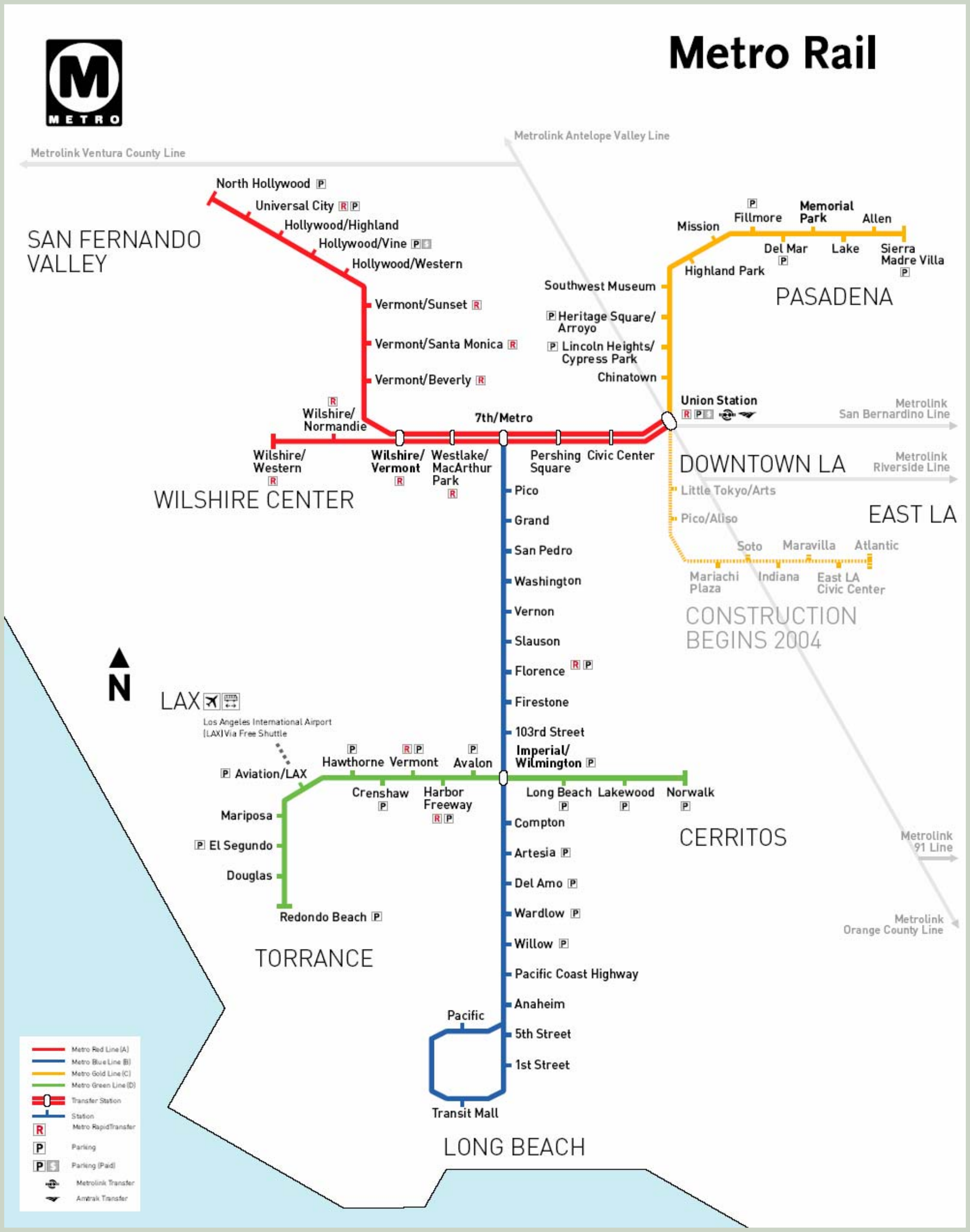
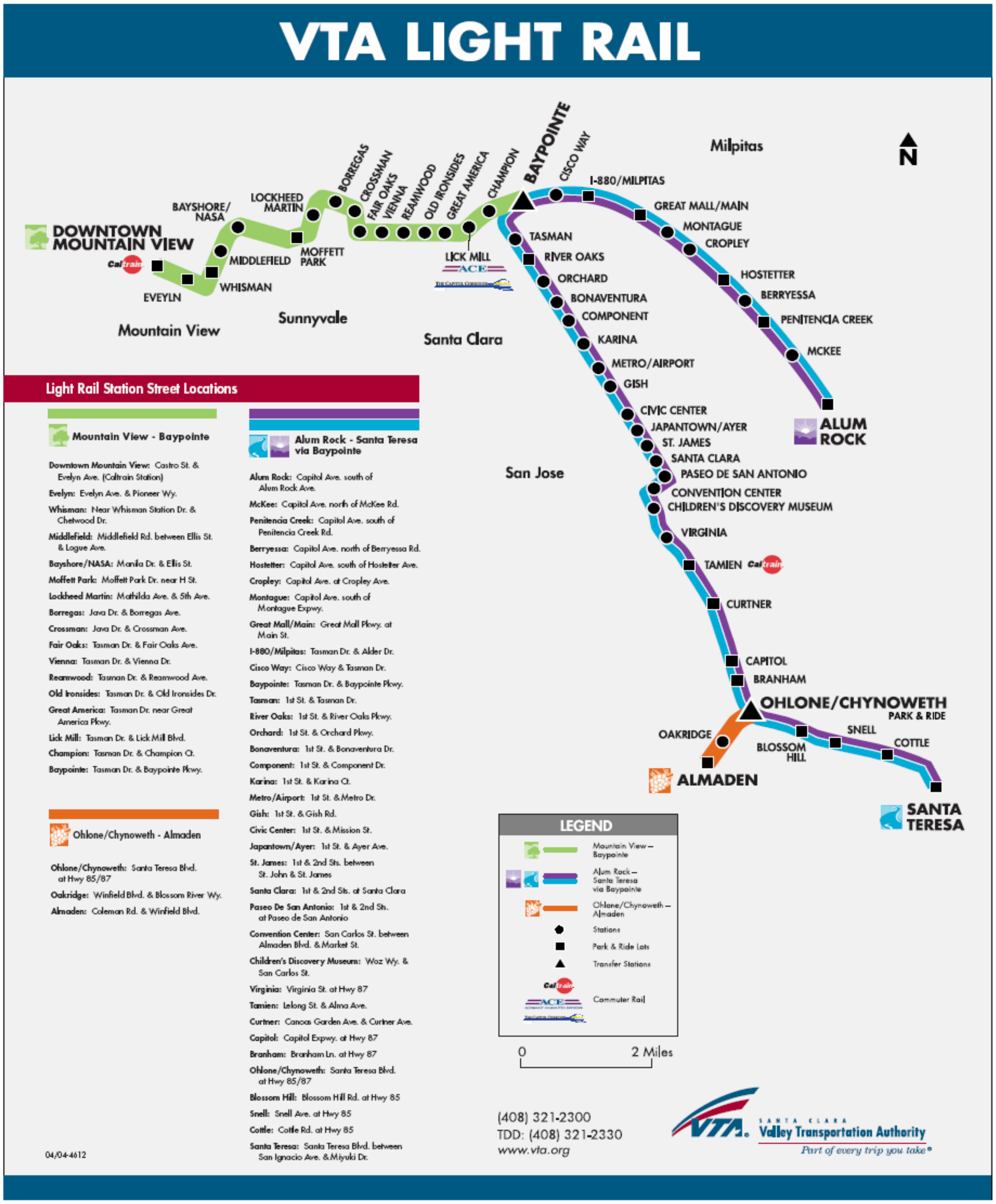


Figure A-2. Map of the VTA Light Rail System



Light Rail Station Street Locations

Mountain View - Baypointe

Downtown Mountain View: Castro St. & Evelyn Ave. (Caltrain Station)
Evelyn: Evelyn Ave. & Pioneer Wy.
Whisman: Near Whisman Station Dr. & Chetwood Dr.
Middlefield: Middlefield Rd. between Ellis St. & Logue Ave.
Bayshore/NASA: Manila Dr. & Ellis St.
Moffett Park: Moffett Park Dr. near H St.
Lockheed Martin: Mathilda Ave. & 5th Ave.
Borregas: Java Dr. & Borregas Ave.
Crossman: Java Dr. & Crossman Ave.
Fair Oaks: Tasman Dr. & Fair Oaks Ave.
Vienna: Tasman Dr. & Vienna Dr.
Reamwood: Tasman Dr. & Reamwood Ave.
Old Ironsides: Tasman Dr. & Old Ironsides Dr.
Great America: Tasman Dr. near Great America Pkwy.
Lick Mill: Tasman Dr. & Lick Mill Blvd.
Champion: Tasman Dr. & Champion Ct.
Baypointe: Tasman Dr. & Baypointe Pkwy.

Ohlone/Chynoweth - Almaden

Ohlone/Chynoweth: Santa Teresa Blvd. at Hwy 85/87
Oakridge: Winfield Blvd. & Blossom River Wy.
Almaden: Coleman Rd. & Winfield Blvd.

Alum Rock - Santa Teresa via Baypointe

Alum Rock: Capitol Ave. south of Alum Rock Ave.
McKee: Capitol Ave. north of McKee Rd.
Penitencia Creek: Capitol Ave. south of Penitencia Creek Rd.
Berryessa: Capitol Ave. north of Berryessa Rd.
Hostetter: Capitol Ave. south of Hostetter Ave.
Cropley: Capitol Ave. at Cropley Ave.
Montague: Capitol Ave. south of Montague Expwy.
Great Mall/Main: Great Mall Pkwy. at Main St.
I-880/Milpitas: Tasman Dr. & Alder Dr.
Cisco Way: Cisco Way & Tasman Dr.
Baypointe: Tasman Dr. & Baypointe Pkwy.
Tasman: 1st St. & Tasman Dr.
River Oaks: 1st St. & River Oaks Pkwy.
Orchard: 1st St. & Orchard Pkwy.
Bonaventura: 1st St. & Bonaventura Dr.
Component: 1st St. & Component Dr.
Karina: 1st St. & Karina Ct.
Metro/Airport: 1st St. & Metro Dr.
Gish: 1st St. & Gish Rd.
Civic Center: 1st St. & Mission St.
Japantown/Ayer: 1st St. & Ayer Ave.
St. James: 1st & 2nd Sts. between St. John & St. James
Santa Clara: 1st & 2nd Sts. at Santa Clara
Paseo De San Antonio: 1st & 2nd Sts. at Paseo de San Antonio
Convention Center: San Carlos St. between Almaden Blvd. & Market St.
Children's Discovery Museum: Woz Wy. & San Carlos St.
Virginia: Virginia St. at Hwy 87
Tamien: Lelong St. & Alma Ave.
Curtner: Canoas Garden Ave. & Curtner Ave.
Capitol: Capitol Expwy. at Hwy 87
Branham: Branham Ln. at Hwy 87
Ohlone/Chynoweth: Santa Teresa Blvd. at Hwy 85/87
Blossom Hill: Blossom Hill Rd. at Hwy 85
Snell: Snell Ave. at Hwy 85
Cottle: Cottle Rd. at Hwy 85
Santa Teresa: Santa Teresa Blvd. between San Ignacio Ave. & Miyuki Dr.

