School Bus Run-off-Bridge Accident Omaha, Nebraska, October 13, 2001

Highway Accident Report

NTSB/HAR-04/01

PB2004-916201
Notation 7610

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. *School Bus Run-off-Bridge Accident, Omaha, Nebraska, October 13, 2001.* Highway Accident Report NTSB/HAR-04/01. Washington, DC.

Abstract: On Saturday, October 13, 2001, about 2:00 p.m. central daylight time, a 2000 Thomas Built Buses, Inc., 78-passenger school bus carrying 27 Seward High School students and 3 adults (excluding the driver) was traveling westbound through a work zone on U.S. Route 6 in Omaha, Nebraska. As the Seward bus entered the work zone lane shift at the approach to the West Papillion Creek Bridge, it encountered a 1986 Motor Coach Industries 52-passenger motorcoach carrying Norfolk High School students traveling eastbound. Although no collision occurred between the Norfolk and Seward buses, the westbound school bus departed the traveled roadway on the right and subsequently struck the W-beam barrier on the approach to the bridge, steered to the left momentarily, and then steered abruptly back to the right, striking the W-beam again and, finally, a three-rail barrier between the guardrail and the concrete bridge railing. The bus passed through the remains of the three-rail barrier, rode up onto the bridge's sidewall, and rolled 270 degrees clockwise as it fell about 49 feet, landing on its left side in a 1-foot-deep creek below the bridge. Three students and one adult sustained fatal injuries. The remaining passengers and the busdriver sustained injuries ranging from serious to minor.

Major safety issues identified in this report include the effect of highway design, speed, and vehicle handling characteristics upon driver performance; adequacy of work zone safety management; lack of emergency preparedness of students; visibility of emergency signage and exit door levers; and school bus extrication training.

As a result of this accident investigation, the National Transportation Safety Board makes recommendations to the Federal Highway Administration, Nebraska Department of Roads, Omaha Fire Department, National Association of State Directors of Pupil Transportation Services, and Thomas Built Buses, Inc.

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Contents

Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ABS	antilock braking system
ADT	average daily traffic
ATSSA	American Traffic Safety Services Association
Bendix	Bendix Commercial Vehicle Systems
CDL	commercial driver's license
CFR	*Code of Federal Regulations*
CVSA	Commercial Vehicle Safety Alliance
DCSO	Douglas County Sheriff's Office
ECM	electronic control module
ECU	electronic control unit
EDGEN	Engineering Dynamics Corporation General Analysis Tool
EDSMAC4	Engineering Dynamics Corporation Simulation of Automobile Collisions
FHWA	Federal Highway Administration
FMCSR	Federal Motor Carrier Safety Regulation
FMVSSs	*Federal Motor Vehicle Safety Standards*
HVE	*Human Vehicle Environment*
MCI	Motor Coach Industries
MUTCD	*Manual on Uniform Traffic Control Devices*
NASDPTS	National Association of State Directors of Pupil Transportation Services
NDOR	Nebraska Department of Roads
NHTSA	National Highway Traffic Safety Administration
NSP	Nebraska State Patrol
SERB	self-energy restoring barriers
SIMON	Simulation Model Non-linear
TCP	traffic control plan
Thomas Built	Thomas Built Buses, Inc.
TLTWO	two-lane, two-way operation
U.S. 6	U.S. Route 6
UMA	United Motorcoach Association

Executive Summary

On Saturday, October 13, 2001, about 2:00 p.m. central daylight time, a 2000 Thomas Built Buses, Inc., 78-passenger school bus carrying 27 Seward High School students and 3 adults (excluding the driver) was traveling westbound through a work zone on U.S. Route 6 in Omaha, Nebraska. As the Seward bus entered the work zone lane shift at the approach to the West Papillion Creek Bridge, it encountered a 1986 Motor Coach Industries 52-passenger motorcoach carrying Norfolk High School students traveling eastbound. Although no collision occurred between the Norfolk and Seward buses, the westbound school bus departed the traveled roadway on the right and subsequently struck the W-beam barrier on the approach to the bridge, steered to the left momentarily, and then steered abruptly back to the right, striking the W-beam again and, finally, a three-rail barrier between the guardrail and the concrete bridge railing. The bus passed through the remains of the three-rail barrier, rode up onto the bridge's sidewall, and rolled 270 degrees clockwise as it fell about 49 feet, landing on its left side in a 1-foot-deep creek below the bridge. Three students and one adult sustained fatal injuries. The remaining passengers and the busdriver sustained injuries ranging from serious to minor.

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the Nebraska Department of Roads to recognize and correct the hazardous condition in the work zone created by the irregular geometry of the roadway, the narrow lane widths, and the speed limit. Contributing to the accident was the accident bus driver's inability to maintain the bus within the lane due to the perceived or actual threat of a frontal collision with the approaching eastbound motorcoach and the accident bus driver's unfamiliarity with the accident vehicle. Contributing to the severity of the accident was the failure of the traffic barrier system to redirect the accident vehicle.

Major safety issues identified in this accident include:

- Effect of highway design, speed, and vehicle handling characteristics upon driver performance.
- Adequacy of work zone safety management.
- Lack of emergency preparedness of students.
- Visibility of emergency signage and exit door levers.
- School bus extrication training.

As a result of this accident investigation, the National Transportation Safety Board makes recommendations to the Federal Highway Administration, Nebraska Department of Roads, Omaha Fire Department, National Association of State Directors of Pupil Transportation Services, and Thomas Built Buses, Inc.

Factual

Accident Narrative

On Saturday, October 13, 2001, about 2:00 p.m. central daylight time, a 2000 Thomas Built Buses, Inc., (Thomas Built) 78-passenger school bus carrying 27 Seward High School students and 3 adults (excluding the driver) was traveling westbound on U.S. Route 6 (U.S. 6), West Dodge Road, in Omaha, Nebraska (see figure 1). Witnesses estimated the vehicle's speed to be about 40 mph. The weather was clear and dry with gusting westerly winds of 20 mph.

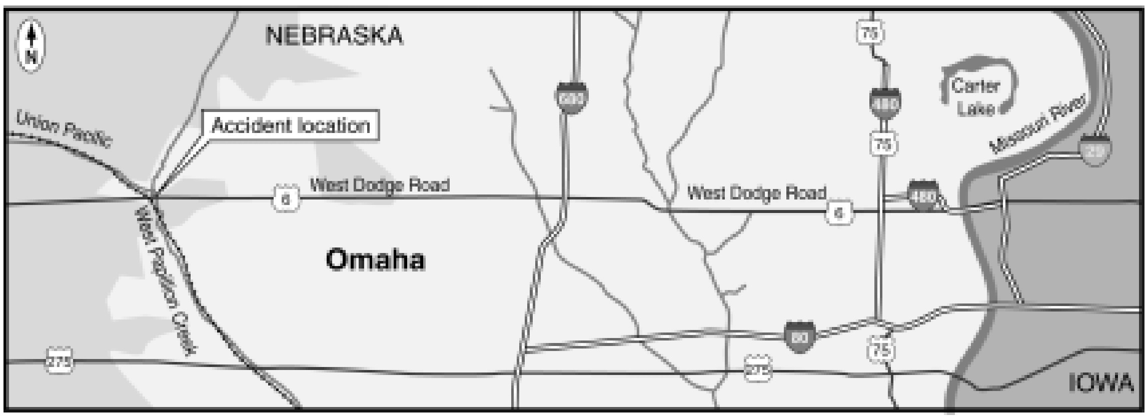

Figure 1. Accident location.

The six-lane highway was under construction,[1] and traffic was being channeled into two 10.5-foot-wide travel lanes (one lane in each direction) using 3-foot-high orange and white retroreflectorized barrels. (See figure 2.)

[1] The construction's purpose was to convert the roadway from a four-lane undivided highway to a six-lane divided highway. East of the accident site, the roadway was a six-lane divided highway.

Figure 2. Transition east of the accident site from a six-lane highway to a two-lane, undivided highway (*upper right*). (Source: Douglas County, Nebraska, Sheriff's Office [DCSO])

As the bus approached the West Papillion Creek Bridge, the roadway shifted slightly to the driver's left and then to the right. (See figure 3.)

Figure 3. Eastbound view of westbound lane shift, as shown in a summer 2001 Nebraska Department of Roads (NDOR) photo-logging image.

As the bus entered the work zone lane shift at the approach to the West Papillion Creek Bridge, it encountered a 1986 Motor Coach Industries (MCI) 52-passenger motorcoach carrying Norfolk High School students traveling eastbound. Although no collision occurred between the Norfolk and Seward buses, the westbound school bus departed the traveled roadway on the right and subsequently struck the W-beam barrier on the approach to the bridge, steered to the left momentarily, and then steered abruptly back to the right, striking the W-beam again and, finally, a three-rail barrier between the guardrail and the concrete bridge railing. The bus passed through the remains of the three-rail barrier, rode up onto the bridge's sidewall, and rolled 270 degrees clockwise as it fell about 49 feet, landing on its left side in a 1-foot-deep creek below the bridge (see figures 4 through 6).

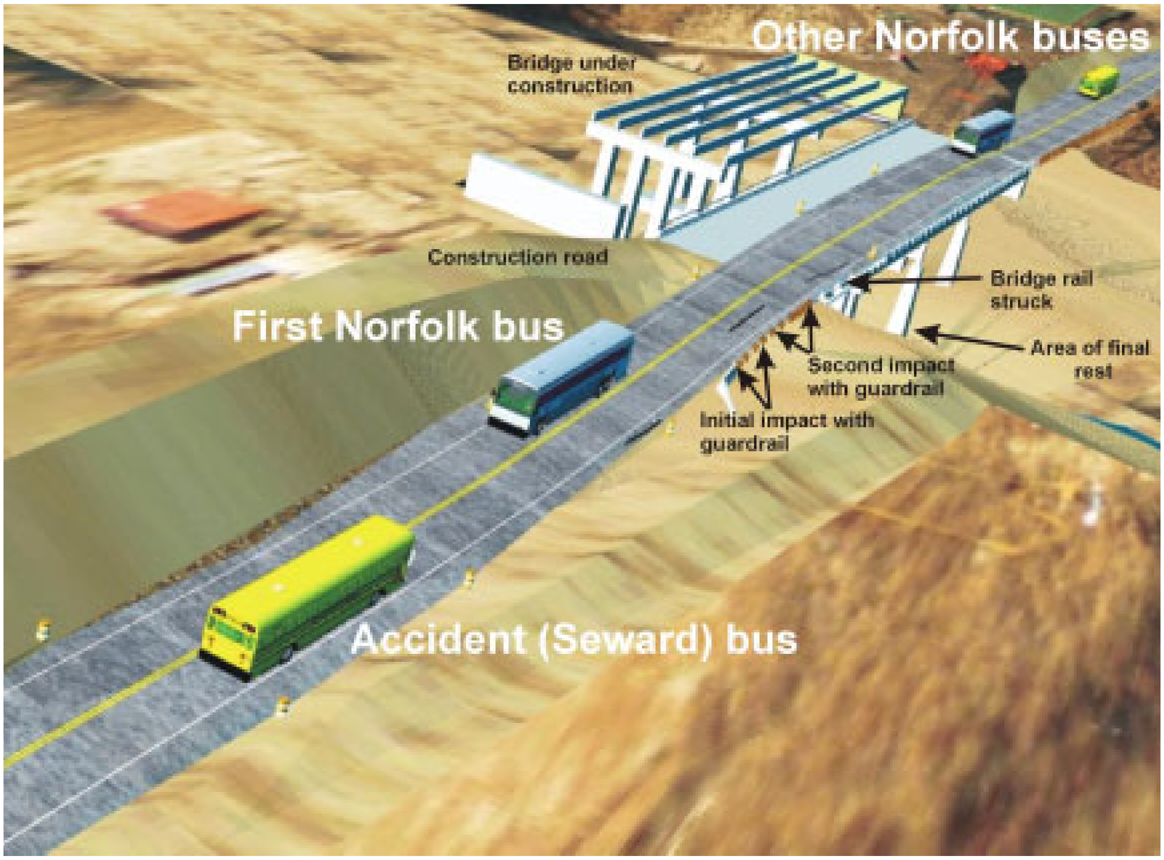

Figure 4. Aerial view of accident site.

