Collision Between Metrolink Train 210 and Ford Crew Cab, Stake Bed Truck at Highway-Rail Grade Crossing, Burbank, California, January 6, 2003

Highway Accident Report

NTSB/HAR-03/04

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Notation 7580

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Adopted December 2, 2003

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2004. ***Collision Between Metrolink Train 210 and Ford Crew Cab, Stake Bed Truck at Highway-Rail Grade Crossing, Burbank, California, January 6, 2003.*** **Highway Accident Report NTSB/HAR-03/04. Washington, DC.**

Abstract: On January 6, 2003, Metrolink commuter train 210 struck a Ford F-550 crew cab, stake bed truck at a grade crossing in Burbank, California. Upon impact, the truck's cab moved with the train, until the train derailed about 1,300 feet from the crossing. The truckdriver was fatally injured. Of the train's 59 passengers and 2 crewmembers, 32 sustained injuries; 1 passenger died 15 days later from internal injuries that were probably sustained during the accident.

The major safety issues discussed in this report are the use of "all-red-flash" railroad hold intervals at signalized highway-rail grade crossings and adherence to applicable engineering guidance in designing traffic signals and other safety features at grade crossings.

As a result of its investigation, the Safety Board makes recommendations to the Federal Highway Administration; the California Department of Transportation; the city of Burbank, California; the American Association of State Highway and Transportation Officials; the Institute of Transportation Engineers; the National Committee on Uniform Traffic Control Devices; the National Committee on Uniform Traffic Laws and Ordinances; and the Transportation Research Board.

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
Amtrak	National Railway Passenger Corporation
BDPW	Burbank Department of Public Works
Caltrans	California Department of Transportation
CDL	commercial driver's license
CFR	*Code of Federal Regulations*
CPUC	California Public Utilities Commission
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
ITE	Institute of Transportation Engineers
LOS	level of service
MUTCD	*Manual on Uniform Traffic Control Devices*
SCRRA	Southern California Regional Rail Authority
TRB	Transportation Research Board

Executive Summary

On January 6, 2003, about 9:30 a.m. Pacific standard time, eastbound Metrolink commuter train 210 struck a Ford F-550 crew cab, stake bed truck at the North Buena Vista Street grade crossing in Burbank, California. Upon impact, the truck's fuel tank was compromised, releasing fuel and resulting in a postcrash fire that consumed the stake bed, which remained at the crossing, while the truck's cab, which was not on fire, continued eastward with the train. The train derailed and came to a stop about 1,300 feet east of the crossing. The cab and second cars of the train came to rest on their sides; the remaining two cars and the locomotive remained upright. The truckdriver was fatally injured. Of the train's 59 passengers and 2 crewmembers, 32 sustained injuries; 1 passenger, who was treated and then released from a local hospital, died 15 days later from internal injuries that were probably sustained during the accident.

The National Transportation Safety Board determines that the probable cause of this accident was the design of the traffic signals' railroad hold interval, which displayed a flashing red arrow for the eastbound North San Fernando Boulevard left turn lane, improperly implying that, after stopping, the truckdriver was permitted to make a left turn onto North Buena Vista Street. Contributing to the accident was the lack of a raised median at the crossing that would have obstructed the path used by the truckdriver to make the left turn.

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Factual

Accident Narrative

On January 6, 2003, about 9:30 a.m. Pacific standard time, eastbound Metrolink commuter train 210 struck a Ford F-550 crew cab, stake bed truck at the North Buena Vista Street grade crossing in Burbank, California. The train consisted of four bi-level passenger cars and one locomotive, positioned at the rear and controlled from a cab car in the lead. The railroad grade crossing is about 50 feet north of the North Buena Vista Street intersection with North San Fernando Boulevard. (See figure 1.)

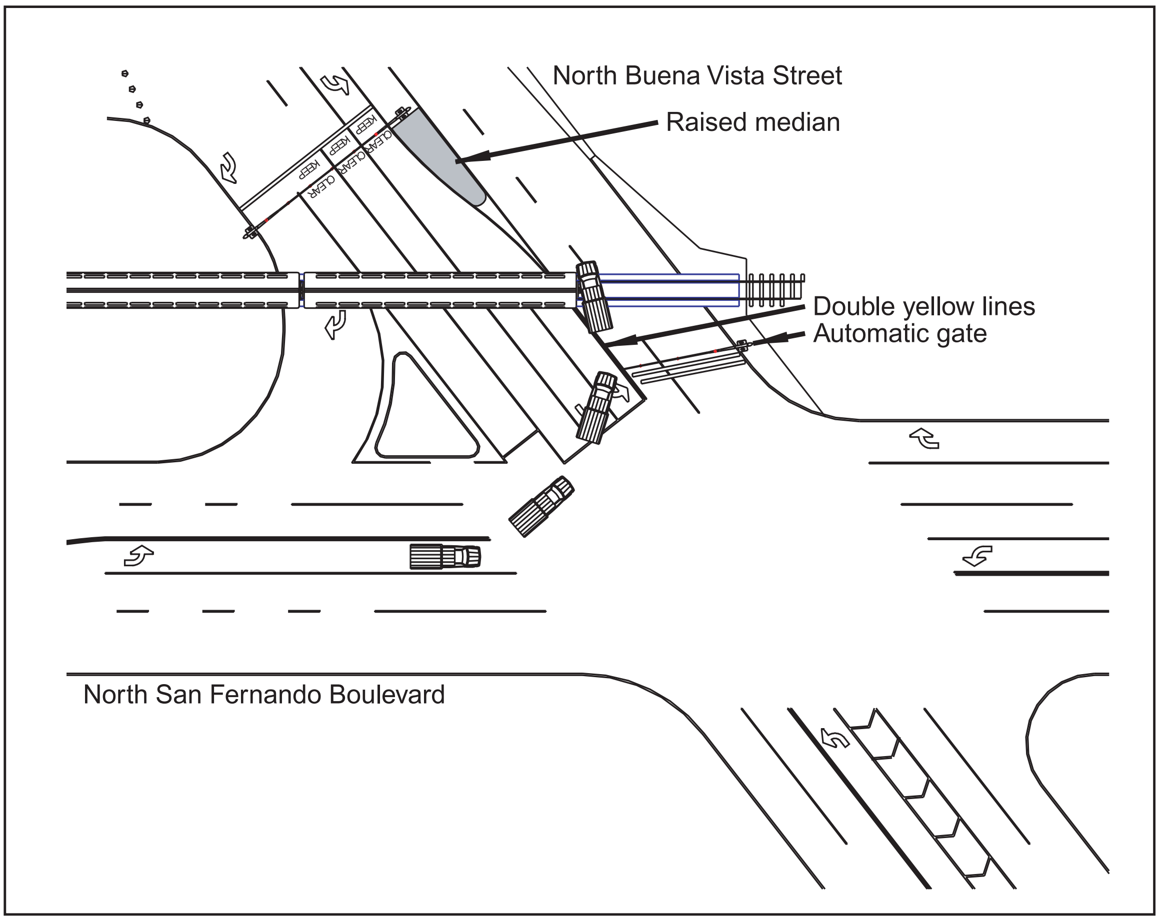

Figure 1. Accident scene.

The train had made all scheduled stops and departed Sun Valley, the last stop before the accident site, about 9:23 a.m. According to the engineer, he had accelerated the train to its authorized track speed of 79 mph and was using dynamic braking[1] to maintain speed on the downgrade to Burbank. The engineer said that as the train approached the accident crossing, he began sounding the cab car's horn at a point adjacent to an airport hotel that was his reference point for the crossing's whistle post; data later downloaded from the train's event recorder confirmed this information. The engineer stated that shortly before the train arrived at the crossing, he saw the accident vehicle make a left turn onto North Buena Vista Street and onto the tracks.

The Ford truck, which had been traveling eastbound on North San Fernando, had stopped for a red arrow traffic light in the left turn lane leading to North Buena Vista Street. The signal from the approaching train preempted the highway traffic signals and, as a result, all traffic lights at the crossing began flashing red. After the lights went into the flashing mode, the truckdriver allowed an oncoming westbound vehicle to pass, accelerated to a witness-estimated speed of 15 to 20 mph, and made the left turn from North San Fernando. A witness in the vehicle immediately behind the accident truck noted that the truck's four-way flashers were operating during this time. The truck drove on the wrong side of the roadway, that is, left of the double yellow centerline, past the end of the lowered crossing gate arm (see exemplar truck in figure 2) and proceeded onto the tracks, where it was struck on the left side by the commuter train. According to the Metrolink engineer, the driver looked toward the train "only a moment" before impact and exhibited a "frightened expression."

Witnesses stated that the automatic crossing gates were down, and witnesses, as well as data from the cab car event recorder, indicated that the train's warning whistle was being sounded at the time of the collision. The engineer did not recall whether he placed the train's brakes into emergency. Data downloaded from the event recorder showed a drop in brake line pressure about 3 seconds before impact. Two witnesses, the one in the vehicle stopped immediately behind the accident truck and a motorist behind the automatic gates on southbound North Buena Vista Street, reported that they sounded their vehicles' horns to warn the truckdriver immediately prior to the collision.

Upon impact, the truck's fuel tank was compromised, releasing fuel and resulting in a postcrash fire that consumed the stake bed, which remained at the crossing, while the truck's cab, which was not on fire, continued eastward with the train. The train derailed almost immediately and came to a stop about 1,300 feet east of the crossing. The cab car of the train came to rest on its side; its leading end faced west. The second car also came to rest on its side at a 90° angle to the track. The remaining two cars and the locomotive remained upright. The truck cab came to a rest about 1,000 feet east of the crossing. The truck was destroyed; estimated damage to the train and track was $3 million.