Figure A-3. Map of the San Diego Trolley System

APPENDIX C-2

REVIEW OF ACCIDENT DATA (Prepared September 2004)

INTRODUCTION AND SUMMARY

This report is an addendum to Task 3: Evaluation of the Effectiveness of Audible Devices Based on Historical Data for TCRP Project D-10: Audible Signals for Pedestrian Safety in LRT Environments. For this addendum, the KORVE Team gathered and analyzed additional accident data from the National Transit Database (NTD) relative to pedestrian accidents at grade crossings and performed supplementary statistical analyses of this data.

Because of the differences in the reporting thresholds and parameters, the previous statistical analysis was based on total pedestrian/LRT incidents over a two-year period (2002 and 2003).[10,11] The supplementary analysis reported herein incorporates accident data from the periods 1997 through 2001 and limits the data to pedestrian/LRT incidents at grade crossings. The goal of the supplemental analysis is to determine whether the additional data and narrowed focus improves the predictability of pedestrian/LRT incidents based on key operational variables that relate to grade crossings. Three operating variables tested in this analysis are at-grade track miles, number of grade crossings, and total track miles.

The primary conclusions are that:

- The additional data greatly increased the number of observations (146). However, the total number of pedestrian/LRT incidents at grade crossings over a 7 year period for 23 LRT systems is very low (52).
- The relationships between pedestrian/LRT accidents at grade crossing and operating variables are clearer when using the average annual values rather than the data from each LRT system for each year (i.e. all 146 incidents as a separate observation).
- When all the LRT systems are included, there is a statistically significant relationship (T-statistic greater than 2) between pedestrian/LRT incidents at grade crossings and total track miles. However, the overall predictive power of this variable (as measured by the R-Squared value) is very weak. The relationships between pedestrian/LRT incidents and at-grade track miles and pedestrian/LRT incidents and the number of grade crossings are not statistically significant.
- When one outlier is excluded for the data, there is a statistically significant relationship between pedestrian/LRT incidents and at-grade track miles, number of grade crossings, and total track miles. The predictive power also increases substantially.
- Overall, the relatively low predictive power is due to the low number of accidents and the wide variation in operating variables.

METHODOLOGY

Accident Data

For the five year period between 1997 and 2001, the NTD data was already separated between incidents with people, vehicles, and objects. From this data we isolated the “Total Collisions with People” and the “Total Collisions with People at Grade Crossings.” Next, the incidents with “Patrons” and “Employees” were removed, leaving only those pedestrian incidents at grade crossings.

For the sequent two years (2002 and 2003), the data was in a different format. The first step was to identify and remove those accidents that didn’t involve “Trespassers”, “Patrons”, “Employees”, or “Occupants” (refer to the NTD for formal definitions for each of these categories). The residual incidents were assumed to involve pedestrians. From this subset of data, we extracted those pedestrian/LRT incidents that occurred at grade crossings.

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[10] Excluding suicides.

[11] Please refer to the Task 3 report for a detailed discussion regarding the differences in reporting thresholds.

Figure 14 is a histogram showing the distribution of the average number of annual pedestrian/LRT incidents at grade crossings. As can be seen, 18 of the 23 LRT systems reported, on average, less than one incident per year between 1997 and 2003. Figure 15 is a graph showing the total number of pedestrian/LRT incidents at grade crossings per year and the average number per year for all LRT systems. More detailed information is included in Table 27 at the end of this report.

Figure 14. Histogram of Average Annual Pedestrian/LRT Incidents at Grade Crossings

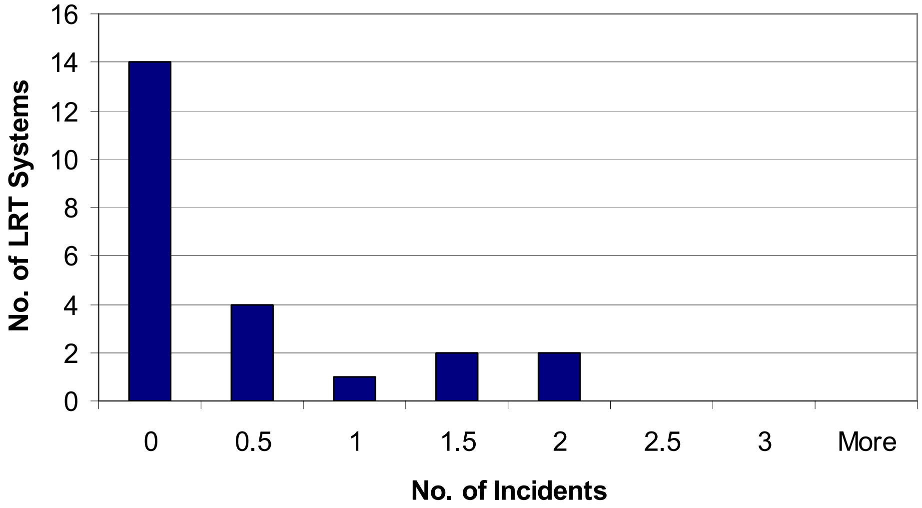
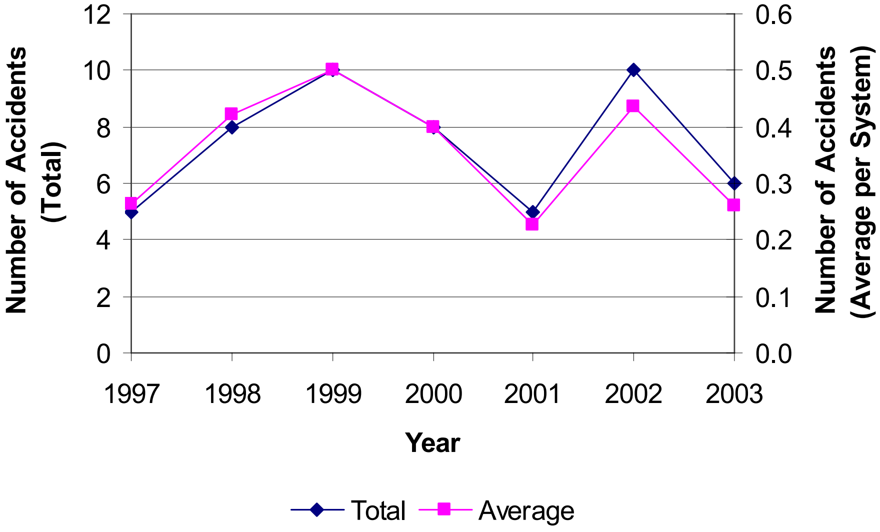


Figure 15. Pedestrian/LRT Incidents at Grade Crossings



Operational Data

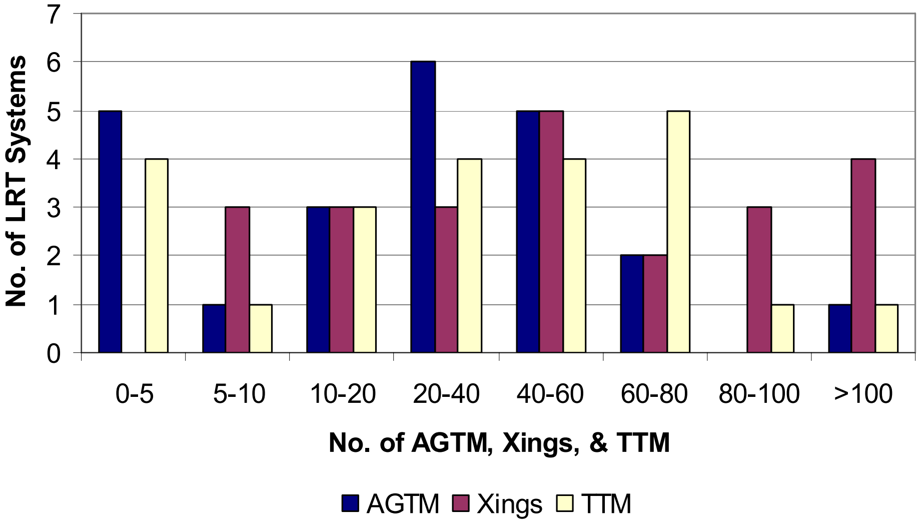
In order to perform a statistical analysis on the pedestrian/LRT incidents at grade crossings for the seven year period from 1997 and 2003, operational data common to both reporting periods (1997-2001 and 2002-2003) was required. In addition, to focus on pedestrian/LRT incidents at grade crossings, the data needed to be relevant to at-grade track and grade crossings. The following data were tabulated for each of the seven years:

- Total Track Miles
- Total At-Grade Track Miles

- Total Number of Grade Crossings

Figure 16 shows the distribution of the operational parameters listed above. These are average values for the period of time each agency reported to the NTD between 1997 and 2003. As can be seen, there is a wide variation in the number of at-grade track miles (AGTM), grade crossings (Xings), and of total track miles (TTM).

Figure 16. Histogram Showing the Breakdown of Operational Parameters



Statistical Analysis

Single-variable and multi-variable linear regressions were run on the total number of pedestrian/LRT incidents and grade crossings (dependent variable) and the at-grade track miles, the number of grade crossings, and the total track miles (dependent variables). Because of the low number of incidents, separate analyses were not run on fatalities or injuries.

Table 17 through Table 20 show the results of the various regressions. Table 17 and Table 18 are based on the average annual pedestrian/LRT incidents at grade crossings and the average annual operational parameters. Table 17 tests each variable independently whereas Table 18 is a multi-variable regression testing all three variables together. Table 19 and Table 20 include the accident data for each system for each of the seven years reported between 1997 and 2003. As can be seen, the multi-variable regressions add little value to the analysis.

Table 17. Regression Results – Individual Variables Using Average Annual Values

		F-Statistic		
	R-Squared	**Value**	**Significance**	**T-Stat**
AGTM	0.07	1.57	0.22	1.25
Xings	0.00	0.00	1.00	0.00
TTM	0.17	4.40	0.05	2.10

Table 18. Regression Results – All Variables Using Average Annual Values

	R-Squared	F-Statistic	T-Stat

		Value	Significance	
Total	0.45	5.27	0.01	
AGTM				-1.10
Xings				-1.55
TTM				2.63

Table 19. Regression Results – Individual Variables Using All Data

		F-Statistic		
	R-Squared	Value	Significance	T-Stat
AGTM	0.02	2.4	0.1	1.5
Xings	0.00	0.0	1.0	0.1
TTM	0.05	7.2	0.0	2.7

Table 20. Regression Results – Individual Variables Using All Data

		F-Statistic		
	R-Squared	Value	Significance	T-Stat
Total	0.13	7.21	0.00	
AGTM				-1.95
Xings				-1.27
TTM				3.58

In terms of outliers, one agency reports a substantially higher number of at-grade track miles, grade crossings, and total track miles. Eliminating that agency from the analysis improves the R-Squared and the T-Statistic for all three single-variable regressions. As a result, the T-Statistic is now statistically significant for at-grade track miles and number of crossings. In terms of the multi-variable regression, although R-Squared increases from 0.45 to 0.50, only the total track miles is statistically significant. Table 21 is a summary of the modified regression results using the annual average values. Figure 17, Figure 18, and Figure 19 are graphs showing the best-fit line for the annual average pedestrian/LRT incidents at grade crossings based on the regression for at-grade track miles, number of grade crossings, and total track miles, respectively (excluding the outlier). Table 22 lists the equations for the best-fit lines shown in these graphs.

