METRORAIL TRAFFIC SAFETY ASSESSMENT

Prepared For:
Metropolitan Transit Authority of Harris County

By:
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Executive Summary

Concern over motor vehicle collisions with METRORail light rail vehicles during the first month of rail service led to METRO requesting the assistance of the Texas Transportation Institute for an analysis of the safety of the rail line. This assessment found that the METRORail design was consistent with the provisions contained in the Manual of Uniform Traffic Control Devices (MUTCD) and general design practice involving traffic safety provisions in constrained alignments.

A research team consisting of experts from TTI and the light rail industry examined data on METRORail's design and operations, on the collisions, and on similar experiences of other light rail systems. The work was initiated in early February and included a review of collisions through that time. The research team also spent three days in Houston to observe the conditions along the rail right-of-way, particularly at locations where rail vehicles and motor vehicles interface. This report summarizes the findings of the assessment.

Background Information

The first 7.5 miles of METRORail was constructed to fulfill part of Houston's long-range transportation plan, and provides for high-capacity transit service in the travel corridor linking the downtown area with Midtown, the Museum District, the Texas Medical Center, and the Reliant Park area. The rail line travels at grade along the surrounding streets, to the left or right of the roadway in some areas and in the street median in others. For most of the rail line, the motor vehicle lanes and METRORail trackway do not overlap, but do interface at intersections; however, in the Texas Medical Center area, left-turn lanes "share space" on the trackway.

Collisions

The most common type of collisions that occurred between motor vehicles and METRORail vehicles through the first month involved illegal left-hand turns by motorists. Despite traffic signs and signals designed to control the location and timing of left-turn movements along the rail line, several motorists have turned into or in front of oncoming LRVs, sometimes turning from an incorrect lane. All collisions examined appeared to have been due to improper or illegal turns or other driver errors.

Illegal left turns are a primary source of motorist-LRV collisions in other light rail systems as well: light rail lines in Los Angeles, San Diego, Portland, Dallas, and Salt Lake City have employed a variety of design features and public education programs in their efforts to reduce unsafe movements by drivers along the rail right-of-way, with varying degrees of success. Some of these solutions, such as extensive operator training and active public education and outreach programs, are already in place at METRORail, while others were included in the research team's list of potential safety enhancements.

METRORail Safety Analysis and Suggestions for Safety Enhancement

METRORail is almost totally in semi-exclusive right-of-way with very limited lateral clearance and some very tight constraints. Safety provisions of the design were found to be generally adequate. Some minor adjustments to the traffic control devices and operational practices are needed to fine tune the system and its operation to work as intended. This includes such aspects as traffic control system adjustments for current operating speeds and adjustment of signing.

The assessment also found that several opportunities exist to further enhance METRORail traffic safety. These generally fall in the categories of modified signing, minor changes in signal and LRV operation, and increased use of pavement markings. There are additional possible enhancements that require engineering and operational analyses to ensure that the improvements will be truly effective and free from unintentional side effects that might create new issues not currently existing.

1.
INTRODUCTION

In its first four weeks of revenue operation, METRORail experienced five LRV crashes with motor vehicles. Five additional crashes had occurred during testing prior to initiation of operations. Correctly or not, this has resulted in a perception that the METRORail operation may possibly be unsafe.

Charge

METRO requested that the Texas Transportation Institute (TTI) perform an independent assessment of the appropriateness and operation of traffic control devices, METRORail operational procedures, and design features that may be related to the crashes involving METRO's LRVs to date. TTI, in association with three outside light rail transit planning, design and operations experts, completed this assessment over a four week period during February 2004.

Scope

The assessment included signs, signals, pavement markings, intersection design, LRV and intersection operations, and related features. It addressed location, visibility, comprehensibility, driver interpretation, operations, and other factors that may have contributed to the crashes experienced. The purpose of the study was to identify good features of the light rail system, to determine if any deficiencies in design or operation exist, and to suggest enhancements that could be made to improve LRV-motor vehicle safety along the METRORail route. Finally, the assessment included a review of METRORail's collision reports and of related start up crash experiences of other U.S. and Canadian LRT systems. The assessment did not, however, involve the collection or analysis of extensive data, in the field or otherwise. The suggestions provided in this report are largely based on the engineering judgment of a panel of experts.

The research team spent three days (February 10-12, 2004) studying intersections and streets along the rail line, observing rail operators and surrounding traffic behavior, and meeting with METRORail staff to obtain information on related aspects of METRORail operations. At the conclusion of this three-day period, the research team met with METRO staff to discuss preliminary findings and to suggest initial actions to METRO. The contents of this report were developed subsequent to that meeting.

Report Contents

The first section of this report summarizes collision-related experience and safety enhancements utilized by several other light rail systems in North America, as well as background information on METRORail's collision experience to date, with emphasis on early accident experience, if information was readily available. The second section addresses the findings of the research team concerning METRORail's accomplishments and effective practices related to safety and possible alternatives for signage, signalization, and/or operating practices that could improve safety for light rail vehicles, motorists, and pedestrians.

Definition of Report Terminology

The METRORail traffic safety assessment was to identify three types of conditions:

- Commendable – positive design, operational or other provisions that make positive contribution to traffic safety and that would not always be found on another start-up light rail system.
- Deficiency – a design or operational feature that fails to comply with normal light rail design or operating criteria or a traffic control device that does not comply with the *Manual on Uniform Traffic Control Devices (MUTCD)*.
- Enhancement opportunity – a feature, condition or operational practice that is not deficient, but for which actions or changes might enhance or increase traffic safety or transit operations related to safety.

An example of the difference between a deficiency and an enhancement opportunity is:

- Deficiency – A sign is improperly designed and does not conform to the MUTCD requirements.
- Enhancement opportunity – An intersection has a "no left turn" sign and a "no right turn" sign facing one approach. This could be simplified to reduce the number of messages to be read by using a "no turns" sign.

2.
BACKGROUND

Houston METRORail Alignment

Houston's light rail transit system, METRORail, originated with the Houston METRO 2020 Regional Transit Plan, published in 1997. The Plan outlined the need, recognized in previous studies, for a high-capacity transit system along the 7.5-mile Downtown to Astrodome travel corridor. The light rail system was proposed and built as a two-track at-grade system mostly within existing street rights-of-way, with electric-powered vehicles. METRORail currently operates from the rail station and Park &Ride lot just south of Fannin and IH-610 northward to the Downtown University of Houston campus. The rail line passes through several distinct neighborhoods, each with its own land uses and travel patterns.

- *Astrodome-Reliant Park Area:* The Astrodome area includes residential, commercial, and industrial development, and is expected to expand in the coming years. Besides the Astrodome and Reliant Park, new entertainment facilities are planned for this area. The rail line's south endpoint is the Fannin South Station/Park & Ride Facility, located on the east side of Fannin Street near the intersection with West Belfort. The two tracks cross to the west side of Fannin and proceed north to the Astrodome complex. Crossings at the south end of the rail line and the Fannin crossing are controlled by automatic gates, due to both traffic and rail operating speeds and sight distances at this section of the rail alignment. The rail line then continues north, turning west on Greenbriar and moving from the side to the center of the street. The center-running tracks then turn east onto Braeswood, then north onto Fannin to enter the Texas Medical Center.

- *Texas Medical Center:* Employees, patients, and other TMC activities result in 150,000 person trips to the Texas Medical Center (TMC) per day. Projected future expansion of the TMC will greatly increase the travel demand for this part of the city, and transit service will be necessary to answer much of that demand. Hermann Park, just north of the TMC, houses the Houston Zoo as well as other public facilities. The rail line continues along the center of Fannin Street through the TMC and Hermann Park, separated from traffic lanes by large 12 inch raised traffic buttons that can be crossed by motorists but act as a visual delineator. Traffic and the rail share lane space at four left-turn lanes located at intersections within the TMC. The rail line splits south of Hermann Drive, continuing northbound on San Jacinto Street, with the southbound track on Fannin Street.

- *Museum District and Midtown:* Rice University and Houston Community College are two major features in this section of town, in addition to six museums and numerous other arts facilities, commercial facilities, and residential and retail areas. The rail line operates in the east curb lanes on the parallel San Jacinto and Fannin Streets throughout the Museum District, separated from traffic lanes by a flush curb topped with the 12 inch traffic buttons. Just north of Highway 59, as the rail line enters the Midtown area, the two tracks converge and transition onto Main Street at Wheeler. From there they travel

in the center median to the north end of downtown. In Midtown, the center-running tracks are separated from traffic lanes by the 12 inch traffic buttons on a flush curb.

- *Downtown:* Dominated by commercial offices, civic buildings, and entertainment venues, the downtown area sees large numbers of commuters and visitors on a daily basis. Pedestrian traffic is heavy during both the day and evening hours. The rail alignment on Main Street is separated from traffic lanes by flush curbs topped with 12 inch traffic buttons. Temporary post and cable fences have been installed between the trackway and traffic lanes in a few blocks in the north end of downtown. There is also decorative fencing in Main Street Square. Turns across the tracks are not permitted in downtown south of Commerce Street. North of Commerce Street, the trackway is located on the west side of the Main Street bridge.

METRORail Operations

The basic operating scenario for the METRORail system is to have the LRVs move from station to station on a green signal (progression) band. In the medical center area, the LRVs operate with traffic, especially in the vicinity of the shared left turn lanes.

Bar Signal Indicators

Throughout the METRORail system, bar indicators are used to inform rail operators whether or not they may safely enter a traffic intersection. A vertical bar indicates that all conflicting traffic movements are being signaled to stop and that the LRV may proceed through the intersection. LRV operators are not permitted to pass a horizontal STOP bar without explicit permission from METRORail Control. This is an appropriate rule for it tells the rail operator that it is not safe to enter the intersection.

Typically, bar indicators are of a size, shape, and color so as not to be confused by motorists as traffic signals. The indicators as used in the METRORail system are clearly different are not a known source of confusion for motorists.

The location of the primary bar indicator head is usually near-side. Indicators are also placed far-side when special conditions are warranted. In the case of the METRORail system, many of the bar indicators are placed at station platforms, a considerable distance from the intersection. Because of the operating rule, rail operators cannot move up to the intersection and enter the turn lanes.

Operator Training and Testing

METRORail operators are selected by application from METRO's bus operator pool. Only operators with exemplary safety and conduct records are considered as applicants. Following acceptance of their applications, rail operator trainees must complete an 8-week training course. The first phase of training is three weeks of classroom instruction and familiarization with the rail line and with rail yard and shop operations. During those three weeks, a trainee must pass six written examinations: three on signals and one each on rail definitions, the METRORail rule book, and a final comprehensive exam. Exams must be passed with a minimum of 80 percent

correct answers (100% on signals). The second phase of training lasts five weeks and includes 40 hours operating a light rail vehicle (LRV) in the rail yard, on the test track, and finally on the actual light rail alignment. Trainees in Phase 2 must pass a final Signals Examination and a Qualifying Run Observation Examination, during which the trainee must demonstrate safe and on-time operation of an LRV on the rail alignment. The Signals Examination, unlike the other exams, must be passed with no mistakes. One re-take examination is permitted per trainee; those who fail to pass the retake examination are disqualified from the class.

METRORail Vehicle Collisions

Information Gathered

There were several sources of background information gathered during this study: police reports and collision diagrams from each LRV collision, METRO Safety reports, onboard LRV closed circuit video, and LRV operational information obtained from the "black box." All of these sources provide insight on conditions just prior to the collision.

Additional background information was gathered from the Bureau of Transportation Statistics and the three years of collision information from the Texas Department of Public Safety.

METRORail Collisions

There were a total of 16 reported collisions involving a METRORail LRV during the pre-service testing and the first month of revenue service. A list of the collisions by date, time, and type is shown in Table 1. The location of each collision is shown in Figure 1.

Table 1. METRO LRV Collision Experience.

ID #	Crash Date	Crash Time	Day of Week	LRV Direction	Location		Type	Severity
1	11/19/03	19:53	Wednesday	NB	Main	Gray	Left Turn	C
2	12/17/03	12:25	Wednesday	SB	Fannin	5200 Fannin	RtAngle Parking Lot	N
3	12/19/03	10:25	Friday	NB	Main	Alabama	Left Turn	C
4	12/20/03	12:16	Saturday	NB	Fannin	John Freeman	Left Turn	C
5	12/30/03	18:25	Wednesday	SB	Fannin	Reliant Park	RtAngle Parking Lot	N
6	1/9/04	8:25	Friday	SB	Fannin	Binz	Left Turn	C
7	1/12/04	13:39	Monday	NB	Main	McGowen	Left Turn	N
8	1/13/04	16:01	Tuesday	NB	Fannin	University	RtAngle from Side St.	N
9	1/17/04	10:23	Saturday	SB	Fannin	Rosedale	RtAngle from Side St.	N
10	1/19/04	14:09	Monday	NB	Fannin	SLMT-TCH	Left Turn	C
11	1/20/04	9:35	Tuesday	SB	Fannin	Dryden	Left Turn	N
12	1/23/04	16:08	Friday	SB	Fannin	SLMT-TCH	Left Turn	C
13	1/23/04	9:00	Friday	EB	Kirby	Holmes	Grade Crossing	A
14	1/26/04	12:57	Monday	SB	Fannin	Southmore	Left Turn	B
15	1/27/04	14:47	Tuesday	SB	Main	McGowen	Left Turn	N

Note: Severity rating codes for Table 1: N= No injury; C= Possible injury; B= Non-incapacitating injury; A= Incapacitating injury

While the limited number of collisions does not show a specific location pattern, there are, however, several similarities that can be gathered from the collisions. These similarities are listed below:

- All the collisions were at intersections.
- 10 left turn crashes, two right angle side street crashes, and two right angle parking lot crashes
- All collisions were with motor vehicles; none involved pedestrians
- There were no fatalities.
- Only minor injuries were incurred. 7 non-injuries, 6 possible injuries, 1 non-incapacitating injury, 1 incapacitating, no fatalities.
- All collisions were a result of the driver's disregard of a sign or signal.
- The majority of the collisions were left turn collisions.
- The collisions were in midtown or in the medical center.
- All collisions appeared to be very sudden/unexpected and unavoidable from the LRV perspective (from vehicles turning from center lanes, or from vehicles stopping and pulling out into the path of the oncoming train).
- All collisions were a result of driver error or improper motor vehicle movements based on the information reviewed.
- The majority of the collisions appeared to be low speed.