[1] Dynamic braking is a method of train braking in which the locomotive's traction motors are converted to electric generators driven by kinetic energy from the moving train. The generated electricity flows into a resistor grid on the locomotive and is dissipated as heat. This electrical "load" on the traction motor/generator acts to slow the motor shaft rotation, resulting in a braking action being applied to the train wheels. Dynamic braking on the locomotive is completely independent of the air braking system on the cars themselves.

Figure 2. Reenactment of accident truck's left turn.

Injuries

As a result of the collision, the truckdriver was fatally injured. Of the train's 59 passengers and 2 crewmembers, 12 were transported to area hospitals and 20 others, who sustained minor injuries, were treated and released at the scene. The conductor's injuries were minor and the engineer suffered a broken wrist. One passenger, a 76-year-old woman, who was treated and then released from a local hospital, died 15 days later from internal injuries that were probably sustained during the accident.

Meteorological Information

The temperature at the time of the accident was 68° F; visibility was clear; and winds were 11.5 to 12.7 mph, gusting from 26.5 to 33.3 mph. The train engineer stated that the glare from the sun did not affect his ability to operate the train but indicated that he may have had the cab car's sun visor down; the truckdriver did not face the sun in the direction that he was traveling.

Personnel Information

Truckdriver

The 63-year-old truckdriver had operated trucks, ranging from small pick-ups to truck tractor-semitrailer combinations, for 30 years in the metropolitan Los Angeles area. He had been a driver-trainer at various times during his career. Family members described him as a "careful driver." He typically worked from 6:00 a.m. to 5:00 p.m.; on the day of the accident, he arose about 4:30 a.m. and reported for work about 5:30 a.m. According to his son, the driver had no known major medical problems and had retired between 9:00 p.m. and 10:00 p.m. and arisen about 5:00 a.m. during the 3 days preceding the accident.

The truckdriver held a valid California class AM1 commercial driver's license (CDL) with a "T" endorsement and no restrictions; it had been issued on March 17, 1999, and was due to expire on April 26, 2004. The M1 designation indicated that he was also a licensed motorcycle operator, and the "T" endorsement allowed him to operate a vehicle towing double or triple trailers. Review of his CDL records showed that the truckdriver had no previous accidents and no convictions for prior traffic violations. He had operated trucks in the area of the accident; whether he was familiar with the accident intersection is unknown.

Three days after the accident, on January 9, 2003, the Los Angeles County Coroner's Office performed an autopsy on the truckdriver's body. According to the pathologist who did the autopsy, no blood or other bodily fluids were available for analysis. The head-on collision had resulted in massive traumatic injuries to the driver. The pathologist conducted toxicology tests on tissue samples from the liver, which revealed an alcohol concentration of 0.09 mg/dL.

Train Crew

The engineer of Metrolink train 210 began working for the National Railway Passenger Corporation (Amtrak) as an assistant conductor in March 1989 and was promoted to engineer in February 1991. He last attended a class of instruction and testing on railroad operating rules in May 2002. Between July 2002 and January 6, 2003, Amtrak records indicate that he successfully completed 80 rules compliance or "efficiency" tests.[2] The engineer told investigators that he was in good health and not taking any medications.

The conductor of Metrolink train 210 was hired by Amtrak as an assistant conductor in March 1987 and was promoted to passenger conductor in October 1988. He last attended a class of instruction and testing on railroad operating rules in September 2002. Between July 2002 and January 6, 2003, Amtrak records indicate that he successfully completed 99 rules compliance tests.

The train crew's most recent Amtrak physical examinations took place on July 11, 2001, and February 28, 2002. The crew did not provide samples for toxicological testing after the accident, nor were they required to do so.[3]

Vehicle and Wreckage Information

The accident truck, owned by Nawola, Inc., and leased to Helldorado Productions, was a two-axle vehicle with a gross vehicle weight rating of 17,500 pounds. Ford Motor Company had manufactured the truck at its Kentucky assembly plant in Jefferson County. The truck was originally built as an incomplete vehicle and later modified by the addition of a Marathon Industries stake bed cargo compartment. In California, any person holding a valid driver's license could legally operate this vehicle without a special license class or endorsement. At the time of the accident, the vehicle was carrying a load that comprised work gloves, some bolts, and a spool of cable; given the nature of the vehicle's operation, the driver was not subject to either interstate or intrastate motor carrier regulations.

As a result of the collision, the vehicle separated into two pieces. Both frame rails were severed near the truck cab. The engine and transmission detached from their frame mounting points and separated from each other. The cab was completely destroyed; the seat assemblies remained within the confines of the passenger compartment, which did not exhibit signs of fire damage. The stake bed cargo area of the truck was heavily damaged from the collision and sustained extensive fire damage. Postaccident inspection of the vehicle did not reveal mechanical conditions or defects that might have contributed to the crash, but the extent of damage precluded examination of the truck's steering, braking, and other controlling systems.

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[2] FRA regulations at 49 *Code of Federal Regulations* 217 require railroads to conduct operational tests and inspections to verify that crews are following proper procedures. These tests, commonly referred to as efficiency tests, typically involve unannounced observations and review of event recorder data.

[3] Federal regulations at 49 *Code of Federal Regulations* 419.201(b) do not require postaccident toxicological testing of train crewmembers involved in highway-rail grade crossing accidents.

The rear section of the truck's chassis and smaller pieces, such as the drive shaft and a cargo door, were observed along the west side of the crossing. Much of the rear chassis assembly came to rest adjacent to the crossing gate, about 55 feet southwest of the impact area. The gate's metal post and the surrounding pavement were discolored from the postcrash fire. The surface of the crossing deck, as well as the wooden cross ties, had cuts and gouges, all of which were oriented from west to east. The north concrete wall separating the railroad tracks from Interstate 5 had impact marks from the collision.

Railroad Information

In 1991, the transportation commissions of Los Angeles, Orange, Riverside, and San Bernardino Counties established the Southern California Regional Rail Authority (SCRRA) as a joint powers agency to plan, design, construct, and administer the operation of regional passenger rail lines (Metrolink) within the multicounty region. Metrolink serves more than 35,000 passengers in 50 cities throughout the region. It maintains 7 scheduled routes, operates about 507 route miles and 138 trains on weekdays, and maintains its headquarters and dispatching center in Pomona, California.

Aspects of Metrolink operations fall under the regulatory authority of the Federal Railroad Administration (FRA), as set forth in 49 *Code of Federal Regulations* (CFR) Parts 200-299. California Public Utilities Commission (CPUC) personnel enforce FRA regulations under a State participation program set forth in 49 CFR Part 212. Metrolink contracts with Amtrak to manage its rail operations. Metrolink conductors, engineers, and line managers are Amtrak employees.

A single Metrolink track crosses North Buena Vista Street (Metrolink milepost 12.77) at grade. The tangent track, which has an eastbound descending grade of 1.33 percent, is constructed of 136-pound continuously welded rail on wood ties set in granite ballast. A switch east of North Buena Vista Street allows eastbound trains to enter Brighton siding through a left turnout. The eastbound whistle post is 1,458 feet west of the accident crossing. (See table 1 for daily train traffic at this location.)

Table 1. Train volumes on the North Buena Vista Street crossing.

Type of train	Number of trains	Train direction
Metrolink	12	East
Metrolink	12	West
Union Pacific	3	East
Union Pacific	4	West

Traffic Control, Intersection, and Grade Crossing Information

The California Department of Transportation (Caltrans) provides legally binding guidance on State traffic control devices and other matters in its *Caltrans Traffic Manual*, which was in substantial conformance with the national *Manual on Uniform Traffic Control Devices* (MUTCD) until publication of the MUTCD 2000 (Millennium Edition).[4] The 1996 edition of the *Caltrans Traffic Manual* remains current until Caltrans adopts the MUTCD 2000 and California supplement, which it planned to do by December 31, 2003, according to the agency. The California supplement will augment the MUTCD 2000 and clarify which State policies, practices, and standards differ from it.

The CPUC regulates railroad operations within the State and must approve any changes to the operation of highway-rail grade crossings.

Reconstruction of the accident intersection and grade crossing was completed in June 2002 to provide more highway traffic-carrying capacity and safer operation when trains approached the crossing, which had a history of train-motor vehicle collisions. Many of these accidents were related to congestion and queuing from the adjacent traffic signal. The reconstruction project included a new eight-phase[5] digital traffic signal controller to regulate traffic at the roadway intersection. The controller provided signal indications and timing for all through, turning, and pedestrian movements. New interconnected railroad signal equipment was installed at the same time. The following tables show the history of traffic accidents at this location.

Table 2. Grade crossing accidents.

Accident date	Number injured	Number killed	Train type	Train speed	Causal factor[a]
12/06/00	0	0	Metrolink	79 mph	Vehicle stopped between crossing gate and tracks
11/22/00	0	0	Metrolink	Unknown	Vehicle stopped between crossing gate and tracks
07/16/00	1	0	Union Pacific	45 to 50 mph	Vehicle stuck on tracks
05/31/95	0	0	Metrolink	Unknown	Vehicle stopped between crossing gate and tracks
01/13/94	0	0	Metrolink	79 mph	Vehicle drove around crossing gate
10/08/92	0	0	Southern Pacific	30 to 10 mph	Vehicle stopped between crossing gate and tracks
09/19/92	0	0	Southern Pacific	Unknown	Vehicle stuck on tracks

a. Causal factors obtained from the investigating officer's report.

[4] The MUTCD, published by the U.S. Department of Transportation, Federal Highway Administration, sets national standards governing traffic control devices placed on streets and highways by authority of a public body or official having jurisdiction to regulate, warn, or guide traffic.

[5] A "phase" is a separate timing element for traffic signal operation. In this case, the controller timed the intersection's four through-traffic and four left turn movements.

Table 3. Intersection traffic accidents.