Table 21. Regression Results – Individual Variables Using Average Annual Values (excluding outlier)

		F-Statistic		
	R-Squared	Value	Significance	T-Stat
AGTM	0.30	8.67	0.01	2.95
Xings	0.18	4.44	0.05	2.11
TTM	0.45	16.51	0.00	4.06

Figure 17. Best-Fit Line for Average Annual Pedestrian/LRT Incidents at Grade Crossings and At-Grade Track Miles

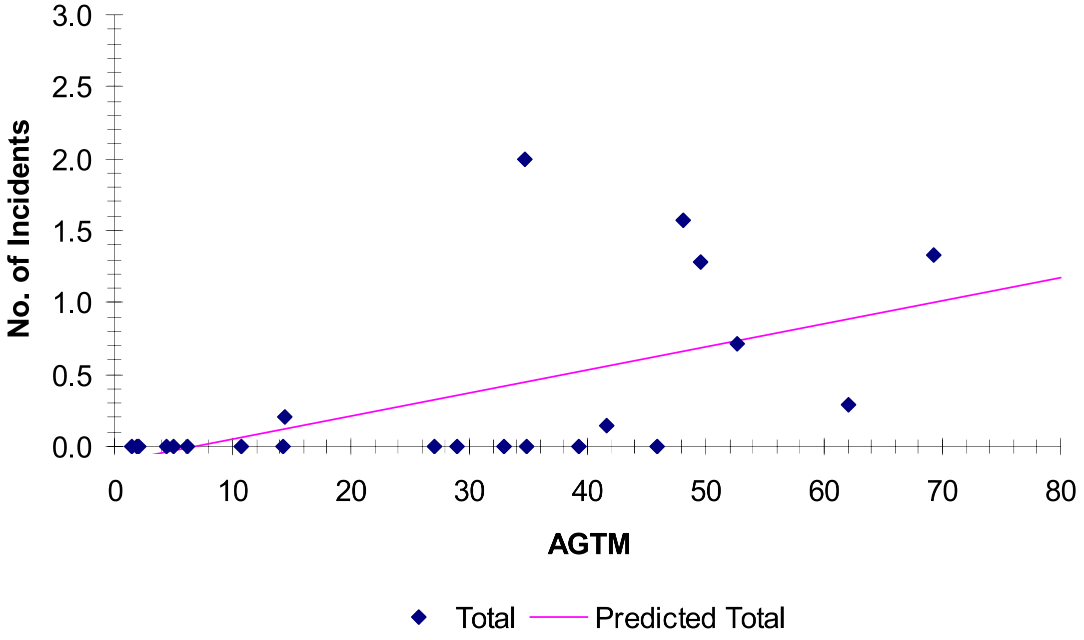


Figure 18. Best Fit Line for Average Annual Pedestrian/LRT Incidents at Grade Crossings and the Number of Grade Crossings

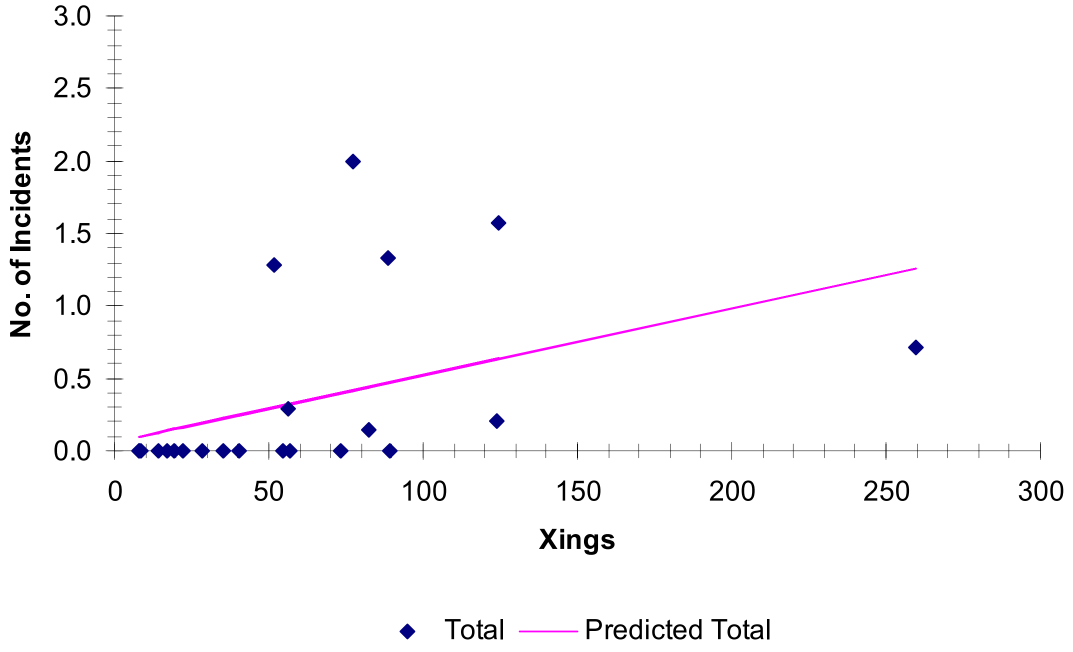


Figure 19. Best Fit Line for Average Annual Pedestrian/LRT Incidents at Grade Crossings and the Number of Total Track Miles

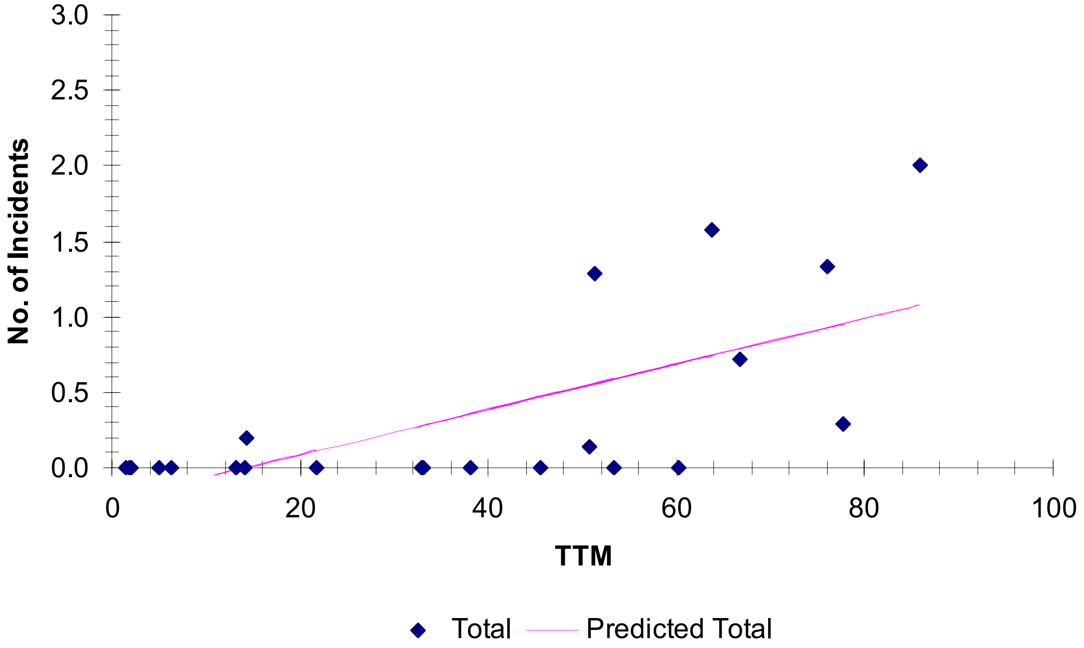


Table 22. Regression Equations for Best Fit Lines

	Slope	Intercept
AGTM	0.016	-0.115
Xings	0.005	0.062
TTM	0.015	-0.214

Table 23 is a summary of the regression results excluding the outlier and using all the remaining data. Again, the R-squared, F-Statistic, and T-Statistic improve when the outlier data is removed. Although the T-Statistic is now significant for all three variables (whereas previously it was only statistically significant for total track miles), the predictive power is very low (R-Squared less than 0.15).

Table 23. Regression Results – Individual Variables Using All Data (excluding outlier)

		F-Statistic		
	R-Squared	Value	Significance	T-Stat
AGTM	0.08	11.4	0.00	3.4
Xings	0.09	12.8	0.00	3.6
TTM	0.13	20.0	0.00	4.5

CONCLUSIONS

When LRT Systems are Included:

- R-Squared values are very low.
- T-Statistics for total track miles is significant.
- T-Statistics for at-grade track miles and number of grade crossings are not significant.
- Annual average values are better predictors than using all the data.

When the Outlier is excluded:

- R-Squared values, F-Statistics, and T-Statistics increase.
- T-Statistics for all three variables are statistically significant.
- Annual average values are better predictors than using all the data.

Other Notes

A panel member requested that a chi-squared analysis be performed on the accident data for the two year period from 2002 and 2003 originally reported in the Task 3 report. However, this is no longer required as the number of years has been expanded to seven, which increases the sample size and therefore eliminates the need for the chi-squared analysis.

Table 24. Number of At-Grade Track Miles per LRT System by Year (1997-2003)

				Year				
System	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**Average**
Baltimore-Maryland-MTA	49	49	49	49	49	50	50	49.6
Boston-MBTA	67	67	60	60	60	60	60	62.0
Buffalo-NFTA	4	4	4	4	4	4	4	4.4
City of Detroit DOT	--	--	--	--	2	1	1	1.4
Cleveland-RTA	27	27	27	27	27	27	27	27.0
Dallas-DART	34	34	34	34	40	66	79	45.9
Denver-RTD	10	10	10	16	16	20	20	14.3
Galveston-Island Transit	5	5	--	--	5	5	5	4.9
Kenosha Transit	--	--	--	2	2	2	2	1.9
King County DOT	2	2	2	2	2	2	2	2.1
LACMTA-Metro	35	35	35	35	35	35	35	34.7
Memphis-MATA	7	7	6	6	6	6	6	6.2
New Jersey Transit-NJT	6	6	6	6	6	26	20	10.7
New Orleans-RTA	14	14	14	14	14	16	16	14.4
Philadelphia-SEPTA	167	167	167	167	167	167	167	166.7
Pittsburgh-PATH	40	40	40	39	39	39	39	39.2
Portland-Tri-Met	24	24	55	55	55	62	62	48.0
Sacramento-RTD	31	31	36	36	36	36	37	34.8
San Diego Trolley-SDTI	44	44	44	88	88	88	88	69.3
San Francisco-Muni	41	41	56	55	58	59	58	52.7
Santa Clara Valley-VTA	32	32	32	47	49	49	49	41.6
St. Louis-Bi-State	15	15	15	15	45	45	51	28.9
Utah Transit Authority-UTA	--	--	30	30	34	34	37	33.0
Average per LRT System	33	33	36	37	36	39	40	35

