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Median Light Rail Crossings: Accident Causation And Countermeasures

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ABSTRACT

This paper focuses on accident causation and countermeasures at arterial median light rail grade crossings. Unlike conventional railroad grade crossings, light rail systems often incorporate a grade crossing into an intersection environment. These complex intersections can be confusing to drivers and lead to a high proportion of accidents where drivers turn into or in front of an LRV traveling the same direction. It can be a matter of centimeters from the left turn lane to the right-of-way on the median trackage. In the case of side-running alignment and right turn accidents, there are often no turn lanes and drivers frequently neglect to use their turn signals. As a result, the light rail operators often lack sufficient warning time to respond to an illegal automobile movement.

Only a handful of literature has been published on this topic and we seek to synthesize accident causation literature from many fields as it relates to the median crossing. Although it is highly relevant to existing light rail systems, this paper should be of particular importance to the startup system still in the design phase.

Key Words: Light Rail Transit, Street Railways, Accidents, Countermeasures, Prevention

EXECUTIVE SUMMARY

This paper synthesizes accident causation and prevention literature from several fields, including traffic engineering, human factors and cognitive psychology, as it relates to the complex LRT grade crossing. This paper should serve as a starting point for addressing the special safety considerations at complex LRT grade crossings.

ACCIDENT CAUSATION

One of four critical events must occur prior to a turning accident at a median LRT crossing. Disobedience refers to an inappropriately low perception of risk and expectations from conventional intersections contribute to driver disobedience. Failure to Perceive occurs when the driver does not perceive the traffic control device. Misinterpretation accidents are related to expectation errors and drivers' cognitive limitations. Drivers' Expectations also play a large role in the occurrence of LRT crossing accidents.

PASSIVE, ACTIVE & REACTIVE COUNTERMEASURES/PROTECTION

In the past, grade crossing protection has been characterized as being passive or active. We add a third classification, reactive. For all three categories, a countermeasure should address drivers' expectations at conventional intersections and work to keep drivers within the law at LRT crossings. A number of potential collision countermeasures are also discussed. Reactive Countermeasures include wayside visual or audible alarms. There may be appropriate applications of audible alarms augmented with LRV Operator Alerts. Communication could be via wayside signals or cab signals.

Passive Countermeasures discussed include Knock Down Delineators to be placed on the far side of the crosswalk, to create a visual barrier to encourage turning drivers to start their turns after traversing the crosswalk. Signing can also provide advanced warning to the driver in a new environment. Also, repeated exposure to advanced warning signs that prescribe the correct course of action should reinforce the message to regular drivers in the area

EDUCATION AND ENFORCEMENT

There is a need to educate the driving public about their duties and responsibilities at LRT crossings. An education program coupled with reinforced compliance is a critical component of any LRT operating strategy. Strategies discussed include punishment and prevention through education.

STANDARDIZATION AND VISUAL CONSTRAINTS

LRT grade crossings should be standardized throughout the system, and if possible, between systems. It is also important to consider the visual constraints inherent in the standard traffic signal systems.

CONCLUSIONS

This paper focuses on the synthesis of literature related to the thorough understanding of accident causation as related to LRT median grade crossings, and the development of effective countermeasures. Transit agencies should strive to work with traffic engineers, law enforcement, and other LRT systems to standardize the visual landscape presented to drivers at intersections with LRT grade crossings, allowing for improved safety and operations at the myriad locations throughout the nation.

INTRODUCTION

To facilitate driver performance, a primary goal of the traffic engineer should be to design the system in ways that will reduce driver uncertainty, both with respect to the occurrence of an event and with respect to its meaning (1).

In California alone, four new Light Rail Transit (LRT) systems have opened since 1981. Unlike older street railways systems (e.g., San Francisco MUNI), these new systems are largely located within exclusive/semi-exclusive rights-of-way. Often, the right-of-way is in the median or adjacent to the shoulder of a major arterial. This trackage placement leads to complex grade crossings incorporated into intersections (Figure 1). The grade crossings are typically protected with conventional traffic signals and possibly supplemental signage. They do not operate like conventional railroad grade crossings and usually do not have any of the traditional grade crossing safety equipment (e.g., crossbucks, flashing lights and gates). Little has been published on these special LRT grade crossings. This paper synthesizes accident causation and prevention literature from several fields, including traffic engineering, human factors and cognitive psychology, as it relates to the complex LRT grade crossing. The primary focus is the median grade crossing (Figure 1A) and left turning drivers who pull in front of approaching Light Rail Vehicles (LRVs). However, much of this work can be extended to other situations such as side running LRT grade crossings (Figure 1B).

With the expansion of existing LRT systems and proposals for several new systems, this paper should serve as a starting point for addressing the special safety considerations at complex LRT grade crossings. It is intended to complement the current Transit Cooperative Research Program (TCRP) effort looking at the Integration of Light Rail Transit Into City Streets, which takes a comprehensive view towards improving the safety of LRT operations in shared rights-of-way (2).