Year	Property damage	Number injured	Fatalities
2002	4	5	0
2001	3	6	0
2000	5	4	0
1999	2	4	0
Total	14	19	0

The Burbank Department of Public Works (BDPW) initiated the reconstruction project on October 15, 2001, when it submitted a request to the CPUC for approval to make modifications to the intersection and railroad grade crossing. The letter stated that the city of Burbank and the SCRRA agreed on the need for the following improvements to the site at North Buena Vista Street and North San Fernando Boulevard:

- Widening of the crossing
- Addition of a westbound right turn lane from North San Fernando Boulevard onto North Buena Vista Street
- Construction of new curb and gutter on both sides of the street
- Installation of raised median islands along the center of North Buena Vista Street
- Modification of the advanced warning devices at the crossing

The letter also detailed improvements, including the installation of six 6-foot-long rubber panels, which allow a smoother ride for vehicles traveling over the rails, that were to be made to the surface of the grade crossing deck. On October 22, 2001, the CPUC approved the BDPW request.

In addition to making the crossing improvements, the BDPW decided, based on a 1998 traffic study, to modify the left turn lane for southbound North Buena Vista Street from a single lane to a dual left turn arrangement that increased storage length and improved traffic capacity. A consulting firm had prepared the study, entitled *Burbank Empire Center Traffic and Circulation Analysis*, in conjunction with a proposed mixed-use redevelopment project to be built at a location formerly used by the Lockheed Corporation as an aircraft manufacturing facility. The site encompassed about 2,237,000 square feet in central Burbank bounded by North Buena Vista Street, Victory Place, Victory Boulevard, and Empire Avenue.

Included in the study was an evaluation of morning and afternoon peak hour traffic conditions at 27 intersections that might be affected by the proposed development. The analysis concluded that the project would have significant adverse operational impacts at many intersections, including the one at North Buena Vista Street and North San Fernando Boulevard. Data showed that even without the new development, the intersection was providing a level of service (LOS) F.[6] The study states:

> The project will add heavy movements between the north and east legs of this intersection. Provision of a second exclusive southbound left turn lane and an exclusive westbound left turn lane would facilitate these project trips and improve the intersection operation, but would not mitigate the project impacts to a level of insignificance, and the intersection would still operate at LOS F. To mitigate the project impacts and achieve an acceptable level of service, this intersection will require construction of a grade separation as identified in the Infrastructure Blueprint and documented in the Project Study Report on Interstate 5 between North Hollywood Way and West Burbank Boulevard.

As proposed in the 1998 study, a grade separation, that is, either an underpass or an overpass that will eliminate the accident crossing, is part of a Caltrans interstate widening project that is scheduled for completion about 2006.

Intersection Signals, Markings, and Other Devices

The 17 signal heads used to control traffic at the accident intersection were mounted on 8 poles (2 at each corner) and were interconnected with the active railroad grade crossing signals, as specified in the *Caltrans Traffic Manual* and the MUTCD.[7] (See figure 3.) The traffic signal heads comprised 12-inch-diameter circular indication lenses and left and right arrow lenses. The arrows were in place at those approaches where turning was permitted, such as the eastbound left turn lane, by which the accident vehicle entered the intersection. Right arrows were also in place on the westbound approach to North San Fernando Boulevard to control traffic turning right onto the crossing.

When an approaching train preempted the operating interval of the traffic control signals, it interrupted the signal timing cycle and activated an interval intended to clear southbound vehicles queued on North Buena Vista Street and the tracks.[8] This 25-second interval, designed to extend beyond the time that the gates were fully deployed, gave vehicles stopped on the railroad tracks an opportunity to clear the tracks as the automatic crossing gates came down. Following the "clear track" interval, and in tandem with the

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[6] According to the American Association of State Highway and Transportation Officials (AASHTO), LOS F for urban and suburban arterials, as described in the publication *A Policy on Geometric Design of Highways and Streets*, provides an average travel speed between 25 and 30 percent of free flow speed. Vehicular backups and high approach delays at signalized intersections are encountered.

[7] The 17 signal heads do not include the 6 signal faces used to regulate pedestrian traffic.

[8] The clearance phase of the preemption sequence began with a 20-second green indication, was followed by a 3.5-second yellow indication, and concluded with a 1.5-second red indication.

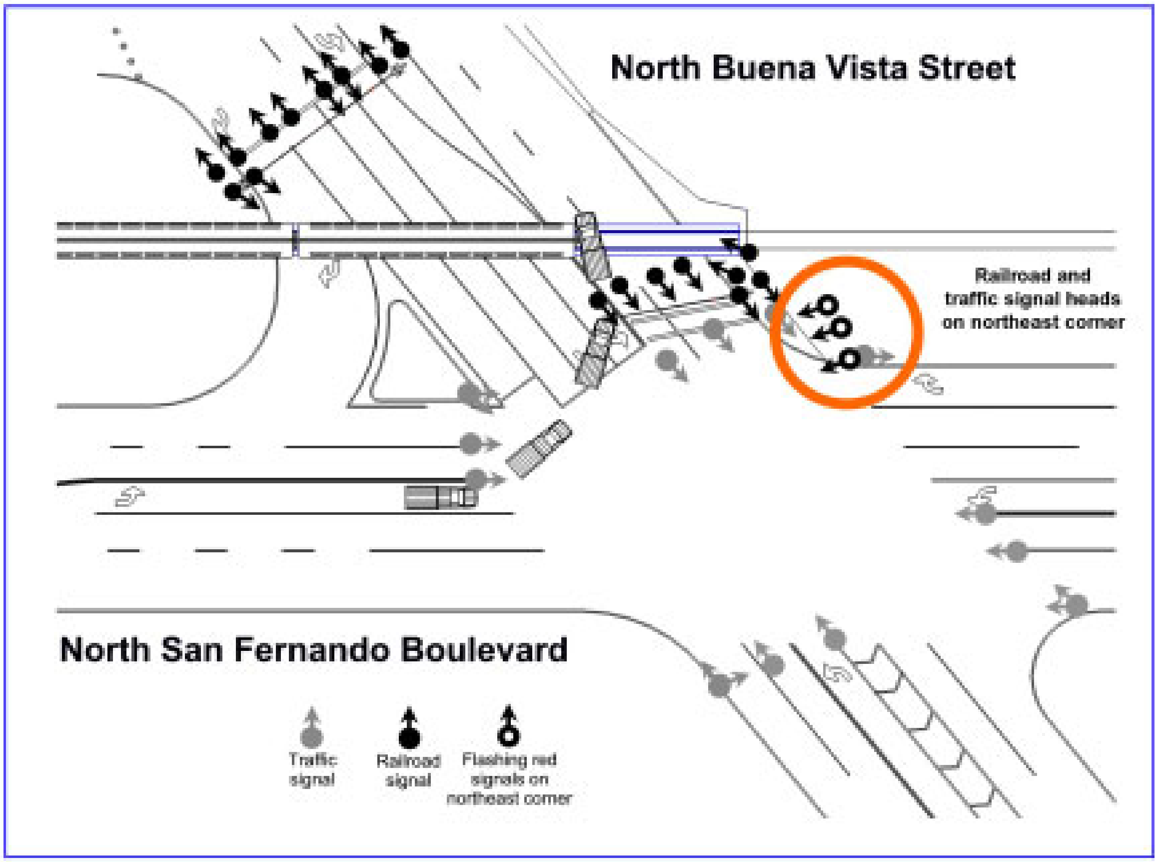

Figure 3. Intersection signals and gates.

flashing-light railroad signals at the grade crossing, the highway traffic control signals transitioned to an "all-red-flash mode" at all intersection approaches and turn signal locations. The all-red-flash mode, also known as a "railroad hold" interval, included the circular red signal indications and the red arrow signal indications.[9]

In events leading up to the accident, witnesses reported that the truckdriver had originally stopped his vehicle at the intersection while facing a left red arrow signal indication. While the truck was stopped, the approaching Metrolink train preempted the traffic signals, and as a result, 25 seconds later, the traffic signals switched to the all-red-flash mode or railroad hold interval. From the eastbound left turn lane, both the flashing red circular and the flashing red left arrow traffic control signal indications would have been in the truckdriver's line of sight. In addition, at least one double-headed railroad crossing flashing light signal would have been within his view (see figure 4). According to witnesses, the truckdriver pulled into the intersection after the signals had entered into the all-red-flash interval.

[9] According to the BDPW traffic signal manager, the traffic control signals only operated in a flashing mode when an approaching train preempted them or when they encountered an operational conflict within the system program.

Figure 4. Accident driver's line of sight (reenactment).

Other regulatory devices, passive and active, at the railroad grade crossing included pavement markings, automatic gates, audible warning devices, and *Do Not Stop on Tracks* signs.[10] The northbound approach had one such sign post-mounted to the traffic control signal support at the northeast corner of the intersection. This sign was aligned so that it was visible to northbound motorists. Another sign posted at this corner on a separate support was oriented toward the southwest and was visible to motorists traveling through the intersection from the eastbound left turn lane; it was most likely to have been within the truckdriver's line of sight as he traversed the intersection. A third sign at this corner was aligned toward the east and was visible to westbound drivers approaching the crossing from the right-turn-only lane. Two other signs, one each posted on the left and right sides of the roadway, were visible to motorists in the southbound approach lanes.

Both the north and southbound approaches also included pavement markings, and adjacent to each marking was a *Highway-Rail Grade Crossing Advance Warning* sign (W10-2 in the MUTCD 2000, Millennium Edition). The advance warning sign on North San Fernando Boulevard along the eastbound approach to the intersection (220 feet west of the left turn lane) was completely obscured by foliage (see figure 5). In each through lane of the northbound approach, standard pavement markings were in place about 325

[10] Listed in the MUTCD 2000, Millennium Edition, December 2001, as R8-8.

feet south of the crossing. In the southbound lanes, the same markings were about 275 feet north of the crossing. The MUTCD does not require use of such markings at this crossing.[11] Nonstandard pavement markings[12] were present on the north side of the crossing; in white thermoplastic letters located between the stop line and the railroad tracks, they displayed the message KEEP CLEAR. The BDPW had applied three of these markings, one in each of the southbound through lanes and a third in one of the two left turn lanes, at the request of the SCRRA.[13]

Figure 5. Obscured advance warning sign.