Note: Systems not reporting are listed as “--"

Table 25. Number of Grade Crossings per LRT System by Year (1997-2003)

	Year							
System	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**Average**
Baltimore-Maryland-MTA	50	50	52	52	52	52	52	51.4
Boston-MBTA	56	56	56	56	56	56	56	56.0
Buffalo-NFTA	8	8	8	8	8	8	8	8.0
City of Detroit DOT	--	--	--	--	8	8	8	8.0
Cleveland-RTA	22	22	22	22	22	22	22	22.0
Dallas-DART	66	66	66	66	68	83	98	73.3
Denver-RTD	34	34	34	34	34	39	39	35.4
Galveston-Island Transit	57	57	--	--	57	57	57	57.0
Kenosha Transit	--	--	--	14	26	19	19	19.5
King County DOT	14	14	14	14	14	14	14	14.0
LACMTA-Metro	77	77	77	77	77	77	77	77.0
Memphis-MATA	40	40	40	40	40	0	0	28.6
New Jersey Transit-NJT	1	1	1	1	1	27	26	8.3
New Orleans-RTA	124	124	124	124	124	124	124	124.0
Philadelphia-SEPTA	1702	1702	1702	1702	1702	1702	1702	1702.0
Pittsburgh-PATH	42	42	42	39	39	39	39	40.3
Portland-Tri-Met	74	74	111	111	111	196	196	124.7
Sacramento-RTD	86	86	90	90	90	90	93	89.3
San Diego Trolley-SDTI	70	70	96	96	96	96	96	88.6
San Francisco-Muni	191	191	191	191	351	351	351	259.6
Santa Clara Valley-VTA	64	64	64	93	97	97	97	82.3
St. Louis-Bi-State	12	12	12	12	23	23	24	16.9
Utah Transit Authority-UTA	--	--	46	46	59	65	58	54.8
Average per LRT System	140	140	142	138	137	141	142	132

Note: Systems not reporting are listed as “--"

Table 26. Number of Total Track Miles by LRT System per Year

				Year				
System	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**Average**
Baltimore-Maryland-MTA	50.9	50.9	50.9	50.9	50.9	52	52	51.2
Boston-MBTA	77.5	77.5	77.5	77.5	77.5	78	78	77.6
Buffalo-NFTA	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1
City of Detroit DOT	--	--	--	--	1.6	1.3	1.3	1.4
Cleveland-RTA	33	33	33	33	33	33	33	33.0
Dallas-DART	46.7	46.7	46.7	46.7	53	83	98.4	60.2
Denver-RTD	10.3	10.3	10.3	28.5	28.5	32.1	32.1	21.7
Galveston-Island Transit	4.9	4.9	--	--	4.9	5	5	4.9
Kenosha Transit	--	--	--	1.9	1.9	1.9	1.9	1.9
King County DOT	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
LACMTA-Metro	85.8	85.8	85.8	85.7	85.7	87	85.7	85.9
Memphis-MATA	6.6	6.6	6.1	6.1	6.1	6.1	6.1	6.2
New Jersey Transit-NJT	8.3	8.3	8.3	8.3	8.3	29	21.3	13.1
New Orleans-RTA	13.7	13.7	13.7	13.7	13.7	16	16	14.4
Philadelphia-SEPTA	171	171	171	171	171	171	171	171.0
Pittsburgh-PATH	46.5	46.5	46.5	44.8	44.8	44.8	44.8	45.5
Portland-Tri-Met	34.4	34.4	71.9	71.9	71.9	81	81.3	63.8
Sacramento-RTD	34	34	39.4	39.4	39.4	39.4	40.7	38.0
San Diego Trolley-SDTI	48.3	48.3	48.3	96.6	96.6	96.6	97	76.0
San Francisco-Muni	54.2	54.2	69	70	73.3	74	72.9	66.8
Santa Clara Valley-VTA	41.1	41.1	41.1	56.3	58.9	58	58.9	50.8
St. Louis-Bi-State	36.2	36.2	36.2	36.2	73.5	74	81	53.3
Utah Transit Authority-UTA	--	--	29.6	29.6	34.2	34.2	37.3	33.0
Average per LRT System	41	41	45	47	45	48	49	43

Note: Systems not reporting are listed as “--"

Table 27. Number of Collisions with People at Grade Crossings by LRT System per Year (1997-2003)

System	1997	1998	1999	Year 2000	2001	2002	2003	Grand Total	Average
Baltimore-Maryland-MTA	0	0	0	7	0	2	0	9	1.3
Boston-MBTA	0	0	0	0	2	0	0	2	0.3
Buffalo-NFTA	0	0	0	0	0	0	0	0	0.0
City of Detroit DOT	--	--	--	--	0	0	0	0	0.0
Cleveland-RTA	0	0	0	0	0	0	0	0	0.0
Dallas-DART	0	0	0	0	0	0	0	0	0.0
Denver-RTD	0	0	0	0	0	0	0	0	0.0
Galveston-Island Transit	0	--	--	--	0	0	0	0	0.0
Kenosha Transit	--	--	--	0	0	0	0	0	0.0
King County DOT	0	0	0	0	0	0	0	0	0.0
LACMTA-Metro	2	4	4	1	0	3	0	14	2.0
Memphis-MATA	0	0	0	0	0	0	0	0	0.0
New Jersey Transit-NJT	0	0	0	0	0	0	0	0	0.0
New Orleans-RTA	0	0	1	--	--	0	0	1	0.2
Philadelphia-SEPTA	1	0	0	0	0	0	0	1	0.1
Pittsburgh-PATH	0	0	0	0	0	0	0	0	0.0
Portland-Tri-Met	2	0	4	0	0	1	4	11	1.6
Sacramento-RTD	0	0	0	0	0	0	0	0	0.0
San Diego Trolley-SDTI	--	4	1	0	3	0	0	8	1.3
San Francisco-Muni	0	0	0	0	0	3	2	5	0.7
Santa Clara Valley-VTA	0	0	0	0	0	1	0	1	0.1
St. Louis-Bi-State	0	0	0	0	0	0	0	0	0.0
Utah Transit Authority-UTA	--	--	0	0	0	0	0	0	0.0
Total per Year	5	8	10	8	5	10	6	52	--
Average per LRT System	0.3	0.4	0.5	0.4	0.2	0.4	0.3	--	0.3

Note: Systems not reporting are listed as “--"

Table 28. Summary of Average Annual Operating Parameters and Pedestrian/LRT Incidents

					Collisions with Pedestrians				
						At Grade Crossings			
	Average Yearly				Average		Average Yearly		
System	AGTM	Xings	TTM	% AG [1]	Yearly [2]	Total [3]	Total [4]	Fatalities	Injuries
City of Detroit DOT	1.4	8	1.4	100%	0.0	0	0.0	0.0	0.0
Kenosha Transit	1.9	20	1.9	100%	0.0	0	0.0	0.0	0.0
King County DOT	2.1	14	2.1	100%	0.1	0	0.0	0.0	0.0
Buffalo-NFTA	4.4	8	14.1	31%	0.3	0	0.0	0.0	0.0
Galveston-Island Transit	4.9	57	4.9	100%	0.0	0	0.0	0.0	0.0
Memphis-MATA	6.2	29	6.2	100%	0.0	0	0.0	0.0	0.0
New Jersey Transit-NJT	10.7	8	13.1	82%	0.0	0	0.0	0.0	0.0
Denver-RTD	14.3	35	21.7	66%	0.7	0	0.0	0.0	0.0
New Orleans-RTA	14.4	124	14.4	100%	0.2	1	0.2	0.0	0.2
Cleveland-RTA	27.0	22	33.0	82%	0.0	0	0.0	0.0	0.0
St. Louis-Bi-State	28.9	17	53.3	54%	0.4	0	0.0	0.0	0.0
Utah Transit Authority-UTA	33.0	55	33.0	100%	0.2	0	0.0	0.0	0.0
LACMTA-Metro	34.7	77	85.9	40%	5.0	14	2.0	1.6	0.4
Sacramento-RTD	34.8	89	38.0	92%	0.7	0	0.0	0.0	0.0
Pittsburgh-PATH	39.2	40	45.5	86%	0.3	0	0.0	0.0	0.0
Santa Clara Valley-VTA	41.6	82	50.8	82%	0.9	1	0.1	0.0	0.1
Dallas-DART	45.9	73	60.2	76%	0.3	0	0.0	0.0	0.0
Portland-Tri-Met	48.0	125	63.8	75%	2.1	11	1.6	0.9	0.7
Baltimore-Maryland-MTA	49.6	51	51.2	97%	2.1	9	1.3	0.4	0.9
San Francisco-Muni	52.7	260	66.8	79%	5.7	5	0.7	0.6	0.1
Boston-MBTA	62.0	56	77.6	80%	5.9	2	0.3	0.0	0.3
San Diego Trolley-SDTI	69.3	89	76.0	91%	1.3	8	1.3	1.0	0.3
Philadelphia-SEPTA	166.7	1702	171.0	97%	4.4	1	0.1	0.1	0.0

[1] Percent of System At-Grade (AGTM/TTM).

[2] Average Yearly Pedestrian/LRT incidents.

[3] Total Pedestrian/LRT incidents at grade crossings between 1997 and 2003.

[4] Average Yearly Pedestrian/LRT incidents – at grade.

Appendix D

Field Test Report (Prepared February 2007)

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FIELD TEST

This report outlines the results of the Task 10 Field Test portion for the TCRP D-10 project entitled "Audible Signals for Pedestrian Safety in LRT Environments." The field test included behavioral observations, a visually impaired field survey, and a public survey of two alternative audible warnings. Each audible warning was tested with and without a visual device and compared to the base case (existing) conditions at the crossing. The field test was located in downtown Salt Lake City, Utah at 50 South Main Street where both of Utah Transit Authority (UTA) light rail lines cross the crossing.

The purpose of the field test was to determine if a new audible warning or a bell warning at pedestrian/rail crossings would improve pedestrian safety. Since occurrences of pedestrian/light rail vehicle accidents are rare the potential safety improvement was measured by observing changes in risky behavior.

First, the background that led to the field test will be provided. The base conditions of the study area will then be discussed followed by the alternatives to be tested. The field tests conducted will then be discussed along with the results. Finally, conclusions will be provided with a summary of the overall results.

BACKGROUND

The scope of this project was to consider the development of an alternative audible warning. To this end, the auditory engineer developed and tested a unique sound in a research laboratory. Based on the laboratory results two warnings were selected for field testing: the conventional bell and the unique "blended staircase" signals.

The unique "blended staircase" consists of two components: the familiar sound of an approaching train and a conventional crossing bell processed through a pitch-shifting algorithm. This unique audible warning was designed such that a pedestrian approaching a grade crossing successively hears both a bell-like sound of rising pitch and an approaching train of increasing loudness. This auditory icon provides more information for the same degree of annoyance. The unique sound and bell signal were evaluated and compared in the field trial in Salt Lake City. Prior research (Fidell, 1978; Fidell *et al.*, 1979; Sneddon *et al.*, 2004) has demonstrated that sounds of equal audibility, regardless of aversiveness, are equally effective in attracting attention for warning purposes. A description and the results of the field tests are provided in the remainder of this report.