Before addressing accident countermeasures, we will briefly examine the accident causation process. Then, we discuss passive, active and reactive countermeasures at the crossing as well as educational and enforcement programs away from the crossing.

ACCIDENT CAUSATION

The most common accidents at median grade crossings are left turn accidents (2). This is based on a survey of ten LRT systems, including data representing 359 total collisions, over an aggregate of 277 track miles. From the driver's perspective, the grade crossing may appear to be a conventional intersection. From most approaches, this error is not significant, and an LRV will still be visually detected by a driver. The left turning driver, however, is unlikely to see an LRV approaching from behind and runs the risk of pulling in front of a train traveling the same direction (Figure 2). For these drivers the additional complexities are unknown and safety is dependent on obedience to the relevant traffic control device, e.g., the red left turn arrow. As shown in Figure 3, and as described below, one of four critical events must occur prior to a turning accident at a median LRT crossing.

Disobedience

An inappropriately low perception of risk and expectations from conventional intersections contribute to driver disobedience. Richards (3) noted that, "Drivers who 'normally' engage in undesirable behavior (at crossings) tend not to accept that their actions are hazardous, and they believe that their actions are legal." Wagenaar and Groeneweg (4) observed that accidents appear to be the result of highly complex coincidences, which can rarely be foreseen by those involved. Accidents occur as a consequence of behavior that is not seen as risky.

Failure to Perceive

Another common critical event occurs when the driver does not perceive the traffic control device. Olson (5) notes that delays or outright failures in detection are most likely to arise from poor stimulus conspicuity. Sometimes, a stimulus that would normally be detected may be overlooked by a driver who is occupied with a great deal of other information. Factors leading to violation typically range from seeing the through-traffic signal turn green and the adjacent through-traffic move, to drivers anticipating the leading left turn phase only to discover that it had been skipped for transit priority. These errors are related to faulty expectations and cognitive limitations.

Misinterpretation

Other accidents are related to expectation errors and drivers' cognitive limitations. For example, drivers may hear the LRV horn behind them and assume it was another automobile urging them into the intersection. Most people err in the direction of over-estimating both the information given and their ability to use it. The phenomenon of overconfidence—as a result of poorly controlled information processing—is present everywhere and hard to overcome both in perception and cognition (6).

Drivers' Expectations

From the driver's perspective, the LRT crossing can appear to be a normal intersection. In fact, when no LRVs are present, it operates as such.

At a normal intersection, as soon as the through-traffic receives the green signal, a turning driver will complete as much of the left turn as possible without entering the oncoming flow of traffic. The driver tries to take advantage of the smallest gap in the oncoming traffic. The driver is not looking at the traffic signal and has already begun the turning maneuver. This disregard for traffic control devices undermines the effectiveness of existing countermeasures at LRT crossings.

Overconfidence or inappropriate expectation of risk can lead a driver to disobey traffic control devices. For left turns, it is the norm to allow movement on “stale yellow” signals or even “fresh red” signals. There is a need to draw drivers' attention to the control devices (red left turn arrows or “No Left Turn” signs) and improve compliance through increased enforcement and education.

Through familiarity with a given intersection, some drivers come to associate the onset of red for the cross traffic with the beginning of the leading left turn phase. Transit priority at crossings can preempt leading left turn phases and make the intersection behave differently when an LRV approaches. From a driver's perspective, it is a relatively rare event to be in the left turn lane

when the left turn phase is preempted. Only the first stopped driver has to make the go/no-go decision based solely on the signals, all subsequent drivers can only move if the vehicle in front of them advances. Thus, the disassociation between the left turn arrow and other signals is only reinforced for the first turning driver and it only occurs when the left turn phase is skipped.

PASSIVE, ACTIVE AND REACTIVE COUNTERMEASURES/PROTECTION

In the past, grade crossing protection has been characterized as being passive or active. We add a third classification, reactive. For LRT crossings, the three categories are defined as:

Passive: Static warning devices that warn the driver of a grade crossing or keep automobiles out of the trackway whether or not an LRV is present, e.g., signs and delineation.

Active: Warning devices that change states and restrict movement when an LRV approaches, e.g., crossing gates and traffic signals. Although it is the common definition of active grade crossing protection, such systems are essentially proactive, they operate independent of driver's actions or the presence of automobiles.

Reactive: Proposed warning devices that respond to illegal or unsafe automobile movements when an LRV approaches, e.g., automated encroachment alarms and other Intelligent Transportation Systems (ITS) devices (7).

Typically, a grade crossing with active warning devices also has passive warning devices. Likewise, the proposed reactive countermeasures will have passive and active warning devices at the same grade crossing. For all three categories, a countermeasure should address drivers' expectations at conventional intersections and work to keep drivers within the law at LRT crossings. A successful collision countermeasure should accomplish at least one of the following goals:

- Remind the driver that there are special risks in the given situation.
- Physically prevent the driver from taking these additional risks.

In many accident situations, it is clear that the drivers do not expect an LRV to enter the intersection. Drivers do not fully understand their duties and responsibilities at these special intersections. The following sections discuss a number of potential collision countermeasures.