[11] MUTCD 2000, Millennium Edition, Part 8, "Traffic Controls for Highway-Rail Grade Crossings," Section 8B.16 – Pavement Markings, states that pavement markings shall not be required at highway-rail grade crossings where the posted or statutory highway speed is less than 60 kph (40 mph) or in urban areas, if an engineering study indicates that other installed devices provide suitable warning or control.

[12] The term nonstandard refers to the fact that the MUTCD does not mention these pavement markings. According to the BDPW, Caltrans uses the markings, which are listed in the 1996 edition of its *Standard Plans Manual*.

[13] The SCRRA made the request in March 2002 because it was concerned about southbound North Buena Vista Street vehicles that frequently stopped on the tracks. The BDPW applied the markings only on the north side because space was insufficient along the south side.

Railroad Crossing Signals and Gate

Each of the 12 flashing-light railroad signals at the crossing comprised two 12-inch-diameter lenses. Signal placement on the south side included three post-mounted assemblies and three signals attached to a cantilever arm. The post-mounted assemblies were aligned so that one faced northbound motorists and one faced southbound motorists; the third was oriented so that a driver who was stopped in the eastbound left turn lane of North San Fernando Boulevard directly faced the signal. The third post-mounted assembly was the railroad signal most likely to have been visible to the truckdriver. Of the three cantilever-mounted signals, two faced northbound motorists and one faced southbound traffic. Signal placement on the north side was similar. One of the three post-mounted signals there was positioned to the left of the southbound approach to the crossing gate; the other two were positioned to the right, one facing northbound traffic and one facing southbound traffic. Of the three cantilever-mounted signals on the north side, two faced southbound motorists and the third faced northbound motorists.

In addition, a single automatic gate spanning both northbound through lanes was in place at the south side of the crossing. Its placement conformed to specifications in the MUTCD.[14] The gate, which was neither parallel to the tracks nor perpendicular to the northbound approach,[15] was not completely visible to motorists in the eastbound left turn lane. Two automatic gates, positioned opposite one another, were also in place on the west and east sides of the roadway at the north side of the crossing. The ends of the gates met about midpoint in the roadway, and both gates were aligned perpendicular to the roadway. The gate on the east side was mounted on a 10-foot-wide raised concrete median.

After the accident, investigators downloaded data from the railroad signal equipment's event recorder, a device that records several data sets associated with the operation of the crossing signals. The data recorded during this accident sequence showed the following:

- Warning time – 41 seconds[16]
- Train speed when first detected – 81 mph
- Average train speed – 76 mph[17]
- Train speed over island circuit – 73 mph[18]

The event recorder download yielded no significant faults in the crossing signal system.

[14] MUTCD 2000, Millennium Edition, December 2001, Part 8, "Traffic Controls for Highway-Rail Grade Crossings," Section 8D.04 – Automatic Gates.

[15] The gate was aligned, using North San Fernando Boulevard as a baseline, so that its relative angle to the roadway was about 11 degrees.

[16] Although warning times can vary due to the effect of environmental conditions on track circuits, the system design ensures a minimum warning time.

[17] Average speed between first detection by the signal equipment and arrival at the crossing.

[18] The island circuit is at the crossing itself, so this measurement is the train's speed as it passed over the crossing.

Railroad Traffic Signal Preemption Design

When the grade crossing signal equipment detects the approach of a train, it sends an electronic signal to the roadway traffic signal equipment. The railroad signal equipment is programmed to provide a minimum warning time sufficient to allow the traffic signal to complete its preemption sequence and clear the crossing of traffic before the train arrives. In the case of the accident grade crossing, the minimum warning time was 35 seconds. After appropriate yellow clearance intervals, this preemption sequence forces the traffic signal into a "clear track" interval. The traffic signal then enters a "railroad hold" interval until the train passes the crossing.

Various options are available for the railroad hold, or traffic signal preemption dwell, interval that immediately follows the clear track interval and remains for the duration of the railroad preemption. Regardless of the mode of operation, the purpose of the dwell interval is to prevent traffic movements toward the crossing, and, if applicable, maintain traffic movements through the intersection. In deciding to implement the all-red-flash mode, the BDPW followed guidance[19] provided by Caltrans. According to the BDPW traffic signal manager, the department has used the all-red-flash mode for the signal preemption dwell interval for about 20 years. Before then, the signals operated in the limited operation mode, allowing green indications for the through traffic on North San Fernando Boulevard but stopping other traffic that conflicted with movement of a train. The traffic signal manager stated that he believed the limited operation mode resulted in a more efficient flow of traffic, but the flash mode resulted in a safer operation.

During reconstruction of the intersection in 2002, the BDPW changed the preemption dwell mode from all-red-flash to limited operation for about a 2-week period in February. The department indicated that it did so because traffic moved more efficiently in the limited operation mode. The BDPW noted that the area had recently experienced tremendous growth in traffic demand and that the limited operation mode allowed more vehicles to move through the intersection during preemption. When asked why the department reverted to the all-red-flash mode, BDPW officials responded that during a February 28 meeting with SCRRA staff, the latter recommended that the lights be returned to the all-red-flash mode. According to the SCRRA, its staff had suggested that only the southbound traffic control signals revert to the flash mode, thereby providing a final escape route for traffic, particularly buses or large trucks, that might otherwise be stopped too close to the tracks.[20]

Caltrans Guidance

Section 9, subsection 9-03.29, of the 1996 edition of the *Caltrans Traffic Manual* provides guidance to be followed in California when grade crossing warning equipment is

[19] The *Caltrans Traffic Manual*, Chapter 9, 9-03.29 (d) Railroad Preemption, permits both the all-red-flash and "limited operation" preemptive dwell modes. The manual contains no criteria for selecting between the two.

[20] According to the BDPW, Caltrans prohibits limited use of flashing red traffic signal indications such as that proposed by the SCRRA. The MUTCD also prohibits it.

located within 197 feet (60 meters) of a signalized intersection. Once a train has occupied the crossing, it states:

> d. Depending on traffic requirements and phasing of the traffic signal controller, the traffic signal may then do one of the following:
>
> (1) Go into flashing operation, with flashing red or flashing yellow indications for the approaches parallel to the railroad tracks and flashing red indications for all other approaches. Pedestrian signals shall be extinguished. If flashing red is used for all approaches, an all-red or other clearance interval shall be provided prior to returning to normal operation.
>
> (2) Revert to limited operation with those signal indications controlling through and left turn approaches towards the railroad tracks displaying steady red. Permitted pedestrian signal phases shall operate normally. This operation shall be used only if the grade crossing warning equipment includes gates.

MUTCD Guidance

The MUTCD 2000, Millennium Edition, (Chapter 4, Section 4D.04 – Meaning of Vehicular Signal Indications**)** defines the meaning of flashing traffic signal indications as follows:

> D. Flashing signal indications shall have the following meanings:
>
> 1. Flashing yellow—When a yellow lens is illuminated with rapid intermittent flashes, vehicular traffic may proceed through the intersection or past such signal indication only with caution.
>
> 2. Flashing red—When a red lens is illuminated with rapid intermittent flashes, vehicular traffic shall stop at a clearly marked stop line; but if there is no stop line, traffic shall stop before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway before entering the intersection. The right to proceed shall be subject to the rules applicable after making a stop at a STOP sign.
>
> 3. Flashing RED ARROW and flashing YELLOW signal indications have the same meaning as the corresponding flashing circular signal indication, except that they apply only to vehicular traffic intending to make the movement indicated by the arrow.

The MUTCD provides a limited discussion of traffic signal preemption near grade crossings. Section 4D.13, which addresses preemption and priority operation of traffic controls, states that when active grade crossing signal devices are within or near a highway intersection controlled by traffic control signals, the two signal systems should be interconnected, as indicated in section 8D.

Section 8D addresses the systemic operation of the circuits that control the two signal systems, as well as the interaction between the systems. It states:

> After the track clearance phase, the highway intersection traffic control signals should be operated to permit vehicle movements that do not cross the tracks, but shall not provide a through circular green or arrow indication for movements over the tracks. This does not prohibit green indications for highway traffic movements on a roadway paralleling the tracks.

Similarly, section 4D.13 notes, "Traffic control signals operating under preemption control or under priority control should be operated in a manner designed to keep traffic moving."

Federal Highway Administration Guidance

Chapter IV, "Identification of Alternatives," of the Federal Highway Administration's (FHWA's) 1986 publication, *Railroad-Highway Grade Crossing Handbook,*[21] is another source of guidance on highway traffic signal preemption. Section 5 of this chapter presents considerations concerning design elements and general guidance on vehicle movements. It does not offer specific guidelines for the operational modes of traffic control signals. The general discussion states, in part:

> When preempted by train movements, the traffic control signal (after provision of the proper phase change intervals) will immediately provide a short green interval to the approach crossing the track. This is done to clear any vehicles that may be on, or so close to, the track as to be in danger, or where vehicles may interfere with the operation of crossing gates. The traffic signal will subsequently display indications to prevent vehicles from entering the track area, while at the same time traffic movements that do not conflict with the railroad movement may be permitted. If, at the time of preemption, the green interval is on an approach that does not cross the track, that green interval would be immediately terminated with a standard yellow phase change interval in order that green time may be given to the approach crossing the track. Conflicting indications must not be permitted and every green signal indication must be terminated with a yellow indication as specified in the MUTCD. Turning movements onto the highway with the crossing should be prohibited through the use of blank out signs that display "No Right Turn" or "No Left Turn" as appropriate.