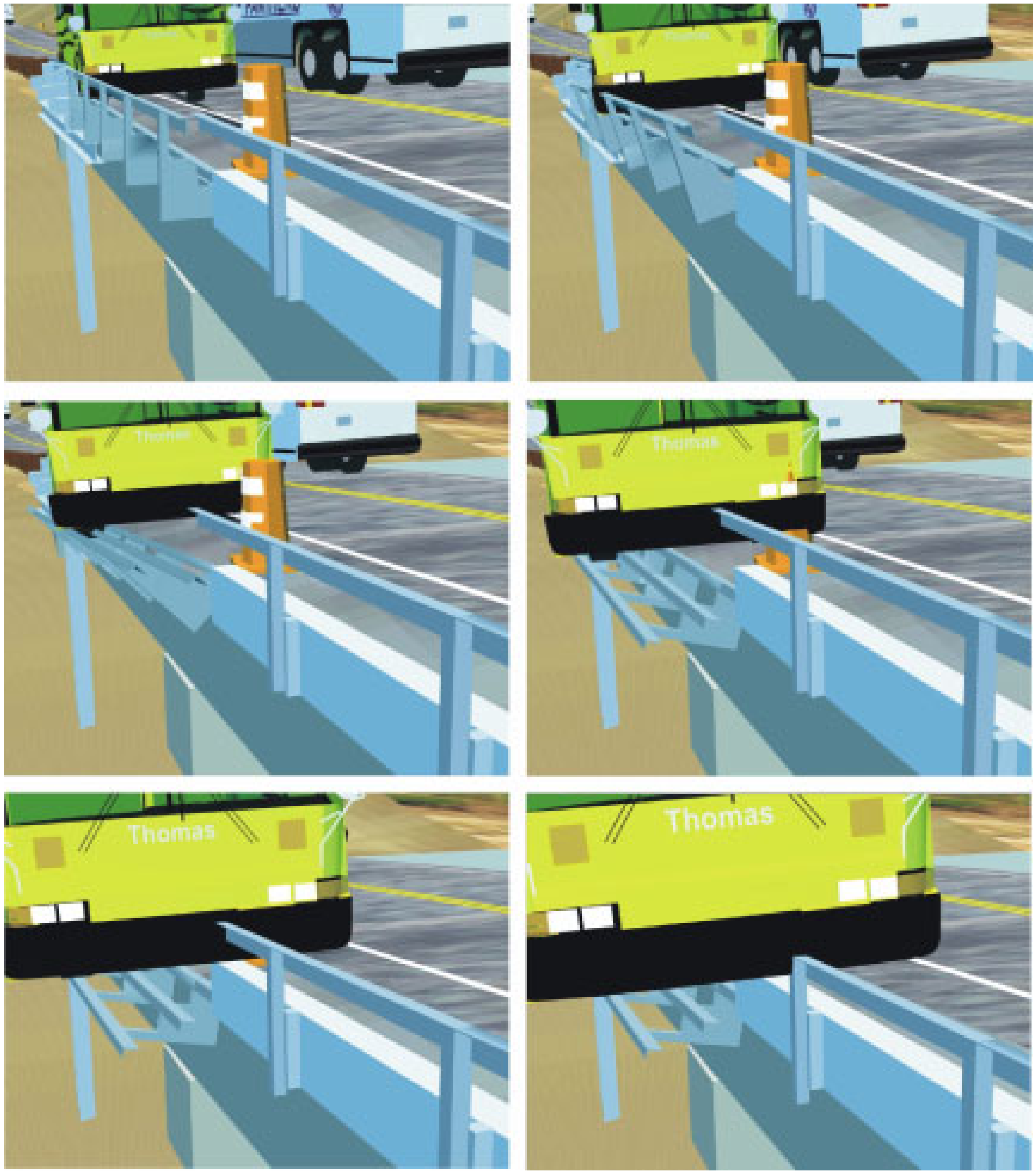

Figure 5. Accident bus departing bridge (simulation).

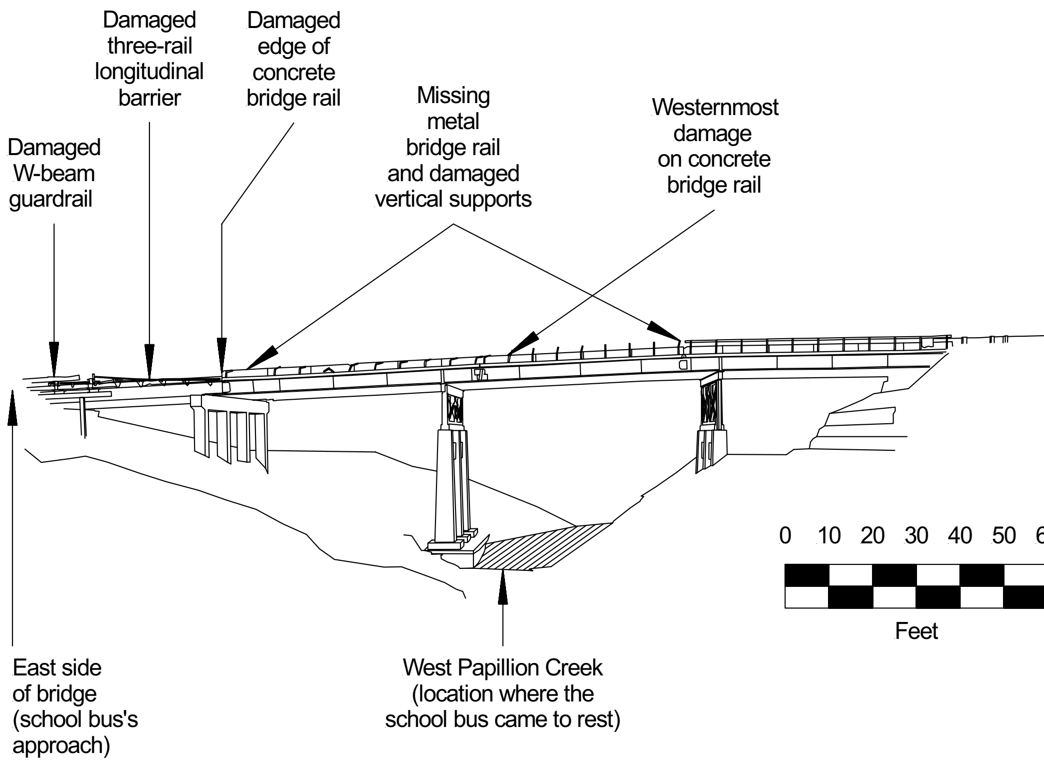

Figure 6. Side view of accident site and damage to West Papillion Creek Bridge. (Note: The diagram does not show the accident bus's initial impact with the guardrail on the east side of the bridge because the area's topography prevented the mapping tool from recording that portion of the bridge.)

Three students and one adult sustained fatal injuries in this accident; the remaining passengers and the busdriver sustained injuries ranging from serious to minor.

Preaccident Events

The night before the accident trip, the accident bus driver stated[2] that he went to bed about midnight and awoke about 7:00 a.m.[3] He said that he arrived at the high school with the accident bus about 10:00 a.m., after conducting a pretrip vehicle inspection at the bus yard.

[2] The accident bus driver sustained serious injuries in the accident, including a loss of consciousness, that prevented him from meeting with National Transportation Safety Board investigators until October 29, 2001, when he was interviewed by investigators from the Safety Board and the DCSO.

[3] The driver stated that on weekdays, he normally went to bed between 11:00 p.m. and midnight and awakened at 6:30 a.m. The accident trip occurred on a Saturday, normally one of the driver's days off.

On the day of the accident, the Seward High School band, which was scheduled to compete in a band competition at Burke High School in Omaha at 1:00 p.m., departed Seward High School about 11:00 a.m., 30 minutes behind schedule for the 1 1/2-hour trip to Omaha. The Seward band was transported in a five-vehicle convoy consisting of three school buses and two vans.

The Norfolk High School band, which was scheduled to compete in the same competition at 4:30 p.m., departed Norfolk High School about 1:45 p.m. in a six-vehicle convoy[4] consisting of two MCI motorcoaches, two school buses, and two vans (to transport the band equipment).

After the competition, the Seward band began its return trip. The first Seward bus was the accident vehicle. The second Seward bus was about 3 to 4 bus lengths behind the first bus, separated by a passenger vehicle, and the third bus was about 1/2 mile behind the first bus. The accident occurred about 10 minutes into the Seward band's return trip, when the first Seward school bus (accident bus) passed the first Norfolk bus traveling in the opposite direction in the U.S. 6 work zone (see figure 4), and then struck the guardrail as it approached the second Norfolk bus. The accident bus driver stated that he did not remember any events that occurred after departing the competition. Therefore, Safety Board investigators relied upon witness interviews to reconstruct the accident sequence.

Seward Witness Interviews

Safety Board investigators interviewed[5] some of the students who had been on the accident bus. They also interviewed the driver of and one parent who traveled on the second Seward bus.

A parent traveling on the second Seward bus, as well as two students on the accident bus, recalled an instance earlier in the day, while en route from Seward to Burke High School. These witnesses observed the right tire or tires of the bus leaving the interstate's travel lane, contacting the "rumble strip" on the right shoulder. The two students noted that they were alerted to the occurrence by the distinctive sound and vibration that accompanies driving on the rumble strip. Although the sound and vibration initially startled them, neither student reported feeling apprehensive or concerned about the driver's subsequent performance.

The parent traveling on the second bus had observed the bus from behind and cited several occasions during which the accident bus was "really on the right side…hugging the white line." She also recalled a curved stretch of road in Gretna, Nebraska, about 20 miles southwest of Omaha, where the bus splashed through a puddle of water on the shoulder. She emphasized that the driver had not "swerved" out of his lane, rather that his general alignment in the lane was frequently off-center, to the right. Yet, while noticeable,

[4] The leading vehicle had become separated from the rest of the convoy earlier, when the five vehicles following it had stopped for a traffic light. For the purposes of this report, the five remaining vehicles will be referred to by their order of procession, excluding the one that had become separated from the others.

[5] Safety Board interviews with the accident bus passengers, October 31 and November 1, 2001.

it caused her no concern at that time. “I really didn’t think anything about it because it was on a curve, and it’s a big bus,” she told investigators. She was familiar with the driver, and regarded him as capable, stating, “He pretty much concentrates on his driving.”

The driver of the passenger vehicle that was traveling directly behind the accident bus at the time of the accident provided a statement to the DCSO and Safety Board investigators on October 15, 2001, 2 days after the accident. The driver stated that just before the bus entered the slight left curve preceding the bridge, its right-rear tire left the pavement, followed by the front of the bus appearing to enter the eastbound lane before returning to the westbound lane, subsequently striking the guardrail. She stated that the accident bus continued along the guardrail until it rolled (clockwise) over the guardrail and off the bridge.

Although she could not recall her precise speed as the vehicles approached the bridge, she stated that all traffic appeared to be traveling at the same pace. She was uncertain whether she saw the brake lights of the bus illuminated and could not recall any details concerning the eastbound traffic. She also noted that traffic appeared unusually heavy for a Saturday. The witness, who travels U.S. 6 over the West Papillion Creek Bridge daily, told investigators that as she travels westbound through the left and right curves, it appears to her that oncoming traffic is moving into the westbound lane, even though she realizes that in fact, it does not. She also explained that just before she arrives at the point where the road narrows, there appears to be insufficient room for vehicles to travel in both directions.

On the return trip, none of the students aboard the accident bus observed the oncoming Norfolk buses, nor did they recall any of the features of the roadway or the work zone outside the bus. Some of the students interviewed stated that they had hung their band uniforms against the windows adjacent to their seats, obstructing their outside view. All were seated (or lying on the seats), and none described any activity that they considered unduly distracting to the driver.

The driver and students traveling on the second Seward bus also witnessed the accident and provided statements to the DCSO about 3 1/2 hours after the accident. One stated that she observed a bus,[6] eastbound on U.S. 6, “swaying into the opposite lane,” followed by what she believed to be the accident bus driver’s attempt to try to “swerve out of the way” of the oncoming bus. Another student stated that she observed an eastbound bus that appeared to “swerve kind of close to” the accident bus, followed by the accident bus swerving to the right. A third student seated in the front of the bus reported that she observed a “white or gray” eastbound bus “kind of swerve into our lane, then drive past.” A fourth student stated that she saw a gray bus “with wording on the side” approaching from the opposite direction. She stated that the gray bus was “just barely in our lane, but was swerving out of it.”

[6] Subsequently identified as an MCI motorcoach that was transporting students from Norfolk High School to the same band competition that the Seward bus had departed.

The 20-year-old driver of the second Seward bus provided a statement to DCSO less than 2 hours after the accident. He indicated that he was not watching at the moment the bus overturned, but had witnessed the events immediately preceding the accident. He stated that, just before the accident, the accident bus was traveling "pretty close to the right side of the road," and thereafter, "went briefly off the [right] curb and dust flew." He stated that they had slowed for the work zone; he was traveling at approximately 40 mph and slowing further on the approach to the bridge.

Safety Board investigators also spoke with one of the adult chaperons that traveled on the second bus and had witnessed the accident. She stated that the accident bus was not traveling very fast; she believed that the buses were driving "very cautiously" and "very reasonably for the conditions."

Norfolk Witness Interviews

Safety Board investigators interviewed the drivers[7] of the three eastbound buses that encountered the Seward bus convoy at the West Papillion Creek Bridge and three passengers[8] (two on the second Norfolk bus and one on the third Norfolk bus) who witnessed the accident. The three interviewed passengers commented on the narrowness of the roadway, one noting, "…it was really close in that S-curve thing. It was so close you could reach out and touch it [the Seward bus]." The Norfolk drivers' accounts of the accident are summarized below.

Driver of First Bus (#1027). The driver of the first bus in the Norfolk convoy stated that he travels to Omaha about six times per year, using U.S. 6, and that he was comfortable driving through the work zone at 40 mph. He stated that he held his speed at 40 to 45 mph as he traveled through the curves and estimated he was about 300 feet ahead of the second Norfolk bus.

He said that he saw the approaching accident bus as they entered the slight curve in the work zone. He did not believe that the roadway was too narrow for the two buses to pass each other. He estimated the accident bus's speed at between 45 to 50 mph, which he thought was too fast for conditions. As he passed the school bus, he glanced in his left sideview mirror and saw the accident bus go off the north side of the roadway. He did not realize the bus was crossing a bridge at the time.