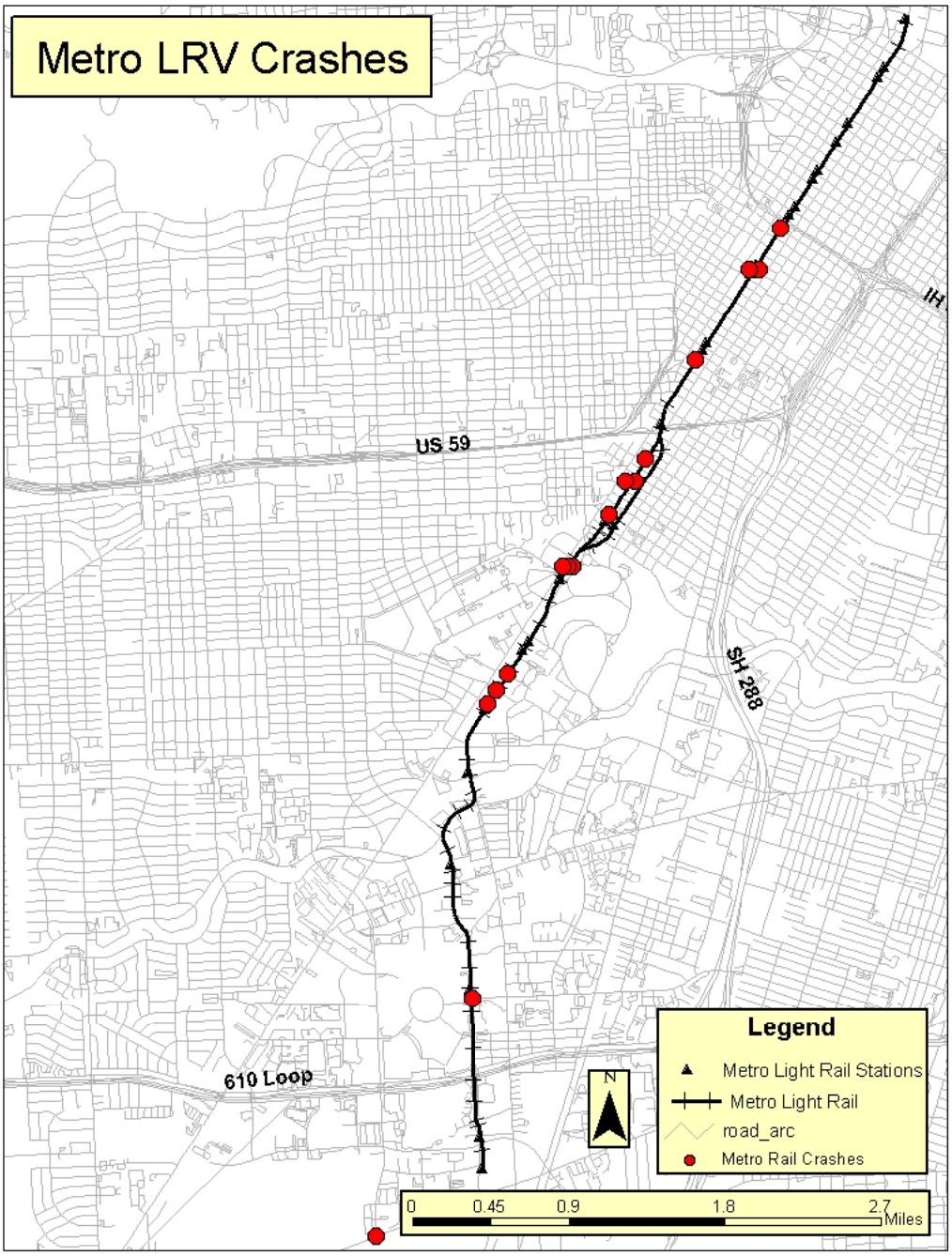

Figure 1. Graphical location of METRO LRV Collisions.

Based on the location of the left turn collisions, the LRV videos, and the somewhat erratic nature of the turns observed, there appears to be some way-finding issues in the midtown and TMC areas. These issues were also observed during the field investigation. The lack of collisions downtown may be attributed to the long term ban on most left turns from Main Street in the downtown area dating back to the 1950s.

While there have been a number of collisions involving LRVs during the initial operating period, these types of collisions are not specific to light rail collisions. Figure 2 shows the 1998 to 2000 collision experience in the area. There were nearly 8,000 total collisions and almost 2,000 were on Main and Fannin alone. Although some major operational changes in the corridor may change the hot spot locations, there will likely still be a large number of collisions in the area due to unfamiliar drivers and high traffic volumes. This is not a problem unique to Houston. Nationally, nearly half of the collisions are intersection or intersection related. Table 2 shows the national 2001 collision statistics.

Table 2. 2001 National Collision Statistics.

Collision Type	Fatal	Injury	PDO	Total
Non-Intersection	27,340	776,000	1,868,000	2,671,340
Intersection or Intersection-Related	8,490	970,000	1,742,000	2,720,490
Other	1,965	256,000	672,000	929,965
Total	37,795	2,002,000	4,282,000	**6,321,795**

Source: National Highway Traffic Safety Administration; DOT HS 809 484

Recommendations

It appears from all the information reviewed that the collisions were a result of driver error or improper motor vehicle movements. However, the research team has identified several recommendations that may help to reduce the potential for driver error and the resulting collisions. The recommendations for reducing the LRV collision experience are:

- Continue to review the collisions and near misses.
- Look for patterns (types of collisions [left turns)] location, etc.).
- Ensure that the recording of train operational characteristics is synchronized with video.
- Continue to concentrate enforcement in intense, periodical bursts.
- Continue public education (particularly emphasizing left turn safety and awareness).
- Provide better indication of how TMC left turn bays should be used to reduce driver confusion.
- Continue to work with TMC and businesses in the Museum District to help them clearly indicate to their patrons the best way to get to the location and parking areas.

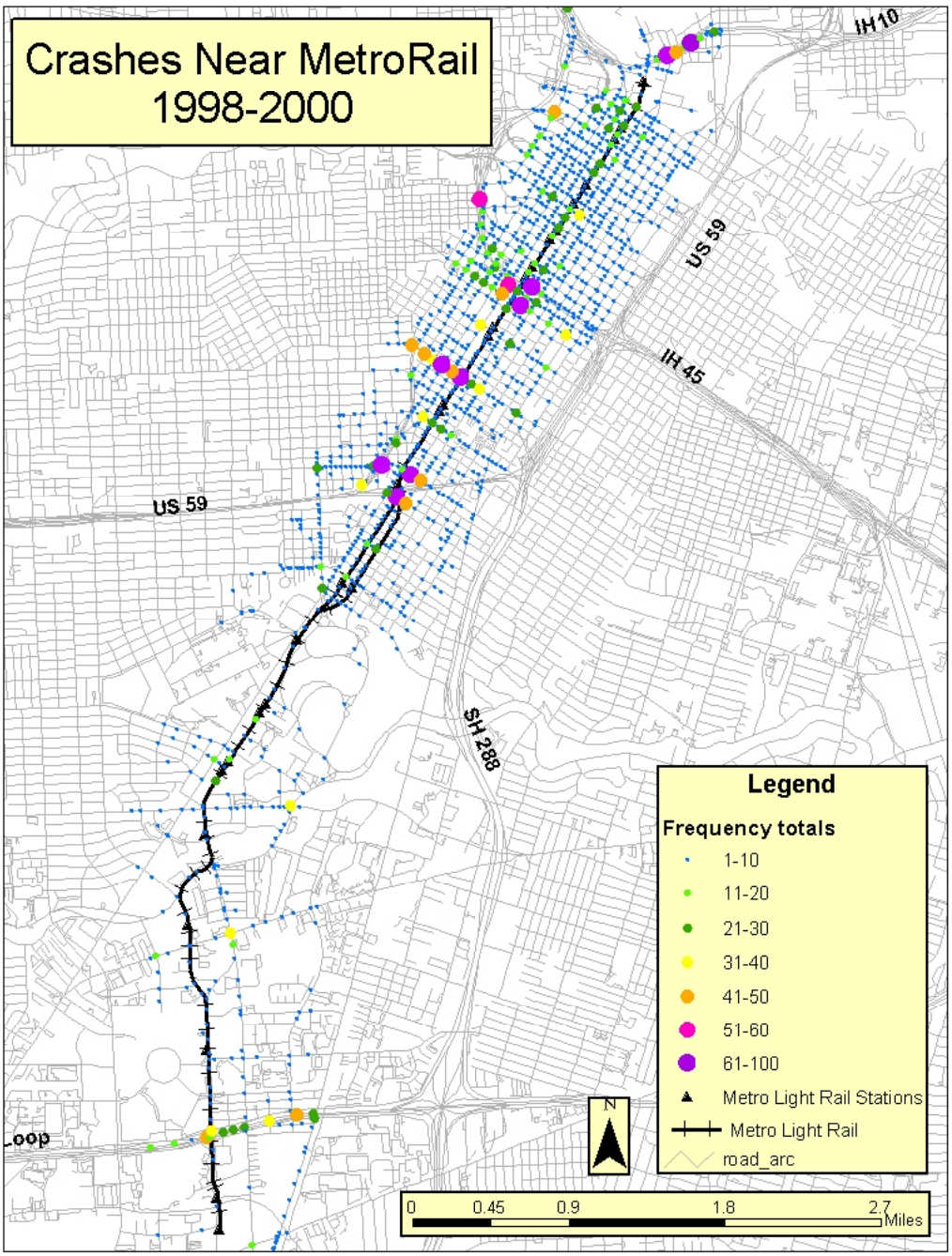

Figure 2. 1998 – 2000 DPS Collisions Along the METRO Main Street Rail Alignment.

Traffic Violations Before and After METRORail

METRO police issued over 8,000 citations to motorists and pedestrians in Houston's Police District 1 for traffic violations during 2003, the year preceding METRORail's opening. District 1 encompasses all but the southernmost stop of the rail line. Nearly 3,000 of the ticketed violations, or approximately one-third of the district total for that year, were along the streets that now share right-of-way with light rail vehicles.

Of the citations issued along what would become the rail line, about 29% were for illegal turns made in violation of traffic signs or signals. Failure to stop at red signals or at stop signs, failure to stop in the designated place, or failure to yield to oncoming traffic accounted for about 16% of the citations. Other motorist movements that disregarded posted traffic signs or signals resulted in about 24% of the citations. Unsafe lane changes, improper turns from the wrong traffic lane, speeding, and driving on the wrong side of the street, in the wrong direction, on rail tracks (under construction during this year), or on a prohibited segment of roadway accounted for the remainder of motorist violations. Pedestrian violations of traffic signs, signals, or regulations accounted for about 20% of the citations.

During the first few weeks of 2004, METRO reported that its enforcement program was increased along the METRORail route, and then reinforced after initial crashes were experienced. METRO estimates it has been issuing approximately 500 citations per week for illegal driving along the METRORail route. It is quite clear that driver behavior in this corridor has not been consistent with driving regulations and the lack of compliance has continued after the opening of the LRT line. This lack of compliance contributes to the accidents that are occurring along the LRT line.