National Cooperative Highway Research Program Findings

In 1999, the Transportation Research Board (TRB) published a paper[22] that included a discussion of railroad hold intervals and strategies used by various localities once queued vehicles have been cleared from the railroad tracks. Among the traffic signal modes employed were: 1) all red, 2) flashing all red, 3) flashing red-flashing yellow, and 4) limited operation. The section on the all-red-flash mode stated:

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[21] U.S. Department of Transportation, Federal Highway Administration, *Railroad-Highway Grade Crossing Handbook*, 2nd ed., FHWA TS-86-215 (Washington, DC: FHWA 1986).

[22] TRB, National Cooperative Highway Research Program, *Traffic Signal Operations Near Highway-Rail Grade Crossings. A Synthesis of Highway Practice 271*. (Washington, DC: TRB, 1999).

> This control mode allows motor vehicles to proceed through the intersection after coming to a complete stop at the stop line similar to an all-way STOP sign controlled intersection. This traffic signal control mode allows motor vehicles traveling toward the highway-rail grade crossing to turn left or right onto the parallel roadway and allows motor vehicles traveling parallel to the rail alignment to cross the roadway that intersects with the tracks.
>
> *It may be confusing to motorists and would be very difficult to differentiate between the railroad flashing operation (during preemption) and late night flashing operation of the traffic signals (automatic flash). Furthermore, the traffic signals may go to all red flashing because of a malfunction, which motorists may confuse as a "train approaching" message if flashing all red is the preferred preemption hold phase*. [Emphasis added.]

While investigating the Burbank accident, Safety Board staff noted that the traffic signals displayed flashing red indications both for traffic movements at the intersection that would conflict with traversal of the grade crossing and for those movements that would not conflict.

The *Uniform Vehicle Code* states that drivers must stop at flashing red grade crossing signals and remain stopped until the train has passed and the flashing ceases.

Discussions with BDPW and CPUC engineers on the design of the intersection revealed that they were unaware of the studies and publications issued following the October 25, 1995, Fox River Grove, Illinois, highway-rail grade crossing accident,[23] a previous fatal collision in which the functioning of the signal systems was a causal factor. As a result of the Fox River Grove accident investigation, the TRB,[24] the FHWA,[25] and the Institute of Transportation Engineers (ITE)[26] all revised or issued new guidance on traffic signal design. Discussions with a random sample of other consulting, State, and local traffic engineers revealed a similar lack of familiarity with these publications.

In its introduction to traffic signal design, the *Caltrans Traffic Manual* lists several references for traffic signal design, including the MUTCD, two publications of the ITE, and two FHWA handbooks. Several of these references were outdated and none had been prepared after the Fox River Grove accident.

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[23] National Transportation Safety Board, *Collision of Northeast Illinois Regional Commuter Railroad Corporation (METRA) Train and Transportation Joint Agreement School District 47/155 School Bus at Railroad/Highway Grade Crossing in Fox River Grove, Illinois, on October 25, 1995*, Highway Accident Report NTSB/HAR-96/02 (Washington, DC: NTSB, 1996).

[24] TRB, *Traffic Signal Operations Near Highway-Rail Grade Crossings. A Synthesis of Highway Practice 271*.

[25] U.S. Department of Transportation, Federal Highway Administration, Highway/Rail Grade Crossing Technical Working Group, "Guidance on Traffic Control Devices at Highway-Rail Grade Crossings" (Washington, DC: FHWA, 2002).

[26] ITE, "Preemption of Traffic Signals at or Near Railroad Grade Crossings with Active Warning Devices," Recommended Practice RP-025A (Washington, DC: ITE, 1997).

Presignals, sometimes called "far-side signals," are one option available to traffic engineers who are designing or redesigning intersections at highway-rail grade crossings. They are traffic signal heads positioned on the approach side of the tracks and, like the intersection signals, are operated by the highway traffic signal controller. When the intersection signals are green for the approach crossing the tracks, the presignal heads are also green. When the approach interval is about to be terminated, the presignals change to red before the intersection signals do, thereby allowing traffic already on the crossing to clear.

Tests and Research

Exemplar Truck

On January 9, 2003, Safety Board investigators and staff from the Burbank Police Department performed on-site testing to evaluate visibility and assess the truck's probable approach path as it traversed the intersection. To perform these tests, the team used an exemplar vehicle similar to the accident truck. (See figure 2.)

Initially, the vehicle was parked in the eastbound left turn lane, the same location from which the accident truck entered the intersection. While the vehicle was stopped, a train passed through the crossing, activating the crossing warning devices and preempting the highway traffic control signals. Observations of the crossing's flashing signals and automatic gates, their visibility, and conspicuity were made from the driver's position. When the driver was looking toward the crossing, the flashing signal mounted at the northeast corner and aligned to the southwest was clearly visible. The flashing red arrow indication on the post-mounted traffic signal head was also in clear view. The alignment of the intersection, in combination with the angle of the automatic gate relative to the roadway, limited the visibility of the flashing red lights mounted on the automatic gate from the driver's seat.

The operator drove the truck from the eastbound left turn lane onto the crossing. The vehicle's turning radius was sufficient to maneuver through the intersection without approaching the face of the south automatic gate. Initially, the vehicle was driven at a slow speed through the intersection and stopped at the approximate location of the tire marks left by the accident truck during the collision. In another test, the vehicle was accelerated to the point that it experienced moderate body roll and a slight loss of traction as it maneuvered through the intersection. At this higher speed, the operator still reported no difficulty in maintaining a sharp enough turn to avoid the crossing's fully deployed automatic gate. In both tests, the path required that the operator drive the truck on the wrong side of the roadway. As the truck entered northbound North Buena Vista Street, it was clearly to the left of the double yellow centerline. Raised medians had not been installed on the centerline near the gates.

Observations of Intersection and Crossing Traffic Operations

Safety Board investigators reviewed the design plans for the intersection reconstruction, new traffic signal installation, and grade crossing signals at the accident site. They also observed traffic at the intersection and crossing, as well as several other intersections near the tracks in the area, and noted:

1. Southbound traffic on North Buena Vista Street routinely queued from North San Fernando Boulevard onto the crossing deck and through the area where the pavement was marked *KEEP CLEAR*. The traffic signal for the intersection of North Buena Vista Street and Winona Avenue caused northbound traffic on North Buena Vista Street to queue onto the crossing. This traffic signal had no railroad preemption to discharge that queue before the arrival of a train.
2. During the preemption or "clear track" interval of the traffic signal at the accident site, vehicles went around the gates or stopped between the gates and the tracks.
3. The path of vehicles executing left turns from eastbound North San Fernando Boulevard onto northbound North Buena Vista Street could be identified by an "oil drip" trail that extended from the left turn lane on North San Fernando Boulevard across the crossing deck. The retroreflective, thermoplastic double yellow centerline on North Buena Vista Street near the southbound left turn lane "stop bar" at the crossing was also worn from left-turning vehicles that had traversed it. This wear mark aligned with the "oil drip" path.
4. Observation of all crossings on both the accident line and another SCRRA line to the west revealed that many of them have similar (or worse) traffic queuing on the crossings. Much of the railroad and highway signal equipment appeared to be older than that at the accident crossing. (See figure 6.)

Figure 6. Postaccident queuing at accident site.

Analysis

General

In the following analysis, the Safety Board will first exclude those factors that did not cause or contribute to the accident. It will then identify the factors that led to the accident, focusing, in particular, on the use of "all-red-flash" railroad hold intervals at signalized highway-rail grade crossings. It will also address adherence to applicable engineering guidance in designing traffic signals and other safety features at grade crossings and consider the ready availability of such guidance.

Exclusions

At the time of the accident, the weather was clear and dry with gusting winds. The Metrolink engineer stated that glare from the sun in the east did not impede his operation of the train, but noted that he may have had the cab car's sun visor down. The truckdriver, who also faced east, had within view the post-mounted railroad signal located south of the tracks and positioned to assist drivers in the left turn lane. The morning sun may have partially backlit this signal, thereby reducing the contrast of the light and, in turn, the conspicuousness of its flashing red arrow. Nonetheless, the driver's actions—he stopped at the red arrow when it was solid and only proceeded to turn after it had begun to flash and traffic had cleared—were consistent with accurate perception of the traffic signals.

A review of maintenance records and event recorder data for the railroad crossing signals did not reveal malfunctions that might have contributed to the accident. Postcollision testing did not yield evidence of malfunctions in the roadway traffic signals or in the interconnection between the roadway signals and railroad crossing signal equipment. Review of track inspection records showed no anomalies with the track.

Postaccident inspection of the model year 2000 Ford truck revealed no mechanical condition or defect that might have contributed to the collision. While extensive damage to and destruction of some systems, such as braking and steering, precluded examination of critical components, the truckdriver apparently accelerated from a stopped position in a controlled manner. Witnesses did not note irregularities in the vehicle's turning maneuver that would suggest a mechanical problem.

The engineer was experienced in operating Metrolink commuter passenger trains and had successfully completed the requisite operational tests and inspections. Event recorder data corroborate the engineer's account of his actions before impact, and evidence does not indicate that he was impaired or fatigued.

The truckdriver held a valid California CDL with a "T" endorsement and no restrictions. He had functioned as a driver-trainer at various times during his career. Review of his CDL records showed that he had no previous accidents or convictions for traffic violations. Although toxicological testing indicated alcohol in the driver's liver tissue, the alcohol detected could have been the result of either ingestion or postmortem production.

Therefore, the Safety Board concludes that the weather, the track, the signal system, the mechanical condition of the train and accident truck, and the qualifications of the train crew and accident driver neither caused nor contributed to this accident.

The Safety Board could not determine whether the driver was impaired by alcohol at the time of the accident because vitreous fluid and urine, substances that do not normally support the postmortem production of alcohol, were not available for toxicological analysis. Although the pathologist who conducted toxicological tests on tissue samples from the driver found an alcohol concentration of 0.09 mg/dL, the alcohol detected could have been the result of either ingestion or postmortem production, particularly given the massive traumatic injuries sustained by the driver and the 3-day delay in obtaining the tissue specimen. Even if the alcohol were known to have resulted from ingestion, the level cannot be used to ascertain potential impairment, since tissue levels of alcohol do not reliably correlate with blood levels, and no blood was available for evaluation.