BASE CASE CONDITIONS

This mid-block crossing is located immediately north of the City Center TRAX Station between two downtown malls. The City Center TRAX Station is one of UTA's busiest stations. This location was selected because of the relatively high number of pedestrian/LRV conflicts. The area has pedestrian activity throughout the day.

The base conditions included audible pedestrian signals in conjunction with pedestrian heads with countdown timers on each side of the crossing. The pedestrian signal stays in the WALK position and turns to DON'T WALK only when an automobile or LRV approaches. Stenciled markings on the pavement that state, "Look Both Ways," are located at each end of the crosswalk, as is common practice in the downtown Salk Lake City area

The base conditions do not include an automated audible LRV crossing warning. There are several non-automated warnings. First, northbound trains stop at the City Center TRAX Station immediately before the pedestrian crossing. Before leaving the station and entering the pedestrian crossing the train operator will sound a gong twice. Second, southbound trains pass through the pedestrian crossing before stopping at the City Center TRAX Station. Trains will gong if a pedestrian is in the train's path or near the tracks. Also, according to UTA's TRAX Rule Book, in the case where a train is already at a station and a second train approaches the arriving train must reduce its speed to 10 mph and sound the gong continuously until the front of the train has safely cleared the rear of the other train (UTA rule 4.24). The operators first use the gong, and if the situation necessitates it, then they will use the louder horn. The horn may be sounded by the operator as a warning whenever an unsafe or emergency condition exists.

TESTED ALTERNATIVES

Three components of the field test were performed consisting of:

- Behavioral observations, which were video taped, and then scored and analyzed;
- A survey of visually impaired pedestrians; and
- A public survey.

This section provides the general setup under which the three tests were performed. The mid-block crosswalk is shown in plan view along with photos of the existing (base case) condition in Figure 1.

The Audible Pedestrian Signal DS-200 Series manufactured by Novax Industrial Corporation were installed by Salt Lake City staff, and Siemens ITS programmed the device into the existing signal system. The speakers for the audible warning were located in two new pedestrian heads (one on each side of the crossing) that were mounted next to the existing pedestrian heads with countdown timers. The typical pedestrian face plates were replaced with a yellow activated LRT sign (W10-7). This visual sign was programmed to turn on and remain on constantly for the duration of the audible warning in the scenarios when the visual sign was used. The new activated LRT sign is shown in Figure 2 next to the existing pedestrian head with a countdown timer.

In addition to the base case four treatment scenarios were explored:

- Conventional bell without the visual sign,
- Conventional bell with the visual sign,
- Unique sound without the visual sign, and
- Unique sound with the visual sign.

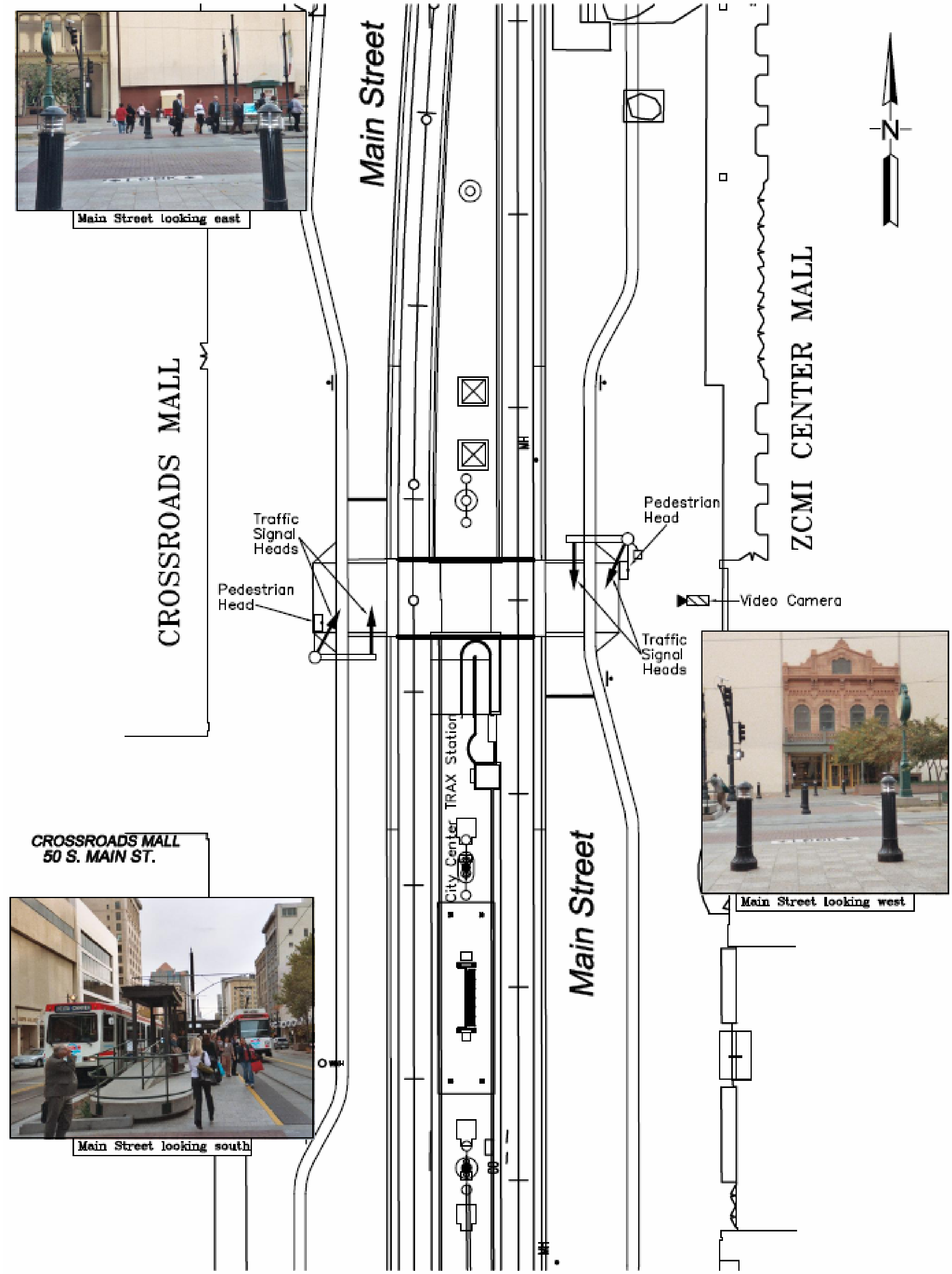

Figure 1 D-10 Field Test Plan Main Street Crosswalk

Figure 2 Visual train warning sign

The conventional bell stays at the same pitch and is currently used at train crossings with automatic gates across the country including in the Salt Lake City area. The unique sound is the “blended staircase” discussed in the background section of this report.

The visual impaired field survey did not consider the “with the visual sign” scenarios. However, a base case scenario, “Normal”, was added where only on-vehicle audible warnings were given as discussed in the base case conditions section of this report.

FIELD OBSERVATIONS

The observation test was completed by video taping pedestrian behavior at the LRT crossing. This provided a direct measure of the effects of each device on pedestrian behavior. At the proposed test site there are often groups of people crossing together and it would be difficult to collect some data such as the latency between the start of the audible device and specific pedestrian behaviors in real time. A fixed camera proved better for scoring latency because of the time code feature in the camera. Also from a video tape it was easier to score the behavior of individuals that are part of a large group, and provided an accurate record of all the data that was collected.

Data was collected by video taping the crossing for three, eight-hour periods for each of the five test scenarios. Korve supervised all the data collection at the Salt Lake City test site. The data from the cameras was sent to Dr. Van Houten, who used research assistants to collect the pertinent data from the video tapes. The video camera was place on the east side of Main Street as shown in Figure 1.

Training Data Collectors

Data collectors were trained how to record each measure of effectiveness (MOE) by senior staff. Training continued until a measure of inter-observer agreement between observers was above 85%. Measures of inter-observer agreement were collected for a minimum of 20% of observations to assure that observers continued to use the same standards when observing target behaviors.

General Scoring Procedure

All data were scored from videotape taken with a digital camera. The camera was located at grade level on the east side of the crosswalk facing the pedestrian signal on the west side of the crosswalk. The camera was set up so the pedestrian signal and train symbol signal were both clearly visible as well as the entire width of the crossing. Observers used fast forward to advance between trains and then rewound the tape until the start of the last WALK indication prior to the train's arrival. This procedure was used in order to keep conditions comparable between audible warning and baseline conditions. In almost all cases when an audible warning was present, it began during the pedestrian clearance interval (flashing DON'T WALK) period. Pedestrians were considered in violation if they began to cross after the start of the flashing DON'T WALK signal. Violators could cross at any time prior to the train's arrival blocking their crossing. Crossing outside the crosswalk was not scored because the location of the platforms prevented crossing outside the crosswalk within the view of the cameras. Because there were often more than one violator per crossing, it was necessary to repeat the scoring procedure for each violator. In general the portion of tape showing an individual train arriving or departing had to be replayed several times in order to accurately score data for all pedestrians.

Measures

- ***Did not violate Signal.*** The pedestrians were scored as being in compliance with the pedestrian control signal when he or she came to a complete stop and waited until the train has cleared the crossing before crossing the rails.
- ***Pedestrian Violations.*** A pedestrian violation was scored whenever a pedestrian crossed the path of an approaching train while violating the pedestrian control signal indicated by the start of the flashing DON'T WALK signal (during treatment this was typically at the onset of the audible warning). Per this criterion, violators could cross at any time from the onset of the flashing DON'T WALK until a train blocked the crossing. It is important to note that this procedure does yield a higher level of non-compliance than one would obtain if one included all pedestrians including those that could not be influenced by the added audible warnings as it excludes pedestrians who crossed when trains were not approaching the crossing, regardless of whether they complied with the WALK/DON'T WALK indication.
- ***Violator who stopped before crossing the rails.*** The pedestrian was scored for this behavior if he or she stopped before crossing the rail in violation of the pedestrian signal. The percentage of pedestrians that stopped during each condition was scored from videotape. A stop was defined as checking forward motion for a period of at least a second when no object or person was blocking the path of the pedestrian.
- ***Violator slowed before crossing the rails***. This behavior was scored if the pedestrian visibly slowed before crossing the rail while violating the pedestrian signal prior to the arrival of a train.

- ***Violator looked at approaching train.*** Looking behavior was defined as turning the head in the direction of the approaching train or glancing in the direction of the approaching train just prior to crossing the track (within 3 seconds of crossing the rails).
- ***Look train latency.*** The time from the onset of the audible warning until the person looked in the direction of the train was scored from the videotapes. The average look latency was computed using a stopwatch.
- ***Time between pedestrian violation and train arrival.*** The interval between a pedestrian crossing in violation of the crosswalk and arrival of the train at the location where the pedestrian crossed was computed using a stopwatch.
- ***Train-pedestrian conflicts (train action).*** A train-pedestrian conflict was scored whenever the train motorman had to suddenly brake in order to avoid striking a pedestrian crossing in front of the train. For a conflict to be scored the person had to be on a collision course with the train before taking evasive action.
- ***Train-pedestrian conflicts (pedestrian action).*** A train-pedestrian conflict was scored whenever a pedestrian had to take evasive action such as jumping back or running faster to avoid being struck by a train. For a conflict to be scored the person had to be on a collision course with the train before taking evasive action.