Driver of Second Bus (#1024). Although the driver of the second bus had driven to Omaha before, this was the first time he had taken U.S. 6 since the construction had begun. He estimated that he was traveling 200 to 300 feet behind the preceding bus, with the third bus another "200 feet or so" behind him. He stated, "I'm not sure if I was even going 40 [mph] when I came into the curves…I slowed down somewhat."

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[7] Safety Board interviews with the Norfolk drivers, October 14 and 30, 2001.

[8] Safety Board interviews with Norfolk passengers, June 27, 2002.

The driver stated that as he neared the curve in the roadway, he clearly saw the accident bus driver approaching from the opposite direction.[9] He estimated the accident bus to be traveling about 55 mph. The driver noted that the first indication he had that the accident bus might be in trouble was when he saw the driver abruptly turn his steering wheel to the right, stating, "everything was routine until then." He added, "…from a distance, I couldn't really tell where his eyes were looking, but his head looked like he was faced straight ahead."

When the accident bus was about 100 feet in front of the Norfolk driver and closing, he said he clearly saw the accident bus driver, with a startled look on his face. He noted that the accident bus driver had both hands on the steering wheel and saw him turn the steering wheel to the [accident bus driver's] right. He believed that the right rear of the school bus then struck the north side of the curbing on the roadway. The rear of the bus began to rotate to the south (clockwise) and tilt to the [the accident bus driver's] left. He estimated it rotated about 20 degrees, and he thought it was going to strike his vehicle as they passed each other. He slowed to about 20 mph. As they passed each other, he glanced in his left side-view mirror and saw the bus "flip over in a cloud of dust" and disappear. He did not remember seeing any brake lights on the accident bus. He did not realize they were on a bridge at the time and thought the bus had just gone off the pavement.

Driver of Third Bus (#12). The driver of the third, and last, Norfolk bus estimated he was 300 to 400 feet behind the second bus (#1024). The driver of the third bus estimated that they had been traveling at 45 mph, slowing to 40 mph after a sign that indicated a curve ahead. He stated that he slowed down further as he went into the curve. He stated that he first saw the accident bus as he was going into the curve and the bus ahead of him proceeded.

He described the accident bus as "kind of hanging off to the right hand side of the road… out of control." He stated that the bus was too far to the right, and he observed the driver gripping the wheel and seemingly trying to bring the bus over to the left, explaining, "then he started coming toward me." He stated that he then tried to steer his bus as far as possible to the right, but before the driver of the accident bus could maneuver his bus to the left, he struck the guardrail. This driver stated that he saw the accident bus move up the guardrail and then appear to straighten out, so that it was no longer heading toward the eastbound traffic lane.

The driver told investigators that his vehicle had not crossed the centerline, stating "…from my point of view, from the back, I did not see any tires or nothing cross that line, the centerline."

Driver of Fourth Vehicle (Van). The driver of the next vehicle in the convoy and the school's band director, a passenger in that van, related that they were traveling about 40 mph through the work zone. They first noticed that something was happening when they saw the brake lights of the school bus in front of them come on and the bus slow rapidly. They then noticed the oncoming accident bus traveling westbound. The rear of the

[9] These events occurred within a few seconds as the vehicles approached and passed each other.

bus was angled to the south and they thought it might strike the school bus in front of them.

The driver and band director saw the bus in front of them move as far to the right as it could without going off the pavement to avoid the accident bus. They said that they could clearly see the accident bus driver's face, that he appeared panicked and was trying to regain control of the vehicle by turning the steering wheel to his left. The bus appeared to "ramp up" the bridge railing, its right front wheel off the ground. They then saw the steering wheel being "ripped" to the driver's right. All the wheels subsequently came off the ground and the bus tipped over to the right (north) and out of sight. They further recalled seeing the undercarriage of the bus as it tipped over the railing.

Injuries

Table 1. Injury codes.[10]

Injuries	Busdriver	Bus passengers	Total
Fatal	0	4	4
Serious	1	16	17
Minor	0	10	10
None	0	0	0
Total	1	30	31

Medical and Pathological Information

All 30 of the accident bus passengers and their driver were injured. The severity of their injuries and their seating locations are shown in figure 7.

[10] 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.

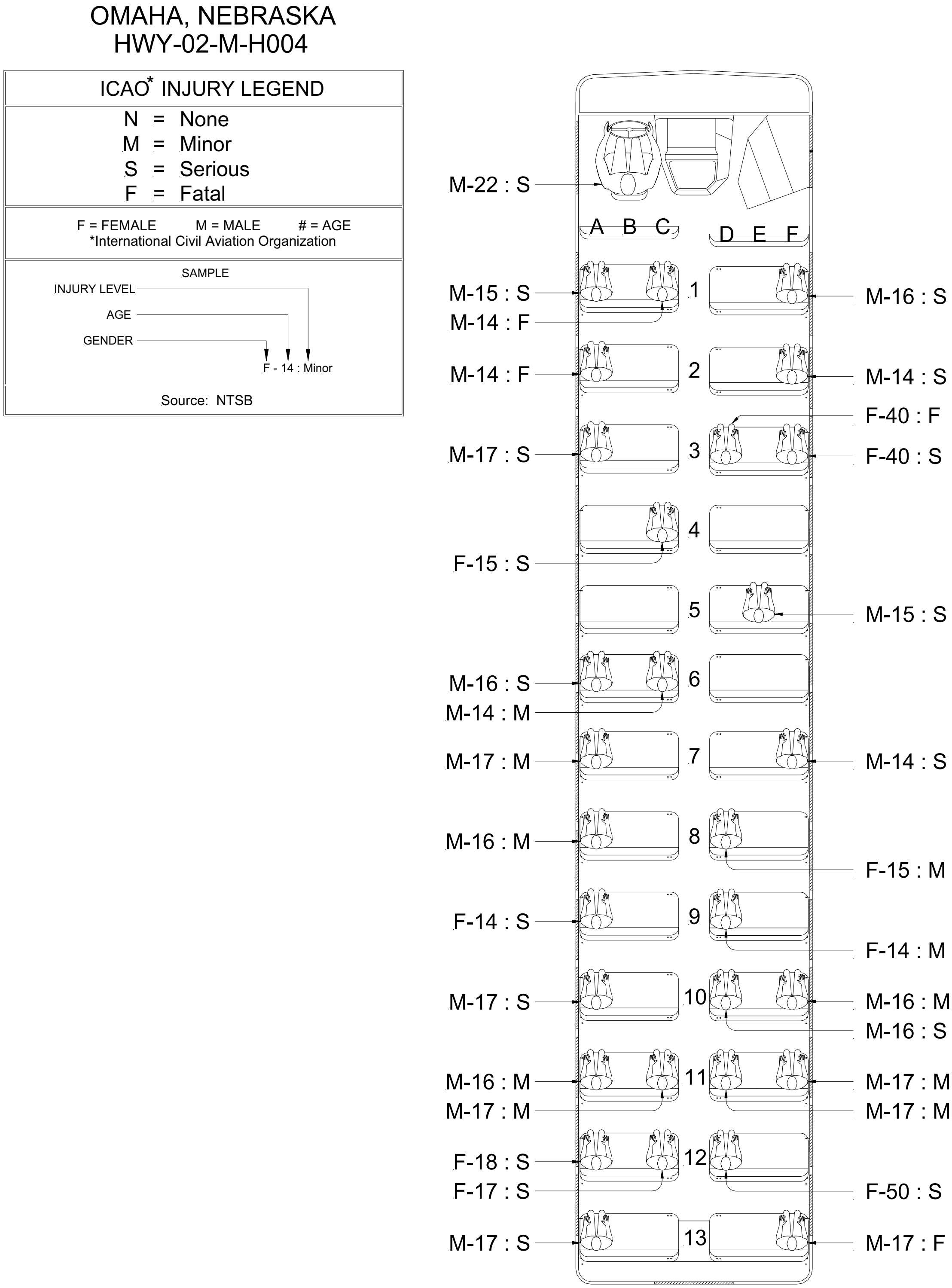

Figure 7. Bus seating chart.

Four passengers (3 students and 1 adult) were fatally injured; the remaining 27 occupants (24 students, 2 adults, and the driver) received injuries ranging from serious to minor. According to autopsy reports,[11] three of the fatally injured passengers (rows 1, 3, and 13) experienced blunt-force trauma to both sides of the thorax and to the right side of the pelvis and head. The fourth fatally injured passenger (row 2) was asphyxiated (drowned). He had been most likely knocked unconscious during the impact with the creek bed and came to rest face down in the water. Typical serious injuries to passengers included hip, rib, arm, and leg fractures. Minor injuries included lacerations, abrasions, and contusions.

Survival Aspects

Many students recalled[12] the bus's rolling and being upside down during the accident sequence. Some reported a sense of floating or weightlessness while the bus was in midair. Others reported grabbing the luggage rack rails when they felt the bus begin its roll off of the bridge. In the accident's aftermath, students reported seeing bus seats and seat cushions strewn about the bus. The student in row 2 who drowned was trapped inside the bus by the left side of the bus and a seatback. Two other students (rows 1 and 12) who were trapped inside the bus, but survived, were pinned between the seat bottoms and loose seat cushions. Another student, who was ejected from row 9, was trapped between the bus's left side and the creek bed.[13] One student interviewed recounted unsuccessfully attempting to free a friend trapped beneath a seat cushion, and another recalled seeing a friend pinned beneath a broken bus seat.

School Bus Emergency Evacuation Drills

Safety Board interviews with student passengers indicated that one student had received school bus emergency evacuation training while in high school. Further, only four students mentioned having received any form of school bus emergency evacuation training in either elementary or middle school. According to the Seward School District's transportation supervisor,[14] although two evacuation drills are conducted each school year, none of the accident bus's passengers had received such training because most of them rode buses only for special events. The director added that Seward's school buses only pick up students who live outside the city limits, noting that friends or family normally drive students who live inside the city limits to school.

[11] Douglas County coroner, October 14, 2001.

[12] Safety Board interviews with accident bus passengers, October 31 and November 1, 2001.

[13] Safety Board interview with the Chief, Battalion 6, Omaha Fire Department (the incident commander during the accident response), March 2002.

[14] Safety Board interview with the Seward School District transportation supervisor, October 15, 2001.

The Nebraska State Department of Education requires[15] that

> At least twice during the school year, each pupil who is transported in a student transportation vehicle shall be instructed in safe riding practices and participate in emergency evacuation drills.

School districts are required to self-certify to the State Department of Education annually that these drills have been conducted. The Federal guideline (commonly referred to as Guideline 17)[16] also recommends twice-yearly emergency evacuation drills. Guideline 17 further recommends that, prior to each departure, students transported on activity or field trips on school buses or school-chartered buses be instructed in safe riding practices and on the location and operation of emergency exits.

Emergency Egress

The accident bus had a total of 6 emergency exits: 1 emergency exit door (row 9, left); 2 emergency exit roof hatches (front and rear); and 3 emergency exit windows (rows 9 and 12, right, and row 13, left). Passengers interviewed during the course of the investigation stated that they exited the accident bus as follows: through the windshield (3), through the front roof hatch (3), through the rear roof hatch (7), through the side windows (2) or were carried off the bus (8) or ejected (1). For seven passengers, the method of egress was unknown.

Postaccident examination revealed that a first aid kit mounted on the front wall of the bus apparently shifted during impact, obstructing the emergency door release handle and instructions for the front-loading door. (See figures 8a and 8b.) In addition, the overhead luggage racks partially blocked the 2-inch-high lettering denoting the three emergency exit windows and emergency exit side door. (See figure 9.)

[15] Department of Education Rule 92, Regulations Governing the Operational Procedures for Student Transportation Vehicles, Section 006, “Emergency Evacuation Drill Procedure.”

[16] NHTSA Highway Safety Program Guideline No. 17, Pupil Transportation Safety (information obtained on September 10, 2003, from <http://www.nhtsa.dot.gov>).

Figure 8a. Obscured emergency door release handle and signage.

Figure 8b. Unobscured view of emergency door release handle and signage.

Figure 9. Unobscured view of emergency exit window signage.

The two emergency roof hatches had already been removed by emergency responders when Safety Board investigators conducted the postaccident vehicle examination on October 15, 2001. Interviews with student passengers indicated that immediately following the accident, three students kicked out the front roof hatch and kicked open the rear roof hatch because they were unfamiliar with their operation. Examination of the hatches showed that the latches used to open the hatch doors were in the closed position. Instructions on the inside of the hatch indicated that the hatch could be opened by turning the knob in the center of the hatch clockwise and pushing upward. (See figure 10.)

School Bus Occupant Protection Standards

The *Federal Motor Vehicle Safety Standards* (FMVSSs)[17] that apply specifically to school bus occupant protection are FMVSS 220, School Bus Rollover Protection, which establishes performance requirements for reinforcing the school bus body structure to withstand forces encountered in rollover crashes; FMVSS 221, School Bus Body Joint Strength, which establishes performance requirements for the strength of the body panel joints in school bus bodies; and FMVSS 222, School Bus Passenger Seating and Crash Protection, which establishes performance requirements for school bus passenger seating and restraining barriers. These standards contain testing procedures and criteria.