Reactive Countermeasures

Unlike automatic braking systems or air bags, a warning from a collision [avoidance] system requires the cooperation of the driver. (8)

One of the major efforts of ITS research is the development of collision-avoidance systems, likely to appear as in-vehicle systems in the future. These motor-vehicle based systems will certainly facilitate safe operations in all potential collision situations, including LRT at-grade crossings. Until the time when these systems are available, some first generation reactive countermeasures will likely include wayside visual or audible alarms. The following discussion of audible alarms is just one example.

Audible Alarm

There is evidence to show that audible alarms are effective for reducing accidents at conventional railroad grade crossings. A nighttime whistle ban ordinance was imposed on the Florida East Coast Railway in 1984 which only applied to gated crossings and required a special advance warning sign for motorists that read, "No Train Horn, 10 p.m. - 6 a.m." The nighttime accident rate at the impacted crossings tripled during the first five years of the ban. At similar crossings where the ban had not been imposed, the nighttime accident rate only increased by 23 percent. The Federal Railroad Administration (FRA) concluded that train whistles (train based audible alarms) are effective in reducing grade crossing accidents (9). Recent legislation put forth by FRA prohibits local whistling ordinances altogether.

Additional evidence from McCormick and Sanders (10) supports the use of audible alarms if the message calls for immediate action. Audible alarms are preferred when the visual system of the receiver is overburdened, e.g., during a left turn maneuver.

Based on the positive effects of audible alarms, the concept is now extended for wayside use as a reactive countermeasure at LRT grade crossings. A wayside audible alarm either may be used as a stand alone warning device or a component of a multimodal alarm system. A directional audible alarm, placed close to the automobile driver, will allow for alarm levels loud enough to penetrate the acoustic insulation of automobiles, while being quiet enough to have minimal impacts on the surrounding neighborhood. If the alarm is only activated in the event of emergency, and not with the passing of every LRV, local residents will be more likely to tolerate the occasional disturbances.

The idea of using wayside audible alarms to protect grade crossings is not a new one. Longrigg (12) proposed a reactive warning system that utilizes directional, audible alarms to protect a conventional railroad grade crossing. At railroad crossings, such a device may not be effective because of high automobile approach speeds. At an intersection with a median LRT crossing, however, such a device could be very effective. Turning automobiles tend to travel at low speeds and the alarms can be placed close to the vehicles.

The wayside alarm should be loud enough to penetrate the passenger compartment of most vehicles but quiet enough so that a driver with an open window will not be injured or startled. In particular, the intensity should depend on background noise. The alarm should be activated infrequently, both to minimize neighborhood disturbance and to decrease the probability of driver habituation. Alternately, two distinct activation levels can be used, a relatively quiet level sounded for most crossing situations and a high intensity level for the relatively rare emergency situations. For audible alarms, McCormick and Sanders (10) advocate:

- Avoid extremes of auditory dimensions.
- Establish intensity relative to ambient noise level.
- Use interrupted or variable signals.
- Test the signals to be used on a representative sample of the potential driver population, both to verify the detectability and the effectiveness of the alarm.
- Avoid conflict with previously used signals.
- Facilitate changeover from previous display.

- Use frequencies between 200 and 3000 Hertz.
- Use signals with frequencies different from those that dominate any background noise.

A wayside alarm should be distinct from other sounds in the road environment. The goal is to find a sound that conveys the urgency of the situation, that is associated with a single event and that always requires the same specific response. In addition, the alarm should be placed such that the source is not easily confused with following automobiles. Placing the audible alarm next to the first position in the turn lane, approximately parallel to the driver compartment, should reduce confusion over the source. Such placement should elicit a head turn reflex reaction in the direction of the sound. For the first driver in the turn lane, the head turn reaction would bring an approaching LRV into the field of view. Driver response to any wayside audible alarm should be measured in a safe environment before deploying such a device.

LRV Operator Alerts

If a reactive collision countermeasure is developed to warn automobile drivers, it should be augmented with a motion indication signal for LRV operators. The added cost and complexity of an operator signal should be negligible relative to the automobile warning system. An operator alert system may also be justified as a stand alone system. In terms of logistic complexity, this reactive countermeasure is the simplest. Instead of warning the automobile driver of an approaching LRV, this countermeasure seeks to warn the LRV operator of a moving automobile. Communication could be via wayside signals or cab signals. Because the LRV operators are highly trained by transit agencies, the specific signal properties are rather flexible.

An LRV traveling at 55 km/h (35 mph) can take ten seconds and 78 m (255 feet) to come to a complete stop under normal braking conditions. Although the LRV operators look for motion cues in the turn lane (brake lights, position of the front wheels and driver's head movements), it can be difficult to detect forward motion from 78 m behind an automobile. A reactive warning system can provide as much as an additional two seconds warning for LRV operators.

The LRV advance warning signal should have a positive response—it should indicate when no vehicle movements are detected. Furthermore, it should have a fail-safe state that indicates the

device is malfunctioning. It must be reliable, or operators will start to disregard it. Care must be taken to prevent operators from becoming dependent on the indicator. Finally, if a wayside system is used, it should be placed out of view from the roadway (e.g., shielded, on the nearside of intersection). It should not use colored signals, as drivers may assume the signals control automobile movement.