EXPERIMENTAL DESIGN

Baseline data, and treatment data were collected on different days. Data were often alternated between data collection between different conditions so that some baseline data were collected before the introduction of audible warnings and some baseline data were collected after the introduction of audible warnings. Because all data on the different audible warnings were collected at the same site, a characteristic of the particular site was not confounded with the type of device tested. This allowed a within comparison of the efficacy of each of the audible warnings with the baseline (no treatment) conditions.

FIELD OBSERVATION RESULTS

The percentage of violators during baseline and the bell and unique sound conditions are presented in Figure 3. The bell alone condition was associated with the highest percentage of pedestrians violating the signal (55.2%) and the other test conditions had a slightly lower percentage of pedestrians violating the signal (47.3% for the unique sound plus visual to 51.7% for the bell plus visual). Note these violation rates were with respect to the train approach periods only, and are significantly higher than the rate if all pedestrian activity was included. The majority of the pedestrians cross during the walk phase, and these pedestrians were not counted in this analysis because a train was not approaching so the audible warning device we were testing was not activated.

Table 1 shows that the differences between these treatments were not statistically significant.

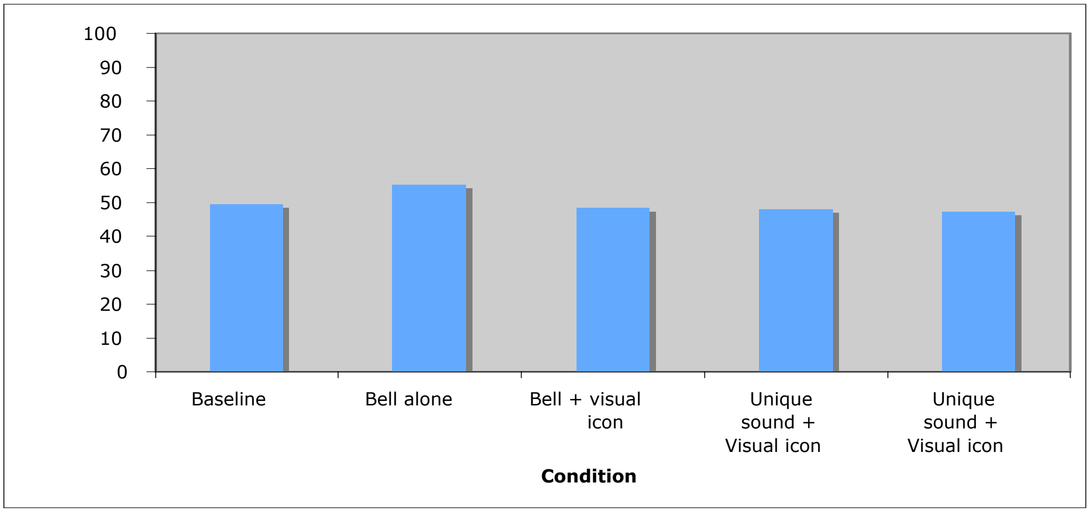

Figure 3 The percent of violators during each treatment condition

Table 1 Proportion of Violators

Description	**Condition**					
	Baseline	**Bell Alone**	**Bell Plus Visual**	**Unique Sound Alone**	**Unique Sound plus Visual**	**Total n**
Non Violator	208	232	261	261	272	1,234
Violator	202	286	244	241	244	1,217
Total	410	518	505	502	516	2,451
% of Violators	49.2	55.2	51.7	48.0	47.3	

A 2 x 5 Chi Square analysis revealed that there were no differences among the treatments, χ^2 (4, N = 2451) = 8.88, p = .075, there is not enough evidence to suggest a difference among these treatment conditions.

The percentage of violators looking for the train just prior to crossing the tracks is shown in Figure 4. Looking was lowest in baseline (34.3% looked) and highest in the unique sound alone condition (42.6% looked), however the differences compared with a chi square test were not found to be significantly different from each other. The results of this analysis are presented in Table 2.

The number of violators that dashed across the rails during each condition is shown in Figure 5 and Table 3. These data show that the percentage dashing ranged from 17.5% in the unique sound plus visual condition to 27.2% during the bell plus visual condition. The chi square analysis revealed a significant difference at the .05 level. A post hoc 2 x 2 Chi Square analysis revealed that there was a difference between the baseline and bell plus visual treatments, (1, N = 2451) = 8.054, p = .005 (Bonferroni corrected alpha = .045).

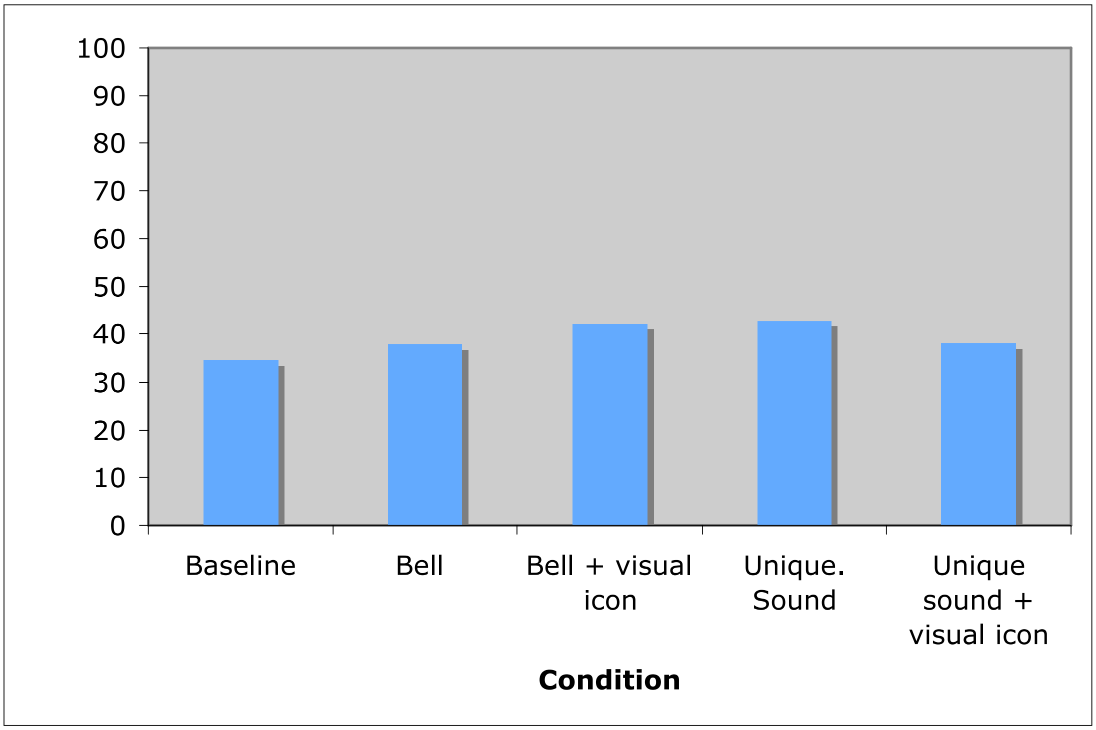

Figure 4 Percentage of violators looking for the train before crossing the track

Table 2 Violator Orientation Results

Violator Visual Orientation	Condition					
	Baseline	Bell Alone	Bell Plus Visual	Unique Sound Alone	Unique Sound plus Visual	Total n
Look	110	95	122	109	53	488
No Look	211	156	168	147	85	767
Total	321	251	290	256	137	1255

A 2 x 5 Chi Square analysis revealed that there were no differences among the treatments, χ^2 (4, N = 1255) = 5.74, p = .219, there is not enough evidence to suggest a difference among these treatment conditions.

The percentage of pedestrians that stopped or broke stride before crossing the rails was consistently low during all conditions and the values were very similar ranging from 1.8% during the unique sound and 3.4% during the bell plus visual condition. A chi square test revealed that these values were not significantly different from each other.

An examination of the interval between the warning and looking was also found to be insignificant.

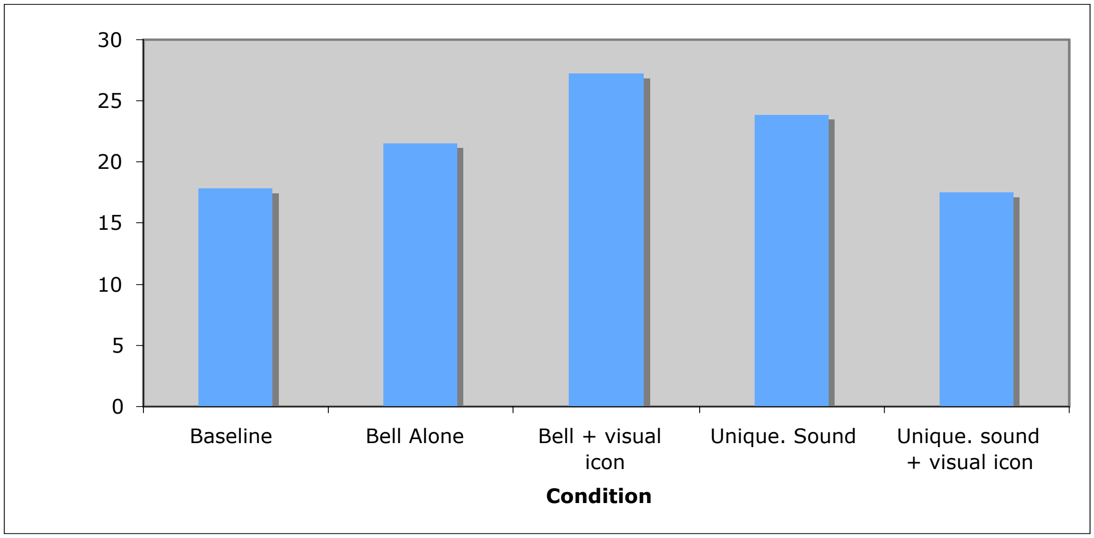

Figure 5 Percent violators dashing across rails during each condition

Table 3 Proportion of Violators that Dash

Violator	Condition					
	Baseline	**Bell Alone**	**Bell Plus Visual**	**Unique Sound Alone**	**Unique Sound plus Visual**	**Total n**
Dash	57	54	79	61	24	275
No Dast	264	197	210	195	113	979
Total	321	251	289	256	137	1,254

A 2x5 Chi Square analysis revealed that there were differences among the treatments, χ^2 (4, N = 1254) = 10.319, p = .035, there is sufficient evidence to suggest a difference among these treatment conditions.

Table 4 Analysis of Variance for the Mean Interval Between Warning and Looking

Source	*Df*	*MS*	F	*p*
Between Groups	1	11.497	.311	.578
Within Groups	172	36.997		
Total	173			

There is not enough evidence to suggest that there is a difference between the treatment conditions in terms of the mean interval between the type of warning and looking.

The mean violation interval in seconds is presented in Figure 6. These data varied between a low of 15.8 seconds in the unique sound alone condition and a high of 16.8 seconds in the baseline condition. Theses data were analyzed using an ANOVA and no difference was found between the mean intervals for each condition.