Collisions: Other Light Rail Systems

When examining light rail accident data, the type of right-of-way (ROW) in which the trains travel must be considered as a factor for comparing different systems and determining appropriate solutions. TCRP Reports 17, *Integration of Light Rail Transit into City Streets*, and 69, *Light Rail Service: Pedestrian and Vehicular Safety*, define several distinct categories of light rail ROW, each interacting with automobile and pedestrian traffic in a different way and to a different extent. The categories are as follows:

- A = Exclusive ROW; grade-separated; no interface with street traffic
- B1 = Semi-exclusive ROW, adjacent to roadway; has at-grade street crossings, otherwise separated by fences or barriers from traffic lanes
- B2 = In-street ROW; separated from traffic lanes by fences/barriers
- B3 = In-street ROW; separated from traffic lanes by barrier curbs
- B4 = In-street ROW; separated from traffic lanes by striping and/or barriers that are easily crossed by vehicles
- B5 = ROW within a pedestrian mall adjacent to roadway, separated by warnings/striping
- C = Trains operate in mixed traffic operations, in traffic lanes with vehicles or in pedestrian mall with pedestrian traffic

METRORail's ROW is type B1 on its southernmost end adjacent to the South Fannin station, B2 in part of Downtown (where temporary fencing was installed for Super Bowl activities), and B4 in the rest of Downtown, Midtown, the Museum District, and in the Texas Medical Center. Left turn lanes at four intersections in the medical center area are type C. Accident information from twelve light rail systems was obtained from the two TCRP reports referenced above and from telephone interviews where possible. Table 3 summarizes the ROW types present within each of the rail systems, the most common accident types experienced, and the actions taken to improve safety. The experiences of the following selected light rail systems have resulted in some safety solutions that are similar to those already implemented at METRORail, and others that might be applied to METRORail facilities and operations as further enhancements:

- *Calgary:* While much of Calgary's light rail is on a separate right-of-way, there are several signalized intersections that are at-grade with cross streets. Calgary Transit is currently conducting an evaluation of every rail-traffic crossing to maximize safety for LRVs, motorists, and pedestrians. At some intersections, Calgary Transit has installed gates parallel to the tracks to block turns across the tracks at intersections when the train is present. Another safety solution has been to keep the signs and signals at each intersection as simple and minimal in number as possible, to prevent visually overloading motorists.

- *Dallas:* The DART rail system, like METRORail, has had collisions resulting from left-turning vehicles crossing the tracks in front of LRVs and from vehicles entering intersections from cross streets against traffic signals. Active "train approaching" and "no left/right turn" signs triggered by approaching trains have been installed at non-gated intersections, as well as lane channelization for both motorists and pedestrians. Automated pedestrian gates have also been installed. DART has also implemented a "near-miss" reporting requirement to document potentially hazardous situations along the rail line; operators observing a near-collision or similarly hazardous behavior immediately make a verbal report to DART's central control. Similar documentation of near-miss situations is recommended for METRORail as a way to collect more data for future safety improvements.

- *Los Angeles:* The Los Angeles MTA's Blue Line has had a large number of accidents involving motorists driving around lowered gates at rail crossings and turning in front of LRVs at intersections. Gates were changed to four-quadrant gates that prevent "drive-around" maneuvers, and signalization was modified at several intersections to include turn arrows. Fiber-optic "train approaching" signs were also added at intersections as supplementary warning information to motorists and pedestrians. Enforcement and education have also been important elements of the MTA's light rail safety program. Automatic cameras have been installed at high-accident rail-roadway intersections, and drivers who are photographed crossing the tracks illegally (against signals/signs) are fined $275; if Texas law permitted, this could be an option for some of METRO's most accident-prone locations. Public education is conducted via radio and television commercials and newspaper ads focusing on specific dangerous behaviors and through school materials such as information flyers and coloring books, similar to METRO's outreach efforts.

- *Portland:* Portland's Tri-Met has progressed through three types of active signs warning motorists of approaching trains: one with the word "train," one with the words "train coming," and the final design incorporating a train icon with the word "warning." All three types of signs flash when a train is approaching, and have been effective in reducing accidents at the intersections where they are used. Several accidents involving pedestrians at train crossings led to Tri-Met commissioning an independent review of the rail system. From that review came a set of "light rail crossing safety" design criteria.

  Safety treatments at pedestrian crossings include such features as pavement markings, z-crossings and swing gates, and/or active and passive signing instructing pedestrians where to cross or not cross and to look for trains. METRORail already incorporates several of these treatments at pedestrian crossings.

  Finally, increasing the permissible traffic movements along certain "problem" streets had positive effects on safety. During initial start-up of the light rail line, Portland's Morrison Street, which had left turns permitted onto cross streets prior to the installation of the rail line, had been changed to prohibit all left turns. A parallel street, Yamhill, continued to allow left turns at intersections following an all-red phase that allowed LRVs to pass through ahead of cars. During the first year, no collisions occurred on Yamhill Street, but several occurred on Morrison Street as motorists disregarded "no left turn" signs. Morrison Street was changed to permit left turns in the same manner as Yamhill Street, and both collisions and near-miss incidents decreased considerably. This design change might apply to the Midtown section of METRORail, which has had similar violations of the no-turns policy.

- *San Diego:* The San Diego Trolley system, like Houston METRO, has implemented extensive training for operators, emphasizing the necessity for extraordinarily defensive driving by train operators. Operator awareness of potentially hazardous motorist and pedestrian behavior, including potential "suicide" collisions, is a primary focus of training for San Diego Trolley operators, and has resulted in a reduction in accidents even as the Trolley system miles have expanded. Other solutions implemented in San Diego include signalized controls for left turns, cross-hatch pavement striping at intersections, and pedestrian gates and z-crossings.

- *Salt Lake City:* Left-turn, U-turn, and encroachment on tracks by parallel-traveling motorists make up the majority of collisions for Salt Lake City's TRAX light rail system. To address illegal left turns that were being made across the rail tracks into and out of business driveways, TRAX installed jersey barriers at these sites, preventing turns across the roadway median and tracks and eliminating collisions at these locations. At other intersections where left turns are not permitted at any time, curb or delineator barriers have been installed to separate traffic lanes from the tracks. Delineator barriers, used at some locations with high levels of motorist and pedestrian traffic, are made of flexible reflector-topped poles (approximately 24 inches tall) and can be driven over without damage, but provide an effective visual barrier to both motorists and pedestrians. At signalized intersections where left turns are permitted except when trains are present,

active “no left turn” signs are accompanied by flashing “train coming” signs to alert motorists to approaching LRVs. Finally, TRAX has had considerable support from local media in spreading public education about light rail safety. While METRO has already made considerable efforts in public education and outreach, a possible addition could be active outreach to editorial boards and public interest programming to help spread information on light rail safety in Houston.

Table 3. LRT Startup Accidents and Countermeasures.

LRT System (data period)	ROW Type					Accident types	Actions taken
	A	B1	B2	B3-B5	C		
Baltimore (1992-1996) 3 accidents		X	X	X		Motorists driving around gates at intersections	Gates made longer, more difficult to drive around Additional train-activated warning signs
Calgary (1981-1996) 76 accidents		X	X		X	Motorists turning across LRT ROW at intersections Pedestrians crossing tracks against signals/warning lights Pedestrians trespassing on tracks Other causes unknown	Left-turn automatic gates/quasi-four-quadrant gates Pedestrian swing gates and barriers “Second train approaching” signs Public outreach to increase awareness and safe behavior.
Dallas (June 1996-August 1996) – 1 accident FY 1998 – 14 accidents		X		X		Motorist ignored, drove through lowered gates Left turns across tracks at ungated intersections Vehicles crossing tracks against signals at intersections	Train-activated “No Right Turn” or “No Left Turn” signs “Train Coming” signs Channelization at LRT crossings to prevent driving around gates Pedestrian gates Traffic signal pre-emption Public outreach and feedback

LRT System (data period)	ROW Type					Accident types	Actions taken
	A	B1	B2	B3-B5	C		
Denver (1994-1996) 1 accident in B1 ROW 13 accidents (from January to July 1996) in B4 ROW		X		X		Motorists driving around safety gates and barriers	Raised medians with barrier curbs near crossings Public education via driver training manual for state of Colorado
Edmonton (1978) 30 accidents (1978-1996)	X	X				Motorists driving around safety gates/barriers Failure of pedestrians to see trains	LRV horn (only when necessary to avoid a collision) Enforcement Pedestrian automatic gates "do not block intersection" signs activated by traffic queuing at train intersections
Los Angeles Blue Line(1990) 309 accidents (1990-1996)		X	X	X	X	Vehicles driving around gates (32) Pedestrians ignoring approaching-train signals (thinking the signals are for a train that has passed already) Lack of signalization for vehicles turning left across tracks	Pedestrian swing gates "second train approaching" sign to provide additional warning photo enforcement at high-accident intersections four-quadrant gates dedicated left-turn lanes with green/red arrow traffic signals public education – school materials, TV spots

LRT System (data period)	ROW Type					Accident types	Actions taken
	A	B1	B2	B3-B5	C		
Portland (1994-2003) 382 accidents		X		X	X	Left turns across tracks at ungated intersections Motorists disregarding traffic signals Pedestrians unaware of trains at crossings	Pedestrian automatic gates, swing gates, channelization Audible warning devices (for pedestrians) Active "train coming" and passive "look both ways" signs warning striping and tactile strips at crossings and bicycle lanes
Sacramento (1987) 20 accidents		X	X		X	Motorist confusion with traffic signals vs. train warning signals/signs – visual clutter, info overload Motorists driving around lowered gates	Vehicle channelization Audible warning device for pedestrians Eliminating excessive unnecessary delays due to prematurely lowering gates Future construction will eliminate "free right" turn lanes; will force motorists to stop before turning to eliminate high-speed conflicts.
St. Louis (1994) (1 accident, 1994-1996)	X	X	X			Motorist drove around gates	Gradual introduction of service (fewer trains, low speeds) until public was accustomed Larger warning lights on gate arms Eliminating excessive unnecessary delays due to prematurely lowering gates Change in operating methods to slow train at potentially dangerous intersections Changes to pedestrian crossings

LRT System (data period)	ROW Type					Accident types	Actions taken
	A	B1	B2	B3-B5	C		
San Diego (1981; 1997 new expansion) 88 accidents		X		X		Illegal left turns from driveways across tracks to roadway Impeded visibility at some intersections	Cross-hatch striping at LRT crossings Automatic pedestrian gates and z-crossings Red arrow on traffic signal to indicate "No Right Turn" when train is approaching Eliminating excessive unnecessary delays due to prematurely lowering gates Extensive operator training program which emphasizes close observation of motorist and pedestrian behavior.
San Jose (1987; extension in 1999) 1 accident, 1987-1996		X		X		(near misses) – pedestrians trespassing in ROW	"second train approaching" signs fencing to provide access control between crossings barrier gates for motorists and pedestrians pre-signals, designed to stop motorists upstream of a track crossing

LRT System (data period)	ROW Type					Accident types	Actions taken
	A	B1	B2	B3-B5	C		
Salt Lake City (1999) 61 accidents, 1999-2003		X	X	X		Left turns across tracks at intersections U-turns across tracks Left turns entering or leaving driveways Motorists drifting into trackway from parallel lanes Broadside collisions from perpendicular streets	Active "no left turn" signs plus flashing "train coming" signs at intersections Jersey barriers at troublesome driveway interfaces "delineator" barriers where no left turns are permitted – reflectors on flexible 24-inch poles to create visual barrier two-second head start for trains at intersections (moving train through intersection ahead of traffic, via signal timing)

Train Bell/Horn Usage: METRORail and Other Light Rail Systems

METRORAIL trains are equipped with four audible signals: a bell/gong, a "low" whistle, a "high" whistle and a horn. The gong is sounded to signal a train approach to a light rail station. The whistle is sounded, by law, when the train approaches a gated crossing. Due to recent collisions with motorists at non-gated rail intersections, METRORAIL operators have been instructed to sound the higher-volume horn as they approach each intersection along the rail route, as a warning to motorists and pedestrians.

The use of train horns and other audible signals on 15 light rail systems in North America is summarized in Table 4. A horn or whistle was used at gated crossings in all applicable cases.

Table 4. Use of Audible Signals on Light Rail Vehicles

System	Gong at non-gated intersections	Horn/whistle at non-gated intersections	Horn for emergency or discretionary use only (at non-gated intersections)
DART	X		X
MTA – Los Angeles		X	
San Diego Trolley			X
Sacramento	X		X
Portland			X
San Francisco			X
Baltimore	X		
Calgary			X
St. Louis			X (gong; no horn)
Philadelphia			X
Camden-Trenton, NJ			X
Hudson-Bergen, NJ	X		X
Boston			X
San Jose	X		X
Denver			X

3.
OPPORTUNITIES FOR SAFETY ENHANCEMENTS

Traffic safety relies on the three "Es" of traffic engineering:

- Engineering – proper planning and design and construction
- Education – providing the users information needed to safely operate and use the system
- Enforcement – making sure the system is used in accordance with applicable laws and regulations

METRO has used all three actions to create and initiate operation of the METRORail system. Enhancement of traffic safety along the METRORail route will rely on all three components being continued and enhanced. The enhancements described in this chapter include elements of all three types of action.

Recommendations and suggestions for traffic safety enhancements to the METRORail are based on a review of METRO documents describing the system and its operation, interviews with METRO staff, reviews of operating information and LRV-motor vehicle accident records and a reconnaissance of the system.

It was anticipated that the traffic safety assessment would identify commendable safety features and efforts as well as some possible deficiencies and opportunities for safety enhancements. Commendable traffic safety features and practices were found, affecting both the entire system as well as specific locations. On the other hand, serious deficiencies were not found. There were a number of minor adjustments that should be made as well as some final installations or replacements of missing or stolen traffic control devices. The research team also identified a number of possible safety enhancements that could reduce the collision potential between LRVs and motor vehicles. The research team also identified a few improvements or modifications that are felt to be worth considering but would need a specific engineering study to properly assess.

