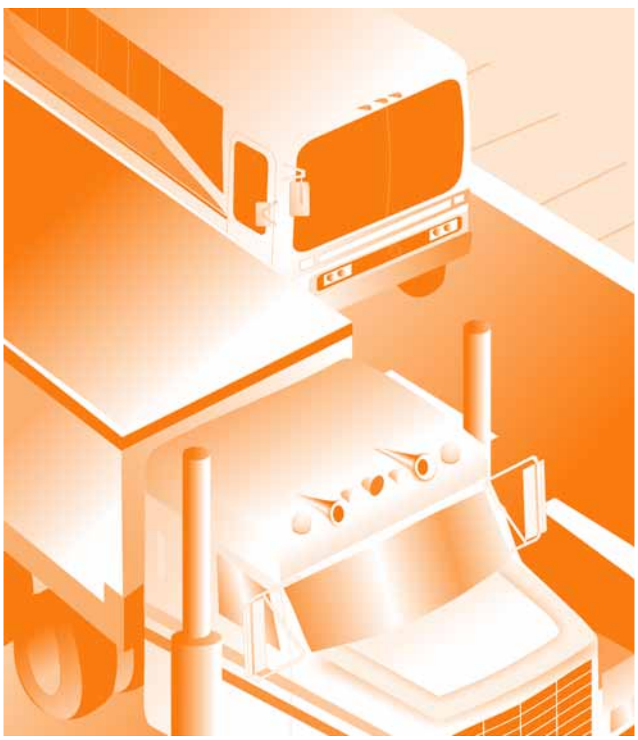
Rear-End Collision and Subsequent Vehicle Intrusion Into Pedestrian Space at Certified Farmers' Market Santa Monica, California July 16, 2003



Highway Accident Report

NTSB/HAR-04/04

PB2004-916204
Notation 7649B

National Transportation Safety Board
Washington, D.C.

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

National Transportation Safety Board. 2004. ***Rear-End Collision and Subsequent Vehicle Intrusion Into Pedestrian Space at Certified Farmers' Market, Santa Monica, California, July 16, 2003.*** **Highway Accident Report NTSB/HAR-04/04. Washington, DC.**

Abstract: On July 16, 2003, a 1992 Buick LeSabre was westbound on Arizona Avenue, approaching the intersection of Fourth Street, in Santa Monica, California. A 2003 Mercedes Benz S430 sedan was stopped on Arizona Avenue at the intersection for pedestrians in a crosswalk on Fourth Street. The Buick struck the Mercedes, continued through the intersection, and drove through a farmers' market, striking pedestrians and vendor displays before coming to rest. As a result of the accident, 10 people were fatally injured, and 63 people received injuries ranging from minor to serious. The Buick driver and both Mercedes occupants were uninjured.

The major safety issues discussed in this report are the unintended acceleration of the accident vehicle, the adequacy of temporary traffic control measures for the protection of pedestrian traffic in the Santa Monica Certified Farmers' Market, and the need to equip motor vehicles with event data recorders.

As a result of its investigation, the Safety Board made recommendations to the Federal Highway Administration, the National Highway Traffic Safety Administration, and the city of Santa Monica.

Contents

Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
CCFD	Culver City Fire Department
CDMV	California Department of Motor Vehicles
CFM	certified farmers' market
CFR	*Code of Federal Regulations*
CHP	California Highway Patrol
CTM	*Caltrans Traffic Manual*
ECM	electronic control module
EDR	event data recorder
GVWR	gross vehicle weight rating
IC	incident commander
IEEE	Institute of Electrical and Electronics Engineers
LACFD	Los Angeles County Fire Department
LAFD	Los Angeles City Fire Department
MCI	multi-casualty incident
MUTCD	*Manual on Uniform Traffic Control Devices*
NHTSA	National Highway Traffic Safety Administration
NPRM	notice of proposed rulemaking
SAE	Society of Automotive Engineers
SMCFM	Santa Monica Certified Farmers' Market
SMFD	Santa Monica Fire Department
SMPD	Santa Monica Police Department
TA	typical application
USDA	U. S. Department of Agriculture
WATCH	*Work Area Traffic Control Handbo*ok

Executive Summary

On July 16, 2003, about 1:46 p.m. Pacific daylight time, a 1992 Buick LeSabre, driven by an 86-year-old male, was westbound on Arizona Avenue, approaching the intersection of Fourth Street, in Santa Monica, Los Angeles County, California. At the same time, a 2003 Mercedes Benz S430 sedan, occupied by a driver and front-seat passenger, was also westbound on Arizona Avenue and had stopped for pedestrians in a crosswalk on Fourth Street at the intersection with Arizona Avenue. The Buick struck the left rear corner of the Mercedes, continued through the intersection, and drove through a farmers' market, striking pedestrians and vendor displays before coming to rest. As a result of the accident, 10 people were fatally injured, and 63 people received injuries ranging from minor to serious. The Buick driver and both Mercedes occupants were uninjured.

The National Transportation Safety Board determined that the probable cause of this accident was the failure of the Buick driver to maintain control of his vehicle due to his unintended acceleration. Contributing to the severity of the accident was the lack of a barrier system to protect pedestrians in the Santa Monica Certified Farmers' Market area from errant vehicles.

The major safety issues discussed in this report are the unintended acceleration of the accident vehicle, the adequacy of temporary traffic control measures for the protection of pedestrian traffic in the Santa Monica Certified Farmers' Market, and the need to equip motor vehicles with event data recorders.

As a result of its investigation, the Safety Board made recommendations to the Federal Highway Administration, the National Highway Traffic Safety Administration, and the city of Santa Monica.

Factual

Accident Narrative

On July 16, 2003, about 1:46 p.m. Pacific daylight time, a 1992 Buick LeSabre (Buick), driven by an 86-year-old male, was westbound on Arizona Avenue, approaching the intersection of Fourth Street, in Santa Monica, Los Angeles County, California. At the same time, a 2003 Mercedes Benz S430 sedan (Mercedes), occupied by a driver and front-seat passenger, was also westbound on Arizona Avenue and had stopped for pedestrians in a crosswalk on Fourth Street at the intersection with Arizona Avenue. The Buick struck the left rear corner of the Mercedes, continued through the intersection, and drove through a farmers' market, striking pedestrians and vendor displays before coming to rest.

The accident occurred moments after the Buick driver had departed the Santa Monica Main Post Office on Fifth Street. The Buick driver told police investigators that he could see the farmers' market as he turned from Fifth Street onto Arizona Avenue. According to witnesses, the Buick approached the Fourth Street intersection; the Mercedes had stopped at the red light, had begun to proceed after the light turned green, and had again stopped to allow pedestrians in the crosswalk to cross Fourth Street. The Buick then struck the stopped Mercedes in the left rear, pushing it into the intersection. Witnesses stated that the Buick continued on Arizona Avenue, where it maneuvered past an orange ROAD CLOSED AHEAD sign on the yellow centerline of the roadway, through barricades, and into the area where the Santa Monica Certified Farmers' Market (SMCFM) had been set up. (See figures 1 and 2.)

The Buick proceeded through the farmers' market for approximately 2 1/2 blocks (750 feet) and came to rest on Arizona Avenue near the alley east of the intersection of Ocean and Arizona Avenues. As a result of the accident, 10 people were fatally injured, and 63 people sustained injuries ranging from minor to serious. The Buick driver and both Mercedes occupants were uninjured.

The Mercedes driver characterized vehicular traffic in the area as "moderate" and pedestrian traffic as "heavy" due to the farmers' market. In a statement to police, she described the Buick's impact to the left rear of her vehicle. The driver stated that she saw the sign indicating that Arizona Avenue was closed ahead, so she slowed to a stop at the red light and prepared to make a right turn onto Fourth Street. As the light turned green, she said she began to proceed, but stopped short of the east-west crosswalk, yielding to pedestrian traffic. At that point, she felt a sudden impact to the left rear of her vehicle, as the Buick pushed it forward into the intersection. The Mercedes driver stated that she looked in her rear-view mirror and saw a maroon-colored car (the Buick) "turn to the left and accelerate around" her vehicle and then around the ROAD CLOSED AHEAD sign. She described the acceleration of the Buick as rapid and very loud and said that the vehicle swerved, then straightened out, and continued to increase its speed as it entered the farmers' market.

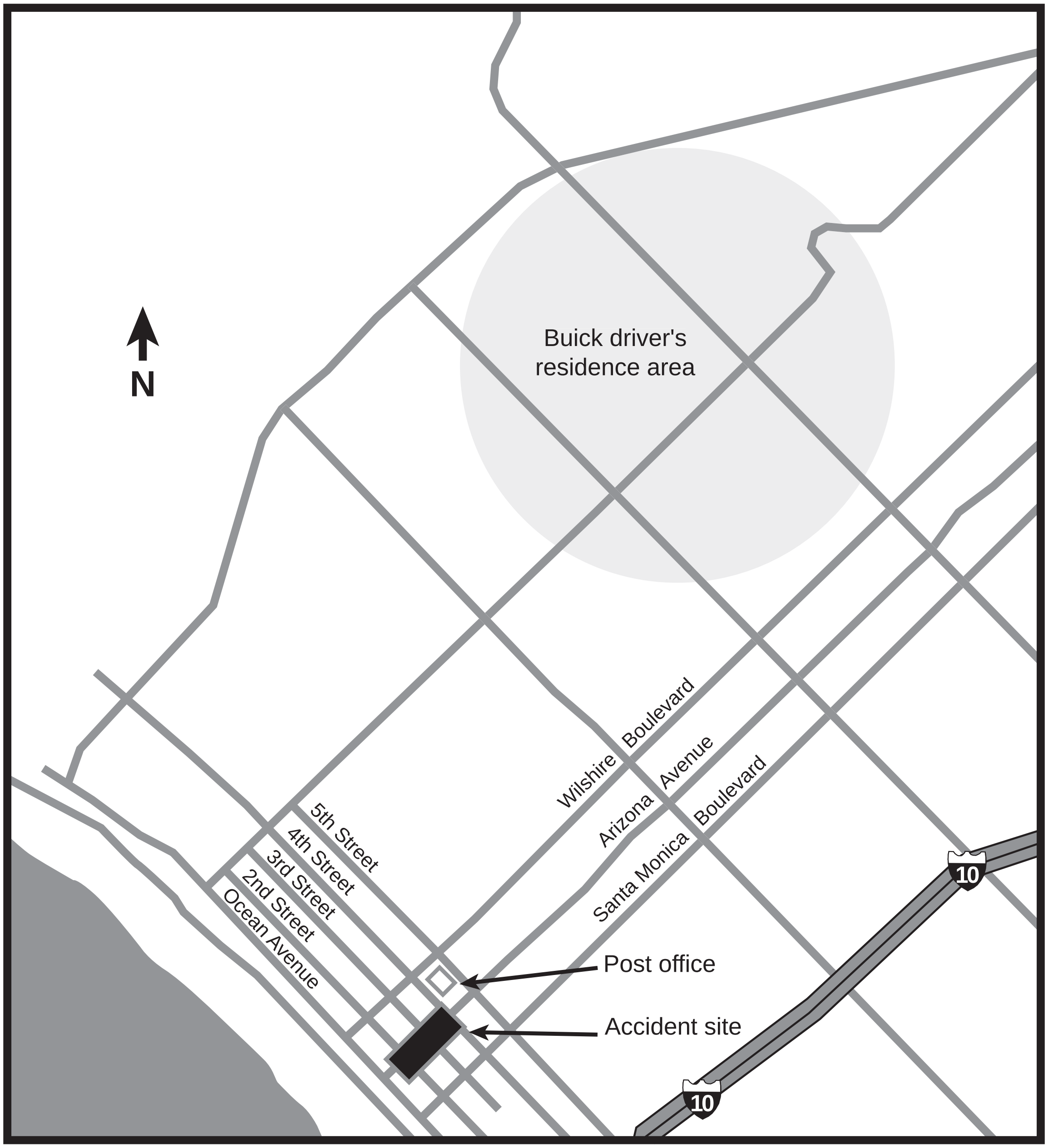

Figure 1. Accident area.

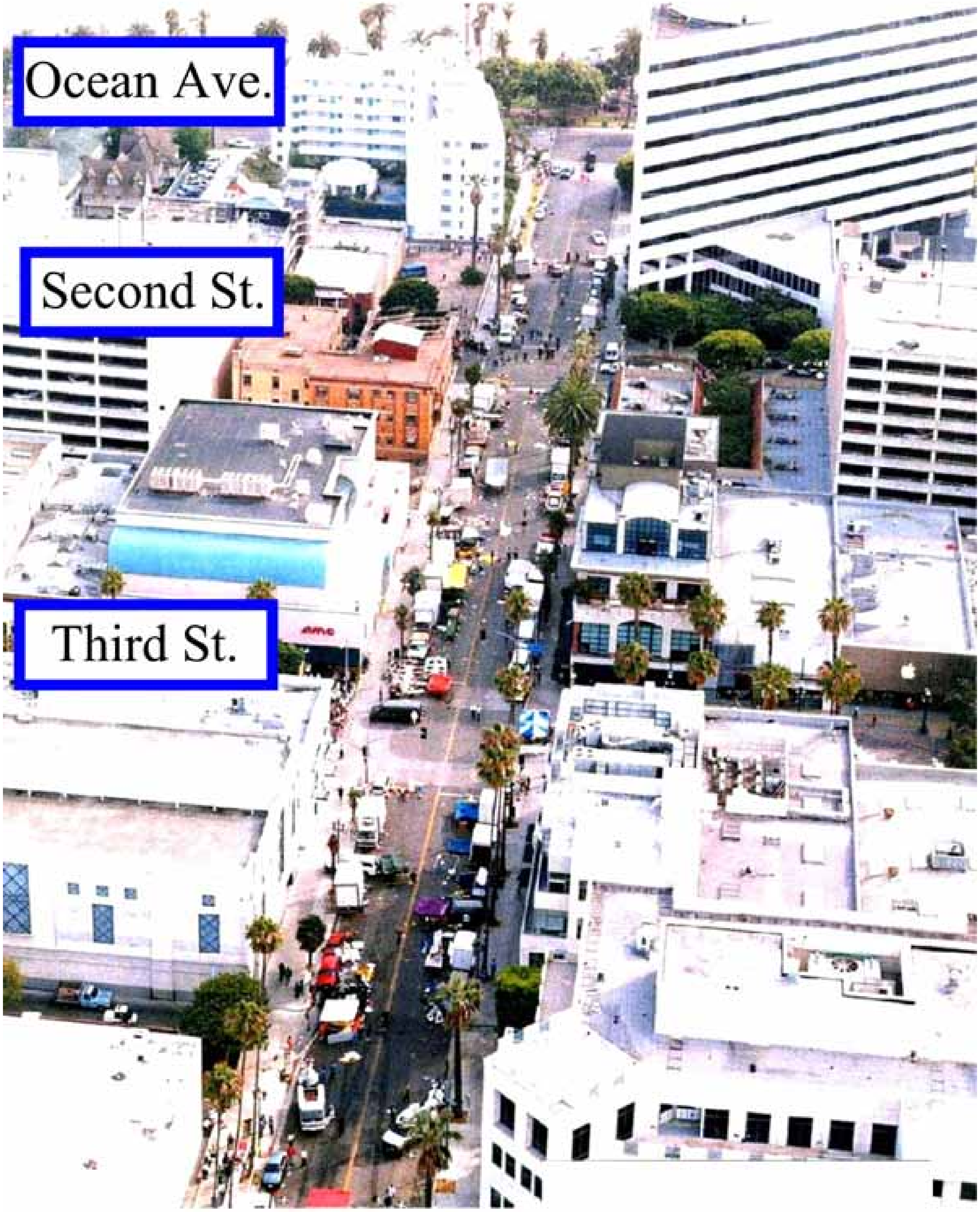

Figure 2. Aerial view of accident site.