[17] Title 49 CFR Part 571.

Figure 10. Emergency roof hatch as shown in manufacturer's literature.

Accident Bus Driver Information

The accident bus driver was a 22-year-old, full-time college student at Concordia University and had recently begun his third year as a busdriver for the Seward School District. He held a Nebraska "Class B" commercial driver's license (CDL) with a passenger endorsement,[18] issued on September 24, 1999,[19] as well as a Nebraska School Bus Driver Certificate. Both were current and valid at the time of the accident.

Prior to being issued the Nebraska CDL, the driver held a Wyoming Class "B" CDL. His driving history showed no traffic convictions or traffic accidents in Nebraska, but did reflect two speeding convictions from Wyoming.[20] The driver applied for the job of busdriver with the Seward School District on August 20, 1999. According to the driver's

[18] Required CDL endorsement for operating a commercial motor vehicle transporting 16 or more people, including the driver (49 CFR 383.5 and 383.93).

[19] When the driver applied for the Seward bus driver's position in August 1999, he still had a valid Wyoming CDL and thus was preliminarily qualified to apply for the job.

[20] April 4, 1997—Speeding (85 mph in a 65 mph zone) and March 31, 1999—Speeding (85 mph in a 75 mph zone). Neither conviction involved a commercial motor vehicle.

employment records, he had previously worked as a laborer for the city of Rawlings, Wyoming, and as a cook and a lifeguard. In addition, the driver told Safety Board investigators that he had worked as a dump truck driver on a ranch in Wyoming for 2 years.

The accident bus driver held a current physical examination card issued on September 1, 2001, and valid through September 1, 2003. The examination form did not indicate any disqualifying physical conditions. The required vision examination was recorded as having been conducted by the examining physician and reported his distance acuity as 20/20 (left), 20/20 (right), and 20/20 (both), with normal color vision. It further reported his horizontal field of vision as 110 degrees (right) and 115 degrees (left).

The accident bus driver stated[21] that he normally began driving about 7:00 a.m. and that his morning route ended about 8:15 a.m. His afternoon route began about 3:00 p.m. and ended about 4:30 p.m. The busdriver, who transported 20 to 25 kindergarten through 12th grade students daily, also drove on student activity trips five to eight times per year. Although he had previously driven to Omaha, he stated that prior to the initial trip on the day of the accident, he had never driven there via U.S. 6 and, until then, was unaware of the roadway construction. According to the accident bus driver and the Seward School District's transportation supervisor, the Seward Band Director selected this U.S. 6 route because it was the shortest way to Burke High School. While driving eastbound on U.S. 6 on the way to the band competition, the busdriver first encountered roadway construction from a different highway project at the intersection of U.S. 6 and Nebraska 31 near 204th Street, about 36 blocks before the accident site. He said that he was not uncomfortable driving through either U.S. 6 work zone.

The accident bus driver normally drove a 1991 59-passenger Thomas Built conventional school bus with an automatic transmission on his daily route. He had driven the accident bus, a 78-passenger Thomas Built transit-style bus,[22] three or four times in the previous 2 years, and stated that he experienced no difficulties on such occasions. The busdriver also stated that he had received about 3 hours of "behind the wheel" training on the accident bus, which was conducted by the Seward District's head mechanic in a rural area outside the city limits, in accordance with State school bus qualification requirements. (For further details, see *Management and Operational Information, State School Bus Driver Qualification Process,* later in this report.)

Most of the witnesses to the accident expressed confidence in the driver, stating that they observed him to be competent and safe. The witnesses consistently described his demeanor, both in general and on the day of the accident, as quiet, yet friendly. Of those interviewed who rode with the driver previously, none could recall having observed anything unusual about his attitude or behavior on the day of the accident.

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[21] Safety Board and DCSO interview with the accident bus driver, October 29, 2001.

[22] Conventional and transit-style school buses will be discussed in further detail in the next section, *Vehicle and Wreckage Information*.

Vehicle and Wreckage Information

Description

The accident bus was a 2000 Thomas Built, Saf-T-Liner ER, model 1405S, two-axle, 78-passenger, rear engine transit-style school bus. The vehicle was 39 feet long and weighed about 22,762 pounds empty. It was equipped with a Cummins, model ISC 8.3L, six-cylinder, in-line diesel engine; an Allison, model 3060, four-speed automatic transmission; and a Dana, model J-230, differential. The bus had type 30 airbrakes and an antilock braking system (ABS). The electronically controlled engine had an electronic control module (ECM); the transmission, and the ABS had electronic control units (ECU s). The odometer reading was 14,233 miles, and the engine had been operated a total of 495.9 hours.

The width of the accident bus, with both mirrors, was about 9.8 feet, and, without mirrors, about 7.8 feet.[23] The first two Norfolk buses, which were MCI buses, measured about 8 feet wide without mirrors and about 10.1 feet wide with mirrors. The third Norfolk bus was similar in width to the Seward bus.

In addition to its greater passenger capacity, this 78-passenger transit-style bus[24] differed from the driver's regular bus, a 59-passenger Thomas Built conventional school bus,[25] in several ways. (See figure 11.) The engine of a conventional school bus is housed beneath the hood in front of the driver, and the right-front corner of the bus is easily visible from the driver's seat, in the lower-right portion of the driver's field of view. In a rear-engine transit-style bus, the right corner is aft of the driver's visual field.

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[23] Measurements for the Seward and Norfolk buses are based upon the Safety Board's mapping of like buses.

[24] A transit-style or "Type D" school bus consists of a body installed upon a chassis, with the engine mounted in the front, midsection, or rear. These vehicles have a gross vehicle weight rating of more than 10,000 pounds and are designed for carrying more than 10 passengers. The engine may be located (1) behind the windshield and beside the driver's seat; (2) at the rear of the bus, behind the rear wheels; or (3) toward the middle of the bus, between the front and rear axles. The entrance door and driver's seat are forward of the front axle.

[25] A conventional or "Type C" school bus consists of a body installed upon a flat-back cowl chassis with a gross vehicle weight rating of more than 10,000 pounds and is designed for carrying more than 10 passengers. The engine is located forward of the windshield; the entrance door and driver's seat are aft of the front axle.

Figure 11a. Transit-style school bus.

Figure 11b. Conventional school bus.

Additionally, the front (steering) axle on a transit-style bus is located beneath and behind the driver, whereas on a conventional bus, the steering axle is positioned beneath the engine, in front of the driver.

Damage

Exterior. The bus's exterior sustained severe damage, particularly on the left side (see figure 12). The left-front and -rear corners of the bus sustained the heaviest damage, resulting in intrusion into the driver's compartment and seat rows 10 through 13. (See figures 13 and 14.) The most significant deformation occurred to the roof at the left-rear corner of the bus, extending 42 inches inboard from the left side and downward 61 inches. The right side of the bus had lesser deformation, extending from floor to ceiling, and penetrating approximately 7 inches at rows 3 and 7. The bus also sustained damage to the lower panels between the axles (figure 15) from aft of the right passenger boarding door and extending to almost the rear axle.

Figure 12. Left side of accident bus.

Figure 13. Left-front roof deformation.

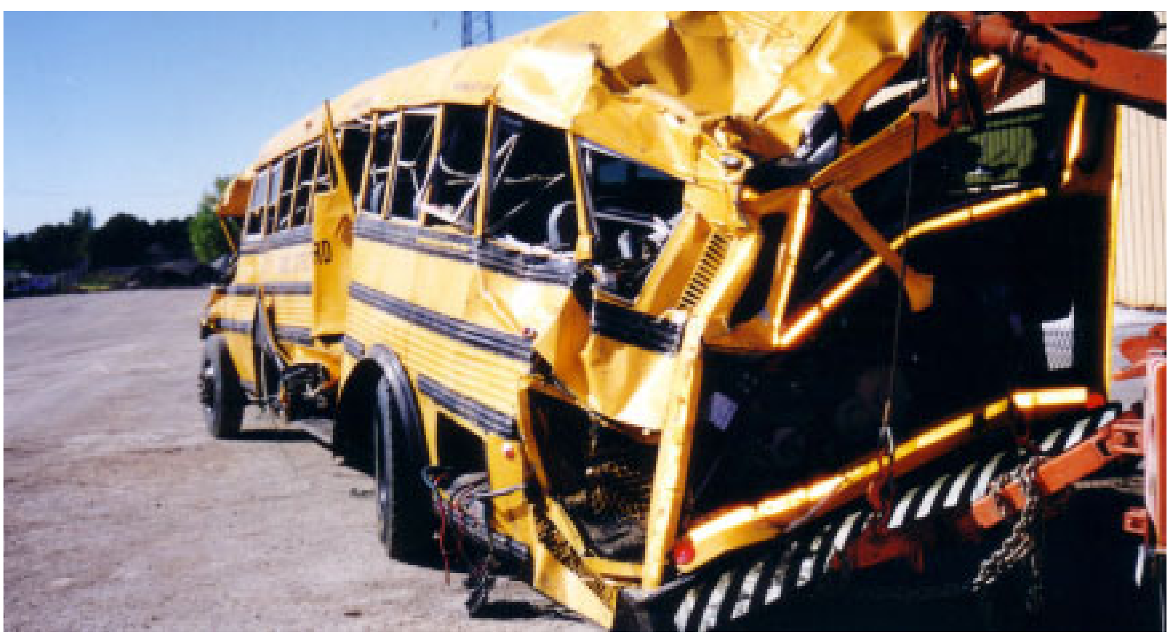

Figure 14. Left-rear roof deformation.

Figure 15. Right side of accident bus.

All of the front lights, including bus stop warning lights, were damaged. Both air tanks were dislodged and the air lines were torn away. The left-rear service/spring brake had separated into two pieces. The right-rear leaf springs were misaligned; the right-front shock absorber was broken. Numerous other dents, scratches, and bent metal (both skin and structural) occurred on various parts of the bus, which was damaged beyond repair. An L-shaped piece of steel bridge railing, approximately 19 feet long, lodged between the bus's undercarriage (floor) and front axle. The guardrail passed underneath the bus and rearward to near the center of the bus, causing damage to the cross members supporting the floor.

The window glazing shattered on the 14 left-side windows and on the 1st, 3rd, and 4th right-side windows, as well as in the windshield and rear window. The glazing on the boarding door window panels (top-right and lower-left and -right) also shattered.

The underside of the bus sustained severe damage, and both of the lower baggage stowage compartments, located between the bus's axles, were destroyed.

Interior. The interior damage generally corresponded to the exterior damage along the bus's left side and ceiling. The floor was intact, with the exception of some distortion near left-side rows 4, 8, 9, and 13.

The front-left corner near the driver's seat was collapsed inward 56 inches at its deepest point and downward 22 inches. The 24-inch-wide driver's seat was deformed inward 8 inches. (See figure 16.)

Figure 16. Damage to driver's seat.

The bus's sidewalls were deformed on both sides. Most severely damaged was the left sidewall, especially at the driver's station and at rows 10 through 13. The left sidewall was also deformed outward about 5 inches between rows 2 and 9. The right sidewall was deformed inward about 8 inches adjacent to the areas between rows 2 and 4 and rows 6 and 9.

The emergency exit door on the left side at row 9 sustained severe damage, but was functional. The standard emergency door latch lift on the side and rear exit doors was also operational.

The rear emergency exit window's frame and door were distorted, rendering the door inoperative, and the glazing was shattered. All three emergency window exits were affixed to their frames. The glazing on the left-side emergency exit window near row 13 was shattered, and the frame was inoperative. Both right-side emergency exit windows at rows 9 and 12 were intact and operational.

The passenger seats did not sustain seat anchorage failures, but the clamps used to attach the seat pans/cushions to the metal frame either broke or became unlatched at rows 1, 2, 3, 4, and 12 on the right side and at rows 1, 8, and 12 on the left side.

The overhead luggage racks, mounted along the right and left sides of the bus, were deformed. Pipe sections from the luggage racks protruded inward near row 7 on the right side and near row 3 on the left side. Postaccident investigation revealed that the midsection of the overhead luggage racks was damaged further during the recovery operation, when the bus was being pulled from the creek bed, and a chain, wrapped around the bus's middle, ripped into the sheet metal.

Inside the bus, first aid and safety equipment consisted of two first aid kits, one biohazard spill kit, two fire extinguishers, and safety triangles, all of which appeared intact and unused.

The bus was equipped with a three-point lap/shoulder belt for the busdriver, which was operable. The belt webbing showed no evidence of stretching or friction rub. No other bus seats were equipped with passenger safety restraints.

Postaccident Examination

On October 19, 2001, representatives from the Safety Board, State and local law enforcement organizations, and Thomas Built conducted a mechanical examination of the accident bus at the Douglas County Maintenance Garage in Omaha. A mechanic from the Douglas County maintenance garage assisted.

Engine and Transmission. The engine's ECM was removed from the bus and subsequently downloaded on October 19, 2001, by a Safety Board investigator assisted by a Cummins technician at Cummins Great Plains in Omaha. This ECM was not designed to record vehicle speed, braking, engine rpm, or other parameters that could provide information about the accident scenario.