Findings of the traffic safety assessment are described in the following sections. The research team identified commendable features and conditions, practices, or other factors and recommended or possible alternative actions to improve traffic safety. Commendable features are briefly described. Recommended or possible improvement actions are described as follows:

- Issue (or condition)
- Importance
- Cause
- Possible actions or alternative actions

These are listed in the following order by METRORail segment:

- System-wide
- Downtown segment
- North midtown segment (Main Street)
- South Midtown/Museum District (1-way pair)

- Texas Medical Center
- Braeswood-Fannin
- Operations

Within each of the line segments, conditions are addressed, if any were identified as having safety improvement potential, in the following order:

- Signals
- Signs
- Crossing gates
- Other

In some cases these have been combined to avoid extensive repetition.

1. SYSTEM-WIDE FEATURES AND PRACTICES

Commendable Features

- METRO staff is very concerned and committed to making the positive improvements to safety and operations of the system.
- The dynamic envelope has been very well delineated, except some transition areas.
- Grade crossings have been appropriately addressed on an individual basis at every location.
- Visual treatment of light rail vehicles (LRVs) is good, including headlights, side stripe, and strobes. The retractable coupler has reduced damage and injury resulting from collisions.
- Effective pedestrian treatments are used extensively throughout the corridor. Use of Z-crossings in some locations provides crossing pedestrians an opportunity to face oncoming traffic before they leave curb. Pedestrian crossing treatments at intersections are also good.
- Median barriers prevent vehicles from driving around crossing gates.

Opportunities For Safety Enhancement

Traffic and LRV Signals

ISSUE: Existing LRT bar signals are placed in advance of intersections, causing LRVs to stop before reaching intersections.

Importance: Establish LRV presence at intersection, enable LRVs to enter intersection before motor traffic after a red signal, and minimize interruption to vehicular traffic

Possible actions:

- Install far side bar signal at all signalized intersections where existing near side signals are located in advance of the signalized intersection. Remove such existing near side bar signals so operators can proceed all the way to intersections. Change operating rules to instruct LRV operators to stop at stop bar when far side bar signal signifies LRV stop.
- Where appropriate, give LRVs a brief "queue jump" head start of 2-4 seconds ahead of motor vehicles to prevent illegal left turns ahead of LRV

Signs

ISSUE: A few locations may need checks of actual field conditions and needed signs or pavement markings.

Importance: Enhance safety

Possible actions:

- Check the following locations for additional signing and marking needs:
  - Westbound Wichita at Fannin – limited sight distance due to fence
  - Westbound Blodget at Main – limited sight distance for right turn
  - Downtown – add yellow edge marking on left edge of traffic lane (preferably paint/thermoplastic stripe for better daytime visibility)

ISSUE: There have been violations of the active no turn signs in conflict with LRV operation.

Importance: Making prohibited turns across tracks when active signs are on creates collision potential.

Causes: Drivers in the one-way pair segment appear to either not understand or respect the active turn prohibition signs (active signs may be on too long prior to LRV arrival), or drivers think they can beat the LRV through the crossings. Due to closing of cross streets in Midtown and the Museum District, there are also few locations along Main Street to make left turns across the trackway. This increases pressure to turn left where such movements can be made, even if prohibited.

Note: Review of 2003 citations issued by METRO police shows that about 29% of those issued on Fannin and San Jacinto (before METRORail initiated operations) were for illegal turns.

Possible actions:

- Increase public education program emphasis on left turns, explaining when and how to tell the turns can be safely made, where and when they are prohibited, and what could happen if prohibited turns are made. Include instructions for accomplishing a left turn by making three successive right turns.

- Consider posting advance signs on Main Street section showing that upcoming left turns can be accomplished by making three right turns starting beyond the cross street.
- Increase enforcement in the Midtown area
- Replace the left turn traffic signal double red balls with double red left turn arrows
- On cross streets, supplement STOP HERE ON RED sign with W10-1 train crossing sign.

Possible alternative actions:

- In the one-way pair segment, conduct an engineering study to determine if sufficient capacity is available to use one existing lane for left turns (on Fannin) or right turns (on San Jacinto) only. If so, convert respective left and right lanes to sheltered exclusive turn lanes, cross-hatching or otherwise treating the unused pavement so it will not be driven on. Sign appropriately.
- Consider permitting left turns at additional locations on Main Street in Midtown where separate left turn lanes can be provided.
- In Midtown Main Street segment, consider use of an alternative traffic control strategy to eliminate the need for turn prohibitions. The alternative strategy would be to provide an all red phase to permit LRV movement at the end of the cross street green phase. The all red would need to come up about 3-4 seconds (dependent upon actual LRV operating speeds) prior to the LRV crossing the stop bar into the intersection. This strategy would provide adequate time for the LRV to block the intersection to left turn conflicts with motor vehicles. Subsequent to the LRV entering the intersection, parallel Main Street traffic could be provided with a green signal indication and vehicles on Main Street wishing to make left turns would pause and do so after the LRV has cleared the intersection. METRO should conduct an engineering study to verify the feasibility of this method of traffic control, given traffic levels, other constraints on area traffic signal timing and progressions, and impact on train operations.

ISSUE: The TRAIN APPROACHING, DO NOT DRIVE ON TRACKS, and NO RIGHT/LEFT TURN ACROSS TRACKS icon LED signs are difficult to read, especially at a distance.

Cause: Pixel density of these devices is not sufficient to provide fine detail for symbols for such complex signs. Train track symbol occludes the turn prohibition (left and right) and the car symbol. Mixing of colors is causing overglow and confusion in the symbol.

Importance: Signs need to be legible at all times under varying light conditions to enable drivers to make correct movements.

Possible actions:

- Replace these signs with text message blank out signs (R3-1a, R3-2a) as shown in current Chapter 10 and Chapter 8 of 2003 MUTCD, or
- Replace these with LED signs with higher pixel density to allow better symbol clarity; use in-place sample(s) to verify legibility during day and night
- Inspect signs and assure even luminance of all LEDs; many looked very uneven which was contributing to legibility difficulties.

Possible alternative actions (Midtown 1-way pair segment):

- Contingent on confirmation of feasibility by an engineering study, convert the shared (through and left-turn) curb lane along Fannin and shared (through and right turn) curb lane along San Jacinto to a series of dedicated turn lanes that could be positively controlled with a left or right turn traffic signal.
- If such turn signals are provided, the turn should be brought up as a "lagging" movement after the through phase so that drivers would become accustomed to waiting to make turns after the through phase on all occasions, regardless of the approach of an LRV from behind.
- If this recommendation is incorporated (subject to engineering study), efforts should be made to avoid the use of "trap" turn lanes (through lanes that terminate in a forced left turn lane) such as the existing left-turn lane to Ewing south of Binz.

ISSUE: Train Approaching signs may not be well understood by motorists.

Importance: Drivers may be unfamiliar with the advisory Train Approaching signs and not fully understand the message or what it instructs drivers to do. The addition of an education plaque will educate the motorist as to the meaning of the sign.

Possible actions:

- Replace existing Train Approaching LED signs with more legible dynamic signs.

Possible alternative actions:

- Affix a dynamic TRAIN COMING text educational plaque below the existing Train Approaching icon sign; or
- Have the TRAIN COMING plaques flash concurrently to attract more attention (this is normal operation for such signs in other cities).

ISSUE: At some of the signalized intersections, the dynamic TRAIN APPROACHING warning signs are being activated long before the train arrives at the intersection. At a few intersections, the sign "timed-out" and went blank before the train arrived and reactivated the sign. This caused the sign to cycle on, off, and then on again for a single train event.

Cause: Problems with the trains staying in the priority coordination timing band, malfunctioning or lack of adequate train detectors, and trains operating at different operating speeds than the design parameters may all be contributing to this problem.

Importance: If motorists perceive that the LRVs will not come even with the active signs on, some may lose respect for the signs and turn in conflict with a LRV.

Possible actions:

- The dynamic train warning signs need to remain illuminated at least until the train passes through the intersection. Eliminate the double cycling (the "on/off/on" cycling) of the warning signs during train events by using the current scheduled LRV operating speeds in the signal control system.
- Code current operating speeds, station dwell times, and LRV detector locations into traffic signal system.
- Reduce the time the advance warning signs are illuminated to more closely align with the imminent arrival of train (25-30 seconds before the train arrives). Signs that are on too long in advance of the trains arrivals will cause driver disrespect for the signs if they do not perceive an immediate need for the signs.
- Adjust timers and detection devices and their locations to accommodate actual train operating conditions and speeds in the corridor.

Possible alternative actions:

- Consider simplifying the operations of the dynamic train warning signs and the traffic signal system by decoupling the activation of the signs from the traffic signal system. The dynamic advance warning signs should be activated based upon their own detection system.

ISSUE: There have been frequent violations of full-time turn prohibitions signs along the METRORail route.

Importance: Illegal left turns across the trackway can compromise safety of both offending drivers and LRV occupants.

Possible actions:

Complete signing:

- Turn prohibitions
  - "No U-Turn/No Left Turn" – Where BOTH left turn and U-turns are prohibited, install new R3-18 combination sign (in 2003 National MUTCD, but not in 2003 Texas MUTCD). This combination sign will help to reduce sign clutter (rather than using both a "No Left Turn" and a "No U-Turn" sign in these locations). Sign should be installed on the left end of the signal mast arm, and on the far left side signal pole or on the median sign/signal pole. The left and U-turn prohibition signs may be removed from right side location.
  - "No left turn" – post on far left and median bar signal poles; may remove from right side location
  - "No U turn" – post on far left and median bar signal poles; may remove from right side location
- Other signs
  - One way signs facing cross streets blocked by Main Street median in Midtown – install R6-1 one-way signs facing blocked streets at station locations similar to those

already installed at other midtown locations. A consistent design for one-way signs should be used throughout the rail corridor (either the R6-1 or R6-2, but not both).

- Check cross street approaches to Main Street for consistency of application of NO RIGHT TURN ON RED signs. Sign should be used where there is a sight distance restriction or where turning path or other operational restrictions make it necessary to prohibit right turns on red.
- Replace downtown median 12 inch "no vehicles on tracks" signs with 24 inch size signs if possible; mount signs so they do not reflect LRV headlights at operator.
- Eastbound Dallas at Main – check signs for mounting height. Minimum height is 7 feet to the bottom of the sign.
- Eastbound McKinney at Main – install correct "divided highway" sign on near right. The "divided highway" sign should be consistent with the turn prohibition signs at the intersection.

ISSUE: Some transition zones could benefit from more effective travel path delineation that directs drivers away from making an incorrect turn into a trackway, including:

- Southbound Main at Commerce
- Southbound Main at Wheeler
- Northbound Greenbriar at Braeswood

Importance: Drivers could mistakenly drive into trackway thinking it is a turn lane or roadway, creating a collision opportunity

Possible actions:

- Place red retro reflective raised pavement markers (RRPM) across the LRT travel way slightly downstream of each intersection. The RRPMs should be arranged in a diagonal pattern that directs an errant vehicle toward the general traffic. The RPMs should have both a red lens and a red body.

Possible alternative actions:

- Consider placing KEEP OUT pavement markings on tracks near each intersection.
- As an alternative to the KEEP OUT message, a do not enter symbol may be used as a pavement marking. This should be considered an experimental alternative and will require permission from the FHWA to use.

ISSUE: There is an emphasis on prohibited movements rather than permitted movements; emphasizing permitted movements provides positive guidance and could reduce violations

Importance: Drivers may be confused about where they can make turn movements and where a through movement is the only permitted movement. Displaying permitted movements could ease decision load on drivers and result in fewer last second decisions in complex driving conditions (e.g., Texas Medical Center area).

Possible actions:

- Consider use of overhead lane use control signs in place of extra turn prohibition signs; each prohibited movement should be included at least once on turn prohibition signs.
- Consider use of (turn) ONLY signs where there is only one permitted movement at an intersection.
- Use green arrow aspects on traffic signal heads instead of green ball and redundant turn prohibition signs
- Provide lane use markings in individual lanes on the approach to signalized intersections. By providing markings on the pavement, drivers are more likely to see them. Markings should be placed so that they are not concealed by the first one or two vehicles in the queue.

Possible alternative actions:

- Supplement the lane use arrows with the word ONLY when only one movement is permitted from the lane.
- In areas with confusing lane configurations, install overhead lane use signs.

Crossing Gates

ISSUE: Some crossing gates were observed to be closed 30 to 90 seconds. At I-610 this was observed to result in major traffic queues on the frontage roads.

Cause: Crossing gates are timed to operate in accordance with design speeds for the LRVs. Initial operations are using reduced speeds in some segments, resulting in gates closing earlier than needed before LRV arrival and some very long gate closure times.

Importance: Drivers who are forced to wait for what they perceive to be an inordinate amount of time get impatient and some may take extra risk not to have to stop at gates.