Several witnesses also stated that the accident driver accelerated after striking the Mercedes, and they characterized the incident as a "hit-and-run" accident. One witness told police investigators that, from his vantage point on the south side of Arizona Avenue at Fourth Street, he observed no brake lights on the Buick. A vendor, who observed the driver as he proceeded through the farmers' market, told Safety Board investigators that he saw the Buick driver with both hands on the steering wheel at the 10- and 2-o'clock positions, looking straight ahead.

Other witnesses described to police investigators the vehicle's movements through the market area as alternating between accelerating and decelerating, sometimes at high engine RPMs, as if the driver "were pressing the accelerator pedal firmly." The driver himself told police investigators that he sensed the car accelerate three or four times as he proceeded through the farmers' market. One witness concurred with reports of hearing high engine RPMs, but noted a "slight hesitation" of the engine. According to another witness, it appeared that every time the Buick struck an object in its path, the vehicle accelerated in response.

The Buick driver stated to police that he tried to stop the car as it went through the market, stepping on the brake, taking his foot off the accelerator, and ultimately trying to put the car's transmission in "park." He indicated that he might have confused the brake and accelerator pedals. The accident driver believed that he was also making steering inputs in an effort to avoid pedestrians and other objects. He was unsure why the car finally stopped, but thought that he might have succeeded in shifting the transmission into "park." In his statement to police investigators, the driver did not recall striking the Mercedes.

Injuries

Ten pedestrians sustained multiple blunt force or traumatic injuries that proved fatal. Of the 63 people who were injured, 18 pedestrians were seriously injured and 45 sustained minor injuries. An undetermined number of pedestrians present at the farmers' market reported no injuries.

Table 1. Injury codes.[1]

Injuries	Drivers and passengers	Pedestrians	Total
Fatal	0	10	10
Serious	0	18	18
Minor	0	45	45
None	3	unknown	3
Total	3	73*	76*

*Excludes "unknown" number of uninjured pedestrians.

Meteorological Information

At the time of the accident, the day was clear, and the roadway was dry. Winds were from the southeast (220º) at 12 mph. According to the official National Weather Service report for Santa Monica at 1:51 p.m., the temperature was 78º F, and the dew point was 67º F. Sun transit time (the point at which the sun appears directly overhead) was 1:00 p.m.

Driver Information

The 86-year-old driver held a valid class C (noncommercial) California driver's license with a corrective lens restriction, issued on November 28, 2000, and valid for 5 years. He was issued a disabled parking placard in 1994 due to "severe hip arthritis" and associated limitations in mobility; it had been renewed biannually and was valid at the time of the accident. Several witnesses told police investigators that the driver was wearing eyeglasses at the time of the accident. In California, drivers 70 years of age and older must renew their license in person.[2]

To renew his license, the driver was required to present the renewal notice or complete an application; permit a thumb print and photograph to be taken for identification; pay a $15 fee; and pass both a vision examination and a written test of traffic laws and signs. A road test is generally not required of California drivers 70 years of age and older who are renewing their licenses, and the driver stated to police that he did not have to take a road test when he renewed his license in 2000. Drivers must have visual acuity of 20/40 or better in each eye and in both eyes together, to pass the vision examination. If corrective lenses are used at the time of testing, the license carries a corrective lens restriction. The written test comprises 18 multiple-choice questions; drivers must answer at least 15 correctly to pass and may retake the test as many as three times.

Accident History

The Buick driver had no moving violations prior to the accident; the California Department of Motor Vehicles (CDMV) revoked his license on July 21, 2003, following the accident, for "lack of knowledge or skill." On January 5, 2004, he was charged with 10 counts of vehicular manslaughter with gross negligence; he entered a plea of "not guilty" to the charges on January 6.

[1] Title 49 *Code of Federal Regulations* (CFR) 830.2 defines a fatal injury as any injury that results in death within 30 days of the accident. It defines a serious injury as an injury that requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; results in a fracture of any bone (except simple fractures of the fingers, toes, or nose); causes severe hemorrhages, nerve, muscle, or tendon damage; involves any internal organ; or involves second or third degree burns, or any burns affecting more than 5 percent of the body surface.

[2] See California Department of Motor Vehicles Web site <http://www.dmv.ca.gov/dl/dl.htm>.

Insurance records indicate that the driver had been involved in two previous incidents, but was not cited, and neither one was reported to the CDMV.[3] In November 1998, he struck an unattended, parked vehicle, causing approximately $200 in damage. According to the owner of the parked vehicle, the driver struck the right front corner of her automobile three or four times with his front bumper at low speeds. Insurance records indicate that she told police the driver was apparently unaware that he was striking her vehicle as he maneuvered fore and aft, in an attempt to park his own vehicle.

In the other accident, which occurred in September 1999, the driver was traveling southbound on 14th Street approaching Wilshire Boulevard in Santa Monica, when the right side of his vehicle was struck by another car, as the driver of that vehicle was backing out of a parking lot.

During its investigation of the 2003 accident, the Santa Monica Police Department (SMPD) learned of another incident involving the driver, which occurred in September 1993. A witness to the 1993 accident provided the SMPD with a videotape of a minor collision with a retaining wall, which took place when the driver was backing down a driveway (not his own) in Montecito, California.

Experience and Local Knowledge

The driver had lived in the Los Angeles area for more than 70 years and had owned the accident vehicle for more than 10 years. The driver stated that he had not patronized the SMCFM in 3 or 4 years, but was familiar with its location. He told police that he saw the market when he turned right from Fifth Street and that he saw the barricades in the roadway before he struck them.

In interviews conducted by Safety Board investigators, the driver's neighbors said they were "surprised" to learn of the driver's involvement in the accident at the farmers' market and stated that the driver had never exhibited any erratic or unsafe behavior during the time they had known him. Neighbors noted that the driver used a cane, but were unaware of any medical problems or prior crashes involving the driver.

One woman, who had been a neighbor for 30 years, stated that she saw the driver almost daily and spoke with him about once a week. She described the driver as "friendly" and "intelligent." She characterized him as a safe driver who never drove too fast, based on her observations of him in the neighborhood.

A neighboring couple first met the driver when they moved into the neighborhood about 2 1/2 years earlier. They told investigators that they spoke with the driver two or three times weekly and saw him walking around the neighborhood regularly. They described the driver as "clear" and "coherent" and said they had observed no indication that he was either physically or mentally unfit to drive.

[3] Section 16000 of the California Vehicle Code requires that all drivers (irrespective of "fault") file a report with the CDMV when they are involved in an accident that results in more than $750 in property damage ($500 for accidents prior to January 1, 2003). The September 1999 incident met the reporting threshold requirements.

Preaccident Activities

Investigators derived the following information about the driver's activities before the accident from the SMPD's postaccident interviews with the driver and his wife. The driver said he awoke between 7:00 a.m. and 7:30 a.m. on the morning of the accident, after a "normal night of sleep," showered, and read the newspaper. He had breakfast about 10:00 a.m. and shortly after 11:15 a.m., left his house to run some errands. The driver told police that he returned home about noon, had lunch, and watched television as he finished writing a letter. Shortly after 1:00 p.m., he again left his house to deliver the letter to the post office at 1248 Fifth Street (near the intersection with Arizona Avenue), where he deposited it in the curbside mailbox. The driver told SMPD investigators that he stopped at the curbside mailbox, put the transmission in "park," and reached out the passenger-side window to drop the letter in the receptacle. He said he then departed the post office and turned onto Arizona Avenue.

Postaccident Toxicological Testing

After the accident, SMPD officers took the driver to the University of California—Los Angeles Medical Center in Santa Monica, where blood was drawn from him at 2:40 p.m. The Los Angeles County Sheriff's Department Scientific Services Bureau tested the blood sample for alcohol, amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates, and phencyclidine; the results were negative. The Department of Justice Bureau of Forensic Services conducted additional testing for prescription medications, which confirmed the presence of quinine.

Medical History

The Safety Board reviewed the driver's medical records from seven physicians, a healthcare facility, and two other healthcare service providers. The records showed no other referrals or indications of treatment by additional providers.

The following medical conditions were noted: bilateral hip replacements in 1993 (right) and 1998 (left); pain in the right thigh (2000), diagnosed as spinal stenosis;[4] and lumbar arthritis. In the most recent entries (during 2001), the orthopedic surgeon noted that the driver's hips were "stable and exhibit[ed] little contracture."[5] The records did not indicate any episodes of seizures, cognitive dysfunction, or loss of consciousness.

A cardiologist examined the driver about 3 weeks after the accident and diagnosed significant atrioventricular node disease. The driver was subsequently implanted with a dual chamber pacemaker. According to the cardiologist's records, the driver had no prior cardiovascular history other than high cholesterol, and the driver denied having any symptoms prior to the diagnosis, including light-headedness, near syncope (fainting), or syncope.

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[4] Spinal stenosis is a narrowing of the spinal canal. The driver's physician noted that the driver was able to walk a mile. No further indication of symptoms was found.

[5] Contracture is a permanent muscular shortening due to tonic spasm or fibrosis or to loss of muscular equilibrium.

The driver walked with a cane. In an interview with police, he stated that he “loses his cane twice a week” and noted that a person who “really needs a cane never loses his.” The driver denied any problem sensing or distinguishing the accelerator and brake pedals and stated that his only problem as a result of hip replacement surgeries was that he walks with a minor limp. The driver denied any problems with the function of his legs.

The Safety Board reviewed the driver’s medical records, including those from local pharmacies. The driver had not been prescribed any psychoactive medications, which affect the mind, mood, or mental processes, and no evidence of prescriptions beyond those listed in the records was found.

Vehicle and Wreckage

Vehicle Information

The 1992 Buick LeSabre was manufactured by General Motors at its Flint, Michigan, plant in January 1992. The Buick was of unibody construction and had a gross vehicle weight rating (GVWR) of 4,573 pounds and a curb weight of 3,456 pounds.[6] The odometer registered 67,026 miles at the time of postaccident inspection.

The Buick was equipped with a 3.8-liter, electronically controlled, fuel-injected, 6-cylinder gasoline engine and an automatic overdrive transmission. Postaccident inspection showed that accelerator cable movement was smooth, without restriction, binding, or sticking, as was throttle movement. Throttle return was consistent and spring force was firm. The throttle position sensor was securely mounted to the throttle body and all associated wiring was secure and in good condition. The vehicle’s electronic control module (ECM), which controls fuel and ignition timing, revealed no fault or error codes. A query of the National Highway Traffic Safety Administration’s (NHTSA’s) Office of Defect Investigation database found no recalls or open investigations involving the vehicle’s throttle controls and no incidents of unintended accelerations. No defect, deficiency, or abnormality was found in the vehicle’s throttle controls.

All tires were examined and found to comply with California’s vehicle inspection criteria for tread depth requirements.[7] The Buick was equipped with P215/60R16 (standard load range) tires, as recommended by the vehicle manufacturer. Results of the tire and wheel assembly inspections were unremarkable, except for an area of scuffing and minor tearing of the left front outer sidewall that extended into the area of the shoulder.

[6] The weight of a vehicle without passengers or payload, but including all fluids and other equipment specified as standard.

[7] *Vehicle Code*, Section 27465.

The Buick was equipped with a power-assisted, dual-circuit hydraulic brake system configured with front disc brakes and rear drum brakes. The master cylinder was adequately filled with fluid and the power booster supply check valve functioned properly. All wheel hubs rotated freely and without indications of drag or out-of-round conditions. Examination of each brake assembly and associated hydraulic lines revealed no leaks, restrictions, or operational defects. The brake pedal was intact and functional, offering consistent resistance and approximately 2 1/2 inches of nonpower-assisted travel. The rubber cover on the brake pedal was worn on the lower right edge, revealing the metal beneath (see figure 3). Separation between the brake pedal and the accelerator at the closest point was 2 inches.

Figure 3. Accident vehicle's brake pedal.

California Highway Patrol (CHP) officers tested the vehicle's brake operation before the Buick was removed from the scene. They reported that an initial (booster-assisted) brake application was held for 30 seconds without pedal drop or fade and that all wheel assemblies locked when force was applied to the brake pedal.

Inspection results of the service and parking brake systems were unremarkable, except for slight fluid seepage noted at the right rear wheel cylinder dust covers. The brake components showed no signs of active fluid loss or contamination.

The Buick was equipped with a hydraulic rack-and-pinion power steering system. The power steering fluid reservoir was filled to the add level with clean, semitranslucent fluid. The pump drive belt was intact and free from obvious glazing, defects, or cracking. The low-pressure return line exhibited active fluid leaking and had been double-clamped at two locations. Results of the examination of the steering linkages and the front suspension were unremarkable. Inspection of the rear suspension revealed dry rotting or cracking of the rubber strut boots on the rear suspension and evidence of oil leakage from each strut assembly. A small area of wear, consistent with tire contact, was also noted within the rear left wheel well.

Review of available maintenance records showed that the vehicle had received general routine maintenance. The records indicated no driver complaints or major repairs to the vehicle's throttle controls, braking, or steering systems. California does not have an annual vehicle safety inspection program, and no inspection certificate was available for review.

Accident-Related Damage

The Buick sustained frontal damage encompassing the front bumper, forward light fixtures, radiator grill, radiator and support, left front quarter panel, windshield, roof, both side mirrors, and rear antenna. (See figure 4.) The two side-view mirrors were missing, and the shattered windshield had two distinct impact or indentation locations; remnants and debris from items struck were found embedded in the windshield. The right side of the front bumper had light blue paint transfer, and the rubber portion of the right rear bumper had white paint transfer. The left bumper quarter panel was missing and exhibited exposed, jagged edges. The bumper was angled upward from the frame, consistent with accident damage. The Buick's airbag had deployed.

Damage to the Mercedes consisted of horizontal surface scratching to the rear bumper cover.

Figure 4. Postaccident damage to 1992 Buick LeSabre.

Highway Information

Highway Design

The accident occurred on westbound Arizona Avenue between Fourth Street and Ocean Avenue. Arizona Avenue is a collector roadway that carries traffic between residential neighborhoods and the arterial street network. Collectors generally have a mixture of residential and commercial land uses along them. According to Santa Monica's "Transportation Circulation Element," average daily traffic volumes on collector roadways are to be held to below 15,000 vehicles in order to maintain acceptable levels of service at intersections and an environment compatible with residential land uses.

Arizona Avenue is a straight, level, asphalt, undivided roadway; it has one travel lane each westbound and eastbound. The roadway is 48 feet wide. The two travel lanes are separated by solid, double-yellow pavement markings. The posted speed limit is 25 mph. Marked parallel parking spaces border the sides of the through lanes, and concrete sidewalks are adjacent to the outer edges of the street.

At the time of the accident, Arizona Avenue was closed to vehicular traffic between the alley east of Ocean Avenue and the alley west of Fourth Street (see figure 5), and the roadway was being used as an outdoor farmers' market from 9:00 a.m. to 2:00 p.m. Prior to the beginning of the market area, westbound traffic was allowed to use Arizona Avenue between Fourth Street and an alley, located between Third and Fourth Streets, to access a bank parking lot on the southwest corner. A full closure was located at the west side of the intersection of Arizona Avenue and the alley between Third and Fourth Streets. Past the closure points on Arizona Avenue, fruit and vegetable vendor canopy tents occupied the outer edges of the roadway from the alley midway between Third and Fourth Streets to the alley midway between Second Street and Ocean Avenue.