Passive Countermeasures

Knock Down Delineator

At a typical median LRT crossing with left turn pockets, the left turn lane is often separated from the trackway by a narrow curb. The curb may end a few meters before the intersection, with the last portion of trackway paved and striped for a pedestrian crosswalk. Because the crosswalk is only delineated by paint, there are no physical barriers to prevent automobiles from driving on the crosswalk. Turning automobiles frequently enter the LRV dynamic envelope within the crosswalk. This problem is compounded by the fact that many drivers pass the stop-bar and stop at the near side of the crosswalk. As a result, it can be less than one second from the time a driver takes their foot off of the brake and when they enter the LRV dynamic envelope (see Figure 2).

Knock down delineators can provide a safe and effective means of restricting automobile movements in the crosswalk. A typical delineator consists of a replaceable, 7.6 cm (3 inch) wide, 1.22 m (4 foot) tall plastic post and a permanent base. The base can either be epoxied to the surface of the pavement or embedded in the pavement. Reflective tape is usually applied to the top of the post. The California Department of Transportation (Caltrans), among other state DOTs, have come to use the knock down delineator as a standard tool for highway traffic control.

The primary delineator placement would on the far side of the crosswalk, in line with the curbing between the left turn lane and the trackway (Figure 4). This placement creates a visual barrier to encourage turning drivers to start their turns after traversing the crosswalk. To reinforce desired behavior, it is recommended that a decal displaying arrows or reading “KEEP RIGHT” be used.

The judicious placement of knock down delineators can prevent drivers from initiating a left turning maneuver before traversing the crosswalk. Because drivers will have to proceed further into the intersection before beginning a turning maneuver, the placement of knock down delineators would effectively reduce the length of the potential LRV-automobile collision zone.

The delineator can be supplemented with pavement striping extending the visual line of the curb to the delineator post. A secondary delineator can be placed on the near side of the crosswalk, at the end of the curb, to visually reinforce the limited clearance in the crosswalk.

The delineators can serve as passive control devices, providing an additional two to three seconds warning to LRV operators. Or, they can be an integrated component of a reactive countermeasure by increasing the time-to-collision for turning drivers and creating a warning zone that drivers have to traverse before entering the LRT right-of-way.

Signing

Advanced warning signs have been used at conventional railroad grade crossings since the early days of automobile travel. Over the years, additional advance warning signs have come into use for unexpected features or situations that require particular care on the part of the driver, e.g., the W10-2, 3, and 4 (parallel) Railroad Advanced Warning Signs (Figure 5). Because of their street-running nature, many LRT systems do not typically employ advanced warning signs on the parallel streets.

Returning to the left turn movement, it has been found in a number of studies that a driver's cognitive load is higher for turning maneuvers (13) than for through movements. Driver attention is divided at the intersection and cognitive processing power is therefore limited. The additional demands of turning reduce driver vigilance for detecting warnings and hazards (6, 10). Furthermore, it has been found that people are more receptive to new information before they make a decision rather than after making a decision (14). Thus, it is desirable to present information to turning drivers as soon as possible. An advanced warning would bring the safety information to the turning driver, upstream of the busy intersection environment. This would

provide an appropriate reminder while drivers are not burdened by the additional task of turning, before they reach the point of making the go/no-go decision.

While there are no standard signs specifically applicable to LRT median crossings, Section 8B-3 of the Manual on Uniform Traffic Control Devices (MUTCD) (15) reads: “The W10-2, 3, and 4 may be installed on highways that are parallel to railroads. The purpose of these signs is to warn a motorist making a turn that a railroad crossing is ahead.” These parallel advanced warning signs may not be the best sign for a median LRT crossing. It is difficult to show that the tracks are in the median (Figure 5). Specifically, W10-2 (Figure 5A) suggests that the track is along the shoulder, not the median. The variation depicted in Figure 5B, on the other hand, could be mistaken for showing two roadways instead of median trackage. In a study of the W10-3, Womak, et al. (16) found that only 69 percent of surveyed drivers correctly chose, “If you turn onto the side road, you will cross a railroad track” as the meaning of the Parallel Advanced Warning Sign. Also, 22 percent of respondents were confused about orientation and chose, “You will cross a railroad track, then come to an intersection ahead.”

Schoppert and Hoyt (11) advise that traffic engineers should use uniformity as a basic principle of signing. Unique warning systems should be developed for unique situations. The principle of uniformity is upheld if these unique systems are reserved for unique situations. Furthermore, a grade crossing protection system should provide adequate advanced warning for every crossing. To avoid the confusion about the median trackage and orientation, we recommend that an advanced warning sign be investigated based on the passive warning sign formerly in place at some arterial median intersections in Santa Clara County (Figure 6A). In particular, an additional arrow should be added to clarify that through movements are allowed at the intersection, e.g., Figure 6B.