Possible actions:

- Modify the delay timers to ensure that the operations of the gates and the track clearance phases more closely reflect actual operating conditions in the field.
- Consider resetting gate closure times for LRT operation.
- Verify correct operation of crossing gates after modifying the coded operating speeds. This should be done each time scheduled operating speeds are changed as the operation matures.

ISSUE: It appears that drivers have difficulty identifying the stop line at some intersections and rail crossings due to the number of transverse markings across the road in the vicinity of the intersection.

Importance and cause: When there is a crosswalk, stop line, and RR markings near an intersection, there can be five lines across the approaching lanes, making it difficult for the driver

to distinguish one from another. Without a clear definition of the stop line, drivers may be confused as to where they need to stop.

Possible alternative actions:

- Reduce the number of transverse lines by using an alternative pattern for crosswalk markings.
- Consider use of contrasting pavements on the near and far sides of the stop bar to increase visibility of the stop bar.
- Where possible, move the RR marking further from the intersection.

ISSUE: Need systematic and comprehensive review of gate signal crossing operations, specifically with clearing tracks.

Importance: Motor vehicles need to be cleared off trackway after the clearance phases to avoid collisions with LRVs and to avoid delays.

Cause: Because of the large separation distances between some of the track locations and the signalized intersections, some drivers appear to be unsure about where they need to stop or how to safely clear the tracks when the gates at the crossing begin to descend.

Possible actions:

- Conduct systematic review of gated crossings and clearance of traffic queues on crossings.
- Consider use of pre-signals and directional heads to better delineate where drivers need to stop and improve track clearance sequencing; time signals to clear out area every cycle (downstream)
- Consider "Do Not Enter" markings on trackway at intersection
- Check timings at adjacent intersections to make sure they permit clearing of queues
- Stagger location of stop bars at angled grade crossings (e.g., northbound at Wentworth)

Other Features

ISSUE:
Drivers need to better understand the risks of violating turn prohibitions when trains are approaching and how to avoid collisions.

Importance:
Left turn collisions are the most frequent type experienced to date. Turn violations are also the most numerous citations issued by METRO police along the METRORail line.

Possible actions:

- Increase emphasis of METRORail public education and outreach program on:
  - how and when to make left turns along the METRORail line

- obeying traffic regulations about where turns are permitted

ISSUE: Traffic turning from cross streets into METRORail streets can mistakenly turn into trackways.

Importance: Errant vehicles could result in additional conflicts.

Possible actions:

- Install red body/red lens raised reflective pavement markers across trackway in back of crosswalk line facing cross street to warn errant drivers.

ISSUE: Curbs of islands and other channelization along METRORail may be difficult for drivers to identify at night.

Importance: Some curbs are large enough to damage vehicles that hit them.

Possible actions:

- Consider providing retroreflective treatments on curbs that change the direction of traffic (islands, curving medians, etc.,) to improve visibility at night. This is typically done with paint and beads, but can also be done by placing RRPMs on top of the curb.

ISSUE: There is a need for more public understanding about driving along LRT route.

Importance: Public education plays a vital role in LRT safety in localities where the public may not be familiar with LRT operations. There appears to be some driver confusion over appropriate stop location, possibly due to number of similar looking lines on street approaching rail crossing adjacent to intersection (i.e., two for railroad pavement marking, one for stop bar, two for crosswalk).

Possible actions:

- Focus the METRORail public education and outreach program on how and when to make left turns along the METRORail line and the importance of obeying traffic regulations.
- Prominently display METRORail safety education materials in businesses and commercial buildings in localities along the LRT alignment having a high rate of non-compliance with traffic regulations.
- Distribute, by location, pamphlets to passing motorists and pedestrians

ISSUE:
The number of traffic violations cited along the METRORail line both before and during initiation of operation indicates need for continuing a strong program of enforcement of traffic regulations along the line.

Importance: All accidents to date appear to be the result of traffic violations and driver error. Enforcement should reduce the frequency of violations and resulting conflicts and collisions with LRVs.

Possible Actions:

- Continue to assign METRO police to enforce traffic regulations, with emphasis on turn violations and running red lights.
- Keep METRO policed officers visible to remind drivers to obey traffic regulations
- Publicize the enforcement program to encourage drivers to take traffic regulations more seriously
- Emphasize in the public education program the importance of driving defensively and that traffic regulations are met for the safety of the traveling public
- Seek cooperation of other law enforcement agencies in enforcing traffic regulations to promote safer driving as part of the Houston region interagency enforcement effort

2. DOWNTOWN

Commendable Features (In Addition To System Features)

- Post-and-cable system used in downtown to discourage jay walking to station platform or across street are effective and good idea

Opportunities For Enhancement

Signs

ISSUE: Drivers attempting to enter closed section of Main Street (Main Street Square area) in downtown.

Importance: Drivers should be able to tell where they need to circulate to pass by Main Street Square.

Cause: Some drivers appear to be confused by unexpected closed Main Street sections northbound at Dallas and southbound at Walker. The same is true for drivers approaching Main Street eastbound on Dallas and Westbound on Walker.

Possible alternative actions:

- On Main Street:
  - Add advance ALL TRAFFIC MUST TURN RIGHT signs midblock on Main Street approaches to the closed blocks
  - Post a R3-5(R) right turn only arrow sign on signal mast arm (see Figure 3)
  - Install a right turn arrow pavement marking to supplement the sign
  - Consider installing (breakaway) bollards across the closed sections of Main Street, locating bollards behind the crosswalks and leaving a sufficient opening for the LRV dynamic envelope.

    - Consider adding paint channelization forcing the right turn
- Add NO LEFT TURN ON MAIN STREET advance signs on Dallas and Walker Street approaches to Main Street
- Remove or replace DIVIDED HIGHWAY signs on Dallas and Walker Street approaches; they illustrate an allowable left turn, when left turns are actually prohibited

Figure 3. Existing Right Turn Only sign configuration in Downtown area.

ISSUE: There are too many signs at many of the downtown intersections.

Importance: Multiple signs increase driver information processing time and increase the potential for missing important information.

Possible actions:

- Consolidate traffic sign messages where possible. Eliminate unnecessary redundancies. Examples of consolidation include:
    - Combine the No Left Turn and No U-Turn signs into the R3-18 combination symbol sign (new in the 2003 national MUTCD).

- Place left- and U-turn prohibition signs in the median, on the far left side, or on the left side of the signal mast arm. Do not place left- or U-turn prohibition signs on the right side of the intersection.
- Place right-turn prohibition signs only on the right side of the intersection.
- When both right and left turns area prohibited at an intersection, use the No Turn sign (R3-3) on the signal mast arm.
- A One-Way sign should be installed at all intersections with One-Way streets. The MUTCD indicates that turn prohibition signs may be omitted if ONE-WAY signs are provided; however, we recommend that where a ONE-WAY sign is provided, it should be supplemented by one turn prohibition sign.

Possible alternative actions:

- As an alternative to turn prohibition signs, Lane Use assignment signs may be used (R3-5, R3-6 series). When these signs are used, they should supplement a One-Way signs and turn prohibition signs should not be used.

Other Features

ISSUE: Delineation of the travel way downtown would be enhanced by using the yellow edge striping to define the travelway, as appears elsewhere in the system.

Importance: Defining the left edge of the travel way may reduce wrong way movements and reinforce driver understanding of lane assignments. It may also help to keep traffic out of the dynamic envelope. Yellow striping has greater daytime visibility than raised reflective pavement markers; most collisions involving LRVs have occurred during daylight hours.

Possible actions:

- Provide a single solid yellow edge marking between the trackway and the left traffic lane to delineate the left edge of the travel way for vehicular traffic (preferably paint/thermoplastic line for better daytime visibility).

ISSUE: Due to the severity of the lane shift, southbound vehicles crossing Commerce may not properly transition to the right.

Importance: A wrong way movement could cause drivers to travel in the wrong direction and/or down the trackway, and lead to a head-on collision.

Possible actions:

- Improve the delineation of the travel path by improving the pavement markings and adding RRPMs. Pavement markings should be retroreflective.
- Provide pavement marking arrows to indicate the travel direction.
- Place red RRPMs to indicate wrong-way movements.

Possible alternative actions:

Consider conducting an engineering study to alter the southbound transition geometry for a more gradual transition north of Commerce. This may require moving the southbound LRV stop location further north. Another option might be automatic swinging gates across the LRT trackway that open inward (toward the south) to allow LRVs to cross Commerce. Standard object marker signs (OM1 type) should be placed on each gate to be visible to southbound drivers.

3. NORTH MIDTOWN

Commendable Features (In Addition To System Features)

- The use of passive NO TURN ON RED signs for westbound traffic approaching San Jacinto at other cross streets where the LRT trackway is nearside will discourage law-abiding drivers from crossing the trackway during the LRV compatible phase.
- The use of the One Way sign at blocked cross streets where vehicles must turn right onto Main Street is a good practice.
- The use of the Z Crossings for low-volume pedestrian movements across the trackway where there is adequate sight distance is a good design feature.

Opportunities For Enhancement

Signs

ISSUE: At some locations where stations are present, the One Way signs have been omitted. A driver could mistakenly make a left-turn heading the wrong way along Main Street.

Importance: Drivers need positive guidance to make sure they turn in the correct direction.

Possible actions:

- Review the blocks that abut stations and where possible install a One Way sign directly opposite approaching cross street in a highly visible location, regardless of the presence of various architectural features of the stations.
- Where the continuous transit median blocks cross streets and no safe location exists to install a One Way sign facing cross streets, paint a right turn arrow and "ONLY" on the cross street approach to Main Street.

Other Features

ISSUE: Jaywalking across Main Street between crosswalks has been reported.

Importance and cause: This increases the potential for pedestrian accidents involving motor vehicles and LRVs. It may be resulting at least partially due to the distance between existing marked pedestrian crossings of Main Street.

Possible actions:

- Monitor pedestrian activity along the corridor and where jaywalking becomes a problem, provide positive channelization such as a cable fence or other device. Alternately, where determined by and engineering study to do so, additional Z-Crossings could be provided.

ISSUE: Motor vehicles are turning left where such turns are not permitted at any time.

Cause: Although left turn movements were not permitted at signalized intersections prior to the construction of the LRT system, left turns were permitted at the minor non-signalized intersections. These intersections are now blocked. Motorists may be frustrated at the inability to make any left turn movements.

Possible actions:

- Create a left turn lane for vehicular traffic where possible at signalized intersections.
- Hold all vehicular traffic on Red until the LRV has passed through the intersection.

Possible alternative actions:

- Use split phasing on Main Street signal phases to accommodate left turns at additional signalized intersections.

4. SOUTH MIDTOWN/MUSEUM DISTRICT

Commendable Features (In Addition To System Features)

- The use of raised islands to block traffic movements across the trackway on the near side at minor roadways is a positive safety feature that should be maintained.
- The use of the active NO RIGHT TURN sign for westbound traffic approaching San Jacinto is a good practice to control drivers that may believe there is no risk of right-turn during the all red LRV phase when no other vehicular traffic would be moving at this intersection.

Opportunities For Enhancement

Signs

ISSUE: Complex geometry of the Fannin-Ewing intersection and signing may be contributing to the improper left turns being made on southbound Fannin at Hermann Drive. Also terminated southbound left through lane into a left turn lane may result in rear end collisions.

Cause: Proper movements starting at Ewing are complex and confusing due to the divider island that splits trackway and through lanes from left turns to both Hermann and Warwick Towers garage. Drivers are not entering Hermann left turn lane which has to happen at just south of Ewing. Directional lane assignment sign on divider island could be interpreted by stopped traffic

in through lanes as implying that the left most through lane is actually the turn lane. Landscaped divider island gives the illusion of a curb and disguises the trackway for traffic stopped in the far left through lane on Fannin. Dropping a through lane into a left turn lane causes some drivers to make evasive maneuvers at the last second to continue in a through lane.

Importance: Confused drivers are having to circle the block to retry a desired movement or are making last-second movements that could surprise drivers of other motor vehicles or LRVs and create collision potential.

Possible alternative actions:

- Change directional lane assignment sign currently located on divider island to illustrate ALL lanes of travel, including all through lanes on Fannin; sign should be simplified to contain no street names (see figure 4).
- Remove small white on green direction information sign facing west from pole in southeast corner of intersection; replace with larger signs as shown in Figures 5 and 6.
- Consider converting the left through lane south of Southmore to sheltered left turn lanes at Binz and Ewing following a merge from 3 lanes to 2 lanes just south of Southmore.
- Conduct an engineering study to determine if the left through lane of Fannin (and the right through lane of San Jacinto) can be converted to a series of sheltered left turn lanes between approximately Hermann and Wentworth.
- Remove, reduce, or replace landscaping on divider island as needed to provide better visibility of tracks for stopped traffic.