The Accident

Operation of Metrolink commuter train 210 conformed to standard procedures, and the trip was uneventful until the accident occurred. As the train approached the grade crossing, the engineer sounded the cab car's horn at the whistle post, as he was required to do. A witness in the vehicle stopped directly behind the accident truck reported that, even though his windows were up, he could hear the train's horn and the crossing's electronic bells; he also said that he could see the train through his left rear view mirror.

Shortly before the train arrived at the crossing, the engineer stated that he saw the accident truck turn left onto North Buena Vista Street and then onto the tracks. He reported that he did not remember whether he placed the train's air brakes into emergency at this point. Data from the locomotive event recorder indicated that the train line air pressure dropped sharply at the approximate time of impact with the truck. The drop may have occurred either because the engineer placed the brake lever into the emergency position or as a result of the impact. Regardless, the stopping distance was insufficient to avoid the collision.

According to witnesses, when the truckdriver approached the North San Fernando Boulevard-North Buena Vista Street intersection, the traffic signal was displaying a solid red left arrow, and the driver stopped in compliance to the signal. While the truck was stopped in the left turn lane, the traffic signal changed to all-red-flash mode because of the approaching Metrolink train, which had prompted the railroad's signal equipment to send an electronic impulse to the traffic signal controller that changed signal aspects at the intersection. The left turn arrow governing the truck's movement, as well as all other traffic signal heads (arrow and circular) visible to the truckdriver, changed from solid to flashing indications.

As the truckdriver initiated the left turn toward the tracks, his vehicle would have been oriented toward 2 of the 20 railroad grade crossing signals that were alternately flashing red and required that he stop. The automatic gates were also in the down position. He apparently either discounted or did not hear the train horn and the horns sounded by nearby motorists. After the truckdriver proceeded left on a wide curved path around the west end of the automatic railroad crossing gate that was in the down position, his vehicle was struck by the Metrolink train. The Safety Board concludes that the accident truck collided with the Metrolink train when the truckdriver made a shallow left turn onto North Buena Vista Street after activation of the flashing red left turn arrow.

The Safety Board considered possible explanations for the accident driver's behavior, which belies his extensive experience as a truckdriver and his record of no vehicular accidents or violations. The discussion below will examine factors related to the driver's actions and explain the potentially confusing message of the all-red-flash mode used for traffic signals at the site.

An anomaly during this accident sequence, as reported by one witness, was the truckdriver's activation of the vehicle's emergency flashers. Typically, an operator uses emergency flashers to signify an unstable or oversize load, a mechanical malfunction, a medical problem, or a temporary stop to make a delivery. The accident vehicle was carrying a load that comprised work gloves, some bolts, and a spool of cable, making the first of these four explanations unlikely. Although the second two cannot be ruled out, the Safety Board notes that the driver accelerated in a controlled manner and at a prudent speed as he was executing the turn; available evidence does not support the occurrence of a mechanical malfunction or medical emergency. Since he was returning from picking up materials near the accident site, the fourth explanation is plausible, assuming he forgot to turn the flashers off after completing the pickup of materials. Or, the driver may have inadvertently activated the flashers. Both visual and auditory cues in the vehicle would have alerted him that they were activated, but he may have failed to perceive them.

Regardless of whether the activation was deliberate or unintentional, it suggests some degree of distraction, either due to the factors that led the driver to activate the flashers or to those that prevented him from noticing that he had inadvertently activated them. Fatigue can reduce an individual's ability to cope with distraction, and the accident driver may have been experiencing sleep restriction and its associated performance effects on the day of the accident. If he retired between 9:00 p.m. and 10:00 p.m. the night before the accident and arose about 4:30 a.m. the following morning, his maximum time in bed would have been 6.5 to 7.5 hours, and he was not necessarily asleep for that entire time.

While individuals vary significantly, adults typically need slightly more than 8 hours of sleep nightly. Thus, the accident driver, who arose earlier than usual due to the constraints of his work schedule, may not have been adequately rested on the day of the accident. Research has shown that even small reductions in sleep can result in measurable changes in vigilance,[27] and the circumstances of this accident suggest that the accident driver's perceptual, attentional, or decision-making performance was less than optimal on January 6, 2003. In light of evidence that the driver did not receive his customary amount of sleep on the preceding night, fatigue cannot be ruled out as a factor in this accident.

The unique geometry of the North San Fernando Boulevard-North Buena Vista Street intersection and close proximity of the railroad tracks to it required a degree of alertness and acuity on the part of drivers turning left from North San Fernando Boulevard to traverse the grade crossing. The intersection is not a perpendicular one; the two streets intersect one another at a 52° angle, and the grade crossing is about 50 feet north of the intersection. As a result, from the vantage point of the left turn lane, drivers may not be aware that the road intersects with the railroad tracks almost immediately upon making the turn.

Because of the acute angle at the intersection, drivers turning left from eastbound North San Fernando Boulevard follow a path that crosses over the south ends of the dual left turn lanes and double yellow centerline on North Buena Vista Street. Wear to the pavement markings in that area and an "oil drip" path on the pavement are evidence of this movement. The path is the same one followed by drivers of the exemplar vehicle during postaccident testing.

The single automatic gate spanning the two northbound lanes of North Buena Vista Street was neither parallel to the tracks nor perpendicular to the northbound approach; it would not have been completely visible to the accident driver, who was in the eastbound left turn lane. Similarly, the alignment of the intersection, together with the angle of the automatic gate, limited visibility from the driver's seat of the flashing grade crossing signals on both the gate and overhead cantilever, as testing with the exemplar truck showed; only the flashing red arrow indication and the two flashing red grade crossing signals, located at the northeast corner and aligned to the southwest, were in clear view for the driver.

An advance warning sign located on North San Fernando Boulevard along the eastbound approach to the intersection (220 feet west of the turn lane) was completely obscured by foliage and, therefore, not visible to the truckdriver and unavailable to increase his expectancy or awareness. This sign, which is W10-2 in the MUTCD, Millennium Edition, graphically depicts railroad tracks just to the left of a roadway intersection (see figure 5).

The active controls in place at this site—signals and crossing gates—do not provide drivers with a spatial representation of the highway-rail grade crossing, that is, they do not give them a complete picture of just how close the railroad tracks are to the intersection. Even if the truckdriver heard the train horn, as witnesses stated they did, his

[27] R.T. Wilkinson, R.S. Edwards, and E. Haines, "Performance Following a Night of Reduced Sleep," 1966, *Psychonomic Science,* 5, 471-472.

ability to localize the sound and project the train's path might not have been intuitive in the absence of familiarity with the intersection, which had been reconfigured 6 months earlier, or the expectation that a left turn would place him immediately in the path of a train. Also, if he did hear the horn and observe the flashing red railroad signals, a lack of spatial awareness is more likely to have been a factor in this accident. The "frightened expression" on the truckdriver's face just before impact, as reported by the train engineer, suggests a surprised driver who was not expecting to encounter a train. Therefore, the Safety Board concludes that the accident driver lost situational awareness in an ambiguous and confusing environment that required significant mental alertness and vigilance; consequently, he missed the cues alerting drivers to an approaching train.

The Signal System

In addition to the spatial challenges that the accident driver encountered at this site, he received confusing, potentially contradictory, messages from the highway-rail signal system that governed traffic movement. The interconnected signal system, which had been installed less than a year before the accident, did not malfunction. As it was designed to do, the approach of the Metrolink train caused the railroad signals at the crossing to alternately flash red, an indication requiring all oncoming traffic to stop until the signal aspect was extinguished. Flashing red railroad signals are intended to have no other meaning.

The approaching train also preempted the normal operation of the highway traffic signals, which, following a track clearance interval, transitioned to all-red-flash mode for all circular red and red arrow indications. The Safety Board concludes that the signal system functioned as designed and that the accident driver behaved accordingly, stopping his vehicle for the continuous red arrow that governed the left turn lane; only after that arrow changed to the all-red-flash mode did he proceed into the intersection and onto the crossing, and the collision occurred. The *Caltrans Traffic Manual* permits use of the all-red-flash mode in California when grade crossing warning equipment is within 197 feet of a signalized intersection, but it thereby presents motorists with a potentially conflicting message that, as in this case, can have fatal consequences. [28]

The MUTCD (Section 8.B.05) explicitly states that "all existing turning movements toward the highway-rail grade crossing should be prohibited during the signal preemption sequences." Yet both the MUTCD and *Uniform Vehicle Code*, which is the primary source for standards on the meaning of vehicular signal indications, agree that the all-flash-red mode essentially has the same meaning as an octagonal STOP sign, that is, vehicles are to stop and then proceed with caution. The accident driver thus encountered railroad signals that directed him to stop and highway signals that could be interpreted more permissively. Possibly compounding the confusion was the fact that southbound traffic on North Buena Vista Street had cleared after the crossing gate on the north side of

[28] The westbound North San Fernando Boulevard approach to make a right turn onto northbound North Buena Vista Street also displayed a flashing red arrow, sending the same potentially conflicting message.

the tracks descended, and, as a result, cross traffic no longer posed a risk to the accident driver.

In fact, the more permissive meaning of the all-red-flash mode is the more common one. If motorists encounter flashing red signals at all, they are most likely to do so either late at night, which is usually a period of lower traffic volume, or when a signal malfunctions and its internal monitoring equipment, having detected a fault, automatically places the signal in all-red-flash.[29] In either situation, drivers may proceed as they would at a four-way STOP intersection. Had a train arrived at this intersection while the traffic signals there were malfunctioning and consequently in the all-red-flash mode, all traffic signals would have been the same indications that they were at the time of the accident.