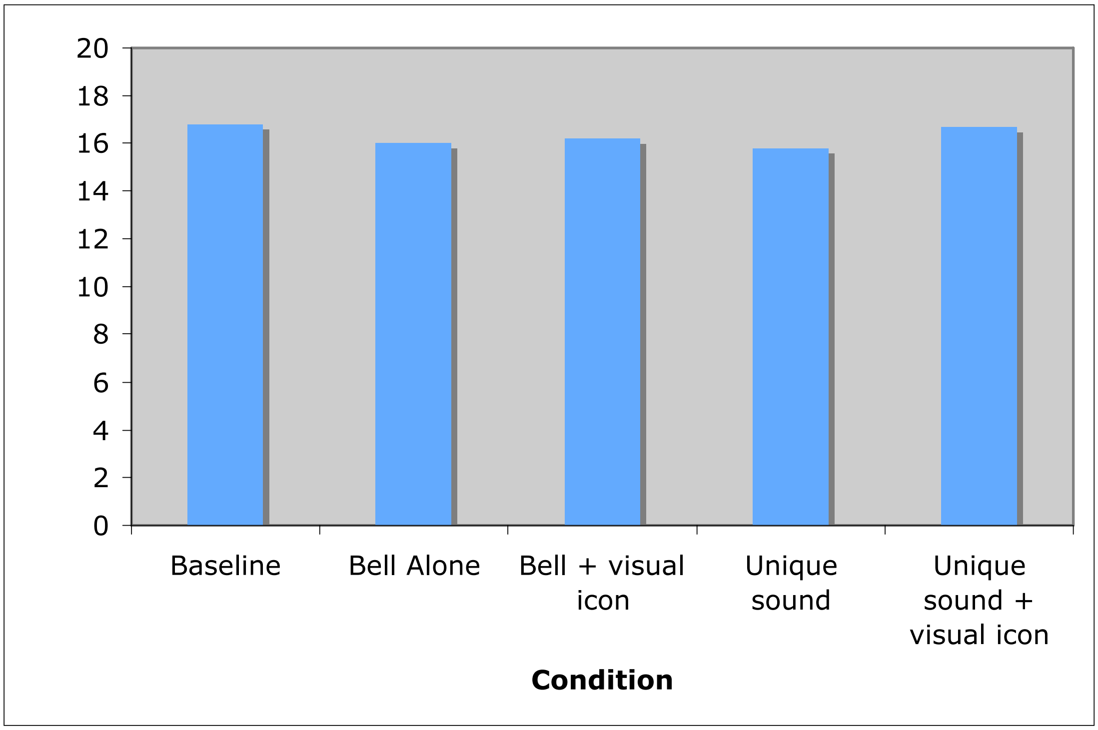

Figure 6 The mean interval between violations and train arrival

Table 5 Analysis of Variance for the Mean Interval of Violator Crossing Before the Train in Seconds

Source	*Df*	*MS*	F	*p*
Between Groups	4	49.597	1.121	.345
Within Groups	1249	44.252		
Total	1253			

There is not enough evidence to suggest that there is a difference among the treatments conditions in terms of the mean interval of violator crossing.

Histograms showing the distribution of times between crossing and train arrival for thee conditions in the experiment are presented in Figure 7. Although there were no significant differences between the mean crossing times and train arrival between each of the five conditions, an examination of these distributions shows that relatively fewer pedestrians crossed within 10 seconds of the train arrival during the warning bell condition. The difference between the base condition and the two audible treatments, the bell and the unique sound, are both statistically significant (Table 6 and 7).

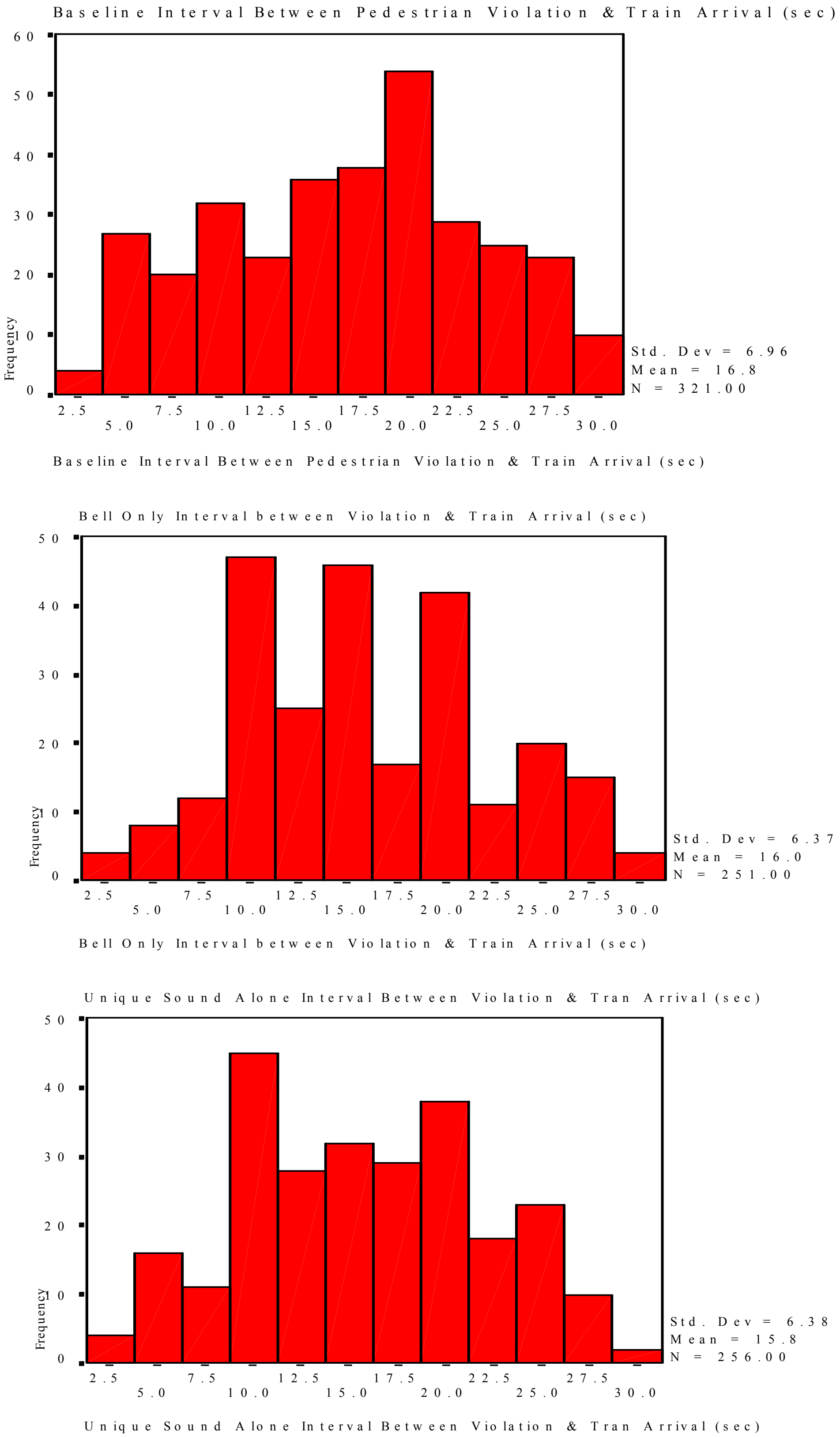

Figure 7 Histograms showing the frequency of violations for each time period

Table 6 Analysis of Variance for the Mean Interval of Violator Crossing Before the Train Arrival at 10 Seconds or Less Between Baseline and Bell Alone

Source	*Df*	*MS*	F	*p*
Between Groups	1	21.75	4.217	.042
Within Groups	123	5.15		
Total	124			

There is enough evidence to suggest that there is a difference between the baseline and bell alone conditions in terms of the mean interval of violator crossing less then 10 seconds before the train arrives. Means: Baseline, 6.99 seconds and Sound Alone, 7.83.

Table 7 Analysis of Variance for the Mean Interval of Violator Crossing Before the Train Arrival at 7.5 Seconds or Less Between Baseline and Unique Sound

Source	*Df*	*MS*	F	*p*
Between Groups	1	8.25	4.03	.048
Within Groups	69	2.04		
Total	70			

There is enough evidence to suggest that there is a difference between the baseline and unique sound conditions in terms of the mean interval of violator crossing less then 7.5 seconds before the train arrives. Means: Baseline, 5.67 seconds and Unique Sound, 4.96.

The incidents of evasive conflicts were very rare in this study. The total of 5 evasive conflicts observed during this study are described here and summarized in Table 8. One occurred during baseline when a train had to brake suddenly to avoid hitting three pedestrians, one of who crossed 3 seconds prior to the train arrival and two of whom crossed 2 seconds before the train arrival. One conflict occurred during the bell alone condition when 2 pedestrians crossed 1 seconds before the train arrival. In this case 1 pedestrian looked and the other did not, both pedestrians lunged forward. Two conflicts occurred during the bell plus visual condition. Both conflicts involved the motorman having to suddenly brake and one pedestrian looked and the other did not. The times between crossing and train arrival for these two independent events were both 1 second. No conflicts occurred during the unique sound alone condition, and one evasive conflict occurred during the unique sound plus visual condition. This conflict involved the motorman suddenly braking and the pedestrian crossing 6 seconds before the train arrival after looking. Unfortunately it is not possible to draw any firm conclusions from this very small sample of conflicts. However, the individual conflicts were associated with short times between crossing and train arrival and all but one involved the motorman braking for the pedestrians. Because of the slow speeds involved it was relatively easy for the train operator to brake.

Table 8 Incidents of Evasive Conflicts During Each Scenario

	Baseline	Bell No Visual	Bell With Visual	Unique No Visual	Unique With Visual
Evasive Conflicts	1	1	2	0	1

VISUAL IMPARED FIELD SURVEY

The visually impaired field survey involved a select group of visually impaired and legally blind individuals at the test site. Each participant was directed through each test scenario to test their understanding of the existing and modified audible devices. The results were assessed by a combination of behavioral measures, and their reactions to each of the devices.

The Korve team coordinated with Sherry Repscher, the Utah Transit Authority (UTA) ADA Compliance Officer. Sherry works closely with the Utah Council of the Blind and State Services for the Blind and arranged for people to participate in the field test. UTA provided transit service to get participants to the test site if they needed assistance with transportation.

The visual impaired field survey consisted of 21 volunteers who crossed the 50 South Main Street crossing when a train was present and then responded to a survey.

Among the volunteers tested were10 males and 11 females. Of these individuals, one person was Hispanic and 20 were Caucasian. There were seven individuals that used a guide dog and 20 individuals that received training in the use of the long cane. The training in the use in the long cane varied from one week to through out school. The results of the visual impaired field survey come from an analysis of the responses to certain research questions.

Research Question 1: Is there any difference between the reported acceptability of the signals from the devices? Responses to the question, “How acceptable was the signal?” were assigned numbers: 1=Poor, 2=Fair, 3=OK, 4=Very Good, and 5=Excellent. The mean responses for the devices were Bell= 3.52, Baseline=3.62, and Unique=2.48 indicating that the Unique signal was rated as less acceptable than the other two.