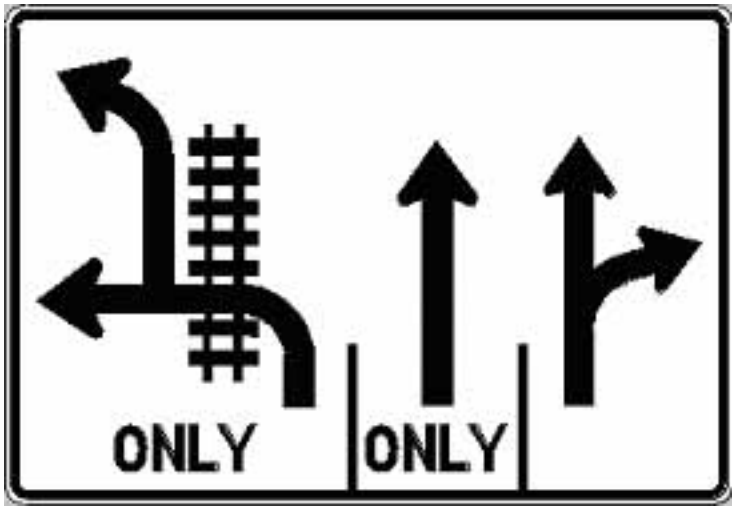

Figure 4. Possible new sign to be mounted on median on SB Fannin at Ewing.

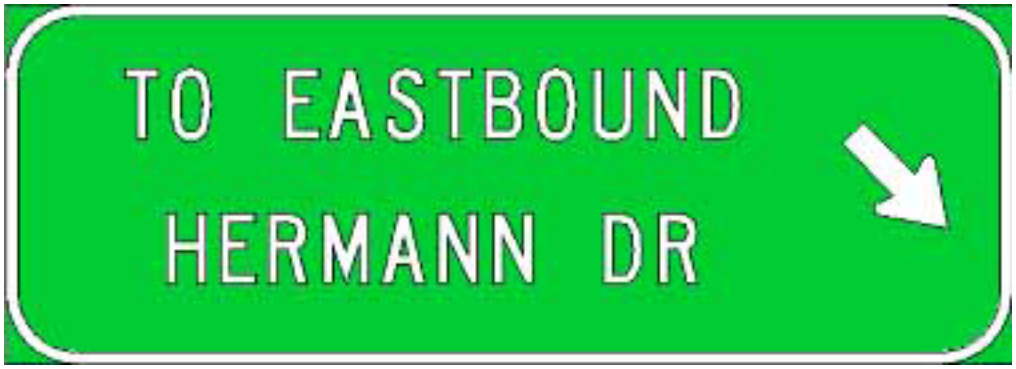

Figure 5. Possible new mast arm sign just south of Ewing over left SB Fannin lane to Hermann Drive.

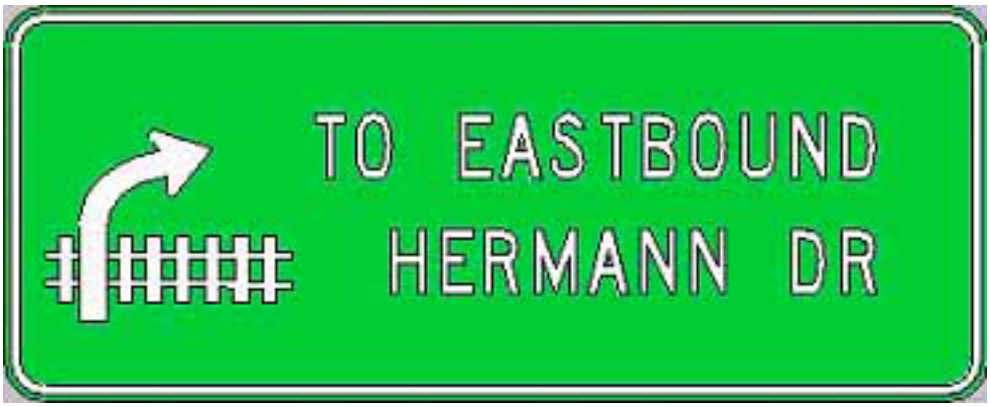

Figure 6. Possible new mast arm sign for EB Ewing at Fannin.

ISSUE: Drivers on cross street approaches are encroaching on intersection and near-side tracks in couplet section. (Section Specific: Wentworth - Herman)

Cause: Stop bars on pavement at a few locations are just beyond tracks, stopping vehicles on the tracks. Drivers are not heeding STOP HERE ON RED signs, possibly because they do not perceive the LRT tracks crossing the approach street prior to the intersection

Possible actions:

- Remove stop bars on pavement just beyond tracks at Main and Wheeler that place stopping vehicles on tracks.
- Remove stop bars on pavement just beyond tracks at San Jacinto and Wentworth that place stopping vehicles on tracks.
- Improve conspicuity of track area on road surface through the use of contrasting pavements on both sides of stop bars.
- Install white body/white lens retroreflective raised pavement markers along tracks facing cross street traffic to warn motorists against encroaching/stopping on tracks.

Possible alternative actions:

- Subject to engineering study, consider installing a traffic signal or pre-signal at Arbor Street to hold traffic in advance of Arbor, thereby keeping the tracks clear at Wentworth on each and every traffic signal cycle, regardless of the presence of an LRV.
- In addition, consider establishing a timing plan for northbound San Jacinto traffic that provides a progression between Rosedale and Blodgett to move roadway vehicles through this entire section without resulting in vehicles being stopped at Wentworth standing on the tracks.
- Consider operation of northbound LRV's during a "queue jump" phase immediately ahead of the parallel San Jacinto green phase so that the LRV would arrive at the Wentworth crossing ahead of the parallel roadway traffic, thereby putting the LRV proceeding northbound along San Jacinto.
- Monitor changes of traffic volumes on Wentworth. If they increase to cause congestion or adversely affect METRORail operations, conduct an engineering study of alternative treatments for the Wentworth crossing, including the impact of additional traffic expected to be generated by the new U.S. 59 northbound exit ramp. It may be necessary to consider a long-term widening of Wentworth and provision of a triple left-turn from Wentworth to San Jacinto or another alternative to address the ultimate capacity needs.
- Vehicle encroachment on the trackway on Wentworth at San Jacinto may be reduced if pavements on either side of the stop bar are made to significantly contrast.

Crossing Gates

ISSUE: Queues at Fannin intersection block traffic from Main Street intersection during clearance interval, requiring LRVs to wait and trapping vehicles beyond and beneath the crossing gates.

Importance: Vehicles block tracks and impede LRV movement across Wheeler.

Possible alternative actions:

- Conduct an engineering study of the traffic signal timing and roadway capacities of Main between Blodgett and Wheeler, and of Richmond – Wheeler between Main and Fannin to determine traffic signal timing (cycle length, splits and offsets) that will reduce the queuing on Wheeler, or
- Considered providing a pre-signal on Main in the vicinity of Rosewood. This pre-signal could be used to meter and control traffic proceeding into the Wheeler / Main intersection while also potentially providing a "queue jump" phase to clear buses out of the on-street bus lane ahead of general roadway traffic.

ISSUE: Fannin intersection at Wentworth occasionally queues vehicles back across southbound trackway and blocks crossing.

Importance: Queues blocking tracks create conflicts that block LRVs and could create accident potential.

Note: The opening of the northbound U.S. 59 exit ramp to Main Street may change traffic volumes and travel patterns in the immediate vicinity of this area.

Possible actions:

- Monitor changes of traffic volumes on Wentworth. If they increase to cause congestion or adversely affect METRORail operations, conduct an engineering study of modifications to the traffic controls at the Fannin intersections with Blodget and Wentworth to consider revision of traffic signal phasing to clear southbound queues at Wentworth and modify the crossing gate placement and orientation closer to the tracks and intersection, enhancement of the stop bar locations, and possible use of a southbound pre-signal on Fannin ahead of the crossing gates.
- As an interim measure, METRO should code in actual operating speeds for LRV's to re-time the gates for existing LRV operating speeds. Operating speeds should be recoded whenever operating speeds are revised.

Other features

ISSUE: METRO staff reported that valets at the Wyndham Warwick Hotel have been disregarding the traffic control devices, making driving maneuvers in violation of the traffic control devices.

Importance: Valet drivers increase accident potential and endanger themselves and other drivers by making wrong way and other prohibited movements.

Possible actions:

- Visit Warwick Hotel management and parking operator to explain why restrictions have been designated and the importance and benefits to Warwick Hotel and the parking operation resulting from abiding by traffic regulations.
- If necessary, patrol around garage and give citations.

5. TEXAS MEDICAL CENTER (TMC) AREA

Commendable Features (In Addition To System Features)

- Design attempted to accommodate many different needs in a tight ROW.

Opportunities For Enhancement

Signs

ISSUE: Motor vehicles are turning left in front of LRVs in the Texas Medical Center area; left turns are being made from through lanes in areas where there are left turn lanes

Importance: Failure to understand the proper behavior at these locations may lead to vehicle-train conflicts.

Cause: The left turn movement for vehicular traffic in the TMC is not easily understood by some motorists. Dynamic lane use signs are not easily comprehensible and not aligned over lanes as in normal conditions. Some drivers do not realize that they are allowed to drive on the tracks in the left turn lane Motorists are not permitted on the brick pavers elsewhere in the LRT system and are not sure if they are permitted on the tracks. The left turn traffic signal arrow is displayed when train approaches intersection, to permit clearing the intersection of any automobiles, but continues to be displayed as the train enters the intersection. This may cause confusion to motorists in the adjacent lane and cause them to turn in front of the train.

Possible actions:

- Improve existing signing that warns and regulates driving approaching the shared left turn lanes; evaluate alternative sign configurations like those shown in Figures 8 through 12 either through surveys or simulations to determine which is most effective.
- Supplement overhead lane use signs by the use of pavement marking arrows indicating allowable movements and ONLY (where appropriate) at each intersection
- Use a programmed left turn signal head.
- Remove the 12 inch traffic buttons along the left turn lane.
- Provide far side bar signal for LRVs to enable them to stop at intersection rather than holding back at the near side signal.
- Queue jump the LRV 3-4 seconds through the intersection where left turns are permitted to enable the LRV to control the intersection and block improper left turns.
- Install overhead advance intersection lane use control (R3-8) signs showing left turn, through and through-right turn lanes.

Possible alternative actions:

- If additional pavement markings and signs do not result in left turns being made from left turn lanes, replace or pave over stamped brick pavement in the left turn lane to provide pavement surface matching through traffic lanes (see Figure 7 for example of similar paving on San Francisco Muni light rail system)

Figure 7. Left turn lanes, San Francisco Muni, with pavement around rail tracks to indicate shared rail and vehicle use. Track is not paved except for shared left turn lanes.

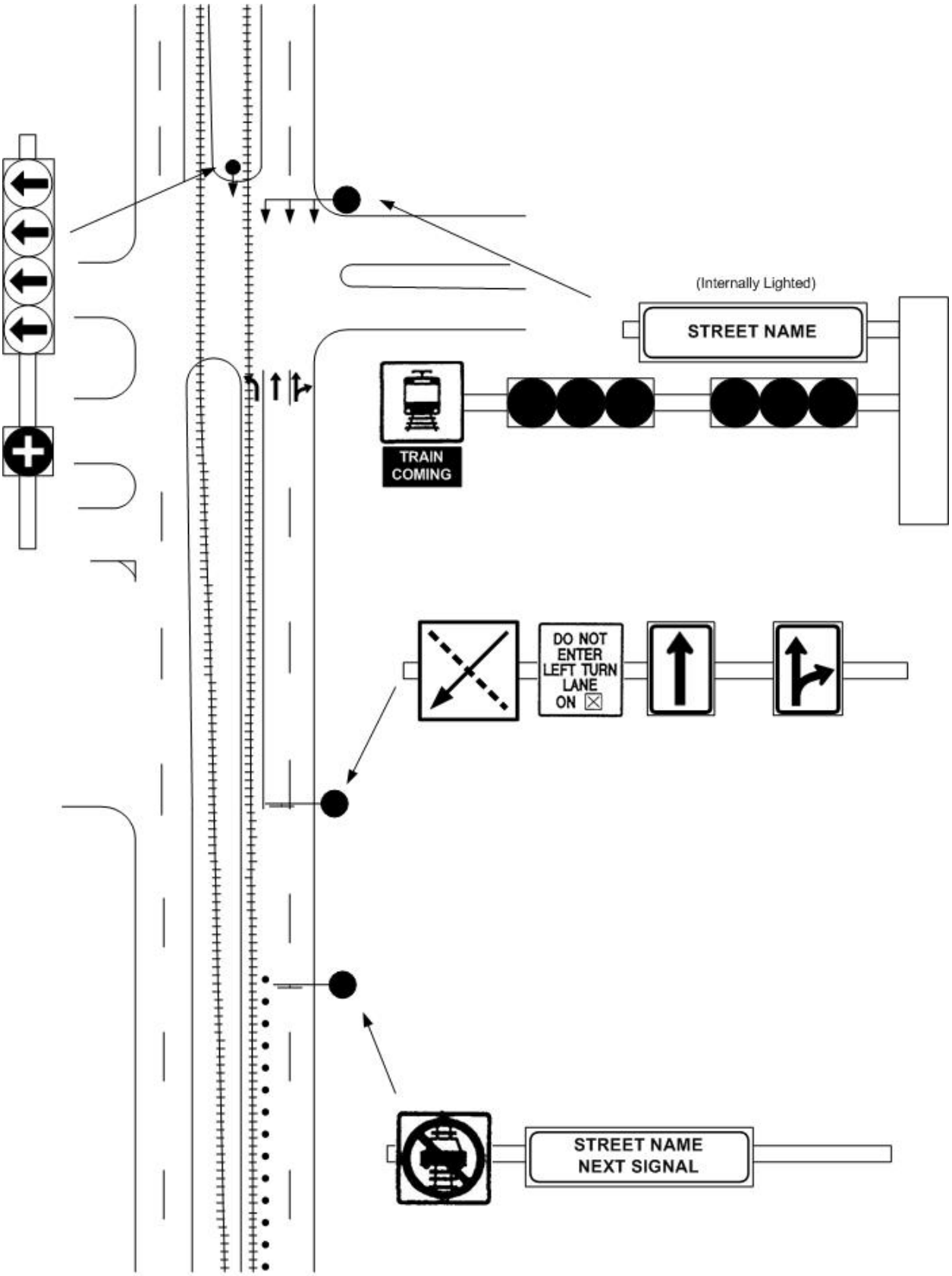

Figure 8. Existing Signing with Improved Destination Identification.