Consistent with Sell, it may be possible to improve the effectiveness of the advance warning sign by adding control instructions in terms of the positive, or desired course of action (17).

McCormick and Sanders (10) note that most linguistic research indicates that active, affirmative statements generally are easier to understand than passive or negative statements. Finally, Whitaker and Stacey (18) found that permissive stimuli (“Do”) produced faster responses than did prohibitive (“Do Not”). The signal control strategy should thus be presented with the parallel

advanced warning sign and phrased in active, positive terms, e.g., “left turn on green arrow only” instead of “do not turn on red arrow.” In this manner, drivers are warned of the special conditions and they are instructed to the correct course of action. Forbes (19) noted that, when multiple signs are on the same pole, subjects tended to detect the top signs first. Likewise, Luoma (20) found that there was a greater probability of perceiving the top signs than the bottom signs. Since compliance with the left turn arrows will ensure safe operation, regardless if a driver is aware of the grade crossing, the control strategy should be placed above the crossing warning (Figure 6C).

No sign will be noticed or understood by all drivers. Therefore, as much redundant information as possible should be provided, without overloading cognitive capacities. It might not be advisable to add signing to the grade crossing environment because of all of the existing distractions; however, an advanced warning would provide information to the driver in a new environment. Furthermore, repeated exposure to advanced warning signs that prescribe the correct course of action should reinforce the message to regular drivers in the area

EDUCATION AND ENFORCEMENT

There is a need to educate the driving public about their duties and responsibilities at LRT crossings, e.g., via Operation Lifesaver. An education program is critical for startup systems where drivers are unfamiliar with street railways. Because a small error can result in a catastrophic accident, there is a need to reinforce compliance. This can take the form of punishment through police enforcement. This can also take the form of positive reinforcement, such as a busboard reading, “The LRT agency would like to thank you for helping us make this our safest year.” Because enforcement can be easily directed at the actors involved, it is much more feasible to implement. However, transit agencies should not overlook inexpensive means of education and positive reinforcement.

Punishment

LAMTA initiated a demonstration project assigning sheriff’s deputies to enforce grade crossing safety along the Metro Blue Line (21, 22). The deputies surveyed violators and found that 45

percent of the violators frequently used the intersections with LRT crossings. Of greater interest were the reasons given for the violations:

- 40 percent “Thought it was safe.”
- 25 percent “In a hurry.”
- 28 percent “Didn't see signal.”

Because of the initial success of the program, additional funding was allocated to keep six deputies on the LRT detail.

Long Island Railroad (LIRR) has also achieved positive results with police enforcement. The number of crossing gates run-through by drivers declined 40 percent from 1993 to 1994 (23). LIRR's strategy includes stationing marked patrol cars at three or four crossings each day during peak hours. The high visibility enforcement is supplemented with unmarked police cars.

Prevention Through Education

Prevention through education is directed toward all possible offenders. Some drivers and pedestrians have learned illegal practices that are safe under many conditions, but may be very risky at an LRT crossing. There is a need to educate those individuals who do not know their actions are illegal. It is also important to address those motorists and pedestrians who knowingly violate the law. Their experiences at conventional intersections or when LRVs are not present at LRT crossings may foster an inappropriately low perception of risk.

The education process can be as simple as witnessing another driver pulled over by the police on the side of the road. The perceived financial risk of a fine becomes a proxy for the inappropriately low perception of a safety risk. Sanders (24) found that at conventional grade crossings, driver awareness of law enforcement appeared to yield more careful behavior overall and tended to increase awareness in general.

The benefits of police enforcement can be increased with posted signs warning of the fines or enforcement. Violation warnings have been used to enforce speed limits, high occupancy

vehicle (HOV) restrictions, laws at conventional grade crossings and laws at LRT crossings. Although little has been published on the effectiveness of these signs, informal studies indicate that the “Minimum Fine for HOV Violation \$271” signs in California have had a positive impact on compliance.

LAMTA has posted violation warning signs in conjunction with their photo enforcement program. The signs have also proven to be effective in reducing the number of illegal left turns at an arterial median crossing, protected by conventional traffic signals and left turn arrows. After the installation of warning signs and issuance of warnings, the red left turn arrow violation rate dropped twenty five percent in two months (21, 22). The long term results at the gated crossing are promising and similar results should be attainable using conventional enforcement techniques. To be effective, a violation warning must maintain the perceived risk of apprehension. Otherwise, local drivers will quickly learn that the signs are meaningless.

With respect to crossing protection, Knoblauch, et al (25) asserted that education and engineering should come before enforcement. Educating the target audiences can yield greater benefits; furthermore, effective grade crossing enforcement may not be feasible with police priorities. Shinar (1) notes that it is difficult to modify established behaviors; everybody thinks they are an expert driver. As a result, he suggests the greatest long term effects can be gained from driver education, before unsafe practices are internalized. LAMTA has acknowledged the benefits of driver education and has lobbied California legislators and the Department of Motor Vehicles (DMV) to emphasize grade crossing safety in DMV Driver Handbooks (21, 22). Further benefits can be gained by producing educational material for driving schools and promoting LRT issues in their curricula.