Research Question 2: Is there any difference between the reported aversive or annoying nature of the signals from the devices? Responses to the question “How aversive or annoying was the signal?” were assigned numbers: 1=Not at all, 2=Very Little, 3=OK, 4=Unpleasant, 5=Nasty. The mean responses for the devices were Bell=2.00, Baseline=1.29, and Unique=2.67, indicating that the Baseline condition was considered the least annoying of the signals and the Unique signal was considered the most annoying.

Research Question 3: Is there any difference between the reported usefulness or effectiveness of the signals from the devices? In response to the question “Overall, how useful or effective was the signal as a warning?” participants were asked to rate the usefulness from 1 to 7 with 1 meaning "not at all" and 7 "very useful". The analysis showed no significant difference between the signals.

Research Question 4: Which device was considered "best" by the subjects?

Bell	9 votes	42.9%
Baseline	8 votes	38.1%
Unique	4 votes	19.0%

Research Question 5: Which device was considered "second" by the subjects?

Bell	11 votes	52.4%
Baseline	5 votes	23.8%
Unique	5 votes	23.8%

Research Question 6: Which device was considered "worst" by the subjects?

Bell	1 vote	4.8%
Baseline	8 votes	38.1%
Unique	12 votes	57.1%

Research Question 7: Is dog guide or cane use related to device considered best?

	Bell	Baseline	Unique
Dog Guide	5	6	3
Cane	4	2	1

Analyses indicated no significant difference responses of the dog guide and cane users.

Research Question 8: Is there a relationship between hearing loss, use of hearing aids, duration of vision loss, and acuity with the rating of device specific acceptability? None of these factors were found to be significantly related to device specific acceptability.

Research Question 9: Is there a relationship between subjects who travel often and travel independently with the rating of device specific acceptability? Neither factor was found to be significantly related to device specific acceptability.

Research Question 10: Is there a relationship between observer rating of the subjects cane skills with the rating of device specific acceptability? No significant relationship was found between cane skills and ratings of device specific acceptability.

In summary, the Unique sound was found to be the least acceptable and the most aversive. The Bell sound was voted "best" and "second" with the Unique sound voted "worst". There were no significant relationships found between participant responses and several differences among participants, (i.e. cane vs. guide dog users and travel often and independently vs. otherwise).

PUBLIC SURVEYS

Surveys of the general public were completed on days when the crossing was being video taped at street level for the behavior observation. When the surveyor heard the audible signal, he/she would look for any pedestrians waiting to cross that were definitely hearing the signal. After the pedestrians were given a walk signal and had crossed the street, he/she would attempt to stop one of the persons noted earlier and ask them the questions on the survey sheet. One intention of the survey process was to question a diverse group of people in regards to age, gender, and frequency of using the crossing. While the sample size (around 30 surveys per scenario) is too small to make any conclusions about the opinions of specific demographics, this approach helped insure that a broad range of views were heard.

The results of the survey come from 106 participants. The participants evaluated one of the following scenarios (number of surveys for each scenario is also provided):

- Bell Sound – No Visual (24 surveys)
- Bell Sound – With Visual (30 surveys)
- Unique Sound – No Visual (28 surveys)
- Unique Sound – With Visual (24 surveys)

The participants included of 52 males and 54 females. There is a good distribution of ages among the participants with most between 20 and 40 years of age. About 85% of the participants use UTA. However, the frequency varies from once a month to more than four times per day with most (38%) of the participants using UTA 2-4 times per day.

The audible signal was noticed by at least 83% of the participants in each scenario. There was a diverse understanding of how to respond reported by the participants. Table 8 shows the percent of each response in each scenario. The responses were divided into two groups; correct responses and incorrect responses. The correct responses include “caution”, “look around”, “look for train”, “stop and wait”, and “stop, but was confused at first”. Incorrect responses include “don’t know”, “confused”, “cross anyway”, and “ignore and rely on ped signal”. Other and blank refer to responses that did not directly answer the question and were unanswered respectively. The correct and incorrect response group percentages are also included in Table 8.

Throughout the system the train gong is only rung just before a train departs the station or when a train is arriving and a pedestrian is on or near the tracks. Prolonged sounding of a crossing bell would not be a typical stimulus at urban intersections with traffic signal control. Many respondents also associated bell alone with look around, and Unique sound with look for train and to a lesser extent the bell with and without visual with look for train. Stop and wait was associated with stop and wait only when the visual was present. In general correct responses were associated more highly with the unique sound with no visual train warning display and the bell with a visual display, which appears to be somewhat contradictory. Incorrect responses were more associated with the bell with or without the visual display.

Given the small sample size for this survey it is difficult to draw any significant conclusions. However, the data tends to indicate three points worth noting:

- No particular treatment stands out as the best (even though the unique audible with visual icon had the fewest incorrect responses, the proportion of correct responses was lower than some of the competing treatments);
- The response to the standard crossing bell sound was more consistent with or without the visual icon display; and
- The unique audible was more comprehensible when used with the visual icon.

Table 9 Survey Responses to the Audible Signal

Responses	**Unique No Visual**	**Unique With Visual**	**Bell No Visual**	**Bell With Visual**
Caution	0%	0%	0%	0%
Look around	0%	13%	25%	10%
Look for train	50%	8%	29%	27%
Stop and wait	7%	25%	0%	20%
Stop, but was confused at first	0%	0%	0%	0%
Correct Response Total	**57%**	**46%**	**54%**	**57%**
Don't know	14%	0%	0%	10%
Confused	0%	0%	21%	13%
Cross anyway	0%	0%	4%	3%
Ignore and rely on ped signal	0%	0%	4%	0%
Incorrect Response Total	**14%**	**0%**	**29%**	**23%**
Other	25%	38%	13%	7%
Blank	4%	17%	4%	10%
Correct Responses Excluding Other & Blank Responses	80%	100%	65%	71%

The following paragraphs describe the results of four additional research questions that were asked of the participants.

Research Question 1: Is there any difference between the reported acceptability of the signals from the devices? The responses to the question, “How acceptable was the signal?” were assigned numbers: 1=Poor, 2=Fair, 3=OK, 4=Very Good, 5=Excellent. The mean responses for the devices were Unique No Visual=3.9, Unique With Visual=3.4, Bell No Visual=3.5, and Bell With Visual=3.6 indicating that there is not much difference between unique scenarios and the bell scenarios.

Research Question 2: Is there any difference between the reported aversive or annoying nature of the signals from the devices? The responses to the question “How aversive or annoying was the signal?” were also assigned numbers: Not at all=1, Very Little=2, OK=3, Unpleasant=4, and Nasty=5. The mean responses for the devices were Unique No Visual=2.4, Unique With Visual=2.6, Bell No Visual=2.0, and Bell With Visual=2.4 indicating that there was not much difference in the aversive nature of the unique and bell scenarios.

Research Question 3: Is there any difference between the reported usefulness or effectiveness of the audible signals from the devices? The responses to the question

"Overall, how useful or effective was the audible signal as a warning?" asked participants to rate the audible signal on a scale of 1 to 7 with 1 meaning "not at all" and 7 meaning "very useful". The mean responses for the devices were Unique No Visual=5.6, Unique With Visual=4.7, Bell No Visual=5.5, and Bell With Visual=5.3. This indicates that the there is not much difference between viewed effectiveness of the bell audible and the unique audible signal.

Research Question 4: Is there any difference between the reported usefulness or effectiveness of the visual signals from the devices? The responses to the question "Overall, how useful or effective was the visual signal as a warning?" asked participants to rate the visual signal on a scale of 1 to 7 with 1 being not very not useful and 7 being very useful. The mean responses for the devices with a visual signal were Unique With Visual=4.3 and Bell With Visual=4.8. Limited conclusions can be made here due to the low number of participants in this question for the both scenarios.

In summary, the two scenarios with the most participants responding incorrectly to how to respond to the signal were the Bell With no Visual and the Bell With Visual. This indicates that the unique sound may better communicate to pedestrians the proper response. The results of the other research questions show little difference between the four scenarios. It should be remembered that the unique sound was novel and the effect could be a novelty effect. The sound would need to be in place for a much longer period of time before firm conclusions could be drawn.

CONCLUSIONS

The overall results of the field study indicate that the addition of audible warnings or audible warning with a visual warning display had little effect on the percentage of persons that complied with the pedestrian signal when a train was approaching or departing the station. However the use of the bell was associated with more pedestrian violations, more pedestrians dashing across the rails when violating and fewer pedestrians violating the signal 10 seconds or less prior to the train arrival at the crossing location. These mixed data need to be viewed in regard to the audible warnings already in place during baseline at these sites.

It is standard UTA policy to install audible accessible pedestrian signals at level grade rail crossings to reduce the risk of crashes between blind travelers and motor vehicles and light rail trains. These signals may also benefit sighted individuals. It is also policy for the motorman to sound the train's gong twice as the train departs the station and to sound the gong when arriving at the station when pedestrians are in the train's path or near the tracks. These procedures provide a salient audible warning in close proximity to the train traversing the crossing. It is possible that these warnings may have produced a ceiling effect at UTA sites that washed out the effect of the added warnings.

The addition of the bell providing a earlier warning of the train approach may have motivated some travelers to dash to clear the train with a wider safety margin which resulted in a smaller percentage of pedestrians crossing 10 seconds or less prior to the train reaching their crossing location. The bell may have produced a larger effect because it is a traditional auditory warning associated with the approach of a train, particularly at high-speed rail crossings.

The visual impaired field survey indicated that the Bell sound was the most desirable. However, the accessible pedestrian signal in place during baseline provided a better warning because it indicated to blind pedestrians when it was safe to cross. It is unclear how a train warning could add to the effectiveness of the accessible signal because blind pedestrians would be unlikely to cross in the absence of the accessible signal because it is highly likely they would be struck by a fast moving motor vehicle while crossing the roadway even in the absence of the much slower moving trains.

The public survey showed little difference between the four scenarios or the two sounds. However, fewer participants responded incorrectly to the two test scenarios with the Unique audible warning. This indicates that the unique sound may better communicate to pedestrians the proper response. The results of the other research questions show little difference between the four scenarios. It should be remembered that the unique sound was novel and the difference obtained could be a novelty effect. The sound would need to be in place for a much longer period of time before firm conclusions could be drawn.

Based solely on the results of the field test of this application we do not recommend a change in current practices at railway crossings. These data are also in accord with the results of the review of the crash data that indicate that light rail crossings are relatively safe. Crashes between pedestrians and LRT are few in number but when crashes occur they are severe; therefore, it is critical to do everything possible to improve safety. Although pedestrians violating the signal might be somewhat less likely to cross just before the train arrives when the bell is present, it is also the case that more pedestrians can be expected to violate the signal when the bell is present. Because of the low incidence of evasive conflicts that served as the crash surrogate measure in this study, it is unclear how these two effects would interact with crashes.

The results are not compelling; however, there is some promise for the unique sound. If there is interest in further pursuing the "blended staircase" sound the following things should be considered:

- Testing over an extended period of time,
- Testing in a wider range of environments, and
- Investigating the use of a speaker that would provide a higher fidelity.

Further testing would be appropriate for other "alternative treatments" of pedestrian crossings including but not limited to changes in visual and audible devices.