The transmission had become completely dislodged from the bus during the accident. Although the transmission was equipped with an ECU, the ECU did not have recording abilities for parameters pertinent to accident reconstruction (such as gear position and recent shifts). The transmission did not have a retarder.[26]

Steering. The bus had a TRW, model TAS 65, integral[27] power steering unit (gearbox). During the vehicle examination, all of the steering linkage was observed to be connected and moved slightly when the 20-inch steering wheel was turned. Due to vehicle

[26] Device that assists the braking system in slowing the vehicle.

[27] *Integral* means that the control valve, hydraulic cylinder (ram), and gearing mechanism are all contained within the steering box housing.

crush in the left front, the wheel did not turn freely. The steering gearbox was removed from the bus and shipped to TRW Commercial Steering in Lafayette, Indiana, for examination by Safety Board and TRW staff.

A TRW engineer examined the exterior of the gearbox and observed no damage. The input shaft was rotated 5 1/4 turns in each direction; it rotated freely without resistance. The gearbox was then disassembled, and no defects were discovered. Slight ball bearing indentations were noted on the worm gear and determined by the TRW engineer to be from accident impact.

Tires. The bus had six original tires, all Goodyear, size 12R22.5. The two front tires were model G159 with highway-type tread, and the four rear tires (dual wheels) were model G124 with mud and snow treads. The air pressure was between 100 and 110 for all except the right rear-inside dual, which was flat due to damage during impact. All of the tires had minimum tread depths of between 15/32 and 20/32 of an inch, within Federal standards.[28]

Brakes. The airbrake-equipped bus had standard S-cam (clamp type) foundation brakes with type 30 chambers and automatic slack adjusters. Because of vehicle damage, the engine could neither be started nor the airbrake system operated; therefore, the airbrake chambers were plumbed directly and shop air was utilized to obtain push-rod measurements. Both front brake push-rods measured 1 7/8th inch.[29] The push-rod travel for the left-rear brake could not be obtained due to the air chamber having been completely dislodged and damaged during the accident. The right-rear air chamber was also plumbed directly and a push-rod measurement of 3/4 inch was obtained utilizing shop air; the wheel rim was bent against the brake drum and the drum was cracked, making the accuracy of the push-rod measurement unreliable. All brake shoes were about 3/4-inch thick and showed only slight wear. No defects were discovered during this examination that were inconsistent with accident damage. The bus was equipped with a Bendix model EC-17 ECU. (For details of the ECU testing, see the *Tests and Research section.)*

Highway Information

Accident Location

The accident occurred in the westbound lane of U.S. 6 (West Dodge Road), approximately 0.33 miles west of Omaha in Douglas County.[30] The school bus ran off the West Papillion Creek Bridge (Nebraska Department of Roads Structure #S006 36012).

[28] Federal Motor Carrier Safety Regulation (FMCSR), 49 CFR 393.75(b)(c), requires front tires to have a minimum tread depth of 4/32 of an inch and all other tires to have a minimum tread depth of 2/32 of an inch.

[29] According to 49 CFR 396.17 and Commercial Vehicle Safety Alliance (CVSA) standards, the maximum allowed stroke for a Type 30 S-cam brake is 2 inches.

[30] Located at construction station number 355, photolog 01+360.110, Federal aid project number EACNH-EACBR-6-7 (133).

The posted speed limits on U.S. 6 varied from 45 mph in urban areas to 55 mph in rural areas. The posted speed limit in the work zone was 45 mph for all vehicle types.

Location of Physical Evidence

On the approach to the bridge, a W-beam guardrail was fastened to a short segment of temporary concrete barrier. The concrete barrier and the initial part of the guardrail flared away from the edge of the road. (See upper-right section of figure 17 below.) In the area where the guardrail was parallel to the edgeline, where the bus first struck the W-beam guardrail, were black rub tire marks that became progressively heavier. Beneath this guardrail, investigators found a tire print in the dirt that matched the right-rear tire. Investigators also found evidence of a second impact in scratch marks on the guardrail from the right-front wheel lug nuts and in yellow paint transfers from the school bus body.

On the roadway, a left-front tire mark started about 23.4 feet past the end of the temporary concrete barrier. This tire mark, measuring 22.7 feet, was about 7.6 feet from the guardrail, 4.9 feet to the right of the centerline, and ran parallel to the edgeline. After a space of 25.4 feet, another left-front mark, measuring about 27.4 feet long, began at a 6-degree angle to the bridge rail. This mark started 6.6 feet from the rail and ended 4.6 feet from the rail.

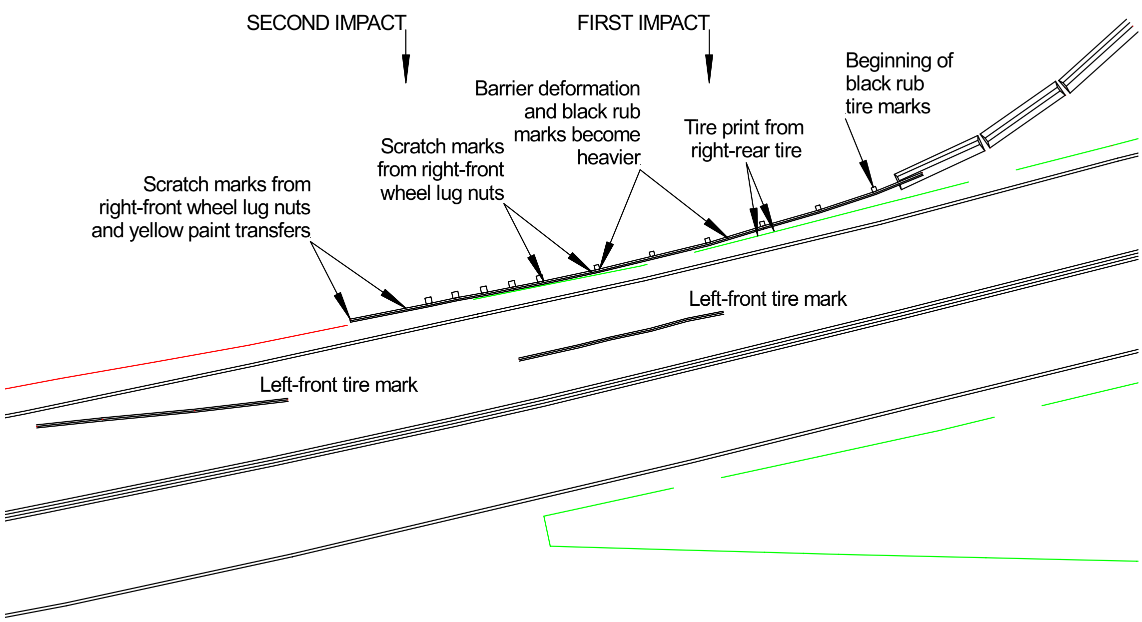

Figure 17. Physical evidence left by school bus impacts to guardrail.

Traffic Volume

U.S. 6 is approximately 373 miles long, spanning the States of Nebraska and Colorado in the west to the Missouri River in the east.[31] According to NDOR, the average daily traffic (ADT) counts on U.S. 6 in the vicinity of the accident location, including the percentage of truck traffic, are as follows (table 2):

Table 2. Average daily traffic volume on U.S. 6 in vicinity of 167th Street (includes accident site).

Year	ADT	Daily trucks	Percentage of ADT
1996	20,400	760	3.7
1997	23,000	835	3.6
1998	25,600	920	3.6
1999	29,500	1,010	3.3
2000	33,400	1,115	3.3
Source: NDOR.			

Work Zone Accident Statistics

No fatal work zone accidents occurred within the boundary of the construction project[32] from March 2000 until the accident on October 13, 2001, according to records provided by the Nebraska State Patrol (NSP). NDOR data for the area in the vicinity of the accident indicated the following (table 3):

Table 3. Accidents occurring within 1 mile of 167th Street.

Year	Fatal accidents			Injury accidents		Property damage only accidents	Total
	Number of accidents	Fatalities	Injuries	Number of accidents	Injuries		
1999[1]	0	0	0	25	42	21	46
2000	0	0	0	12	15	5	17
2001[2]	1	4	27	4	5	12	17
Totals	1	4	27	41	62	38	80

Source: NDOR.
[1]Data cover the year before construction began.
[2]Including the accident discussed in this report.

[31] This segment of U.S. 6 is part of the National Highway System (23 *United States Code* 103b), which consists of the highway routes and connections to transportation facilities depicted on the map submitted by the Secretary of Transportation to Congress.

[32] This construction project boundary extended from 162nd Street in the east to 174th Street in the west.

Work Zone Definitions and Geometry

The *Manual on Uniform Traffic Control Device*s (MUTCD)[33] defines a "construction activity area," or work zone, as,

> …the area of a roadway where the work takes place. It is comprised of the work space, the traffic space and may contain one or more buffer space.
>
> The *work space* is that portion of the roadway closed to traffic and set aside for workers, equipment, and material. Work space may be fixed or may move as work progresses. Long-term work spaces are usually delineated by channelizing devices or barriers to exclude traffic and pedestrians.
>
> The *traffic space* is the portion of the roadway in which traffic is routed through the activity area.
>
> The *buffer space* is an optional feature in the activity area that separates traffic flow from the work activity or a potentially hazardous area and provides recovery space for an errant vehicle. Neither work activity nor storage of equipment, vehicles, or materials should occur is this space. Buffer spaces may be positioned longitudinally and laterally with respect to the direction of traffic.
>
> 1. Longitudinal Buffer Space—[Does not apply.]
>
> 2. Lateral Buffer Space
>
> A lateral buffer space may be used to separate the traffic space from the work space…or a potentially hazardous area, such as an excavation or pavement edge drop off. A lateral space may also be used between two travel lanes, especially those carrying opposing flows. The width of the lateral buffer space should be determined by engineering judgment.

At the time of the accident, the West Dodge Road approach to the construction work zone was a six-lane divided median highway. The accident segment of U.S. 6 was a temporary two-lane, two-way, undivided asphaltic concrete roadway inside a work zone. Each 10.5-foot-wide lane had narrow or no shoulders. On the east end of the project, the two-lane segment had been shifted northward about 5 1/2 feet to accommodate the toe of the slope (area where the fill dirt needed to construct the future eastbound lanes met the original roadway grade). East of the West Papillion Creek Bridge, the two-lane roadway was shifted southward to intercept the existing bridge deck. This shift resulted in a short-length horizontal curve to the left, followed by a short-length horizontal curve to the right.[34]

The westbound lane shift had an offset width (distance a lane shifts from the roadway's original centerline, as shown in figure 18) of approximately 5 1/2 feet and was 184 feet long near the east end of the bridge. The eastbound and westbound travel lanes had cross slopes of 2 percent toward the north side of the roadway. The westbound approach lane to the bridge had a 3-percent ascending grade.

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[33] U.S. Department of Transportation, Federal Highway Administration, *Manual on Uniform Traffic Control Devices* (Washington, DC: FHWA, 1988), chapter 6 (revision 3–1993).

[34] These right and left horizontal curves, which were in place at the beginning of construction, are referred to as "lane shifts" in this report.

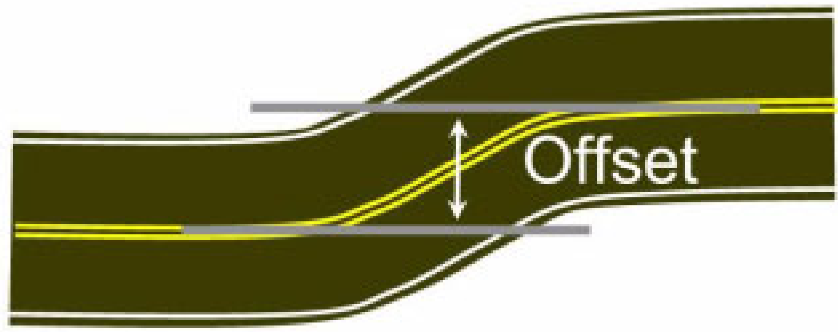

Figure 18. Offset width. (*Note:* Not to scale.)

Four-inch-wide, solid, double, yellow retroreflective pavement markings divided the traffic lanes. Four-inch-wide, solid, white retroreflective edgelines were used to mark both the north and south edges of the traffic lanes. All pavement markings met MUTCD[35] requirements; the MUTCD[36] also includes guidance for the design of lane shifts in construction areas. The lane shift offsets met these requirements.

The construction plans allowed the contractor to use the south side of both the West Papillion Creek Bridge and the Union Pacific railroad bridge to the west for construction work space, while the north sides of the bridges carried traffic in two directions at a posted speed limit of 45 mph. On both bridges, construction traffic and equipment had access to U.S. 6. Construction equipment and personnel moved about in an approximately 24-foot-wide work space available on the southern half of the bridges. (See figure 19.) No buffer area existed between the work activity area and the two-way traffic.[37]

[35] MUTCD, 1988 edition.

[36] MUTCD, 1988 edition, chapter 6 (revision 3-1992).

[37] The work space and traffic space were separated only by orange and white traffic barrels.

Figure 19. Aerial view of the construction site. Arrow indicates work activity area on south side of bridge. (Source: DCSO)

The two lane shifts resulted in short-radii reverse curves (that is, "sharp"[38] curves) on the westbound approach to the narrowed bridge deck. After the first curve to the left, westbound traffic was momentarily directed toward oncoming eastbound traffic and then parallel to the construction work space and activity on the south side of the bridge deck.