To be effective, safety information must be seen, understood, and acted upon. To this end, it should be targeted at specific behaviors. General safety campaigns which have a message like, “safety matters” or “drive safely” tend to be ineffective if the drivers hold the common opinion that they are already safe drivers. The information (“propaganda”) must show that something can be done, not that accidents are inevitable. Similarly, driver information systems should tell drivers the safe course of action, not just tell them that an LRV is approaching.

Sell (17) asserts that safety posters and other propaganda can be made to produce the desired behavior modification. To be effective, they should:

- Be specific to a particular task and situation.
- Give positive instruction (“Do...”).
- Be placed close to where the desired action is to take place.
- Build on existing attitudes and knowledge.
- Emphasize non-safety aspects.

They should not:

- Involve horror, as horror may bring out defense mechanisms in the target audience.
- Be negative (“not...”), because this can show the wrong way of acting when what is required is the correct way.
- Be general, because almost all people think they act safely. This type of propaganda is thus seen as only relevant to other people.

These guidelines are in accordance with McCormick and Sanders (10), who note that most linguistic research indicates that active, affirmative statements generally are easier to understand than passive or negative statements.

One example where educational information can be used at the intersection is in signing. LRT accident reports suggest that some left turning drivers cue off of the cross traffic signals, anticipating a leading left turn phase. It is difficult to completely mask the cross traffic signals from the turning drivers. Programmed visibility heads may be able to achieve some success in this area, but the high cost of installation and reduced visibility on the cross street might not warrant this investment. On the other hand, using the principles described by Sell (23), a simple sign reading “watch for trains” underneath the cross traffic signals should yield some improvement. The sign prescribes the correct action to take, serving to remind the drivers that the LRT crossing is a special intersection, and that they should snap out of automatic pilot and into a conscious level of processing. In addition, the use of the word “train” rather than “trolley” communicates the hazard more effectively.

LIRR offers free educational programs for schools and community groups, distributes grade crossing safety literature at stations, sponsors public service announcements on radio and television, and participates in Operation Lifesaver (23). LAMTA has an impressive education program that includes participation in Operation Lifesaver and Trooper on the Train safety programs, school and community outreach presentations, a rail safety place mat game at local fast food restaurants, enlisting scout troops to distribute safety literature at grade crossings, safety posters in local businesses, safety reminders in local church bulletins, and regular meetings with local businesses (21, 22).

Startup LRT systems can face a large safety learning curve with the local community. Education campaigns are particularly important for such operators. Even if a full scale media campaign does not prove to be cost effective for an established transit agency, the resourcefulness of the LAMTA and LIRR has demonstrated that there are a number of low cost avenues for safety education and they should not be overlooked. Transit agencies can single out specific audiences in need of special attention, for example, non-resident pedestrians and drivers who have not been exposed to LRT systems. Literature and posters at rental car agencies could be beneficial in reducing the number of out of town drivers involved in LRT accidents. Another target audience is the student driver; teach them the safe and proper driving strategies before unsafe habits become ingrained.

STANDARDIZATION AND VISUAL CONSTRAINTS

At many LRT crossings, the traffic signal is the only control device to keep drivers out of harm's way. Every effort should be made to:

- Standardize LRT grade crossings throughout the system, and if possible, between systems. Thus, drivers will only face a couple of unusual intersection configurations (2).
- Guarantee that the LRT grade crossing functions the same from the driver's perspective, whether or not an LRV is present. Transit priority that skips a normal signal phase can catch drivers by surprise. If possible, the normal sequence of signal phases should not be

disrupted. Priority should be achieved by shortening phases and providing a “green wave” to the transit vehicles.

- Make the LRT grade crossings accommodate (undesirable) driving habits common at conventional intersections.
- Make it clear to drivers that the LRT grade crossing is a special intersection, commanding particular care and attention. In terms of Lourens (6), the drivers have to switch out of automatic pilot and into a conscious level of functioning. Drivers’ experiences at intersections without LRT grade crossings can certainly affect their compliance with the left turn arrows and “No Left Turn” signs at intersections with LRT grade crossings.

In addition to recognizing the need for standardization at intersections with LRT crossings, it is also important to consider the visual constraints inherent in the standard traffic signal systems. In standard traffic signal layouts, there are more signal heads for through-movements than there are for left-turn movements. In addition, the surface area of the green ball is much greater than that of a left-turn arrow, and the transmittance of a green filter is much greater than a red filter. As a result of the combination of these factors, the through-traffic signals have a greater probability of being perceived by a driver than do the left-turn signals.

Efforts should be made to reduce the chance that a turning driver will mistake the through traffic signals for controlling turning movements. Judicious use of programmable visibility heads, louvers and arrow filters on through-traffic and cross-traffic signals can improve left turn arrow compliance. If a vertical arrow is used for the through traffic signal, instead of a green ball, the signal clearly indicates the permitted movement. Furthermore, the illuminated surface area is comparable to the left turn arrow. Thus, reducing the chance that a turning driver will mistake the through traffic signals for the turning movement.