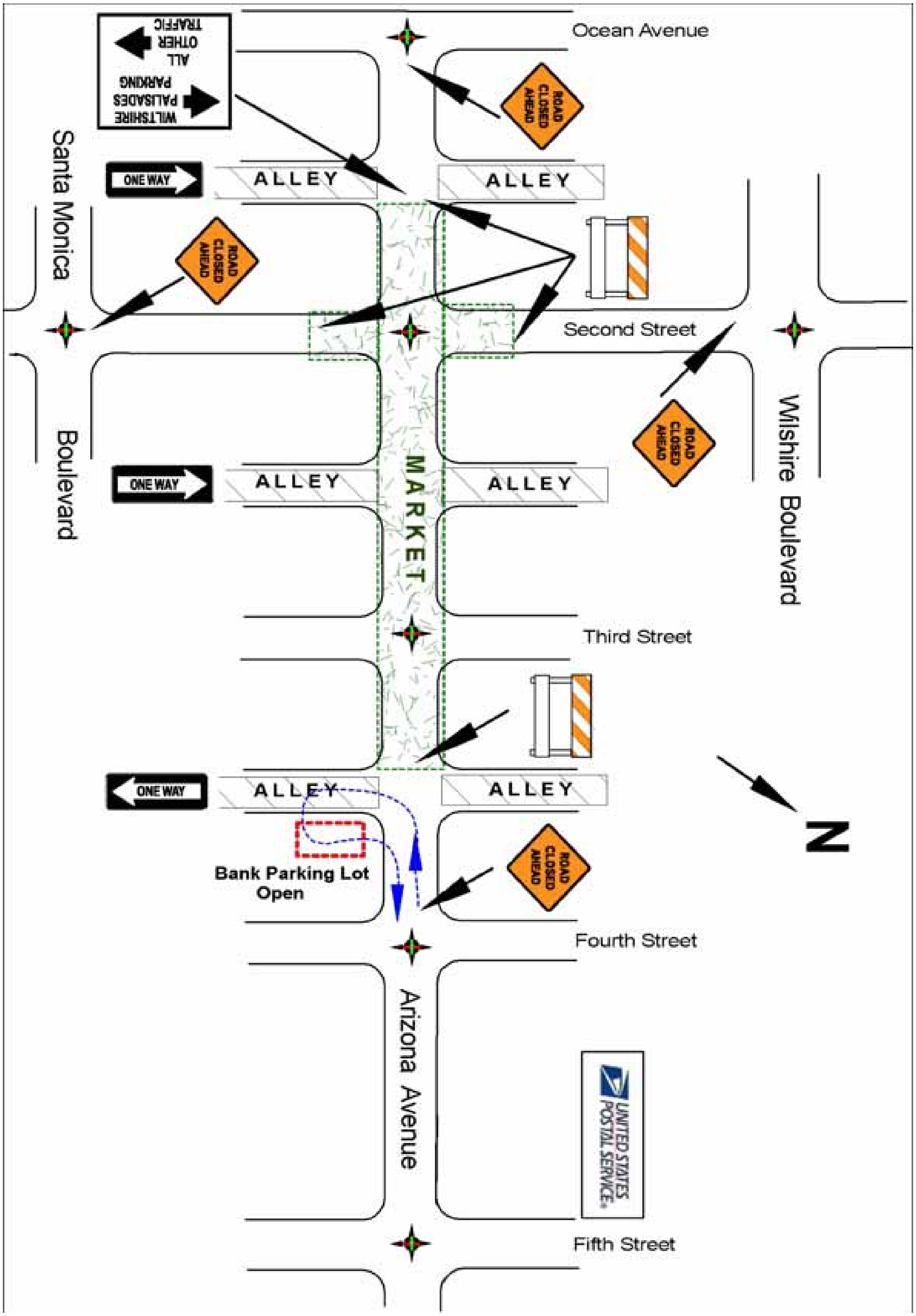

Figure 5. Road closures in place for SMCFM.

Traffic Volume and Accident History

Santa Monica reported that weekday peak-hour traffic counts were last obtained in October 2002 and indicated the following traffic volumes:

Table 2. Traffic counts.

Intersecting roadways	Traffic count
Ocean Avenue and Arizona Avenue	9,867
Second Street and Arizona Avenue	6,675
Third Street and Arizona Avenue	7,706
Fourth Street and Arizona Avenue	9,987

The city provided the following statistics, which it obtained from California's Statewide Integrated Traffic Record System, regarding the number of accidents recorded on Arizona Avenue between Ocean Avenue and Fifth Street for the period from January 1, 1999, to June 30, 2002:

Table 3. Accident history.

Intersection	Number of accidents reported	Number of pedestrian accidents
Ocean Avenue and Arizona Avenue	21	2
Second Street and Arizona Avenue	11	0
Third Street and Arizona Avenue	4	0
Fourth Street and Arizona Avenue	14	1
Fifth Street and Arizona Avenue	14	1

No fatal accidents were reported at any of these locations during that period. According to the city, the SMCFM has had no reported accidents during its hours of operation (9:00 a.m. to 2:00 p.m.) since it opened in 1981.

Traffic Control

Santa Monica provided a temporary traffic plan for the SMCFM to Safety Board investigators. The undated and unsigned temporary traffic plan consisted of a single sheet of paper (8 1/2 x 11 inches) on which a roadway diagram was hand-drawn (see figure 6); the diagram indicated where barricades should be placed in the roadway. The plan did not cite any specific *Manual on Uniform Traffic Control Devices* (MUTCD) or *Caltrans* [California Department of Transportation] *Traffic Manual* (CTM) barricade types or traffic channelization devices[8] to be used. According to the director of the SMCFM, the traffic plan had been developed in 1981 when the market opened and revised in 1986 when the market expanded onto Second Street. It had not been revised, reevaluated, or updated since then.

[8] Traffic channelization devices include barricades, cones, and drums that are placed in the roadway.

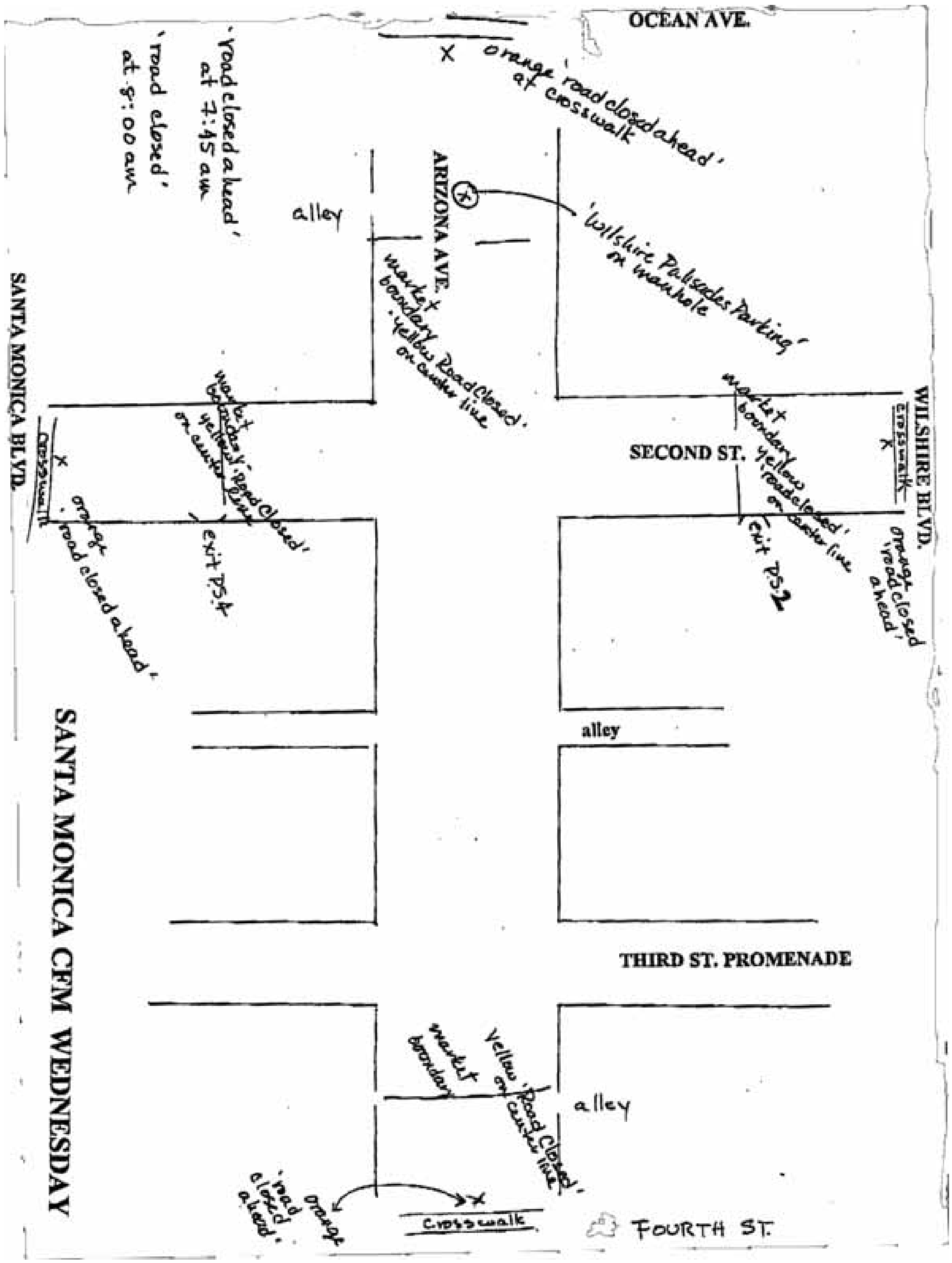

Figure 6. Temporary traffic plan (1986 version).

According to the SMCFM director, Arizona Avenue was blocked at the entrances to the market by two MUTCD type I barricades,[9] supplemented by two A-frame plastic barricades (see figure 7). The barricades were placed in the roadway about 7:00 a.m. every Wednesday, remained in place during the event, and removed about 3:00 p.m. Orange, diamond-shaped ROAD CLOSED AHEAD warning signs (designated “W-20” signs in the MUTCD and “C-19” in the CTM), attached to temporary fixtures, were placed on the centerlines of Arizona Avenue and Second Street (see figure 8),[10] about 1/2 block before the road closure. No other advance warning signs were used. When Safety Board investigators observed the SMCFM in operation on July 23, 2003, barricades were in place at those locations indicated in the temporary traffic plan. Contract personnel, hired by the city’s Office of Economic Development, placed and removed the barricades and warning signs.

Figure 7. Market barricades.

[9] The CTM, Chapter 5, Section 5-05.6, “Channelizing Devices, F. Barricade Application,” recommends the use of type III barricades for full road closures, as shown in Typical Application 5-8 on page 5-99, “Road Closed with Off-Site Detour.”

[10] In this photograph, taken a week after the accident, a small pickup truck is parked in the middle of the street. No vehicles were parked in the middle of the street on the day of the accident.

Figure 8. Advance warning sign on Arizona Avenue, just west of Fourth Street (postaccident).

Traffic Signals

Three-phase, electrically operated traffic signals were in place at all street intersections on Arizona Avenue between Ocean Avenue and Fifth Street. Traffic signals were not in place at the alley intersections. The signal at Arizona Avenue and Third Street was a "pedestrian only" signal; Third Street is a promenade (or pedestrian mall), and vehicles do not approach Arizona Avenue from it. Even when the SMCFM was operating and vehicles were prohibited on Arizona Avenue from the alley between Second Street and Ocean Avenue and the alley between Fourth and Third Streets, all traffic signals continued to operate in their normal mode. The traffic signals at Second Street and the Third Street promenade continued to operate, even though vehicular traffic did not cross either intersection while the farmers' market was in operation. Both signals were visible to traffic on north- and southbound Arizona Avenue, and the signal at the Second Street intersection was visible to east- and westbound Second Street traffic. (See figure 9.)

Traffic Control at Service Alley

As investigators walked from Fourth Street to Ocean Avenue, they noted a service alley, intersecting Arizona Avenue midway between Second and Third Streets, that was open to traffic. When they first passed this alley, no barricades were in place. Upon returning from Ocean Avenue less than 15 minutes later, the investigators observed that market personnel had placed three-wheeled vehicles at the service alley in an apparent attempt to block vehicular traffic.

Figure 9. Traffic signal at Second Street and Arizona Avenue.

Third Street Promenade

The Third Street promenade intersects Arizona Avenue midway in the SMCFM. It is a dedicated pedestrian mall that is permanently closed to vehicular traffic. Metal bollards[11] are positioned at the entrances to the mall at Arizona Avenue, Colorado Avenue, and Wilshire Boulevard. According to the city, "the bollards are intended to keep vehicles off the Third Street promenade on a full-time, permanent basis." Four bollards are embedded into the Third Street roadway at each intersection, and they extend approximately 24 inches above the ground. (See figure 10.) They are locked into place with a padlock and can be lowered into the ground to allow access by emergency vehicles. Emergency response personnel have keys to the padlocks.

According to city officials, the metal bollards were installed at the mall entrances because the promenade was designated a permanent pedestrian mall. Officials indicated that bollards were not considered for the SMCFM entrances because the market does not operate on a full-time basis, necessitating permanent closure of Arizona Avenue.

[11] A bollard is a thick, low vertical post used to exclude or divert motor vehicles from a road, lawn, or other restricted area.

Figure 10. Bollards in place at the Third Street pedestrian promenade.

Emergency Response

About 1:47 p.m. on July 16, 2003, the SMPD Communications Center in Santa Monica received several wireless 9-1-1 calls reporting an accident at Second Street and Arizona Avenue. SMPD officers arrived within 1 minute to the scene. In all, some 400 municipal employees and law enforcement, emergency medical service, and fire department personnel from the SMPD, CHP, Beverly Hills Police Department, Los Angeles Police Department, Culver City Police Department, Los Angeles County Sheriff's Department, Santa Monica Fire Department (SMFD), Los Angeles County Fire Department (LACFD), Los Angeles City Fire Department (LAFD), and the Culver City Fire Department (CCFD) responded to the accident. Responders provided triage, patient care, patient transport, traffic control, and investigation.

The SMFD dispatched 21 vehicles and 41 personnel to the scene, and once mutual aid was requested, other agencies provided additional support. The LAFD, LACFD, and CCFD sent 24 vehicles, 3 helicopters, and 66 personnel. In all, 107 fire department personnel responded to the scene. The SMFD, which is responsible for an 8.2-square mile area, has six certified advanced life support units; four are fire engines and two are ambulances. All SMFD firefighters are certified emergency medical technicians or paramedics. In the event of a large-scale response, the SMFD has an agreement with a private ambulance company to provide transportation for medical emergencies, and multiple units responded to this accident scene.

The closest SMFD fire station was about 5 blocks from the scene. By 1:50 p.m., the first fire and emergency medical services had arrived on scene via the Arizona Avenue-Fourth Street entrance to the SMCFM. All units were on scene within 10 minutes of the accident dispatch.