[38] The survey data collected during the accident investigation revealed that the curves did not have a constant radius over their length. The MUTCD, 1988 edition, chapter 6 (revision 3-1992), paragraph 6C-3, implies that short-length lane shifts do not require constant radius curves.

Traffic Control Construction Signing

The westbound approach to the accident site had the signage recommended in the 1988 MUTCD.[39] Safety Board investigators documented the following construction warning signs and devices (listed in order of appearance):

- W20-1 sign: *ROAD CONSTRUCTION AHEAD* (left and right sides).
- W4-2 sign: Lane reduction transition (left and right sides).
- Flashing arrow panels (left and right sides).
- Nonstandard warning sign: *STAY IN YOUR LANE*.
- Nonstandard warning sign: *BE PREPARED TO STOP*.
- W6-3 sign: Two-way traffic (left and right sides).
- R4-1 sign: *DO NOT PASS* (at least two signs were mounted on other traffic control devices, including on a W6-3 sign and on a barricade).

Maintenance History

NDOR had constructed U.S. 6[40] in the early 1930s as an undivided two-lane highway with 10.5-foot-wide travel lanes. Part of the original construction included, on the north side of the bridge, a 1-foot-high, single, steel, L-shaped rail mounted on an 18-inch-high concrete wall and a 4-inch-wide concrete gutter. In 1935, NDOR improved the grade line, constructed a 42-foot curb and gutter concrete cross section, and built bridges over the west branch of the Papillion Creek and the Union Pacific Railroad tracks. These improvements widened the roadway into an undivided four-lane highway.

In 1962, the West Papillion Creek Bridge was lengthened about 46 feet on its east end to accommodate water flow in the creek, according to NDOR representatives. During the project, a 46-foot-long three-rail barrier[41] was placed on both sides of the east end of the bridge.[42] The west end barriers (the end of the bridge not involved in the accident) and bridge railing were not modified. According to NDOR, no information existed in its bridge inventory database about these particular types of barriers (both the single-rail barrier installed as part of the original bridge construction and the three-rail barrier added during the 1962 bridge lengthening project). The ongoing construction project has replaced this bridge (and its abutments) with a new bridge that conforms to current Federal and American Association of State Highway and Transportation Officials (AASHTO) guidelines. According to NDOR, a statewide bridge barrier replacement project is underway to replace several types of old bridge barrier systems with ones that meet current design guidelines.

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[39] MUTCD, 1988 edition, chapter 6 (revision 3–1992), figure TA-39.

[40] Much of U.S. 6 across Nebraska is a two-lane rural highway.

[41] Identified as a curb and handrail in the 1962 bridge plans.

[42] NDOR engineers believe that the three-rail barrier treatment met 1962 State standards. Little detail about this barrier design is available on the 1962 bridge design plans.

In 1985, NDOR resurfaced U.S. 6 from 204th Street to east of 132nd Street with asphaltic concrete and constructed W-beam approach barrier transition sections[43] for both ends of the West Papillion Creek Bridge, in conformance to AASHTO standards.[44] The east-end detail on the plans showed the 37-foot-long breakaway terminal section of the W-beam transition barrier faired into (joined smoothly with) the existing three-rail barrier section on both the north and south sides of the roadway. This design conformed to existing AASHTO guidelines.[45]

In March 2000, NDOR and the Federal Highway Administration (FHWA) initiated a joint 3-year, $35 million reconstruction project to expand the highway from a four-lane undivided highway (two eastbound and two westbound lanes) to a six-lane divided highway. The section of U.S. 6 east of 162nd Street had already been completed. The 1.06-mile (1.716-kilometer) construction project[46] encompassed U.S. 6 from 162nd Street in the east to 174th Street in the west. The project, which included replacement of the existing bridges, barrier systems, and abutments, was intended to accommodate increased traffic. In addition, the project called for expanding existing lane widths from 10 1/2 feet to 12 feet and adding paved shoulders and a median.

In November 2000, 8 months after the construction project began, three 10-foot-long, 3-foot-high, and 2-foot-wide portable concrete barriers replaced the end treatment section of the 1985 W-beam section barrier for westbound traffic. These temporary portable concrete barriers were flared into an embankment on the north side of the roadway.

On May 15, 2001, during the construction project, a large, off-the-road earth moving truck was parked in the construction work space just west of the accident site. Unoccupied, it began to roll from a work access road and eastward down the 3-percent grade on U.S. 6, diagonally across the West Papillion Creek Bridge, and collided with the barrier transition on the northeast corner of the bridge. The truck struck the barrier transition where the 1962 three-rail barrier and the 1985 W-beam came together. NDOR was unable to provide photographs of the damage prior to repair, and no record of a police accident report could be located for the incident. The accident was recorded in the NDOR project inspector's daily report. According to the Nebraska Code, NRS 60-699:

> (1) The operator of any vehicle involved in an accident resulting in injuries or death to any person or damage to the property of any one person, including such operator, to an apparent extent of more than one thousand dollars shall within ten days forward a report of such accident to the Department of Roads.

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[43] Guardrail or other device that provides continuity of protection when two different roadside barriers are joined together. (American Association of State Highway and Transportation Officials, *Roadside Design Guide 2002* [Washington, D.C.: 2002], page 5-23.) In this case, the transition was from the roadway guardrail to the bridge railing.

[44] American Association of State Highway and Transportation Officials, *Guide for Selecting, Locating and Designing Traffic Barriers* (Washington, D.C.: AASHTO, 1977).

[45] *Guide for Selecting, Locating and Designing Traffic Barriers,* 1977. The 1977 edition would have been in effect in 1985 and was superseded in 1989.

[46] Federal aid project number EACNH-EACBR-6-7 (133).

The general contractor evaluated the condition of the barrier following the May 15, 2001, incident. The NDOR contract for the construction project incorporated the following sections from NDOR's 1997 metric edition of *Standards and Specifications for Highway Construction*:

> *Section 105.11—Restriction on Moving and Use of Heavy Equipment, item 13.* The Contractor shall be responsible for all damages done by the equipment.
>
> *Section 107.09—Preservation and Restoration of Property, Trees, Monuments, etc., item 1.* The Contractor shall preserve, protect, and prevent damage to all public and private property.

Soon after this evaluation, the contractor had its bridge maintenance personnel devise and install a repair for the barrier. No engineers were involved in the barrier's design or its repair. In addition, no one evaluated the structure's strength or compliance with established guidelines. With the exception of NDOR photo-logging[47] images, no known photographs exist of the completed repair.

The segment of barrier affected by the May 2001 truck incident was visible in NDOR photo-logging images of the site made during the summers of 1996 and 2001. (See figures 20a and 20b. For further information on the repair area's relationship to the accident sequence, see figure 26 later in this analysis.) The 2001 photo-logging image (figure 20b) shows that the concrete transition block[48] constructed in the 1985 project was dislodged from the bridge deck and pushed to the north. The W-beam connected to the anchor block and several of the wooden posts supporting the W-beam transition were also missing or damaged.

These images indicate that several feet of the three-rail barrier installed on the east end of the barrier in 1962 was removed and not replaced during the repair work.

The images also show that a section of W-beam was attached to the remains of the 1985 W-beam barrier installation. This beam extended past the damaged area but was not anchored to the remains of the three-rail system. This W-beam was connected only to metal posts that were attached to the repair's "stacked" H-beam arrangement. (See figure 20b.) This arrangement resulted in the W-beam not being secured at its west end and lacking the strength provided by tension from another structure. None of the assembly conformed to known guidelines for barrier design or construction.

[47] Many highway agencies periodically make photographs or digital images at 100 feet ± intervals along their roadway systems while traveling in each direction. These images are typically used for system analysis, inventories, and other purposes. NDOR photo-logged approximately every 3 years. Images from the summers of 1996 and 2001 were available; the 2001 images showed the "repaired" barrier in several frames.

[48] Rectangular block of concrete into which an anchoring device, such as a bolt, is inserted, in this case, to secure part of the W-beam transition barrier.

Figure 20a. Summer 1996 NDOR photo-logging image of the barrier system installed in 1985 (westbound view). Arrow indicates transition from W-beam to three-rail barrier.

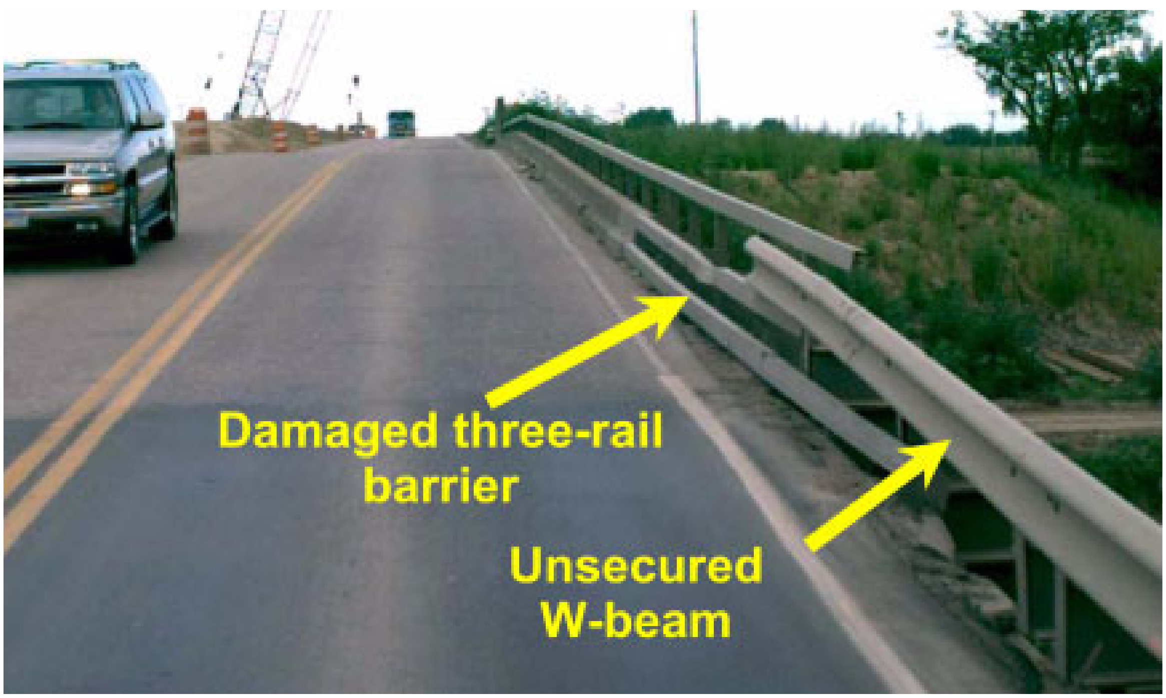

Figure 20b. Summer 2001 NDOR photo-logging image of the repair to the barrier system after the May 2001 truck incident (westbound view). Shown is the east end of the remaining three-rail barrier and the west end of the repair to the three-rail barrier.

Photographs taken during the investigation of the October 13, 2001, accident show a structure made of an H-girder supporting an area from the northeast end of the bridge to east end of the damaged three-rail barrier. (See figure 21.) Connections between the H-beam stacks and the girder had failed due to the school bus's impact.

Figure 21. Bridge repair by contractor shown immediately after October 13, 2001, accident. (Source: DCSO)

After the accident, NDOR placed portable concrete barriers that were 32 inches high, 10 feet long, and 2 feet wide[49] on the north side of the bridge to protect that section of the bridge railing damaged in the accident, and the portable concrete barrier was extended to the west end of the bridge. As a result, the centerline of the traveled roadway was moved approximately 2 feet south of its initial location. The construction work space on the south side of the bridge, which was not protected by a lateral buffer space or barrier, remained in place.

[49] According to National Cooperative Highway Research Program Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, this type of temporary barrier is neither designed to restrain large vehicles, such as the accident school bus, nor required to follow any design guide.

Work Zone Safety Guidelines

The MUTCD[50] (in effect at the time of the accident) stated,

> A Traffic Control Plan (TCP) describes traffic controls to be used for facilitating vehicle and pedestrian traffic through a temporary traffic control zone. The plan may range in scope from being very detailed, to merely referencing typical drawings contained in the MUTCD, standard approved highway agency drawings and manuals, or specific drawings contained in contract documents. The degree of detail in the TCP depends entirely on the complexity of the situation, and TCPs should be prepared by persons knowledgeable about the fundamental principles of temporary traffic control and the work activities to be performed.

The MUTCD provides the following guidance for supervision of traffic control and safety in work zones:

> Each person whose actions affect temporary traffic control zone safety-from upper-level management personnel through field personnel-should receive training appropriate to the job decisions each is required to make. Only those who are trained in safe traffic control practices, and who have a basic understanding of the principles established applicable standards and regulations (including those of the MUTCD), should supervise the selection, placement, and maintenance of traffic control devices in work and incident management areas.
>
> When warranted, an engineering analysis should be made (in cooperation with law enforcement officials) of all accidents occurring in temporary traffic control zones. Temporary traffic control zones and accident records should be monitored to identify and analyze traffic accidents or conflicts. For example, skid marks or damaged traffic control devices may indicate the need for changes in the traffic control.
>
> *Two-Lane, Two-Way Traffic on One Roadway of a Normally Divided Highway*
>
> Two-lane, two-way operations (TLTWO) on one roadway of a normally divided highway is a typical application that requires special consideration in the planning, design, and construction phases. As unique operational problems (for example, increasing the risk of serious head-on collisions) can arise with the TLTWO, this typical application will be discussed here.
>
> Before including a TLTWO in the traffic control plan for a project, careful consideration should be given to its appropriateness. The following items should be considered during the decision-making process:
>
> - Is a suitable detour available?
> - What are the characteristics of the traffic?
> - Can traffic be maintained on the shoulder?
> - Can temporary lanes be constructed in the median?