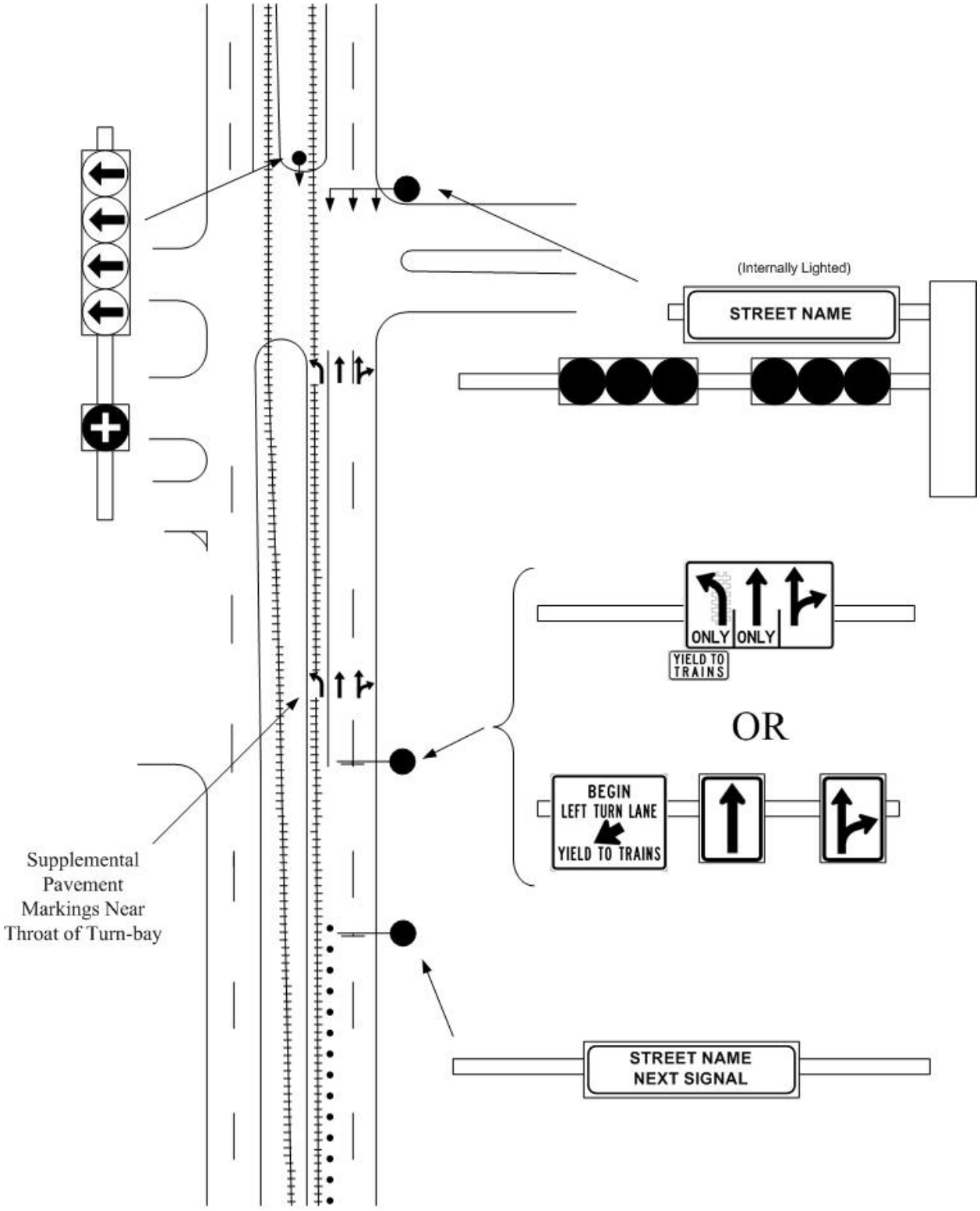

Figure 9. Possible New Mid-Block Lane Assignment Sign -- No Active Controls.

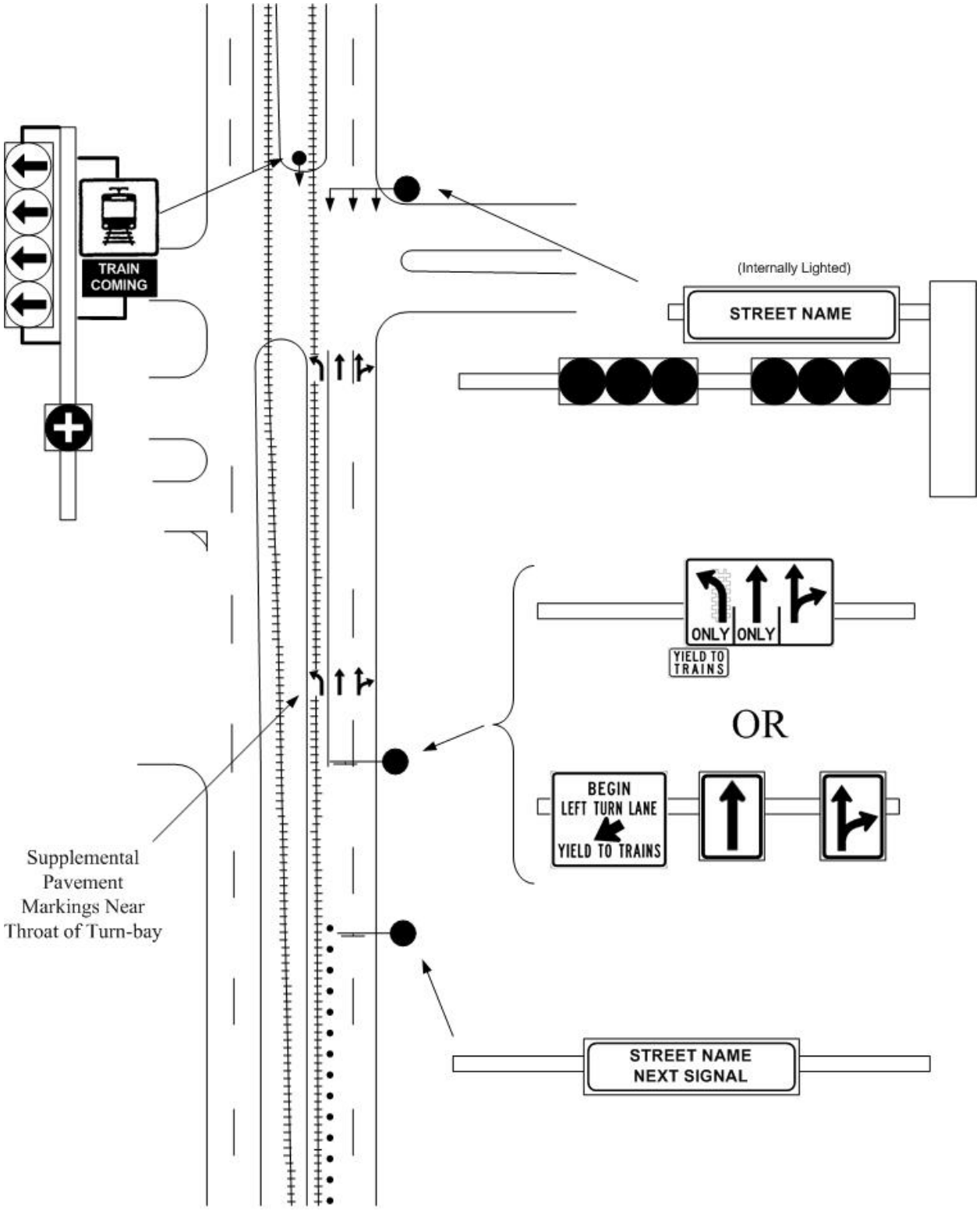

Figure 10. Possible New Mid-Block Lane Assignment Sign with Active Train Warning in Median.

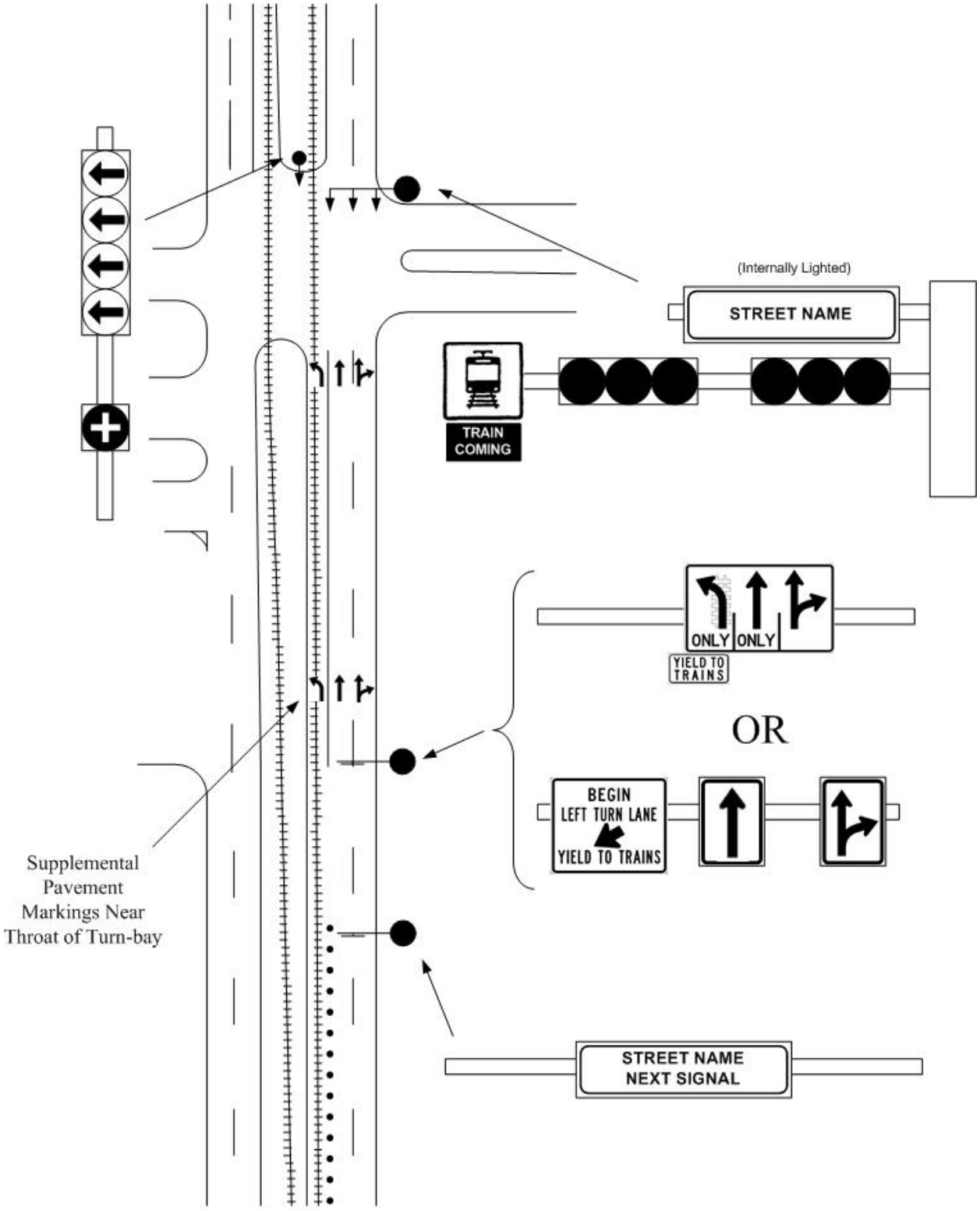

Figure 11. Possible New Mid-Block Lane Assignment Sign with Active Train Warning in Existing Location.