The first fire officer on scene became the incident commander (IC) and immediately declared the scene a multi-casualty incident (MCI), initiated the MCI plan, and called for six more ambulances and two more engine companies. A medical command position was initiated and the SMFD firefighter who assumed the role of medical commander began contacting the nearest hospitals to advise them of the situation and to expect numerous patients. A firefighter-paramedic was designated treatment unit leader and began to set up a treatment area at the scene. The IC did a walk-through of the entire scene and, after further assessment, called for all remaining SMFD units, 15 additional ambulances, and 4 engine companies. The IC also requested the use of medical "cache" trailers. The SMFD maintains one of these trailers at each station in Santa Monica for deployment during disasters, and they were a source of medical supplies and backboards[12] during the response. According to the SMFD fire chief, these trailers were "vital" to the response effort, since the number of injured was larger than the supply of backboards and other equipment available from the responding units.

After the injured were triaged at their locations, they were moved to ambulances for transport to a hospital or to the treatment location on scene. When all eight local hospitals began to fill up, helicopters were requested for transport of the injured to other hospitals. Among the patients treated at the scene, 22 were considered "walking wounded" and were transported by city bus to a hospital. The more seriously injured, as determined by on-scene triage, were transported to hospitals by ambulance and helicopter.

During the emergency response, the IC requested mutual aid from other local fire departments to assist the SMFD, since all available SMFD units had responded to the scene. The LAFD, LACFD, and CCFD responded to the 2:09 p.m. request and were either on scene 11 minutes later or filled in at the SMFD stations and handled calls there while the SMFD units were on scene.

The emergency responders to this accident carried out their activities in accordance with the "California Fire Service and Rescue Emergency Mutual Aid Plan," which supports the concepts of the incident command system, the integrated emergency management system, and multihazard response planning. The purpose of the State mutual aid plan is to provide for systematic mobilization, organization, and operation of the State's fire and rescue resources in mitigating the effects of disasters, whether natural or man-made.

[12] A backboard is a rigid board splint on which patients are secured by straps. It is commonly used in instances of known or suspected spinal injury to prevent further injury during transport.

Under the coordination of the SMFD, Santa Monica has participated in regularly held drills, covering scenarios such as earthquakes, fires, and other natural disasters. The purpose of these drills is to test the readiness and response of fire, police, public works, transportation, and other city departments.

Operational Information

History of Farmers' Markets

The number of farmers' markets in the United States exceeds 3,100,[13] a figure that increased by 79 percent from 1994 to 2002. The U.S. Department of Agriculture (USDA) supports and promotes farmers' markets. In August 1998, the USDA, through its Agricultural Marketing Service, developed a "Direct Marketing Action Plan"[14] to identify direct marketing issues and opportunities affecting farmers, promote development and operation of farmers' markets, and conduct, support, and promote research. The USDA has no Federal regulatory or enforcement authority over farmers' markets. It maintains a database of market locations throughout the Nation; inclusion is voluntary, and the database does not track safety issues affecting farmers' markets. The decision to place a market in a certain location, the permitting requirements, and any traffic control plans necessary to ensure the safety of a market are left to the discretion of local jurisdictions.

The State's Department of Agriculture certifies farmers' markets in California. Only certified farmers, nonprofit organizations, or governmental entities can operate a certified farmers' market (CFM) in the State. Both a market's operator and the individual vendors must receive certification from their county's agricultural commissioner. The State promotes the markets in order to provide California farmers with an outlet for and the public with access to fresh farm products at lower cost. According to the California Department of Agriculture, to receive State certification, a market operator must complete an application form and pay a fee. The State requires a map of the proposed location but does not approve or control the physical location of the market; it does not require that a traffic control plan be submitted. The purpose of the map is to allow State inspectors to visit sites to determine where certified and noncertified products are being sold.

The State's Department of Agriculture reports more than 300 CFMs in California, of which 80 are located within the Los Angeles County limits. The number of county markets that operate on dedicated roadways requiring temporary road closures is 27.

Santa Monica sponsors four CFMs: the Wednesday Market, the Sunday Market, the Saturday Downtown Market, and the Saturday Pico Street Market. The city, which organizes and manages these markets, estimates that 900,000 shoppers visit them every year. The accident occurred at the Wednesday Market.

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[13] See <http://www.ams.usda.gov/farmersmarkets/facts.htm>.

[14] See <http://www.ams.udsa.gov/directmarketing/frmplan.htm>.

The Wednesday Market operates on Arizona Avenue between Fourth Street and Ocean Avenue every Wednesday from 9:00 a.m. to 2:00 p.m. It opened in July 1981 and was the first CFM established in Santa Monica. The Saturday Downtown Market, established in May 1991, operates in the same location where the accident occurred. The Saturday Pico Street Market and the Sunday Market operate in off-street facilities.

The Wednesday Market received its most recent annual certification prior to the accident on February 25, 2003. The market includes approximately 90 vendors who set up portable canopy tents along Arizona Avenue's parking lanes. The city estimates the Wednesday Market draws about 9,000 visitors per week.

City of Santa Monica

Santa Monica's city manager reports directly to the city's mayor and seven-person council. The city manager oversees Santa Monica's 10 departments, including the Office of Resource Management, which, through its economic development unit, was directly responsible for the operation of the SMCFM.

The city's Transportation Management Division is part of the Office of Planning and Community Development, another of the 10 departments that report to the city manager. That division's traffic operation unit studies parking and traffic conditions throughout the city and develops plans and recommendations to improve the movement and safety of pedestrians, bicycles, buses, trucks, and cars. The city accomplishes many of these functions through private consultants and contractors.

The Open Space Management Division is responsible for issuing the city permits required by individuals and organizations seeking to hold community events on public property. When such events require the closure of a city street, the Transportation Management Division must approve any temporary traffic control plans deemed necessary to hold the event safely. It also assesses the level of traffic disruption and determines the level of temporary traffic control necessary to safely conduct the event under consideration. According to Santa Monica officials, the Transportation Management Division uses the *Work Area Traffic Control Handbook* (WATCH)[15] to determine the level of temporary traffic control needed.

The traffic operations unit is responsible for installing, maintaining, and repairing all traffic control devices, including traffic signals, traffic signs, roadway striping, painted curb zones, and parking meters. The city has approximately 160 traffic signals, 25,000 traffic signs, and 6,000 parking meters. In emergency situations, this unit also provides personnel and materials to assist with emergency traffic control. Services provided include installing road barricades and traffic signs and repairing traffic signals.

[15] Uniform Practices and Utility Coordination Committee, Southern California Chapter, American Public Works Association, Eighth Edition (Anaheim, CA: BNI Publications, 1996).

Community Event Permitting Requirements

Santa Monica Municipal Code, Sections 4.68.040 through 4.68.220, governs the requirements for and application and issuance of community event permits.[16] Section 4.68.040 requires a permit for (1) any gathering of 150 or more people on city-owned, -controlled or -maintained property; or (2) any activity or event on public property that requires the placement of a tent, canopy, or other temporary structure. The city owns and operates the SMCFM, and, according to city officials, the community event permitting statute does not apply to the SMCFM.

The permitting process addresses requirements for certain events when street closure is explicitly requested; it does not require submission of a traffic control plan for those events. Applicants seeking street closure must submit for review by the fire and police departments a scaled site map that includes the placement of all event equipment. The purpose of this review is to ensure that emergency vehicles will have access to the affected area throughout the event; it is not a review for pedestrian or traffic safety.

Other Information

Manual on Uniform Traffic Control Devices

The MUTCD, which is produced under the authority of the U.S. Department of Transportation, Federal Highway Administration, contains the basic principles governing the design and use of traffic control devices for all streets and highways open to public travel, regardless of type or class or the public agency having jurisdiction. At the time of the accident, the MUTCD 2000, or Millennium Edition, was current.[17]

Chapter 6 of the MUTCD, entitled "Temporary Traffic Control," applies to the deployment and use of devices for traffic control when the normal traffic flow is disrupted. It defines the primary function of temporary traffic control as providing for the safe and efficient movement of vehicles, bicyclists, and pedestrians through or around all temporary traffic control zones while reasonably protecting persons and equipment. The MUTCD provides the following standards:

> Temporary traffic control plans and devices shall be the responsibility of the authority of a public body or official having jurisdiction for guiding road users. There shall be adequate statutory authority for the implementation and enforcement of needed road user regulations, parking controls, speed zoning, and incident management. Such statutes shall provide sufficient flexibility in the application of temporary traffic control to meet the needs of changing conditions in the temporary traffic control zone.[18]

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[16] Administrative Instruction No. II-4-4, July 15, 2003.

[17] In November 2003, the Federal Highway Administration issued the MUTCD 2003, which California adopted, with a State supplement, on May 20, 2004. The chapter on temporary traffic control in the MUTCD 2003 is substantially the same as the corresponding chapter in the MUTCD 2000.

[18] MUTCD 2000, Millennium Edition, December 2001, Section 6A.01.

Chapter 6B.01 of the MUTCD, “Fundamental Principles of Temporary Traffic Control,” notes: “The control of road users through a temporary traffic control zone shall be an essential part of highway construction, utility work, maintenance operations, and incident management.” The MUTCD makes no distinction pertaining to the reason for a road closure or other measure. Section 6C.01 states:

> Temporary traffic control plans play a vital role in providing continuity of safe and efficient road user flow when a work zone, incident, or other event [emphasis added] temporarily disrupts normal road user flow.

The MUTCD lists several typical applications (TAs) to aid in selecting the most appropriate temporary traffic control devices. The applications can be altered to suit the specific conditions of a particular site; supplemental devices may be added and devices included in a TA can be deleted.

The model application for road closures with off-site detour is model TA-8 (see figure 11). It states that a ROAD CLOSED[19] sign mounted on type III barricades (see figure 12) may be located at the edge of a roadway that is not being closed to all traffic.[20] If the road is closed a short distance beyond the intersection and a few origin or destination points are also beyond the intersection (for example, a few residences), the ROAD CLOSED sign may be placed on a type III barricade[21] placed in the center of the roadway.

Section 6F.75 of the MUTCD, which describes the use of temporary traffic barriers, states:

> Temporary traffic barriers are devices designed to help prevent penetration by vehicles while minimizing injuries to vehicle occupants, and designed to protect workers, bicyclists, and pedestrians …. They are also used for certain special events or in other temporary traffic control contexts where separation and channelization of vehicle and pedestrian movements are needed.

The MUTCD defines crash cushions in section 6F.76, which refers the reader to the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide* for more information on the use of crash cushions. Section 6F.76 of the MUTCD states:

> Crash cushions are systems that mitigate the effects of errant vehicles that strike obstacles, either by smoothly decelerating the vehicle to a stop when hit head-on, or by redirecting the errant vehicle. The two types of crash cushions that are used in temporary traffic control zones are stationary crash cushions and truck mounted attenuators. Crash cushions in temporary traffic control zones help protect the drivers from the exposed ends of barriers, fixed objects, shadow vehicles, and other obstacles.

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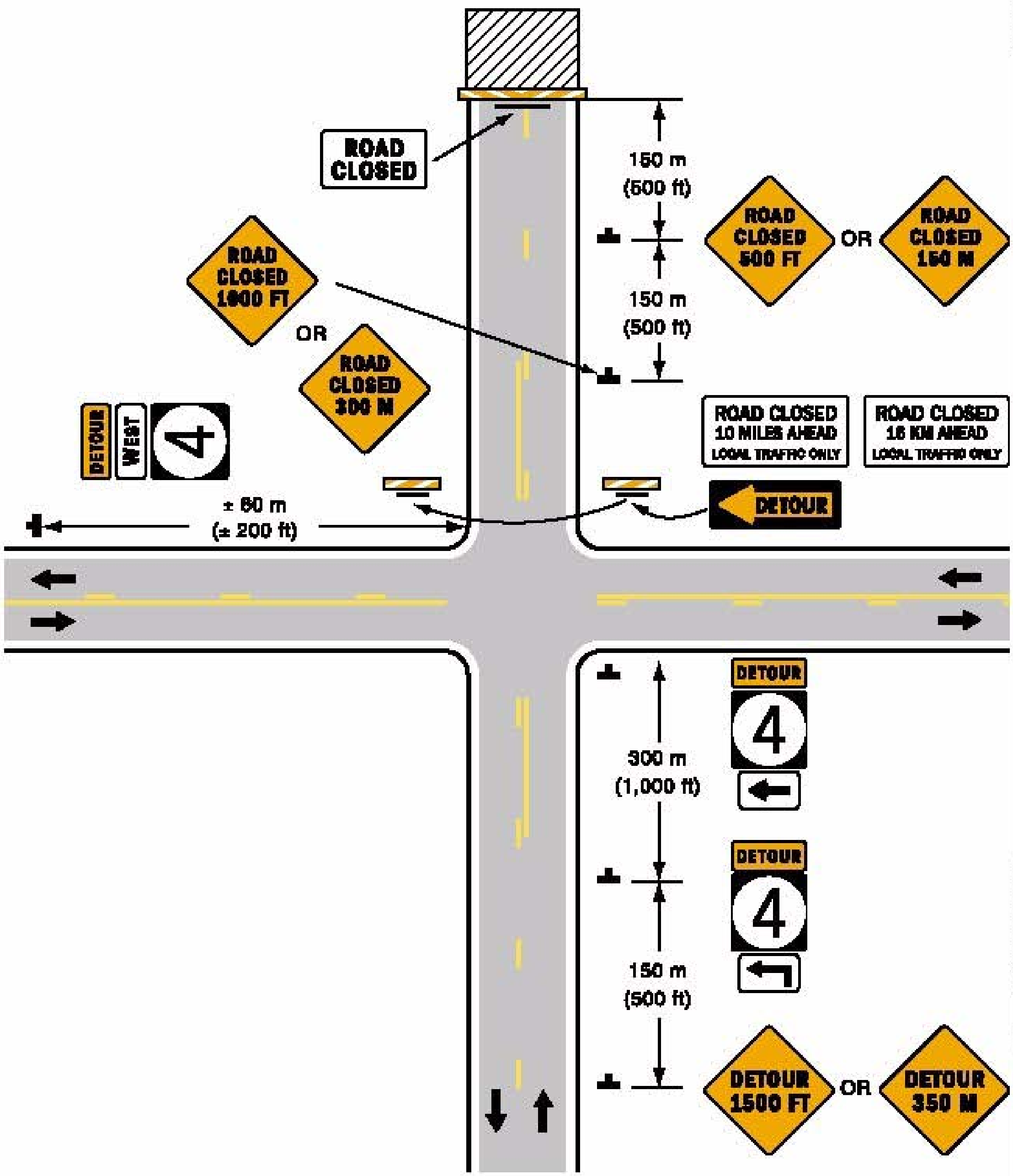
[19] MUTCD 2000, Millennium Edition, December 2001, Section 2B-42, “ROAD CLOSED Sign (R11-2).”

[20] The MUTCD designates traffic barricades as types I, II, and III. Type I and II barricades are to be used when traffic is maintained through a work area; type I barricades are for use on urban or low-speed roads or streets, and type II barricades are for use on expressways, freeways, and other high-speed roadways. Type III barricades are to be used to close or partially close a road.

[21] MUTCD 2000, Millennium Edition, Section 6F-4, “Channeling Devices.”

Figure 6H-8. Road Closure with Off-Site Detour (TA-8)



Typical Application 8

Note: See Tables 6H-2 and 6H-3 for the meaning of the symbols and/or letter codes used in this figure.

Figure 11. TA-8, the model application for road closures with off-site detour.

Figure 12. Type III barricade.