[50] MUTCD, 1988 edition, chapter 6 (revision 3-1992), page 6C-10.

> - Can the work be accomplished by closing only one directional lane? If this option is selected for consideration, will it result in additional hazard to temporary traffic control zone personnel?
> - If a TLTWO is selected, will this result in a shorter contract time?
> - Will the TLTWO allow a contractor to perform the work more efficiently and thus result in a substantial decrease in contract cost?
> - What is the "track record" of similar installations?
> - Are there any width or height restrictions that would preclude the TLTWO or the use of a shoulder or the median as a temporary lane?
> - What are the condition of the pavement and the shoulders in the proposed TLTWO section? Due to width restriction, traffic may drive on the shoulders, which must be structurally adequate.
>
> The traffic control plan as shown in figure TA-39 shall include provision for separate opposing traffic whenever two-way traffic must be maintained on one roadway of a normally divided highway. The TLTWO shall be used only after careful consideration of other available methods of traffic control.
>
> When traffic control must be maintained on one roadway of a normally divided highway, opposing traffic shall be separated either with portable barriers (concrete safety-shape or approved alternate), or with channelizing devices throughout the length of the two-way operation. The use of striping, raised pavement markers, and complementary signing, either alone or in combination is not considered acceptable for separation purposes.

In 2000 and 2003, the MUTCD was updated and the guidance provided regarding TLTWO was strengthened:

> When two-lane, two-way traffic control must be maintained on one roadway of a normally divided highway, opposing vehicular traffic shall be separated with either temporary traffic barriers (concrete safety-shape or approved alternate) or with channelizing devices throughout the length of the two-way operation. The use of marking and complementary signing *by themselves shall not be used.* [emphasis added]

FHWA policy[51] in the *Federal-Aid Policy Guide* contains further requirements:

> <u>Section 630.1010(a), Part 5(i)</u>
>
> Two-lane, two-way operation on one roadway of a normally divided highway (TLTWO) shall be used only after careful consideration of other available methods of traffic control. Where the TLTWO is used, the TCP [traffic control plan] shall include provisions for the separation of opposing traffic except:

[51] U.S. Department of Transportation, Federal Highway Administration, *Federal-Aid Policy Guide*, 23 CFR 630j, Subchapter G—*Engineering and Traffic Operations*, Part 630—*Preconstruction Procedures*, Subpart J—*Traffic Safety in Highway and Street Work Zones*, transmittal 30 (Washington, DC: January 2002).

(A) Where the TLTWO is located on an urban type street or arterial where operating speeds are low;[52]

(B) Where drivers entering the TLTWO can see the transition back to normal one-way operation on each roadway; or

(C) Where FHWA approves nonuse of separation devices based on unusual circumstances.

Section 630.1010(a)-5(ii)

(b) Responsible person. The highway agency shall designate a qualified person at the project level who will have the primary responsibility and sufficient authority for assuring that the TCP and other safety aspects of the contract are effectively administered. While the project or resident engineer may have this responsibility, on large complex projects another person should be assigned at the project level to handle traffic control on a full-time basis.

(2) Construction zone accidents and accident data[53] shall be analyzed and used to continually correct deficiencies which are found to exist on individual projects, and to improve the content of future traffic control plans.

(d) Training. All persons responsible for the development, design, implementation, and inspection of traffic control shall be adequately trained.[54]

In the late 1970s, the Safety Board investigated an accident in Laramie, Wyoming,[55] that was similar to the one that occurred in Omaha. The Laramie accident, which also occurred in a work zone with TLTWO operation, involved two tractor-semitrailers and a motor home in a head-on collision that killed nine people. The investigation found that TLTWO was used routinely by the States during divided freeway pavement maintenance (resurfacing) and that it was common practice to separate the opposing traffic flows with only yellow pavement markings. As a result, frequent and severe head-on collisions and other types of traffic accidents had been experienced.

As a result of its investigation of the Laramie accident, the Safety Board made Safety Recommendation H-80-11 to the FHWA:

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[52] The term *low operating speeds* is not defined in any known Federal publication. Many freeways typically operate at posted speed limits of 55 mph; the speed limit in the accident work zone was 45 mph.

[53] The 1988 MUTCD (1993 revision) states that this should be done only “when warranted.”

[54] According to NDOR, none of the staff assigned to the U.S. 6 project had such training.

[55] National Transportation Safety Board, *Multiple Vehicle Collision in a Construction Zone, U.S. Interstate 80, Near Laramie, Wyoming, August 22, 1979,* Highway Accident Report NTSB/HAR-80/01 (Washington, DC: NTSB, 1980).

H-80-11

Promote the development of a traffic control device to fill the gap between the shaped concrete barrier and traffic cones to serve as a continuous visual barrier to separate traffic in work zones.

This and other accidents prompted the FHWA to begin to issue guidance to State departments of transportation and highways for the positive separation of traffic flows in these work zones. Based upon the FHWA's development of design and performance criteria[56] to improve the barrier options available for use by highway agencies, on March 22, 1984, the Safety Board classified Safety Recommendation H-80-11, "Closed—Acceptable Action."

Work Zone Traffic Control Plan

The 1988 MUTCD[57] allowed the use of traffic control plans that are not specific to a particular project. Such a "generic" plan was used for this project and consists of a set of accepted traffic control strategies for the conditions and situations frequently encountered in work zones. Construction engineering management personnel may then choose an appropriate plan element to fit the conditions that they might encounter during a project, as also noted in the 1988 MUTCD:

> A traffic control plan, in detail appropriate to the complexity of the work project or incident, should be prepared and understood by all responsible parties before the site is occupied. Any changes in the traffic control plan should be approved by an official trained in safe traffic control practices.

The engineering judgment involved in determining the complexity of a construction project would include evaluating variables such as:

- Traffic speed and volumes,
- Alternative routes,
- Duration of the construction project,
- Physical size and complexity of the work site, and
- Other variables specific to individual projects.

As part of ongoing construction, the eastbound lanes of U.S. 6 were closed to accommodate construction of the three new eastbound lanes. The westbound lanes were open for two-way traffic and consisted of one 10 1/2-foot-wide eastbound lane and one 10 1/2-foot-wide westbound lane divided by solid, double yellow, retroreflectorized lines. The roadway edges were marked with solid, white, retroreflectorized lines. The north side barriers on the bridge and its approaches remained the same as before the beginning of the

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[56] *Design Considerations for Two-Lane, Two-Way Work Zone Operations* (FHWA/RD-83/112) and *Performance Criteria for Channelizing Devices Used for Two-Lane, Two Way Operations* (FHWA/RD-83/057).

[57] MUTCD, 1988 edition, chapter 6 (revision 3-1992).

project. The south side of the roadway and bridge was lined with 3-foot-high, retroreflectorized, orange and white channelization drums in the construction work space area. The traffic control plan for this project had been in place since March 2000, but it did not specifically describe any of these traffic control arrangements.

The generic traffic control plan being used did not include a traffic control design for an urban divided median facility. It had typical plans for a "rural four-lane divided highway" and an "urban undivided four-lane roadway." The traffic controls used on U.S. 6 most closely compare to the urban roadway example, although NDOR stated to investigators that it considers this to be a "rural" area. The AASHTO publication *A Policy of the Design of Highways and Streets* defines "urban" areas as "places within the boundaries set by responsible State and Local officials having a population of 5,000 or more." Rural areas are defined as those areas outside of urban areas. The accident site was essentially on the city limit line for Omaha and was predominately residential.

The MUTCD states that changes or deviations from the traffic control plan are left to the discretion of the project engineer and must be documented. According to NDOR, the applicable generic traffic control plan for the accident site was followed with no changes. The generic traffic control plan did not include a requirement for separating the two opposing lanes of traffic, even though the 1988 MUTCD required separation of the opposing lanes. .

The applicable 1988 MUTCD included the following guidance:

> Before including a TLTWO in the traffic control plan for a project, careful consideration should be given to its appropriateness. The following items should be considered during the decision-making process.

The MUTCD then cited eleven items that should be considered before installing TLTWO in a construction work zone to include: the characteristics of the traffic, the availability of other methods of traffic control, and the need to separate opposing traffic "whenever two-way traffic must be maintained on one roadway of a normally divided highway."

According to NDOR and its general contractor, the use of the two-lane, two-way-operation in the work zone "sort of evolved" over the life of the contract. NDOR and the contractor further stated that they did not consider the following options in developing a traffic control plan: constructing a temporary retaining wall to avoid the "lane shift" in the temporary two-lane roadway where the crash occurred; physically separating the opposing flows of traffic as required in 23 CFR 630.1010, Part 5(i) and the applicable MUTCD, even though it was not possible to see from one end of the TLTWO to the other due to the crest vertical curve near the crash site.

Work Zone Speed Selection

The Institute of Transportation Engineers' *Traffic Engineering Handbook*[58] furnishes guidance on speed zoning application, stating,

> Work zones represent a special speed zoning challenge to transportation agencies. Speed zones are typically established during the development of the traffic control plans for the construction project; hence data on prevailing speeds are not available when the decisions are made. Consequently, the selection of the speed limit must often be made by considering design speeds, proximity of workers and equipment to traffic, the presence of positive barrier separation and other factors.

The *Traffic Engineering Handbook*[59] indicates how the States generally approach determining speed limit reductions for work zones by noting "Avoid Reduction," "Always Reduce," and "Consider Factors." Nebraska is noted as "Consider Factors."

Work Zone Safety Evaluation

NDOR stated that it relied upon its district construction engineer, project manager, and assistants to ensure the contractor's conformance with the traffic control plan. None of these NDOR employees had specific or general training in traffic engineering but were reported by NDOR to have had American Traffic Safety Services Association (ATSSA)[60] training, which did not include traffic operations and safety engineering training. The general contractor's project management personnel had no training in construction work zone safety. The duties of the general contractor's "safety consultant" were associated with occupational safety of the workers and not traffic safety or operations.

NDOR further stated that its traffic engineering office did not periodically inspect work zones or monitor traffic crash experience in work zones. Traffic engineering personnel did participate in annual joint work area inspections by NDOR and divisional FWHA personnel.

The FHWA and NDOR conducted statewide work zone traffic control reviews annually, as required by FHWA policy. In 2001, a team of engineers from FHWA and NDOR traveled approximately 2,000 miles in a 4-day review of approximately 50 Nebraska work zones.[61]

No specific criteria existed for evaluating or "grading" work zones; the committee of FHWA and NDOR engineers said that it used several factors as general guidelines:

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[58] Institute of Transportation Engineers, *Traffic Engineering Handbook,* fifth edition, (Washington, DC: Institute of Transportation Engineers, 1999), page 201.

[59] Institute of Transportation Engineers, *Traffic Engineering Handbook,* fifth edition, (Washington, DC: Institute of Transportation Engineers, 1999), figure 8-10, "Work Zone Speed Limit Reduction Policies." Handbook data obtained from L.R. Crowther and K.S. Opiela, "Procedure for Determining Work Zone Speed Limits," *National Cooperative Highway Research Program Results Digest 192* (Washington, DC: Transportation Research Board, September 1996).

[60] ATSSA is an international trade association that trains 10,000 roadway safety workers yearly, in areas such as worker safety, traffic control, and work zone inspection.

[61] FHWA and NDOR, "Study of Work Zone Crashes in Nebraska" (unpublished report, August 2001).

- Safety,
- Signage,
- Traffic maintenance, and
- Accident statistics.

The FHWA's[62] required "process review and evaluation" for NDOR's July 26, 2001, review, graded the work zone on U.S. 6 (West Dodge Road) as "fair"[63] for the year 2001. This grade was given with the following comments:

> Barricade was covered with plants, dirty barrels, many dirt covered barricade[s], barrels are down on their side[s], left lane closed signs on temporary stands when they should be on permanent posts. Sharp Drop Off at Pavement Edge sign in use (discontinued sign).

NDOR's 2001 Statewide work zone report included the following rating statistics: poor (2), fair (12), good (34), and very good (1). NDOR defines these ratings as follows:

- Poor—Changes must be made to the traffic control devices. Typically, a poor score results in a call to the district or project manager to inform the manager about the problems and require that the project manager or contractor correct them.
- Fair—Work zone could benefit from minor adjustments or from improved oversight to see that cones and barrels are correctly located.
- Good—Traffic control devices are in better position and condition than for a project that is graded "fair," with fewer minor adjustments noted.
- Very Good—Little, if anything, is wrong with the work zone traffic control plan.

The earth moving truck's May 15, 2001, damage to the barrier had occurred before this inspection; the inspection mentions neither the incident nor the subsequent repair. In addition, no one commented about the proximity of the work space to the traffic space on the two bridges or proposed separating the opposing traffic lanes.