The Safety Board therefore concludes that use of the all-red-flash mode for traffic signals at a railroad grade crossing has ambiguous meaning, can be confusing to motorists, and, as a result, creates unnecessary risks to life and property. The Board believes that Caltrans should prohibit the all-red-flash option for traffic signal indications during the railroad hold interval at grade crossings. The Board further believes that the National Committee on Uniform Traffic Control Devices and the National Committee on Uniform Traffic Laws and Ordinances should limit the use of highway traffic signals in the all-red-flash mode to situations in which they permit motorists to stop and proceed with caution.

In 2002, during reconstruction of the accident intersection, the BDPW had briefly changed the preemption mode from all-red-flash to limited operation, an option allowed by the *Caltrans Traffic Manual*. Under limited operation, a steady red arrow or circular signal indication prohibits traffic movements that conflict with the grade crossing. Traffic movements that do not conflict, such as those that run parallel to the railroad tracks, are permitted. Thus, at the accident intersection, traffic along North San Fernando Boulevard continued to flow during the period of limited operation from February 13, 2002, through February 28, 2002. After those 2 weeks, the BDPW returned the signals to the all-red-flash preemption mode.

City engineers stated that they had changed to the limited operation mode to improve efficiency during preemption by allowing traffic that did not conflict with the crossing to continue to move. They reverted to all-red-flash after a meeting between representatives of Metrolink and the BDPW, during which Metrolink expressed concern that southbound traffic on North Buena Vista Street continued to stop inside the automatic gates and on the crossing during normal signal operation. This situation had contributed to several previous accidents at the crossing in the preceding decade (see table 2).

Metrolink was concerned that the steady circular red traffic signal indication displayed after the "clear track" interval and during the "railroad hold" interval would discourage "trapped" vehicles from exiting the crossing.[30] Metrolink officials asked Burbank to instead configure the signal system to display a flashing circular red indication

[29] Both the *Caltrans Traffic Manual* and the MUTCD also allow the option of all-yellow-flash on one street and all-red-flash on the other street; they defer to "engineering judgment" in choosing between options.

during the limited operation mode. The city correctly maintained that such a combination of steady and flashing red signals would conflict with both MUTCD and *Caltrans Traffic Manual* guidance. Burbank then decided to return traffic signals at the crossing to the all-red-flash mode.

This exchange with Metrolink offered the city another opportunity to review the design of and operations at the intersection and crossing before reconstruction was complete. Clearly, queuing of southbound traffic on North Buena Vista Street was still creating a hazard at the crossing.

Limited operation along North San Fernando Boulevard could have served as a deterrent to vehicles that might otherwise have turned left onto the crossing. When drivers perceive a risk of collision because opposing traffic has not ceased, they often ignore traffic signals that give them the right of way. Thus, had westbound traffic continued to flow along North San Fernando Boulevard, as would have been the case if the limited operation mode of preemption were in place, the accident driver might have been deterred from or not had the opportunity to turn onto North Buena Vista Street before the train arrived. The limited operation mode of preemption would have presented the truckdriver with the following signal indications:

- Driving east on North San Fernando Boulevard, as he approached the intersection, the accident driver would have seen steady red arrow and red circular displays on the traffic signal heads. At this point, the signals would have been in the “clear track” interval for North Buena Vista Street.
- Next, the traffic signals would have entered the “railroad hold” interval, during which any traffic that did not cross the railroad tracks would have been allowed to move in normal sequence. Since westbound traffic on North San Fernando Boulevard did not traverse the railroad tracks, the accident driver would have continued to encounter that traffic as he waited to turn.
- The truckdriver would also have continued to see a steady red arrow on the left turn signal display because the turn conflicted with train movements.
- Once the train had passed, the traffic signals would have returned to normal operation.

Therefore, the Safety Board concludes that, had the limited-operation mode of traffic signal preemption been in place, giving the accident driver a solid red arrow and allowing traffic parallel to the railroad tracks to continue to move, the truckdriver might have been discouraged from making a left turn onto the grade crossing.

Burbank had ample opportunity to determine that this crossing and intersection presented hazardous conditions. Several serious grade crossing accidents had occurred in the decade before the reconstruction project began; this accident history should have prompted the city to research all sources of information pertaining to the design of

[30] In postaccident observation of traffic at the crossing, investigators noted that vehicles were in fact “trapped” during almost every cycle of the traffic signals.

roadway intersections near grade crossings. In addition, the concerns expressed by Metrolink before completion of the project served notice that the intersection and crossing continued to pose problems that merited an intensified search for design solutions. Burbank was also aware of the 1998 traffic study that recommended construction of a grade separation at this site and, following the accident, developed plans to construct one. Therefore, the Safety Board concludes that, had the city of Burbank been aware of information available for redesigning and reconstructing intersections near grade crossings, the likelihood of this accident occurring would have been reduced and safety at the site would have improved significantly.

Presignals

Several months after the accident, queuing was still occurring on this crossing, and Safety Board investigators also observed vehicles queuing from the traffic signal at the intersection of North Buena Vista Street and Winona Avenue just north of the accident site. The traffic signal at North Buena Vista Street and Winona Avenue apparently was not interconnected with the signals at the accident intersection, thereby compounding the queuing problem and adding to the potential hazard. Although storage of vehicles queued onto the crossing from an adjacent traffic signal was not a factor in this accident, it did contribute to several previous train-vehicle accidents at the Burbank crossing.

Use of presignals can reduce the problem of queuing and, in particular, reduce the likelihood that vehicles will queue on the grade crossing itself. Presignals are traffic signal heads erected on the side of the crossing opposite the intersection traffic signal and in advance of the automatic railroad gates. In normal operation, the presignal heads begin to cycle through the green-to-yellow-to-red sequence before the traffic signals at the intersection do so, thereby preventing vehicles from stopping on the crossing deck or inside the automatic gates (assuming motorists obey the signal indications). After the traffic signals go through their sequence for the other traffic movements, the presignals change to green before the traffic signals at the intersection do, allowing traffic to approach an upcoming green signal at the intersection.

When the approach of a train activates the railroad crossing signals, the crossing should be clear of vehicles because traffic has stopped at the presignals outside the automatic gates. As an additional safety measure, the traffic signals still cycle through a "clear track" interval to allow any violators of the presignal indications to move off the crossing. The traffic signals then change to a "railroad hold" interval until the train clears the crossing.

If the reconstructed accident intersection and crossing had included a presignal system, traffic safety could have been enhanced. As in the case of the limited operation mode of preemption, information on presignals was readily available to city officials and traffic engineers. Several reports issued following the Safety Board's investigation of the 1995 Fox River Grove, Illinois, grade crossing accident recommended use of this traffic control measure. The city stated that it had not considered the presignal option because it was unaware that it existed. Construction of a grade separation at this location, tentatively scheduled for completion about 2006, will eliminate any need for traffic or railroad signals. In the meantime, to reduce the incidence of southbound traffic on North Buena Vista Street stopping on the deck and tracks of the accident crossing, the city of Burbank could install presignals on the North Buena Vista Street approach to the intersection with North San Fernando Boulevard.

Extended Median

To enter northbound North Buena Vista Street, the accident driver drove around the west end of the crossing's automatic gate while making a shallow left turn. Since the gate extended across both northbound lanes of the roadway, the driver briefly operated his truck on the wrong side of the yellow double centerline pavement markings, but the turn was not a difficult or unusual one to execute. Figure 2 shows an exemplar truck, driven by a Burbank police officer, reenacting the accident vehicle's precollision path to the area of impact. Unless traffic or a barrier prevents it, a shallow left turn may be easier for a driver to execute than the wider turning maneuver demanded by the intersection geometry.

Use of raised medians for the centerline approaches to grade crossings is often an effective way to discourage gate running. These medians are barriers several inches high that are intended to prevent or discourage drivers from violating the traffic laws regarding railroad grade crossing signals and automatic gates. At the accident intersection, raised median barriers could also be useful in restricting shallow turns, thus forcing motorists to encounter the grade crossing gates. Several publications issued following the Fox River Grove accident investigation recommend use of raised medians at grade crossings.

The design for the reconstruction of the accident intersection included raised medians on the north side of the crossing, but the medians did not extend to the immediate vicinity of the crossing (see figure 7).[31] The Safety Board concludes that if the design of the accident crossing and roadway had included a raised median that extended from the crossing to the end of the double yellow centerlines just south of the tracks, the accident driver might have been discouraged from attempting to cross that median to execute a shallow turn, thus avoiding the lowered gate. While an extended median would have to be broken for the "dynamic envelope"[32] of the tracks, it would still present a physical and visual barrier to drivers and deter them from traveling on the wrong side of the yellow centerlines on North Buena Vista Street. The Safety Board believes that the city of Burbank should install a raised median or other barrier system at the North San Fernando Boulevard-North Buena Vista Street grade crossing that extends from the crossing to the end of the double yellow centerlines south of the tracks.

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[31] If a raised median were extended to this point, it would have to be discontinued upon reaching the "dynamic envelope" of the tracks, leaving about a 16-foot gap between the end of the median and the tracks. Even so, it would provide a barrier sufficient to discourage gate running.

[32] The MUTCD 2000 defines *dynamic envelope* as the clearance required for the train and its cargo overhang due to any combination of loading, lateral motion, or suspension failure.