Section 6G.04 of the MUTCD, “Modifications to Fulfill Special Needs,” provides guidance on adding supplemental devices to temporary traffic control applications. According to section 6G.04, “When conditions are more complex, typical applications should be modified by incorporating appropriate devices and practices from the following list,” which includes temporary traffic barriers (#8) and crash cushions (#9).

Roadside Design Guide

The AASHTO *Roadside Design Guide* synthesizes current information and operating practices related to roadside safety. Chapter 9, “Traffic Barriers, Traffic Control Devices, and Other Safety Features for Work Zones,” describes the safety, functional, and structural aspects of traffic barriers, traffic control devices, and safety features used in work zones and provides guidance for their application. The guide indicates that chapter 9 is not a stand-alone document and that the information in it must be used in conjunction with traffic control guidance in the MUTCD.

Section 9.2 of the *Roadside Design Guide*, “Traffic Barriers,” states that work zone traffic barriers are designed either as permanent barriers or as temporary barriers that can be easily relocated. It notes that one function of these barriers is “to separate pedestrians from vehicular traffic." Subsection 9.2.1 describes various temporary longitudinal barriers used to segregate vehicle traffic from pedestrians, workers, or equipment; these barriers are of sufficient structural strength to redirect or resist errant vehicles. Section 9.3, "Crash Cushions," describes stationary crash cushions available for temporary use.

Caltrans Traffic Manual

In 1996, the California Department of Transportation published its CTM, which set State standards for traffic control devices at the time of the accident. Prior to publication of the MUTCD 2003, California had chosen not to adopt the national MUTCD, as the Federal Highway Administration allows;[22] therefore, the MUTCD was not controlling at the time of the farmers' market incident. The CTM was very similar to the 1988 MUTCD with revision 3 (3/1993). Section 5-01.1 of the CTM defined a workspace as a location where the normal function of the roadway is suspended. The CTM also listed TAs, and application 5-8 was identical to the MUTCD 2000 TA-8.

WATCH Manual

According to Santa Monica's Transportation Management Division, the WATCH manual provides guidance for the setup and operation of all work areas occupying city streets. The manual sets forth basic principles and recommends standards to be observed by all those who perform work in a public street. It defines the term *work* to include activities such as store openings, news and theater events, and commercial filming. As do the MUTCD and the CTM, the WATCH manual includes several examples of lane and road closures to be used as guides, one of which is an application for "closing of local streets." The application calls for the roadway to be closed using two ROAD CLOSED (C5) signs mounted on type III barricades and advance warning signs on the three approaches to the intersection.

Bourbon Street Promenade, New Orleans, Louisiana

Bourbon Street was dedicated as a public thoroughfare in 1751, and in 1971, the New Orleans City Council enacted an ordinance designating the 100 to 800 blocks of Bourbon Street as a pedestrian mall during nighttime hours as a means to promote tourism. To protect pedestrians on this segment of the street, the city uses removable bollards, which are hollow cast-iron poles, painted yellow, and placed into metal collars embedded in the roadway. The bollards extend approximately 40 inches above the ground and 6 inches into the ground. According to the traffic engineer for the New Orleans Department of Public Works, the city does not maintain records of whether the bollards are effective in stopping errant vehicles from entering the pedestrian mall; the bollards are often observed to be bent and to require replacement.

[22] MUTCD 2000, Millennium Edition, Section 1A.07, "Responsibility for Traffic Control Devices," states: "When a State or other Federal agency manual or supplement is required, they shall be in substantial conformance with the national Manual on Uniform Traffic Control Devices." Title 23 CFR 655.603 requires that traffic control devices on all streets and highways open to public travel in each State be in substantial conformance with standards issued or endorsed by the Federal Highway Administrator.

Unintended Acceleration

NHTSA, in *An Examination of Sudden Acceleration,* has defined unintended acceleration (also known as sudden acceleration) as "an unintended, unexpected, high-power acceleration from a stationary position or a very low initial speed accompanied by an apparent loss of braking effectiveness."[23] The definition includes the phrase "an apparent loss of braking effectiveness," according to NHTSA, because drivers often claim they were pressing on the brake pedal but the vehicle would not stop. The study concluded:

> For a sudden acceleration incident in which there is no evidence of throttle sticking or cruise control malfunction, the inescapable conclusion is that these definitely involve the driver inadvertently pressing the accelerator instead of, or in addition to, the brake pedal.

Both Transport Canada[24] and the Japanese Ministry of Transport[25] have also examined this issue; the former concluded that driver error is the cause of the unintended acceleration phenomenon, and the latter found no common mechanical cause for sudden or unintended acceleration.

Highway Vehicle Event Data Recorders

The accident vehicle was not equipped with an event data recorder (EDR), nor was it required to be. It did have an electronic air bag control module and an engine ECM; neither device was designed for, or capable of, recording accident data. Currently, a small number of late-model automobiles and light-duty trucks are equipped with air bag control modules that can capture and record a limited amount of accident data. Additionally, many heavy-duty trucks are equipped with ECMs or with transmission control modules that record critical vehicle performance data. On a limited basis, General Motors, Ford, and, more recently, Daimler-Chrysler, have begun integrating crash data collection technologies in their vehicles. In the absence of industry standards or government regulations, each manufacturer has determined which parameters to record and methods to use in accessing the data from these devices. Manufacturers currently record different data parameters and use different formats, tools, and procedures to access the recorded data.

NHTSA and the automobile industry have been examining the utility of highway vehicle EDRs since the mid-1970s. In 1974, as part of its Disc Recorder Project, NHTSA equipped 1,000 vehicles with EDRs in several fleets that logged a total of 26 million miles. Researchers subsequently analyzed 26 crashes in which EDR-equipped vehicles were involved, measured Delta Vs up to 20 mph, and collected deceleration-time histories. During the same year, General Motors introduced the first regular production driver-passenger airbag systems in selected vehicles. These systems incorporated a data-recording feature designed to activate when the air bags deployed during severe crashes.

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[23] U.S. Department of Transportation, Transportation Systems Center, *An Examination of Sudden Acceleration*, Report HS-807-367 (Cambridge, MA, January 1989).

[24] Transport Canada, *Investigation of Sudden Acceleration Incidents* (1989).

[25] Japanese Ministry of Transport, *An Investigation on Sudden Starting and/or Acceleration of Vehicles With Automatic Transmissions* (1989).

As a result of its 1997 public forum[26] on air bag, seat belt, and child restraint use, the Safety Board issued an EDR recommendation to NHTSA and a companion recommendation to the automobile manufacturers. The Board urged NHTSA to:

> <u>H-97-18</u>
>
> Develop and implement, in conjunction with the domestic and international automobile manufacturers, a plan to gather better information on crash pulses and other crash parameters in actual crashes, utilizing current or augmented crash sensing and recording devices.

In response, NHTSA formed an EDR working group in 1998 that included representatives from the Safety Board and automobile manufacturers. The group's objective, as stated by NHTSA, was to facilitate the collection and utilization of collision avoidance and crashworthiness data from on-board EDRs. The working group issued a final report in 2001 addressing issues such as the status of EDR technology, data elements, data retrieval, data collection and storage, permanent records, privacy and legal implications, customers for and uses of EDR data, and demonstration of EDR technology. As a result of these efforts, the Safety Board classified the recommendation to NHTSA "Closed—Exceeds Recommended Action" on July 18, 2002, and classified the recommendation to the automobile manufacturers "Closed—Acceptable Action" on April 22, 2004.

In 1998, as the result of an accident investigation in Slinger, Wisconsin, involving four vehicles,[27] the Safety Board issued EDR recommendations to the American Trucking Associations, the International Brotherhood of Teamsters, the Motor Freight Carrier Association, the Independent Truckers and Drivers, the National Private Truck Council, and the Owner-Operator Independent Drivers Association, Inc. The circumstances of the accident made it difficult to reconstruct the events, and the Safety Board concluded that, had the accident vehicle been equipped with an EDR, investigators would have been able to determine the speed at which the striking vehicle was traveling prior to losing control. The Safety Board therefore asked the trucking industry to:

> <u>H-98-23 and -26</u>
>
> Advise your members to equip their commercial vehicle fleets with automated and tamper-proof on-board recording devices, such as tachographs or computerized recorders, to identify information concerning both driver and vehicle operating characteristics.

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[26] National Transportation Safety Board, *Proceedings of the National Transportation Safety Board Public Forum on Air Bags and Child Passenger Safety*, Report of Proceedings NTSB/RP-97/01 (Washington, DC: NTSB, 1997).

[27] National Transportation Safety Board, *Multiple Vehicle Crossover Accident, Slinger, Wisconsin February 12, 1997*, Highway Accident Report NTSB/HAR-98/01 (Washington, DC: NTSB, 1998).

The industry generally declined to do so, and the Safety Board classified the recommendations "Closed—Unacceptable Response" for all of the associations.

In 1999, the Safety Board again addressed the need for highway vehicle EDRs in its special investigation report on school bus and motorcoach safety.[28] The report noted that in several studies, drivers of EDR-equipped vehicles have demonstrated a decrease in accidents, and the Safety Board concluded that EDRs could help reduce the accident rates of fleet vehicles. The Board recommended that NHTSA:

> H-99-53
>
> Require that all school buses and motorcoaches manufactured after January 1, 2003, be equipped with on-board recording systems that record vehicle parameters, including, at a minimum, lateral acceleration, longitudinal acceleration, vertical acceleration, heading, vehicle speed, engine speed, driver's seat belt status, braking input, steering input, gear selection, turn signal status (left/right), brake light status (on/off), head/tail light status (on/off), passenger door status (open/closed), emergency door status (open/closed), hazard light status (on/off), brake system status (normal/warning), and flashing red light status (on/off) (School buses only). For those buses so equipped, the following should also be recorded: status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy. The on-board recording system should record data at a sampling rate that is sufficient to define vehicle dynamics and should be capable of preserving data in the event of a vehicle crash or an electrical power loss. In addition, the on-board recording system should be mounted to the bus body, not the chassis, to ensure that the data necessary for defining bus body motion are recorded.
>
> The Safety Board also recommended that NHTSA:
>
> H-99-54
>
> Develop and implement, in cooperation with other government agencies and industry, standards for on-board recording of bus crash data that address, at a minimum, parameters to be recorded, data sampling rates, duration of recording, interface configurations, data storage format, incorporation of fleet management tools, fluid immersion survivability, impact shock survivability, crush and penetration survivability, fire survivability, independent power supply, and ability to accommodate future requirements and technological advances.

[28] National Transportation Safety Board, *Bus Crashworthiness Issues*, Highway Special Investigation Report NTSB/SIR-99/04 (Washington, DC: NTSB, 1999).

NHTSA responded that its EDR working group would consider the recommended data elements, and in 2000, NHTSA established a second working group to concentrate on EDRs for trucks, motorcoaches, and school buses.

In August 2001, the EDR working group issued a final report. Its findings include:

1. EDRs have the potential to greatly improve highway safety, for example, by improving occupant protection systems and improving the accuracy of crash reconstructions.
2. EDR technology has potential safety applications for all classes of motor vehicles.
3. A wide range of crash-related and other data elements have been identified which might usefully be captured by future EDR systems.
4. NHTSA has incorporated EDR data collection in its motor vehicle research databases.
5. Open access to EDR data (minus personal identifiers) will benefit researchers, crash investigators, and manufacturers in improving safety on the highways.
6. Studies of EDRs in Europe and the U.S. have shown that driver and employee awareness of an on-board EDR reduces the number and severity of driver's crashes.
7. Given the differing nature of cars, vans, SUVs, and other lightweight vehicles, compared to heavy trucks, school buses, and motorcoaches, different EDR systems may be required to meet the needs of each vehicle class.
8. The degree of benefit from EDRs is directly related to the number of vehicles operating with an EDR and the current infrastructure's ability to use and assimilate these data.
9. Automatic crash notification systems integrate the on-board crash sensing and EDR technology with other electronic systems, such as global positioning systems and cellular telephones, to provide early notification of the occurrence, nature, and location of a serious collision.
10. Most systems utilize proprietary technology and require the manufacturer to download and analyze the data.

The Safety Board classified Safety Recommendations H-99-53 and -54 "Open—Acceptable Response" on April 15, 2004.

In 2002, the Society of Automotive Engineers (SAE) and the Institute of Electrical and Electronics Engineers (IEEE) agreed to work together to voluntarily develop standardization of data output and retrieval protocols that would facilitate analysis and promote compatibility of EDR data. In October 2002, NHTSA published a request for comments on EDRs that addressed major issue areas, such as the standardization of data and privacy issues. The Safety Board responded, encouraging NHTSA to maintain its progress toward requiring that (1) all school buses and motorcoaches be equipped with EDRs and (2) standards for on-board recording of bus crash data be developed. NHTSA also began participating in an International Harmonized Research Activities EDR working group in 2002.

In December 2002, the Safety Board issued additional recommendations regarding EDRs as the result of its investigation of an accident near Canon City, Colorado, in which a motorcoach lost control on an icy roadway, left the roadway, and overturned before coming to rest.[29] The Safety Board asked the IEEE and the SAE to:

> H-02-35
>
> Work together, as part of your initiative to establish on-board vehicle recorder standards, to develop standards for brake and transmission electronic control units that require those units to store a full history of electronic fault codes that are time stamped using a recognized clock synchronized with other on-board event data recording devices.

As a result, the IEEE is developing an amendment to its EDR standards that would require brake and transmission electronic control units to store a full history of electronic fault codes that are time-stamped by a recognized clock synchronized with other on-board EDRs. The Safety Board classified Safety Recommendation H-02-35 to the IEEE "Open—Acceptable Response" on March 2, 2004. The SAE indicated that it is not developing an EDR standard or recommended practice for heavy vehicles. The Safety Board continues to urge the SAE to work with the IEEE on EDR technology for heavy vehicles and classified Safety Recommendation H-02-35 to the SAE "Open—Acceptable Response" on March 19, 2004.

In December 2003, the SAE issued Surface Vehicle Recommended Practice J1698, which established a standard format for displaying and presenting crash-related data recorded or stored by electronic components that are already installed in many light-duty vehicles. The format applies specifically to the postevent format of downloaded data and does not direct how data should be collected or which vehicle systems should be monitored. The recommended practice addresses some 70 data elements. The SAE has stated that it continues to develop Surface Vehicle Recommended Practice J1698/2 "Vehicular Data Extraction," which will address the collection of event data.

On June 4, 2004, the IEEE completed its work on a proposed "Standard for Motor Vehicle Event Data Recorders." This voluntary EDR standard for highway vehicles will be available throughout the 175 nations that accept IEEE standards. It is scheduled to go before the IEEE Standards Association in September 2004 for final adoption.

[29] National Transportation Safety Board, *Motorcoach Run-Off-the-Road Near Canon City, Colorado,* Highway Accident Brief NTSB/HAB-02/19 (Washington, DC: NTSB, 2002).

NHTSA issued a Notice of Proposed Rulemaking (NPRM) concerning EDRs on June 10, 2004. In it, the agency stated:

> Manufacturers have been voluntarily installing EDRs as standard equipment in increasingly larger numbers of light vehicles[30] in recent years. They are now being installed in the vast majority of new vehicles. The information collected by EDRs aids investigations of the causes of crashes and injuries, and makes it possible to better define and address safety problems. The information can be used to improve motor vehicle safety systems and standards. As the use and capabilities of EDRs increase, opportunities for additional safety benefits, especially with regard to emergency medical treatment, may become available.
>
> We are not presently proposing to require the installation of EDRs in any motor vehicles. We are proposing to (1) require that the EDRs voluntarily installed in light vehicles record a minimum set of specified data elements useful for crash investigations, analysis of the performance of safety equipment, e.g., advanced restraint systems, and automatic collision notification systems; (2) specify requirements for data format; (3) increase the survivability of the EDRs and their data by requiring that the EDRs function during and after the front, side and rear vehicle crash tests specified in several Federal motor vehicle safety standards; (4) require vehicle manufacturers to make publicly available information that would enable crash investigators to retrieve data from the EDR; and (5) require vehicle manufacturers to include a brief standardized statement in the owner's manual indicating that the vehicle is equipped with an EDR and describing the purposes of EDRs.