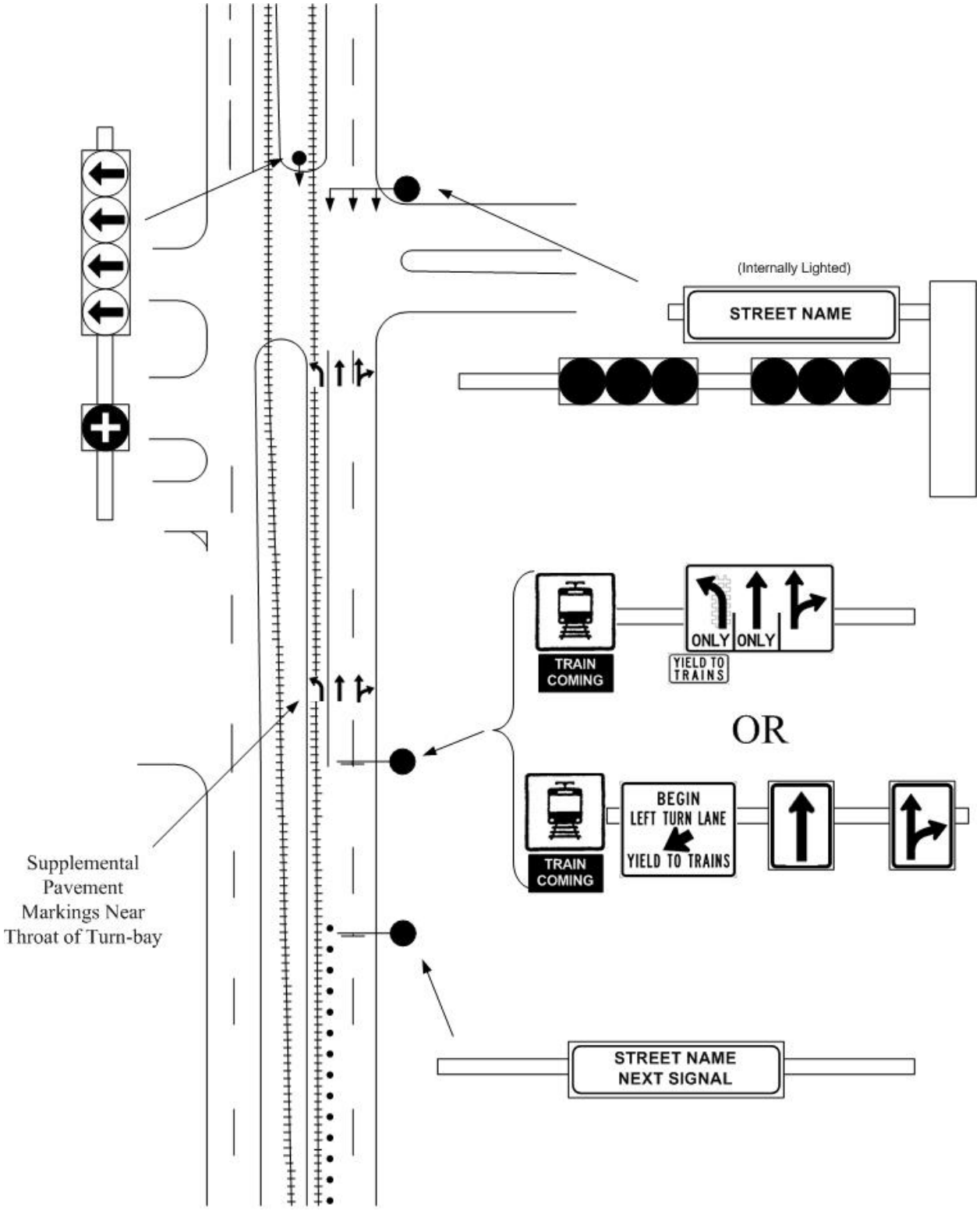

Figure 12. Possible New Mid-Block Lane Assignment Sign with Active Train Warning on Upstream Mast Arm.

Other Features or multiple factors

ISSUE: Drivers in Medical Center area appear to have difficulty recognizing their destination buildings and access points and were seen turning at the last second from an incorrect lane.

Importance: Many drivers in the TMC area are unfamiliar with the area, may be distracted, and may not be able to easily find their way in an unfamiliar environment. At the last second some were seen making an improper turn or other movement, potentially affecting other drivers. TMC area drivers need extra help finding their destination, otherwise there is extra re-circulation and possible risky driving.

Cause: Drivers do not realize that the upcoming intersection is their desired street until they reach the intersection. This results in some drivers choosing to make illegal left turns from the through lane to reach desired intersection.

Possible alternative actions:

- Use oversize, internally lighted street name signs on mast arms; include block number
- Provide mid-block advance street name signs, including block numbers
- Add pavement markings showing allowable movements on all intersection approaches
- Improve general way-finding throughout TMC area by providing destination information on a system of wayfinding signs (already planned by Texas Medical Center for installation on Fannin Street, probably in 2005).
- If driver uncertainty associated with left turns persists after above changes, consider trimming or removing trees obscuring view of parking and building entrances
- Improve on-premise signing, including name of building and street number in large letters (legible from street upstream of entrance) with good color contrast, good illumination, and consistent location on building facades
- Improve wayfinding on parallel and approach streets to encourage traffic to move to other routes (already planned by Texas Medical Center for installation in phases during 2004 and 2005).

ISSUE: Queues from valet parking at St. Luke's Medical Tower and Methodist Hospital garages back into and block southbound lane of Fannin in TMC area, particularly during the middle of the day.

Importance: Queued traffic blocks right southbound lane, reducing capacity of Fannin and creating congestion. It also periodically blocks the Fannin intersections at University and Dryden so left turns from northbound Fannin cannot clear ahead of LRVs, creating LRV delays and delaying northbound left turn traffic. Vehicles blocking intersection after signal is no longer green creates increased collision potential.

Possible actions:

- Work with the Texas Medical Center to eliminate valet parking practices that queue vehicles back on to the street. This may require using an independent parking operator or consultant to advise on how to modify the operation and current practices.

ISSUE: There is frequent jaywalking across Fannin in the Texas Medical Center area; this is not limited to METRORail passengers but includes people crossing between hospitals and garages, offices, etc.

Importance: Jaywalking increases pedestrian accident potential

Possible alternative actions:

- Install fencing or post/wire barriers along the outer curbs of Fannin Street throughout the TMC area
- Install fencing or other effective barrier treatments in the median (will not stop all jaywalking to platforms)
- Prior to the above installation(s), increase program to issue citations to jaywalkers

6. S. BRAESWOOD/S. FANNIN

Commendable Features (In Addition To System Features)

- The placement of the stop bar on northbound Greenbriar at the crossing gate location makes the intersection signal a de facto "pre signal" as defined by the MUTCD and as identified in the US DOT document "Guidance on Traffic Control Devices at Highway-Rail Grade Crossings" developed by the Technical Working Group established in the aftermath of the grade crossing collision in Fox River Grove, IL. As such, it is a positive element to control traffic.
- The use of a track clearance phase to allow vehicles that may have crept into the crossing area during the red phase is a good feature given the location of the stop bar behind the grade crossing.

Opportunities For Enhancement

Crossings

ISSUE: Traffic queues across the track at northbound Greenbriar just south of Braeswood.

Importance: Queues can block crossing if not cleared.

Possible actions:

- To enhance the operation of the northbound traffic signal that functions like a pre-signal, consider, subject to engineering study, installation of additional, near-side traffic signal heads and refinement, if needed, of the crossing gate and crossing gate stop bar placement, to obtain better control of traffic.
- If additional traffic signal heads are installed, consider providing a green extension for the (existing) downstream traffic signal heads so that vehicles passing beyond the first line of traffic signals as they turn yellow would also enter the downstream intersection on the yellow indication (while the upstream heads would display red).
- Additionally, if a green extension is provided, consider installing programmed visibility heads on the downstream traffic signals so that drivers do not observe conflicting displays.
- Finally, during the track clearance phase, the upstream traffic signals should provide a red display while the downstream signals display the track clear green, thereby reducing the likelihood that vehicles would attempt to dive under the crossing gate arm as the track clearance phase is activated.
- Same recommendations for signaling of southbound Fannin at Greenbriar as are described above for northbound Greenbriar.

ISSUE: Overheight warning device on eastbound I-610 frontage road approaching Fannin is located where the only escape is the U-turn lane (limited clearance).

Importance: Overheight vehicles need an escape to avoid conflict with low catenary at Fannin METRORail crossing.

Possible actions:

- Relocate overheight warning device ("head bangers") to a location west of the eastbound on ramp from Kirby Drive.

7. OPERATIONS

Commendable Features (In Addition To System Features)

- System has excellent operators and a very effective selection and training process. Examples seen of LRV operator alertness to potential traffic hazard; evidence of good training
- It appears that none of the accidents were avoidable by the LRT operators.
- Interdepartmental safety committee meets regularly and is very committed to solving safety considerations. Extends to all levels of organization
- Metro police department is dedicated to understanding and enforcing issues; strong presence along METRORail in the field.
- Strong, extended public information campaign to inform and educate public on issues associated with rail safety.

Opportunities For Enhancement

ISSUE: "Near (collision) misses" are currently not being recorded.

Importance: Near misses are as important in identifying safety or operational needs as are actual collisions; they can assist in targeting problem locations for traffic improvements and traffic enforcement.

Possible actions:

- Report and record by location near collisions and LRT related traffic violations committed by motorists to assist in identifying locations and conditions that have higher accident potential
- Request LRV operators to report incidents to Control, as they occur.
- Controllers report incidents on Daily Log
- Submit Logs to Safety and the Transit Police divisions

ISSUE: The use of the horn should be restricted to times when it is critical to warn motorists and pedestrians of imminent hazards associated with the LRV.

Importance: The use of the horn at all times diminishes the importance of the warning and the immediacy of the danger. It also results in motorists and pedestrians ignoring the horn.

Possible actions:

- Restrict use of the horn to imminent hazards with motorists and pedestrians.
- Continue the practice of whistling at gated crossings.
- As appropriate for the operating environment, use the bell or low whistles on approaches to shared left turn lanes.
- Have an acoustical engineer evaluate the frequency and sound levels of the horn. Select a frequency that can be heard in a vehicle with closed windows and air conditioning and/or radio on.

ISSUE: Dwells at LRT platforms are sometimes longer than necessary. At some LRT stations, trains sometimes wait for the second CLEAR indication before continuing their run.

Importance: Long dwells cause the LRT predictive traffic control software to establish a progression for the LRV movement several blocks downstream. Motorists may be confused by the turning prohibition or illumination of the Train Approaching sign when no LRV is within the immediate vicinity.

Possible actions:

- Evaluate LRT running times from terminus to terminus.
- Adjust traffic controlling timing to actual LRT running times.

- Educate LRT operators of the importance of not dwelling longer than necessary at LRT platforms.
- Increase layover times at termini, if necessary.

4.
CONCLUSIONS

This traffic safety assessment was conducted and completed in a four week period. It provides a comprehensive review of safety related features, conditions, and practices associated with traffic safety of the METRORail system. However, it was not an attempt to reconstruct and analyze in detail the accidents that occurred along the METRORail line during the first month of revenue operation or during the previous testing period. It was also not intended to be a complete review of compliance of all traffic control devices with the latest Manual on Uniform Traffic Control Devices (MUTCD). Suggestions contained in the report reflect the best judgments of the experts involved.

A review of videos recorded by the cameras mounted on LRVs involved in collisions demonstrated that all of the collisions appear to be due to motor vehicle driver errors. None appeared to be preventable by LRV operators based on the available video. Moreover, field observations demonstrated that there are many motor vehicle drivers who practice aggressive driving: several instances of unsafe driving, illegal turns across tracks, running of red signals, and other infractions. In the year before METRO initiated METRORail service, METRO police issued over 8,000 citations for moving violations along the route. About 29% of the citations were for illegal turns, which correlates with left turn accidents being the most frequent type of LRV-motor vehicle collisions so far.

A review of other LRT systems indicated that some have had similar early accident experiences. Few have as much semi-exclusive trackway without barrier curbing as has the METRORail line, but that was not considered a reason for the accidents that have occurred so far. Some systems that had an initial high frequency of accidents have had the same pattern as METRORail – a high percentage of left turn collisions. Those systems took actions to try to reduce accident frequency, with reported success.

The assessment identified several commendable features and practices. Perhaps most impressive was METRO's genuine and strong commitment to maintain and improve safety throughout the system. METRO also did a very commendable job of developing a design under constraints of:

- Limited right-of-way
- Many crossings and transitions between adjacent segments with different cross-sections
- Unique features and needs along the route that had to be accommodated

METRO also has an exemplary LRV operator selection and training program and an excellent public education program to help the public understand how the light rail system works and how to drive on streets along and crossing the route.

METRORail is almost totally in semi-exclusive right-of-way with very limited lateral clearance and some very tight constraints. Safety provisions of the design were found to be generally adequate. Some minor adjustments to the traffic control devices and operational practices are needed to fine tune the system and its operation. This includes such aspects as traffic control

system adjustments for current operating speeds and completion of signing (including replacements of missing or stolen signs).

The assessment also found that several opportunities exist to further enhance METRORail traffic safety. These generally fall in the categories of modified signing, minor changes in signal and LRV operation, and increased use of pavements markings. In a few cases, it appears that additional enhancements could be made if engineering studies indicate feasibility.