CONCLUSIONS

LRT systems will continue to expand and develop throughout the nation, with even greater numbers of at-grade crossings. This paper has focused on the synthesis of literature related to the thorough understanding of accident causation as related to LRT median grade crossings, and

the development of effective countermeasures. Much of this work can be extended to the other LRT crossing types, including grade crossings in side-running situations.

Accident causation and prevention should continue to be the subject of careful research and field data collection. First generation reactive countermeasures, including audible alarms and LRV operator alert systems should be given full consideration prior to the ultimate testing and implementation of in-vehicle collision avoidance systems. There seems to be a great need to develop and standardize some relatively simple and low-cost passive countermeasures; the introduction of knock down delineators at intersections, and the use of appropriate signing are just two examples. Ongoing education and enforcement strategies for LRT at-grade crossings, particularly those innovative and successful programs currently sponsored by LAMTA, should be shared with all LRT operators and expanded. Increased synergistic relationships with law enforcement, motor vehicle licensing agencies and public educational systems should be pursued with vigor. Finally, transit agencies should strive to work with traffic engineers, law enforcement, and other LRT systems to standardize the visual landscape presented to drivers at intersections with LRT grade crossings, allowing for improved safety and operations at the myriad locations throughout the nation.

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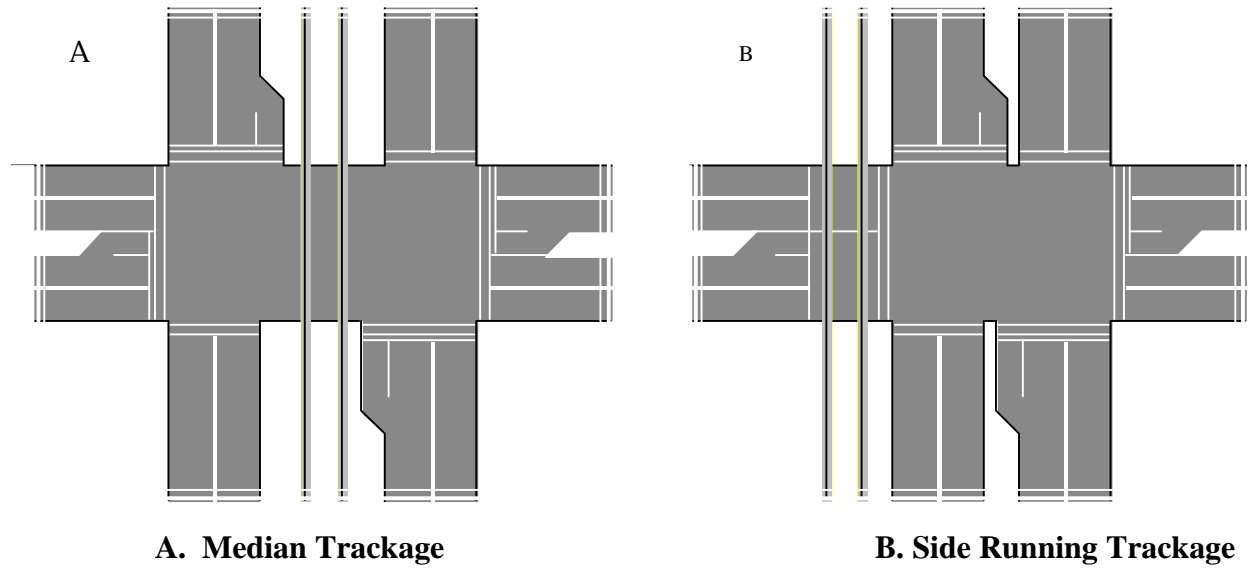