[30] As defined in the NPRM, light vehicles include passenger cars, multipurpose passenger vehicles, and trucks and buses with a GVWR of 8,500 pounds or less and an unloaded vehicle weight of 5,500 pounds or less.

Analysis

In the following analysis, the Safety Board will first exclude factors that neither caused nor contributed to the accident and then examine those factors that led to or had a role in the accident. The discussion that follows will focus on the accident driver's unintended acceleration, the adequacy of temporary traffic control measures for the protection of pedestrian traffic in the SMCFM, and the need to equip motor vehicles with EDRs.

Exclusions

The weather was clear and dry on the afternoon of the accident; the sun was almost directly overhead, indicating that visibility issues apparently did not affect the driver's performance. Postaccident examination of the 1992 Buick LeSabre by both the CHP and Safety Board investigators revealed no mechanical defects or conditions that would have caused the vehicle to accelerate in an uncontrolled manner. Therefore, the Safety Board concludes that neither weather conditions nor the mechanical condition of the vehicle contributed to this accident.

The driver had lived in the Los Angeles-Santa Monica area for more than 70 years and had owned the accident vehicle for more than 10 years. The SMCFM had taken place at the same location and on the same day of the week for 21 years and, although he had not patronized the market for a few years, the driver had some familiarity with it and indicated in his statement to police that he visually identified it ahead of him on Arizona Avenue. Therefore, the Safety Board concludes that the driver's experience and familiarity with his vehicle and the area of the farmers' market were not factors in this accident.

Toxicological testing by the Los Angeles County Sheriff's Department was negative for alcohol, amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates, and phencyclidine. A review of the driver's medical and prescription drug records indicated that the driver had not been prescribed medications that would have adversely affected his ability to operate a motor vehicle. Therefore, the Safety Board concludes that neither alcohol, nor illicit drugs, nor the driver's use of prescription medications was a factor in this accident.

Only limited information on the driver's usual sleep habits and rest, particularly during the 72 hours preceding the accident, could be obtained from police interviews of the driver and his wife. However, the circumstances of the accident and eyewitness accounts of the driver's behavior during the accident sequence do not indicate that the driver fell asleep or that his judgment or performance were fatigue-impaired. The driver's statements to the SMPD and the press suggest that he was alert, aware, and cognizant of what was happening throughout the accident sequence, beginning with his departure from the post office, through the period of unintended acceleration, and continuing to the point at which the vehicle came to rest and he was taken into custody. Therefore, the Safety Board concludes that neither insufficient sleep nor fatigue was likely to have had a role in this accident.

The separation between the accelerator and brake pedals was 2 inches at the closest point. Many studies have been conducted on the size, shape, and placement of automobile pedals; the consensus is that a minimum horizontal separation of 50 mm and a vertical separation of 50.8 mm (2 inches) are necessary.[31]

The primary concern about pedal placement is dual activation, that is, the driver depressing both the accelerator and the brake when he or she only intends to depress one or the other. The pedal separation in the accident vehicle was at the recommended minimum,[32] and two factors suggest that dual activation did not occur in this accident. First, witnesses reported they did not see the vehicle's brake lights illuminate, which would have occurred if the brake pedal had been depressed, even in conjunction with the accelerator. Second, witness descriptions of the vehicle's motion and the physical evidence indicated significant increases in acceleration and speed during the accident sequence and did not indicate a retarding force, which would be expected if the brake pedal had been depressed.

Moreover, the Safety Board notes that the 1992 Buick LeSabre does not have a history of pedal problems since its production. Data maintained by NHTSA would probably indicate whether the horizontal separation between the vehicle's pedals has resulted in pedal misapplication errors or unintended acceleration more frequently than expected. Furthermore, the driver had owned and operated the accident vehicle for 10 years and thus was familiar with the placement and operation of the Buick's pedals. Absent evidence that the 1992 Buick LeSabre was predisposed to pedal misapplication errors or unintended acceleration and in light of physical evidence, witness accounts of the vehicle's motion during the accident sequence, and the driver's familiarity with the vehicle, the Safety Board concludes that the horizontal separation of the pedals in the vehicle neither caused nor contributed to this accident.

The driver stated that he was aware that he was entering the farmers' market. He made steering inputs while driving through the market, but he apparently failed to recognize that he was depressing the wrong pedal and to correct his error. A comprehensive review of the driver's medical records disclosed no evidence of a medical condition that would have accounted for or contributed to these circumstances.

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[31] For example, see Joint Army-Navy-Air Force Steering Committee, *Human Engineering Guide to Equipment Design* (New York: John Wiley & Sons, 1972); J. Weiman, *Handbook of Ergonomics and Design Factors* (New Jersey: Prentice Hall, 1993); J.A. Adams, *Human Factors Engineering* (New York: MacMillan Press, 1989); and S. Konz, *Work Design: Industrial Ergonomics* (Worthington, OH: Publishing Horizons, Inc., 1990).

[32] Pedal separation is also a consideration in reducing brake response times; an increase in the distance between pedals is associated with a corresponding increase in time to make a brake application.

Although the driver had a significant history of orthopedic conditions affecting his lower spine and legs, and although he had been issued a disabled parking placard due to "severe hip arthritis" and associated limitations in mobility, the circumstances of the accident do not appear to have been associated with these conditions. The driver had been issued his disabled parking placard in 1994 and subsequently underwent surgery to replace his left hip and to revise an earlier right hip replacement. The driver's medical records document no persistent problems postoperatively, a finding that is consistent with research on human performance following hip replacement.[33] While the driver used a cane, at times, to walk, evidence does not indicate that his general ability to move his hips and legs in order to operate the accelerator and brake pedals was impaired. In fact, the driver was able to maneuver effectively, only moments before the accident, to deposit a letter from the passenger side window into the curbside receptacle at the post office. Finally, the absence of other medical conditions that might indicate impaired cognitive function; of a tendency toward syncope (fainting), near-syncope, or loss of consciousness; and of other impairment or incapacitation suggests that the driver's health was not a factor in this accident.

Therefore, the Safety Board concludes that, although the driver had a history of medical treatment for orthopedic conditions, neither these conditions nor his general health were likely to have been a factor in this accident.

Unintended Acceleration

During postaccident inspection of the Mercedes, Safety Board investigators found minor contact damage, consisting of horizontal surface scratching to the rear bumper cover. This minimal level of damage is consistent with witness statements indicating that the Buick was traveling at a comparatively low rate of speed when it struck the Mercedes, even though it attained much higher speeds as it accelerated away from the point of initial collision.

The accident vehicle's high-speed acceleration after it struck the Mercedes may have given the appearance of a "hit-and-run" incident, as some witnesses believed was the case. However, the available evidence does not support such an interpretation. Some witnesses, for example, observed the vehicle decelerate, as well as accelerate, as it proceeded through the market, and the driver himself told police that he did not recall striking the Mercedes. He also had no record of reckless or aberrant behavior over many years as a licensed driver. Moreover, even if he realized that he had struck the Mercedes, the accident driver is highly unlikely to have made a conscious decision to enter a crowded market area, thereby endangering his own life and the lives of many others, to flee the scene of a comparatively minor collision.

[33] See, for example, S.B. Ganz, A.Z. Levin, M.G. Peterson, and C.S. Ranawat, "Improvement in Driving Reaction Time After Total Hip Arthroplasty," *Clinical Orthopaedics* Vol. 413 (2003): 192-200; P.P. Gogia, C.M. Christensen, and C. Schmidt, "Total Hip Replacement in Patients With Osteoarthritis of the Hip: Improvement in Pain and Functional Status," *Orthopedics* Vol. 17, No. 2 (1994): 145-150; and W. MacDonald and J.W. Owen, "The Effect of Total Hip Replacement on Driving Reactions," *Journal of Bone and Joint Surgery* (British Volume), Vol. 70, No. 2 (1988): 202-205.

A more plausible explanation of the circumstances of this accident is that the driver unintentionally accelerated his vehicle. A human performance analysis of unintended acceleration needs to account for two behaviors: the driver's inadvertent activation of the accelerator and the driver's subsequent failure either to recognize the initial mistake or to correct it.[34] The factors underlying unintended acceleration are described below.

Inadvertent Activation

Moving the foot to the accelerator instead of the brake is a well-documented, but rare occurrence, accounting for 0.03 percent of the accidents reviewed in one study.[35] Drivers press the wrong pedal either due to an error in response choice or an error in response execution.

Errors in response choice entail making the wrong choice when presented with alternatives. This kind of error is probably not a major factor in unintended acceleration, since drivers almost always make the correct conscious choice about which pedal they intend to press. In this accident, the driver of the Buick said he intended to apply the brake pedal and, in fact, believed he had.

Errors in response execution involve making the correct choice—for example, to press the brake—but failing to execute the response effectively. In the case of braking, factors affecting execution include response force (the more force used, the greater the variability in the movement), response time (the faster the movement, the greater the force needed), limb size (the larger the limb, the more variability in the motion), head and body position (if the head or body is out of position, the normal, habitual movement may result in an error), direction of gaze (looking to the right or left when executing the movement may introduce error), and negative transfer from other vehicles (the learned movement in one vehicle may produce an error in another), to name a few.

This accident sequence began when the Buick struck the Mercedes before entering the farmers' market. As the traffic light on Arizona Avenue at Fourth Street changed from red to green, the driver of the Mercedes, which had stopped at the red light, and the driver of the Buick, which was behind the Mercedes and may not have slowed or stopped,[36] both expected to proceed. As the Mercedes driver began moving into her turn, the movement would have served as a cue to the accident driver that traffic was about to resume flowing. However, the Mercedes driver observed pedestrians in the crosswalk and halted her turning maneuver. This action—stopping on a green light (especially after beginning to proceed)—would have violated the expectancy of the Buick driver. From his vantage point behind the Mercedes, the Buick driver had no reason to anticipate the Mercedes'

[34] R. Schmidt, "Unintended Acceleration: A Review of Human Factors Contributions," *Human Factors* Vol. 31, No. 3 (1989): 345-364.

[35] U.S. Department of Transportation, NHTSA, *Analyzing the Role of Driver/Vehicle Incompatibilities in Accident Causation Using Police Reports*, Technical Report HS-801-858 (Washington, DC: NHTSA, 1976).

[36] Evidence was insufficient to allow investigators to determine whether the accident driver slowed or stopped before reaching the Mercedes.

sudden stop. If his attention was focused on the movement of the Mercedes rather than on the pedestrians to the right, the Buick driver would have lacked advance warning of both the impending conflict between the pedestrian traffic and the Mercedes and the resulting braking by the Mercedes driver. This lack of advance warning, coupled with the possible violation of expectancy, would have created a situation conducive to human error.

Moreover, shortly before his vehicle struck the Mercedes, the Buick driver had deposited a letter in a curbside mailbox less than a block away. He had done so while remaining inside the automobile, requiring that he maneuver across the seating area and place the letter through the passenger-side window and into the outside receptacle. Thus, the accident driver may have been slightly out of position as he resumed driving toward the Fourth Street intersection. As noted above, one factor that can contribute to an error in response execution (such as applying one's foot to a pedal) is having the body out of position, in which case normal or habitual movement can result in a mistake.

Rear-end crashes at intersections where a vehicle ahead is stopped represent a majority of all rear-end crashes in which the struck vehicle is stopped (as opposed to rear-end collisions in which both vehicles are in motion).[37] Research indicates that a violation of driver expectancy can account for many accidents involving turning movements, and usually the actions of other drivers, rather than roadway geometry, are what violate expectancies.[38] When a driver slows or comes to a stop to turn, the following driver may be unprepared for the vehicle in his or her path, and a rear-end collision may ensue. Such situations frequently give rise to a hypervigilant reaction, or panic, on the part of the following driver, and human performance under hypervigilant conditions is generally less reliable than it is otherwise.

Hypervigilant Reactions (Panic)/Perceptual Narrowing. This term describes situations in which an individual is exposed to a strong, startling stimulus, sometimes perceived as life-threatening, accompanied by the perception that a solution must be found quickly. This combination of stimulus and perception can cause a temporary impairment of cognitive function; often, the individual appears to freeze, taking no action at all because his or her internal information processes are overloaded. The individual's attention narrows to the stimulus, and all other cues are missed. Some studies[39] have

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[37] T. A. Dingus, S.K. Jahns, A. D. Horowitz, and R. Knipling, "Human Factors Design Issues for Crash Avoidance Systems," in *Human Factors in Intelligent Transportation Systems*, W. Barfield and T.A. Dingus, eds. (Hillsdale, NJ: Lawrence Earlbaum Associates, 1998).

[38] R. Storm, "Pavement Markings and Incident Reduction," *The 2000 MTC Transportation Scholars Conference, Ames, IA*, 2000.

[39] See, for example, E.G. Beier, "The Effect of Induced Anxiety of Flexibility of Intellectual Functioning," *Psychological Monographs* Vol. 65, No. 326 (1951); M.M. Burkun, H.M. Bialek, R.P. Kern, and K. Yagi, "Experimental Studies of Psychological Stress in Man," *Psychological Monographs* Vol. 75, No. 534 (1962); H.H. Kelly, J.C. Condry, A.E. Dahlke, and A.T. Hill, "Collective Behavior in a Simulated Panic Situation," *Journal of Experimental Social Psychology* Vol. 1 (1965): 20-54; R.S. Weinberg and V.V. Hunt, "The Interrelationships Between Anxiety, Motor Performance, and Electromyography," *Journal of Motor Behavior* Vol. 8 (1976): 219-224; R.S. Weinberg and J. Ragan, "Motor Performance Under Three Levels of Trait Anxiety and Stress," *Journal of Motor Behavior* Vol. 10 (1978): 169-176; and W.D. Fenz and G.B. Jones, "Individual Differences in Physiological Arousal and Performance in Sport Parachutists," *Psychosomatic Medicine* Vol. 34 (1972): 1-8.

shown simplistic reasoning and thinking, primitive motor control, and strong emotions among individuals who are in a hypervigilant state. Due to stress, this hypervigilant state can set the stage for a habitual response.

Habitual Responses Under Stress. When expectancies are violated and a driver suddenly perceives a dangerous situation, for example, an impending collision, the driver is placed under stress and may revert to a generic or habitual response, such as hard braking. Actions executed under stressful conditions, coupled with limitations on the time that the driver has to respond, can result in error. Under such conditions, an individual may attempt to emit more than one response simultaneously[40]—in the case of the accident driver, moving the foot to the brake pedal (the reasoned response) while simultaneously attempting to exert force on the pedal (the habitual response). The driver may not realize he has performed these responses in parallel, rather than serially, as intended. To complicate matters further, because the driver believes his or her foot is already on the brake when it is, in fact, on the accelerator, "hard braking" produces more acceleration. The unexpected acceleration again violates the driver's expectancy, producing more stress, and so on.