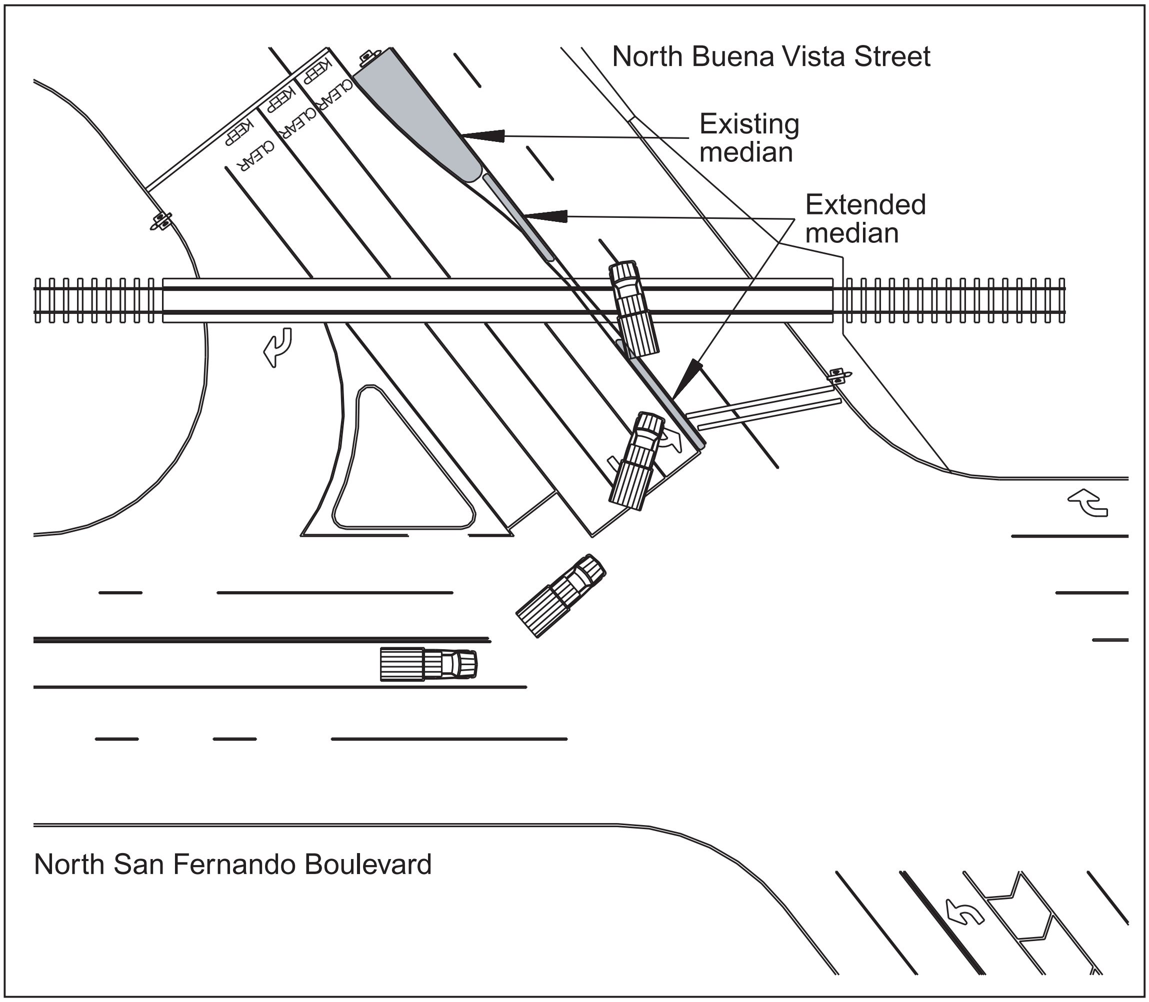

Figure 7. Existing and extended medians at accident site.

Availability of Design Guidelines and Information

During its investigation, Safety Board staff reviewed frequently used publications, Internet Web sites, and other sources of guidance on traffic engineering design.[33] These included AASHTO's publications on the design of highway intersections near highway-rail grade crossings, as well as its 2001 publication, *A Policy On Geometric Design of Highways and Streets*, which refers users to the MUTCD for information on the design of traffic signals and signing. However, the MUTCD contains only general information on the design of highway-rail signals near crossings and does not include references.

[33] Engineers for Burbank delegated responsibility for design of the grade crossing and signals to the city's consulting engineering firm. The consultant declined to respond to the Safety Board's request for information on which, if any, resources the firm used in designing the site. The city's engineers stated that they did not have knowledge of current signal or grade crossing design guidelines.

Handbooks published by the ITE, all of which had been revised since the Fox River Grove accident, contained little useful information. Most referred readers to the MUTCD. Only the ITE's *Traffic Control Devices Handbook - 2001* had extensive guidance on the design of signals near grade crossings. Through its Web site, ITE also made available its in-depth 1997 publication, *Recommended Practice for Preemption of Traffic Signals at or Near Railroad Grade Crossings with Active Warning Devices*, which had guidance directly relevant to the design of the accident crossing. It discouraged use of the all-red-flash preemption mode for the railroad hold interval, for example, and also defined and explained application of presignals for crossings such as the one at the accident location.

The TRB did list its research paper, *Traffic Signal Operations Near Highway-Rail Grade Crossings. A Synthesis of Highway Practice 271*, which provides useful discussions of railroad hold intervals and related topics. However, several searches were required to locate it. Moreover, like AASHTO and ITE publications, it was not available to government or other agencies without cost.

The FHWA's Web site had the most valuable resources, including the FHWA Grade Crossing Safety Task Force's 1996 report, *Accidents That Shouldn't Happen*, issued following the Fox River Grove accident, and a 2002 report prepared by the task force's Technical Working Group, entitled *Guidance on Traffic Control Devices at Highway-Rail Grade Crossings*. Both reports could be downloaded from the site without cost, but locating them required extensive searching. Also on the FHWA Web site was the *Railroad-Highway Grade Crossing Handbook*, 2nd edition, FHWA TS-86-215, September 1986, which is currently being updated.

The Safety Board concludes that current information and guidelines for designing safe highway-rail grade crossings and traffic signals are available but can be difficult to find and expensive to obtain. Therefore, the Safety Board believes that the FHWA, AASHTO, the ITE, and the TRB should improve the ease with which transportation and civil engineers can locate and obtain safety design guidelines and related information on Internet Web sites, as well as through other means, and make available to governmental entities a no-cost option for obtaining critical safety design guidelines. The Safety Board further believes that the National Committee on Uniform Traffic Control Devices should incorporate into chapter 1 of the *Manual on Uniform Traffic Control Devices*, at the time of each update, a list of references, including Internet Web sites, for traffic and safety engineering design guidelines.

Conclusions

Findings

1. The weather, the track, the signal system, the mechanical condition of the train and accident truck, and the qualifications of the train crew and accident driver neither caused nor contributed to this accident; whether the driver was impaired by alcohol at the time of the accident could not be determined.

2. The accident truck collided with the Metrolink train when the truckdriver made a shallow left turn onto North Buena Vista Street after activation of the flashing red left turn arrow.

3. The accident driver lost situational awareness in an ambiguous and confusing environment that required significant mental alertness and vigilance; consequently, he missed the cues alerting drivers to an approaching train.

4. The signal system functioned as designed and the accident driver behaved accordingly, stopping his vehicle for the continuous red arrow that governed the left turn lane; only after that arrow changed to the all-red-flash mode did he proceed into the intersection and onto the crossing, and the collision occurred.

5. Use of the all-red-flash mode for traffic signals at a railroad grade crossing has ambiguous meaning, can be confusing to motorists, and, as a result, creates unnecessary risks to life and property.

6. Had the limited-operation mode of traffic signal preemption been in place, giving the accident driver a solid red arrow and allowing traffic parallel to the railroad tracks to continue to move, the truckdriver might have been discouraged from making a left turn onto the grade crossing.

7. Had the city of Burbank, California, been aware of information available for redesigning and reconstructing intersections near grade crossings, the likelihood of this accident occurring would have been reduced and safety at the site would have improved significantly.

8. If the design of the accident crossing and roadway had included a raised median that extended from the crossing to the end of the double yellow centerlines just south of the tracks, the accident driver might have been discouraged from attempting to cross that median to execute a shallow turn, thus avoiding the lowered gate.

9. Current information and guidelines for designing safe highway-rail grade crossings and traffic signals are available but can be difficult to find and expensive to obtain.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the design of the traffic signals' railroad hold interval, which displayed a flashing red arrow for the eastbound North San Fernando Boulevard left turn lane, improperly implying that, after stopping, the truckdriver was permitted to make a left turn onto North Buena Vista Street. Contributing to the accident was the lack of a raised median at the crossing that would have obstructed the path used by the truckdriver to make the left turn.

Recommendations

To the California Department of Transportation:

Prohibit the all-red-flash option for traffic signal indications during the railroad hold interval at grade crossings. (H-03-28)

To the city of Burbank, California:

Install a raised median or other barrier system at the North San Fernando Boulevard-North Buena Vista Street grade crossing that extends from the crossing to the end of the double yellow centerlines south of the tracks. (H-03-29)

To the National Committee on Uniform Traffic Control Devices and the National Committee on Uniform Traffic Laws and Ordinances:

Limit the use of highway traffic signals in the all-red-flash mode to situations in which they permit motorists to stop and proceed with caution. (H-03-30)

To the National Committee on Uniform Traffic Control Devices:

Incorporate into chapter 1 of the *Manual on Uniform Traffic Control Devices*, at the time of each update, a list of references, including Internet Web sites, for traffic and safety engineering design guidelines. (H-03-31)

To the Federal Highway Administration, the American Association of State Highway and Transportation Officials, the Institute of Transportation Engineers, and the Transportation Research Board:

Improve the ease with which transportation and civil engineers can locate and obtain safety design guidelines and related information on Internet Web sites, as well as through other means, and make available to governmental entities a no-cost option for obtaining critical safety design guidelines. (H-03-32)

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Adopted: December 2, 2003

Appendix A

Investigation and Public Hearing

The National Transportation Safety Board was notified of the Burbank, California, accident on January 6, 2003. Investigative team members were dispatched from the Fort Worth, Texas, and Los Angeles, California, offices.

Participating in the investigation were representatives of the Federal Railroad Administration, the California Public Utilities Commission, the Southern California Regional Rail Authority, and the city of Burbank, California.

No public hearing was held; no depositions were taken.

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