Figure 1 LRT Crossing Layouts

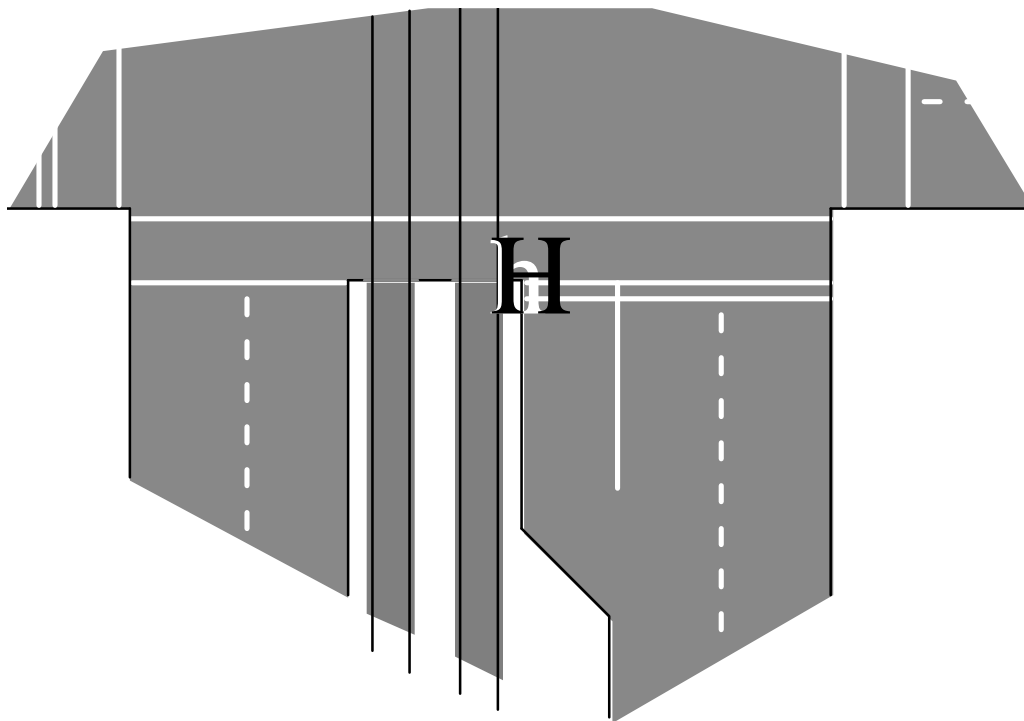


Figure 2 Example Of A Left Turning Driver Entering The LRV Dynamic Envelope Before Traversing The Crosswalk.



Figure 3 **Accident Causation Tree**

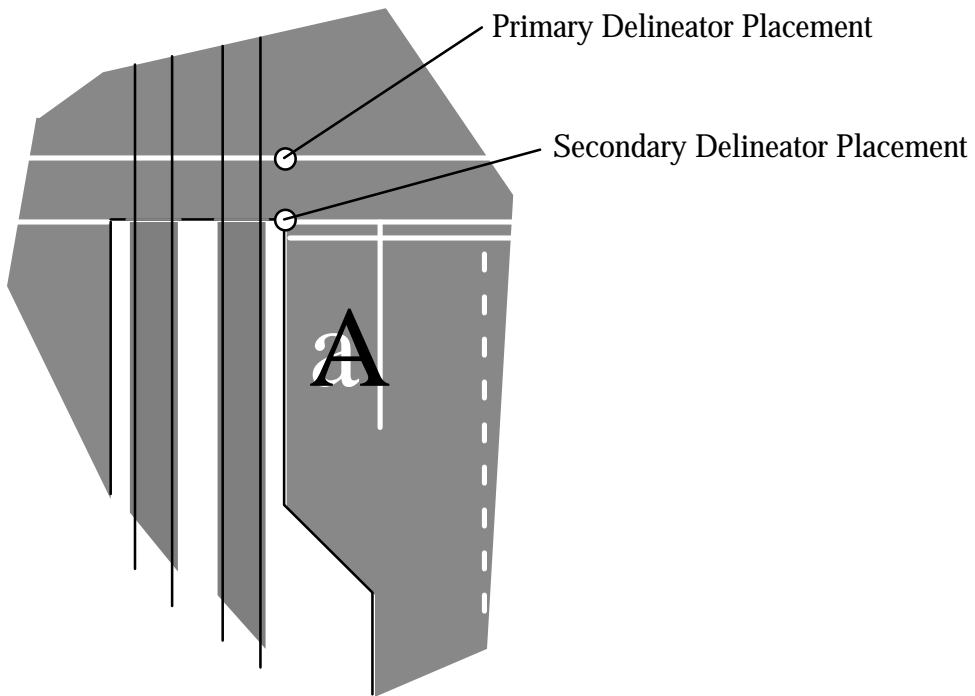
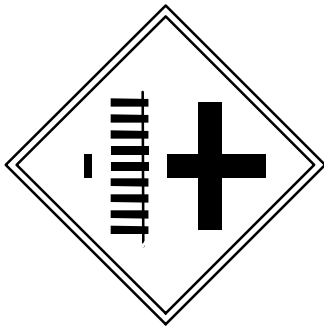
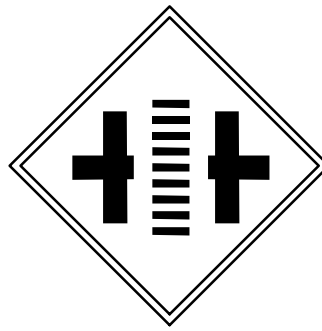


Figure 4 Proposed knock down delineator placement

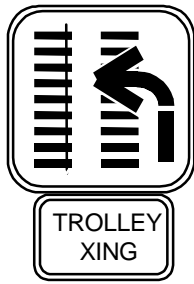


**A. W10-2 Parallel railroad
advance warning sign**

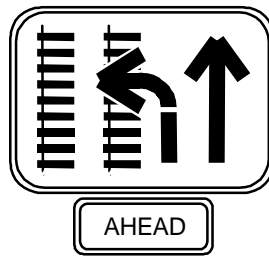


**B. Modified W10-2 suggesting
median trackage.**

Figure 5 Advanced Warning Signs



A. Existing static crossing warning sign.



B. Proposed parallel advance warning sign.



C. Proposed parallel advance warning sign prescribing signal control at grade crossing.

Figure 6 Crossing Warning Signs