In statements to police, the accident driver indicated that he might have gotten the brake and the accelerator confused. These statements show the driver was aware that he needed to stop his vehicle, knew that braking was the appropriate response, and attempted to execute that response, thereby eliminating an error in response choice as a potential factor. Therefore, the Safety Board concludes that the accident driver made an error in response execution, inadvertently accelerating when he intended to brake, that resulted in the collision with the Mercedes Benz.

Error Detection and Correction

Although unintended acceleration is a rare phenomenon, the failure to detect inadvertent activation of the accelerator is comparatively common, explaining why drivers frequently insist they were pressing the brake when, in fact, they were pressing the accelerator.[41] This detection failure may result from the limited feedback provided after the response is executed. Among the human factors concepts that help account for the error are "efference copy"[42] (the brain orders a response and erroneously assumes it will be correctly executed) and selective attention (the driver, as a consequence of paying attention to the environment, steering, shifting, and so forth, is never able to verify the foot's actual position). Admittedly, such factors, regardless of their validity, fail to explain

[40] A situation similar to that described by Kantowitz in B.H. Kantowitz, ed., "Double Stimulation," *Human Information Processing* (Hillsdale, NJ: Lawrence Earlbaum Associates, 1974).

[41] Schmidt (1989).

[42] Efferent neural signals arouse or stimulate the muscles. When a neural signal or motor command produces certain sensory consequences with reasonable consistency, that consistency can make it unnecessary for the brain to conduct detailed sensory feedback processing. The term "efference copy" refers to what happens when the body sends a "copy" or duplicate of a frequently sent command to a body part (a limb, for example) to the sensory part of the brain in lieu of independent feedback from the actual response (for example, a limb movement). In other words, the *intent* is misperceived as the *effect.*

why the driver is not alerted to the mistake by the difference in expected vehicle position and dynamics when pressing the brake. But the fact that this difference again violates the driver's expectancies may at least partly account for the failure to immediately comprehend the incongruities.

Reaction times in simulated braking situations are on the order of 0.5 seconds. Unintended acceleration, however, can persist for as long as 12 seconds.[43] In this accident, the driver proceeded for approximately 2 1/2 blocks before coming to rest, some 10 seconds later. Thus, the driver's delay in correcting his initial error is consistent with prior findings on unintended acceleration.

The driver knew that he needed to brake and said that he attempted to do so. Instead, he pressed the accelerator pedal, propelling his vehicle into the Mercedes, through the intersection, and into the farmers' market. The fact that he did not detect his response execution error, which resulted in the unintended acceleration, may have been due to sensory processing errors, selective attention, violated expectancies, or a combination of some or all of these factors. The Safety Board concludes that the driver of the 1992 Buick failed to detect his error in response execution, thereby inadvertently accelerating his vehicle and propelling it through the SMCFM.

The witness descriptions of a racing engine, as the Buick continued to accelerate through the market, are consistent with an habitual driver response. As the driver's stress level rose and he focused on trying to stop his vehicle, he probably reverted to the habitual response of hard braking, but did so before he had moved his foot from the accelerator to the brake pedal. When he perceived that "hard braking" was not working, the driver probably tried to "pump" his brakes—a trained response and one that suggests he was selectively focused on stopping. Because his foot was on the accelerator rather than the brake, the result would have been "revving" or racing of the engine and acceleration of the vehicle. One witness reported that the Buick appeared to *accelerate* in response to striking various objects; such acceleration is consistent with more forceful application of the accelerator pedal—or, in the mind of the driver, more forceful brake applications. Additionally, the driver stated that he attempted to move the column transmission shift into park, a maneuver that would have further distracted his attention from the foot pedals. Efforts to move the vehicle immediately after the accident prevented the police or Safety Board investigators from determining what gear the Buick was in when it stopped.

The Safety Board concludes that the accident driver most likely reverted to the habitual response of hard braking or "pumping" the brakes as his stress level increased and the vehicle failed to slow, but because his foot was on the accelerator rather than the brake pedal, this response led to increased acceleration. The Safety Board further concludes that the ineffectiveness of the accident driver's efforts to stop his vehicle and the realization that he was striking objects in his path very likely increased the already high level of stress affecting him, thereby impeding his ability to quickly detect and correct his earlier response execution error.

[43] Schmidt (1989).

Although the accident resulted from the driver's error in response execution and his failure to detect that error, Safety Board investigators were unable to gather sufficient information to determine with certainty whether the 86-year-old driver's age or use of nonprescription medications contributed to this accident. Neither the CHP or the SMPD cooperated with the Safety Board's investigation, and both declined to provide the Board with needed accident-related information, including witness and driver identities or statements, toxicological specimens, and on-scene data, until 6 months after the collision. As a result, the Safety Board conducted its investigation without the involvement of the police and without the access to certain critical and perishable information that the police had collected.

Older drivers are generally more susceptible to conditions that diminish cognition, perception, and physical reaction. An examination of the driver's medical history revealed that neither his orthopedic conditions, which affected his lower spine and legs, nor his general health were likely to have been factors in this accident. However, Safety Board investigators were denied access to the driver and, therefore, were unable to further evaluate his performance capabilities at the time of the accident.

Safety Board investigators were also unable to obtain a specimen of the driver's blood from the police, who tested for illicit drugs and prescription medications but did not test for nonprescription medications. Consequently, whether the driver used nonprescription medications, and, if he did, the possible effect on this accident are unknown. The Safety Board has found in previous investigations that over-the-counter medications can have detrimental effects on driver performance. The Board routinely tests toxicological specimens for evidence of the presence of such medications, which are not typically part of police-related toxicological testing. The Safety Board concludes that the contributions of the 86-year-old driver's age and use of nonprescription medications, if any, to his error in response execution and to his failure to detect that error could not be determined.

Adequacy of Temporary Traffic Control

When the Wednesday and Saturday SMCFMs were not in operation, Arizona Avenue was a through collector roadway open to vehicular traffic. Street closure to accommodate the SMCFMs involved a complex section of an urban collector road that included intersecting streets, alleyways, and traffic signals. Santa Monica was responsible for the maintenance and safety oversight of Arizona Avenue; it also sponsored and operated the two other farmers' markets located elsewhere, for a total of four, in the city. Each week, city contractors restricted vehicular traffic on Arizona Avenue by erecting traffic control devices based on a 1986 temporary traffic plan for the farmers' market. The temporary traffic plan failed to provide barriers and allowed vehicular traffic from the alleyway between Second and Third Streets to flow unimpeded into the pedestrian zone.

The full closures on Arizona Avenue at the alley between Third and Fourth Streets, as well as the Second Street closure, had only type I and A-frame plastic barricades in place, although the CTM,[44] the WATCH manual, and the MUTCD all recommend type III barricades. Furthermore, as this accident demonstrated, the barricades erected at the time provided no positive or rigid barrier between vehicular and pedestrian traffic along Arizona Avenue or any of the intersecting streets. In addition, Santa Monica apparently never recognized that, although Arizona Avenue was closed during the operation of the SMCFM, the traffic signals at the Second and Third Street intersections continued to operate on a normal green-yellow-red cycle, potentially providing motorists who were looking beyond the road closures, or who could not see them because of traffic, with conflicting signals.

The SMCFM on Arizona Avenue had been operating since 1981; however, Santa Monica had not revised or updated the traffic plan since 1986. Thus, the city apparently had not compared the traffic plan with its own internal guidance or with State and Federal guidance regarding temporary road closures.

At the time of the accident, Santa Monica indicated that it used the WATCH manual to determine what traffic controls should be in place for temporary street closings in the city. But the temporary traffic control devices erected on Arizona Avenue during operation of the SMCFM did not conform to the guidelines in this handbook. During street closures, the handbook called for two ROAD CLOSED signs mounted on type III barricades and advance warning signs on the approaches to the closed road. Figure 13 depicts the traffic controls that probably would have been in place for the SMCFM, had Santa Monica complied with its own traffic control handbook.

The CTM and the MUTCD were also available to the city's Transportation Management Division before the accident. The CTM sets forth basic principles governing the design and use of traffic control devices for all streets and highways open to public travel in California. It also specifically requires protection of pedestrians and workers in temporary traffic control areas. Both the CTM and the MUTCD call for ROAD CLOSED signs, advance warning signs, *at least* [emphasis added] type III barricades, and optional detour and route marking signs. Figure 14 depicts the probable traffic control plan that would have been in place, had Santa Monica complied with State and Federal guidelines.

Thus, Santa Monica failed to comply not only with its own guidance, but also with State and Federal guidelines regarding temporary road closures for the SMCFM. As a result, the temporary traffic control devices erected along Arizona Avenue at the time of the accident did not provide the more robust barricades recommended in city, State, and Federal manuals and sent conflicting messages to motorists by, for example, allowing traffic signals at Second and Third Streets to function, even though the road was not open to through traffic. While the signage is unlikely to have affected the accident driver's actions, it could be critical in another situation in which a driver is impaired or distracted and does not understand that Arizona Avenue is closed to vehicular traffic.

[44] Section 5-05.6, "Channelizing Devices."

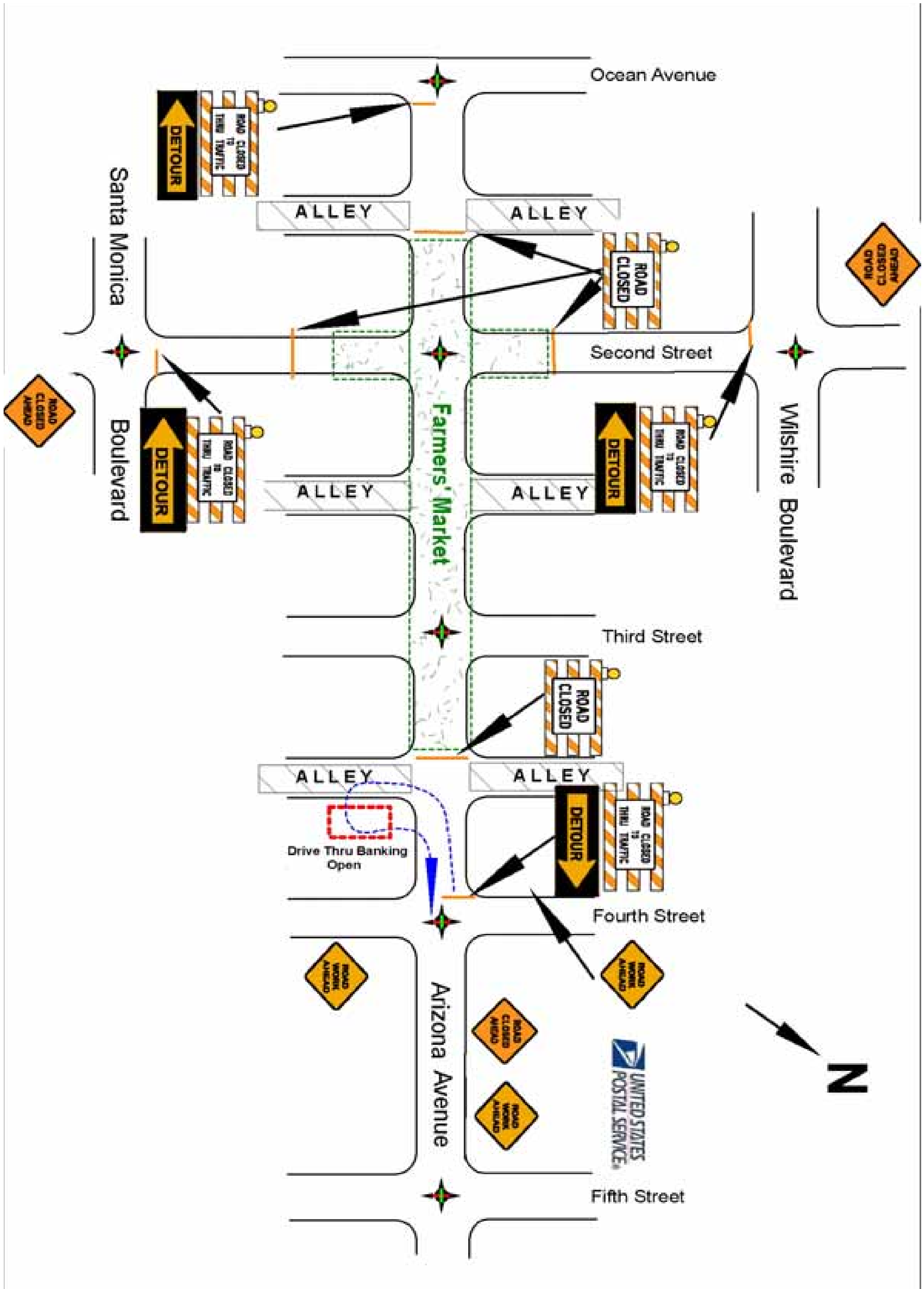

Figure 13. SMCFM traffic control measures that comply with city guidelines.

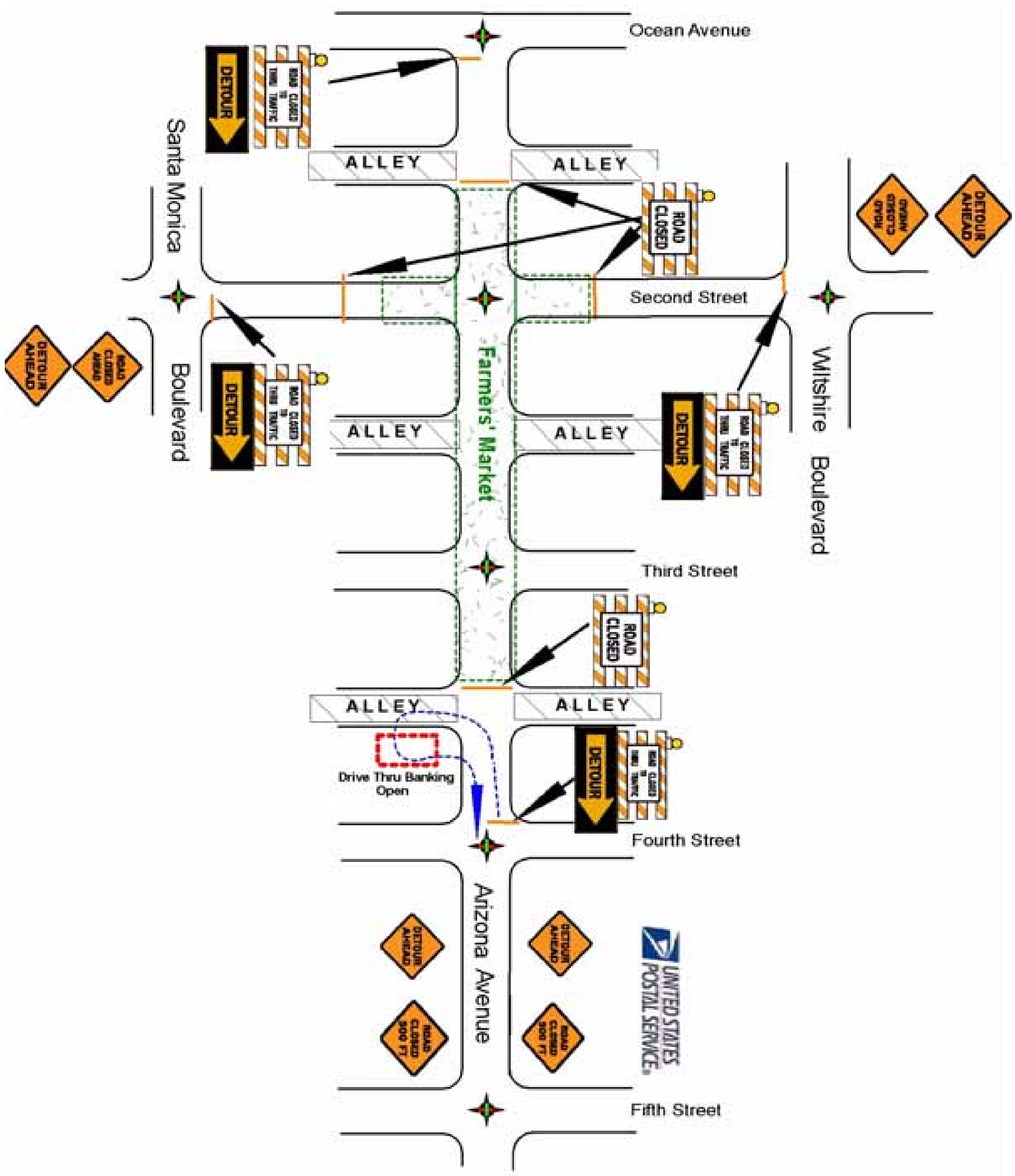

Figure 14. SMCFM traffic control measures that comply with CTM and MUTCD guidelines.

The Safety Board therefore concludes that the city's temporary traffic plan for closure of Arizona Avenue to accommodate the SMCFM was not consistent with established local, State, or national guidelines and was inadequate to ensure the safe flow of vehicular and pedestrian traffic in the area. The temporary traffic control plan for the market had been developed more than 2 decades ago and revised only once 5 years later. Since the 1986 revision, both the CTM and the MUTCD were updated several times.

Considering the changes in traffic engineering guidelines and practices, as well as local traffic patterns and volumes, over time, the Safety Board believes that Santa Monica should update its temporary traffic plans for roadway closures to ensure the safe operation of its certified farmers' markets and should review and evaluate the adequacy of the plans annually.

Additional signs and type III barricades alone would not have prevented the accident vehicle from entering the pedestrian zone in the SMCFM. The premise underlying the use of such barricades, as well as the guidance provided in the WATCH manual, the CTM, and the MUTCD, is that the road closures in question are indeed temporary situations. However, the SMCFM was a regularly recurring, albeit intermittent, event and, thus, different from the typical one-time work areas addressed in the guides. The Arizona Avenue road closure for the Wednesday SMCFM had occurred twice each week for more than 20 years and was therefore a sustained and predictable operation.

Furthermore, encouraging patrons of the SMCFM and other pedestrians to occupy the roadway when it was closed should have led city officials to consider measures to protect those pedestrians from vehicular traffic. Following the accident, vendors in the SMCFM, recognizing the need for more substantial protection from errant vehicles, moved their personal vehicles to block access to Arizona Avenue. Although the vendors' intent was to provide a barrier between traffic and the market, vehicles are not generally an appropriate countermeasure for this purpose. Vehicles are not specifically designed to absorb a collision from, or to redirect, an errant vehicle, and they contain flammable liquids and components. When vehicles are used for such purposes, for example, in mobile work zones, they are typically equipped with crash attenuating devices. In situations such as the SMCFM, however, other, more appropriate options for positive separation are available to protect pedestrians from errant vehicles.

Segregating pedestrian from vehicular traffic is a key element in pedestrian safety. Positive barriers between pedestrians and vehicles, although not always viable, are the best method of ensuring this segregation. During temporary road closures, the nature, frequency, and duration of the closure does not always allow for durable positive barriers. However, in situations such as the SMCFM, which took place every Wednesday and Saturday, the temporary closure was scheduled, recurring, and of sufficient duration to warrant use of positive barriers. A positive rigid barrier system would very likely have prevented the accident vehicle from intruding into the pedestrian area.

Santa Monica recognized the need for and value of positive, rigid barriers to protect pedestrians when the city installed removable bollards on the Third Street pedestrian promenade (see figure 10). Metal bollards at the entrances along Arizona Avenue protect the Third Street promenade, a dedicated pedestrian mall that was once a through street. The bollards, while designed to be permanently placed in the roadway, can also be lowered to allow passage of traffic, if necessary. By providing a rigid, positive separation between vehicles and pedestrians, bollards reduce the likelihood of vehicular incursion into pedestrian traffic areas.

Other jurisdictions have also recognized the utility of such barriers in protecting pedestrians during temporary road closures. For example, in the early 1980s, the New Orleans city council passed an ordinance making Bourbon Street a pedestrian mall during nighttime hours. To protect pedestrians on the closed street, the city placed removable bollards in the roadway. The Bourbon Street bollards, which extend about 40 inches above ground and 6 inches into the ground, are placed into metal collars embedded in the roadway. According to the traffic engineer for the city's Department of Public Works, New Orleans does not keep records of the bollards' effectiveness in stopping errant vehicles from entering the pedestrian mall. However, the poles are often bent and need to be replaced, showing that they have successfully deterred vehicles from entering the closed area.

The *Roadside Design Guide* does not specifically reference bollards. Santa Monica indicated that it did not consider bollards for the SMCFM because the road closure for the farmers' market was not permanent. However, as the New Orleans experience demonstrates, rigid barriers can be utilized effectively for recurrent, temporary road closures. Therefore, the Safety Board concludes that had Santa Monica installed a temporary rigid barrier system, such as bollards, at the closure limits of the SMCFM, the barrier system might have arrested or reduced the forward motion of the accident vehicle, thereby preventing it from continuing into the farmers' market and eliminating or greatly reducing the number of casualties. The Safety Board believes that Santa Monica should install a temporary rigid barrier system at the closure limits of the SMCFM to provide a physical barrier to errant vehicles entering the market.

Currently, the MUTCD provides guidance on the use of additional countermeasures, such as concrete traffic barriers or crash cushions, to protect pedestrians. Additionally, the *Roadside Design Guide*, referenced in the MUTCD, discusses the design and application of such countermeasures. However, the majority of the information presented in both the MUTCD and the *Roadside Design Guide* focuses on work zones. While the countermeasures in question may also be deployed for other types of street closures, the references and information in the guides have a strong enough emphasis on work zones that users may have difficulty recognizing their applicability to other situations. For example, the *Roadside Design Guide*'s section on traffic barriers specifies "work-zone traffic barriers" as it begins its discussion of the subject. Similarly, chapter 6B.01 of the MUTCD states: "The control of road users through a temporary traffic control zone shall be an essential part of highway construction, utility work, maintenance operations, and incident management."

Although the principles of incident management set forth in the MUTCD and related guidance are intended to apply equally to road closures for events such as the SMCFM, parades, and similar activities, that intent is not highlighted and may be overlooked. Therefore, the Safety Board concludes that the MUTCD's guidance on temporary traffic control is insufficiently clear to ensure that users will apply it to road closures not associated with highway construction or maintenance. The Safety Board believes that the FHWA should revise the *Manual on Uniform Traffic Control Devices*, Chapter 6, "Temporary Traffic Control," to provide specific references and guidance on the use of barricades, barriers, crash cushions, and other devices, as appropriate, for road closure situations other than highway construction or maintenance. The Safety Board will inform AASHTO, the American Public Works Association, the U.S. Conference of Mayors, the National Association of Counties, and the National Association of Towns and Townships of the circumstances of this accident, emphasizing the importance of physical barriers, as well as periodic reviews of traffic control plans, in protecting the public at farmers' markets and similar events.

Event Data Recorders

Had the accident vehicle been equipped with an EDR, the recorder would probably have collected valuable information about this accident. Driver and witness statements indicate that an unintended acceleration, initiated by pedal misapplication, most likely led to the accident. However, precise information about the Buick driver's actions before and during the collision with the Mercedes is unavailable. Similarly, the driver's precise actions—for example, whether he steered, braked, or accelerated—while traversing the farmer's market are not known. Additionally, how the vehicle was finally brought to a stop cannot be determined. While preliminary observations suggested that the driver's age or medical condition might have contributed to the accident, no age-related or medical factors were identified during the investigation. As a result, determination of the cause of the accident driver's actions had to be based on analysis of the limited investigative information, such as witness statements, available. Therefore, the Safety Board concludes that, had the accident vehicle been equipped with an event data recorder, a significantly higher level of science could have been applied to assessing and understanding the driver's behavior, as well as its contribution to this accident and the broader issue of unintended acceleration.

As in most accidents, the role of human factors in the Santa Monica accident could not be definitively determined or completely understood. By providing more comprehensive data on driver performance and behavior, EDRs assist safety researchers, accident investigators, and automotive designers in developing effective means for preventing similar occurrences. Better information about driver inputs and responses helps researchers understand whether certain brake and throttle geometry relationships affect the accident rate and whether certain drivers are at higher risk for performance-related accidents.

In addition, by providing prompt and impartial crash-related information, EDRs benefit law enforcement personnel, who are responsible for determining the facts and circumstances of highway accidents. Manufacturers can also use such data to improve vehicle design and to assist in the diagnosis of vehicle systems. EDR data have value for the health care community, which can base on-site injury triage decisions on more accurate and complete information, and assist in the deployment of appropriate emergency services by triggering automated systems that alert responders to the nature of an incident. Private vehicle owners have access to EDR information on how their vehicles have been operated and whether vehicles have been in previous crashes. Thus, vehicle EDRs provide qualitative and quantitative information critical to improving highway safety.

Recent integration of the event recording function with the crash detection and deployment functions of automotive air bag system controls has provided a hitherto unavailable source of unbiased, factual information. Some U.S. vehicle manufacturers have integrated limited event recording capability into their products by including this functionality in the vehicle's air bag control system. However, the parameters recorded and the manner in which the data are accessed are not uniform. Through years of experience with EDRs in the aviation, rail, and marine modes of transportation, the Safety Board and the transportation industry have learned a great deal about the effective integration and use of recording technology. Establishing industry standards for recording in these modes has been critical to effective EDR implementation. Industry standards ensure consistency and compatibility and prevent the unnecessary and inefficient proliferation of multiple formats and configurations.

The factors identified in developing event data recording standards for other modes of transportation provide a basis for formulating highway EDR standards in areas such as the specific data parameters to be recorded, sampling rates, recording duration, data extraction interface configurations, and data storage formats. Additionally, data survivability issues, such as backup power supplies and resistance to fluid immersion, impact shock, crush penetration, and fire must also be considered. The benefits of industry standards already realized in other modes of transportation demonstrate the need for similar EDR standards in the automotive industry.

NHTSA, the IEEE, and the SAE have efforts under way that provide a standardization platform to build upon, thereby ensuring that the benefits of EDRs can be realized quickly and efficiently for all light-duty vehicles. NHTSA's recently announced NPRM regarding EDR standards for light-duty vehicles is a welcome step forward and is necessary to ensure the timely and efficient implementation of EDR technology into the highway transportation system. In that NPRM, NHTSA has indicated that it does not propose to require that newly manufactured vehicles be equipped with EDRs. It has also predicted that 65 to 90 percent of new vehicles will be equipped with EDRs. The Safety Board is concerned that, unless installation of EDRs is mandatory, collection of national crash data will be incomplete. Effectively developing and establishing highway safety policy is dependent on accurate information about the causes of accidents. Collection of only partial fleet information could undermine the implementation of the most appropriate and cost-effective highway safety countermeasures. Therefore, the Safety Board concludes that NHTSA's proposed rulemaking on standards governing voluntary, rather than mandatory, installation of EDRs in light-duty vehicles will not result in obtaining the maximum highway safety benefits from this technology. The Safety Board believes that once standards for EDRs are developed, NHTSA should require their installation in all newly manufactured light-duty vehicles.

Conclusions

Findings

1. The weather; the mechanical condition and design of the vehicle, in particular, the horizontal separation of the control pedals; and the driver's experience and familiarity with his vehicle and the area of the farmers' market were not factors in this accident.

2. Although the driver had a history of medical treatment for orthopedic conditions, neither these conditions, nor his general health, nor his use of prescription medications, nor insufficient sleep or fatigue were likely to have been factors in this accident; test results did not indicate that alcohol or illicit drugs were likely to have contributed to the accident.

3. The accident driver made an error in response execution, inadvertently accelerating when he intended to brake, that resulted in the collision with the Mercedes Benz.

4. The accident driver failed to detect his error in response execution, thereby inadvertently accelerating his vehicle and propelling it through the Santa Monica Certified Farmers' Market.

5. The accident driver most likely reverted to the habitual response of hard braking or "pumping" the brakes as his stress level increased and the vehicle failed to slow, but because his foot was on the accelerator rather than the brake pedal, this response led to increased acceleration.

6. The ineffectiveness of the accident driver's efforts to stop his vehicle and the realization that he was striking objects in his path very likely increased the already high level of stress affecting him, thereby impeding his ability to quickly detect and correct his earlier response execution error.

7. The contributions of the 86-year-old driver's age and use of nonprescription medications, if any, to his error in response execution and to his failure to detect that error could not be determined.

8. Santa Monica's temporary traffic plan for closure of Arizona Avenue to accommodate the Santa Monica Certified Farmers' Market was not consistent with established local, State, or national guidelines and was inadequate to ensure the safe flow of vehicular and pedestrian traffic in the area.

9. Had Santa Monica installed a temporary rigid barrier system, such as bollards, at the closure limits of the Santa Monica Certified Farmers' Market, the barrier system might have arrested or reduced the forward motion of the accident vehicle, thereby preventing it from continuing into the farmers' market and eliminating or greatly reducing the number of casualties.

10. The *Manual on Uniform Traffic Control Devices*' guidance on temporary traffic control is insufficiently clear to ensure that users will apply it to road closures not associated with highway construction or maintenance.

11. Had the accident vehicle been equipped with an event data recorder, a significantly higher level of science could have been applied to assessing and understanding the driver's behavior, as well as its contribution to this accident and the broader issue of unintended acceleration.

12. The National Highway Traffic Safety Administration's proposed rulemaking on standards governing voluntary, rather than mandatory, installation of event data recorders in light-duty vehicles will not result in obtaining the maximum highway safety benefits from this technology.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the Buick driver to maintain control of his vehicle due to his unintended acceleration. Contributing to the severity of the accident was the lack of a barrier system to protect pedestrians in the Santa Monica Certified Farmers' Market area from errant vehicles.

Recommendations

To the Federal Highway Administration:

Revise the *Manual on Uniform Traffic Control Devices*, Chapter 6, "Temporary Traffic Control," to provide specific references and guidance on the use of barricades, barriers, crash cushions, and other devices, as appropriate, for road closure situations other than highway construction or maintenance. (H-04-25)

To the National Highway Traffic Safety Administration:

Once standards for event data recorders are developed, require their installation in all newly manufactured light-duty vehicles. (H-04-26)

To the city of Santa Monica:

Install a temporary rigid barrier system at the closure limits of the Santa Monica Certified Farmers' Market to provide a physical barrier to errant vehicles entering the market. (H-04-27)

Update your temporary traffic plans for roadway closures to ensure the safe operation of the city's certified farmers' markets and review and evaluate the adequacy of the plans annually. (H-04-28)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Adopted: August 3, 2004

Appendix A

Investigation and Public Hearing

The National Transportation Safety Board was notified of the Santa Monica, California, accident on July 16, 2003. The Safety Board dispatched an investigative team consisting of members from the Washington, D.C., Atlanta, Georgia, and Denver, Colorado, offices. Groups were established to investigate human performance and highway, vehicle, and survival factors.

Representatives of the city of Santa Monica participated in the investigation.

No public hearing was held; no depositions were taken.

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