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[62] Title 23 CFR 630.1010-5(ii)(e)(1), *Process review and evaluation*, states "A review team consisting of appropriate highway agency personnel shall annually review randomly selected projects throughout its jurisdiction for the purpose of assessing the effectiveness of its procedures. The agency may elect to include an FHWA representative as a member of the team. The results of this review are to be forwarded to the FHWA Division Administrator for his review and approval of the highway agency's annual traffic safety effort."

[63] Grade options were "very good," "good," "fair," and "poor."

Management and Operational Information

State School Bus Driver Qualification Process

The Nebraska Department of Education's Rule 91 contains the requirements for obtaining a school bus driver's license and school bus driver's certificate, which applicants must accomplish in the order shown below:

- Complete a 12-hour training period.[64] Level I training consists of (at least) 2 hours of surpervised behind-the-wheel training in a school bus and instruction in the pretrip vehicle inspection process.
- Complete a 10-hour classroom course consisting of lectures, video presentations, and hands-on equipment training[65] by a State-certified instructor.[66] The instructor also reviews the applicant's behind-the-wheel evaluation form from the school district. This course is not a defensive driving course; it is a busdriver orientation course.
- Obtain a Nebraska class "A" or "B" CDL with a passenger endorsement[67] and pass a physical examination.
- Apply for a Nebraska School Bus Driver Certificate, issued by the Department of Motor Vehicles at designated testing centers throughout the State. The applicant must pass a 20-question written test (100 percent is passing), possess a current physical examination card, and pass an additional eye exam conducted at the testing center. This certificate must be renewed every year on the applicant's birthday. Renewing the certificate requires another complete physical examination (using 49 CFR 319.67 criteria), passing another written 20-question test, and passing the eye examination.

After successfully completing the Rule 91 requirements, school bus drivers generally receive additional training and orientation from the school districts that hire them.

Seward School District Driver Hiring and Training

On October 15, 2001, the Safety Board interviewed the transportation supervisor of the Seward School District regarding the district's hiring and training and transportation operations. According to the transportation supervisor, the Seward School District

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[64] The Level I training can be waived for up to 60 days after employment. However, the applicant must have a valid class "A" or "B" CDL with passenger endorsement and School Bus Driver Certificate before driving a school bus.

[65] The course, which covers topics such as school bus equipment operation and rules of the road, does not include driving.

[66] To become a State-certified instructor, one must attend a training course and conduct a lecture for evaluation purposes. Nebraska has 20 certified instructors.

[67] As of June 12, 2000, this part of the licensing process consisted of a 25-question knowledge test; the applicant was not required to perform the walk-around pretrip inspection.

employs 17 full-time[68] school bus drivers and 10 substitute and activity bus drivers. Each full-time driver is assigned a permanent route and drives the same vehicle every day. All full-time and substitute drivers are eligible to drive activity vehicles, usually on an overtime[69] basis.

Of the 27 drivers employed at the time of the accident, 5 were local college students (from Concordia University) ranging from 19 to 22 years old. According to the transportation supervisor, these drivers are usually employed only while attending the university; all other drivers are over 24. (The minimum age for school bus drivers in Nebraska is 18.)[70] The transportation supervisor conducts a driver's history check for traffic violation convictions (most recent 6 years) and for traffic accidents (most recent 4 years). She also conducts a criminal history check. Each driver must successfully pass a preemployment drug screen and be enrolled in the school district's random drug testing program.

The transportation supervisor stated that the school district follows the State's procedures for training busdrivers (see *State School Bus Driver Qualification Process* in the preceding section), which is conducted by the head mechanic. District training consists of 2 to 3 hours of behind-the-wheel orientation and evaluation. Completed evaluations for each trainee, covering topics such as pretrip preparation, vehicle operation and maneuvering, approaching railroad crossings, and loading and unloading passengers, are submitted to the State instructor as part of the State-mandated, one-time Level I school bus driver training. No formal in-service training exists for busdrivers. According to the transportation supervisor, the small number of drivers allows her to become familiar with each driver's strengths and weaknesses and to address citizen complaints on a case-by-case basis.

The transportation supervisor further stated that school bus drivers must attend Level II training every 4 years. This training consists of 2 hours of classroom instruction by a State-certified instructor and changes every year to meet varying needs and issues. Drivers are also provided the State of Nebraska's *School Bus Driver's Guide* and the school district's *School Bus Driver's Handbook* for reference and study.

Operations

The city of Seward is about 20 miles west of Lincoln and has a population of about 5,300. According to the transportation supervisor, the school district comprises an elementary school, middle school, and senior high school. Of the 1,312 students in the school district, 634 are transported on school buses;[71] a majority of the 18 regular school

[68] "Full-time" drivers are regularly employed to drive a school bus, once in the morning and once in the afternoon. The driver usually works less than 40 hours.

[69] Time worked other than regularly scheduled route driving time. The transportation supervisor selects overtime drivers from a volunteer pool, making assignments to those volunteers having the least overtime hours. Overtime assignments are not made based upon experience.

[70] Nebraska Department of Education, Rule 91, Section 004.01D.

[71] The total includes 226 senior high school, 94 middle school, and 314 elementary school students.

bus routes are in rural areas. The district also provides transportation for two private schools in Seward: St. John's Lutheran School (72 students) and St. Vincent's Catholic School (6 students). These private school students are picked up on regular (established) school bus routes.

Vehicles. The transportation supervisor stated[72] that all vehicles owned by the school district are available for use as student activity vehicles, although only three are designated for that purpose. The transportation supervisor further stated that the school district operates 24 school buses (twenty 59-passenger buses, one 78-passenger bus [the accident vehicle], one 77-passenger bus, one 60-passenger bus, and one 10-passenger bus) and ten 12-passenger vans. The school buses have onboard video equipment to monitor student activity. The accident bus was equipped with a video camera; no tape was in the machine at the time of accident. According to the transportation supervisor, not using a tape is normal practice on a student activity trip because the bus sits, unused, for several hours, and recording a video would run down the vehicle's battery.

The transportation supervisor noted that the school district reserves the buses best suited to transporting students longer distances (most mechanically sound and comfortable) for student activity trips; such vehicles are generally not used for regular school routes. Nonschool bus vehicles, such as vans or passenger vehicles owned by the school district, may be used only when the number of students is insufficient or the length of the trip is inappropriate for school bus vehicle transportation. The trip from Seward to Omaha was about 80 miles one way, and school buses were used to transport the bands due to the number of students and the band equipment required for the competition.

Maintenance. The transportation supervisor stated that the school district employs two vehicle mechanics, who conduct all maintenance except tire changes, which are done at a local International Harvester dealership. The transportation supervisor also stated that diesel-powered vehicles (21) receive a lube and oil change every 3,000 miles. After 6,000 miles, according to the transportation supervisor, vehicles receive an inspection of the undercarriage components, including brake lining and adjustment, and all lighting, tires, and other safety equipment. In addition, hydraulic fluid levels are checked on vehicles that have hydraulic brake systems. According to the transportation supervisor, the same components are checked every 1,500 miles for the district's three gasoline-powered buses.

The transportation supervisor stated that school bus drivers are required to conduct a daily pretrip vehicle inspection before departing the bus yard[73] and to record the results in a book kept inside each bus. At the end of the month, drivers submit this record to the head mechanic for review. In addition, drivers can report directly to a mechanic defects requiring immediate attention, such as those constituting a CVSA out-of-service violation or deemed critical by the driver (such as a broken heater during winter).

[72] Safety Board interview with the Seward School District transportation supervisor, October 15, 2001.

[73] Required by Nebraska Statute 79-602 and Title 92, Chapter 92, Section 003, Department of Education Code. Five drivers have take-home buses and conduct the pretrip inspections at their homes.

The mechanic maintains work orders and repair documents on a computer. Defects noted during the daily pretrip inspection are addressed on a priority system; those requiring immediate action are corrected before the vehicle leaves the bus yard, others when the mechanics have the opportunity to correct them.

In addition to the daily pretrip inspection, the State requires a quarterly vehicle inspection for school buses. This inspection is conducted by the mechanics and consists of the items listed on the pretrip inspection form. If defects are noted, they are listed on the back of the form and corrective actions described. According to the transportation supervisor, the school district retains this form and sends a certificate of compliance to the State Department of Education at the end of the school year. The accident vehicle's records indicated that it had received the following maintenance work:

- October 13, 2000—Right-side body repair.
- October 23, 2000—Replace luggage lock and key.
- May 5, 2001—Replace a turn signal switch.
- June 18, 2001—Oil change, oil filter, and fuel filter.

Inspection records for the Seward School District indicated no mechanical defects or equipment deficiencies.

Meteorological Information

The weather report on the day of the accident called for partly cloudy skies and visibility at 10 miles with gusting westerly winds of 20 mph. At 2:03 p.m., about the time of the accident, the temperature was 61 degrees Fahrenheit (16 degrees Celsius) and the dew point was 43 degrees Fahrenheit (6 degrees Celsius).[74] The roadway was clear and dry.

Emergency Response

The Douglas County 911 communications center received a citizen call reporting the accident at 2:06 p.m. The first Douglas County deputy sheriff arrived on scene at 2:11 p.m., followed shortly afterward by four other deputies. Additional police units from the Boystown and Valley, Nebraska, jurisdictions (2 and 14 miles away, respectively), along with the NSP, arrived at 2:28 p.m.

[74] Weather data obtained from Eppley Airfield, Omaha, <http://www.nndc.noaa.gov>.

At 2:07 p.m., the Omaha Fire Department dispatched one engine company and one medic company in response to a call indicating a "vehicle accident with injuries, bus in a ditch."[75] Engine 55, which was about 3.5 miles away, and medic 52, housed about 7 miles away, responded. The commander of battalion 6, Omaha Fire Department (referred to in this report as the incident commander), heard the dispatch on a radio scanner and additional radio traffic describing a school bus in the creek with many injuries.

The incident commander arrived at the accident scene about 2:12 p.m.[76] He parked several hundred feet from the bridge and walked to the scene. Engine 55 and medic 52, who had arrived at the scene less than 1 minute before the incident commander, parked on the roadway approaching the bridge. Those units, whose personnel had advanced life support capabilities, went directly to the bus. The engine 55 captain subsequently requested a fire alarm assignment. (A fire alarm assignment consists of three engine companies, one aerial unit,[77] one battalion chief, and one medic company.)

At 2:15 p.m., the incident commander initiated a call for additional equipment. At 2:25 p.m., the incident commander requested a second alarm assignment, initially asking for five additional medic units from the Omaha Fire Department. In accordance with the fire department's emergency preparedness plan, the incident commander identified the scene as a mass casualty incident.[78] He also requested a medical helicopter from Omaha and asked for an estimated response time for four helicopters (two from Omaha and one each from Lincoln and Norfolk, Nebraska).[79]

Additional resources requested by the incident commander and responding within 25 minutes of his arrival included rescue 1 (a hazmat and high-angle rescue company consisting of four firefighters), engine 33 (a similarly trained company consisting of four firefighters), rescue 32 (a specialty equipment vehicle with two firefighters), three helicopters, and supervisor 1 (the paramedic shift supervisor).

[75] This is the Omaha Fire Department's standard response to a collision with injuries and no extrication needed.

[76] Based upon a Safety Board investigator's conversation with the incident commander during the investigation. Not all times were recorded in the logs because of communications problems.

[77] Hook-and-ladder truck or ladder truck.

[78] At the time of the accident, the Omaha Fire Department had an emergency preparedness plan for handling a multiple casualty, mass casualty, or disaster incident. The plan generally designated incidents requiring one or two medic units as multiple casualty incidents, incidents requiring more than two medic units but confined to one general area as mass casualty incidents, and incidents requiring multiple outside resources and not confined to one area as disaster incidents. The designation of mass casualty incident allows the area hospitals to prepare for multiple injuries and provides the incident scene officer (transport officer) with information on how many patients each hospital can accommodate.

[79] In accordance with normal operating procedures, the incident commander attempted to contact the helicopters via channel 4, a nonrepeated frequency without PL (private line within a designated frequency) codes, but the helicopters did not respond. According the fire chief, two of the helicopters were from outside the Omaha area and may not have known the Omaha Fire Department's radio frequencies and procedures.

The incident commander realized shortly after establishing command that communication via radio required the radio to be held as high as possible while standing at the crown of the bridge above the scene. At any other location, the radio could not access the repeater, and therefore no communication was possible. (See figure 22.)

Figure 22. Accident scene.

Communications between the incident commander and the extrication sector commander (battalion 5), whose unit arrived at 2:25 p.m., were hindered because the bridge was between the two radios. Further, when the commander of battalion 4 arrived at 2:35 p.m., he was unaware of the nature of the incident, believing that he had been dispatched to an automobile accident to assist with a medical helicopter landing, according to initial reports from dispatch. He had been given radio channel 2[80] as his operating frequency, which did not have the ability to reach the fire dispatcher from the accident location.

Additionally, the incident commander had to move between two locations to establish radio communications with the various groups conducting rescue operations: (1) on the crown of the bridge (the high point) and (2) about 100 yards away, partway down the creek bank. While the incident commander was at the second location, inbound and outbound communications between him and other rescue personnel were severely limited due to the distance from dispatch. For example, the incident commander attempted to establish a staging area for emergency equipment at 164th and California Streets, just north of the incident, but none of the transmissions were received.

Most students were still inside the bus when rescuers arrived. According to the incident commander, multiple passengers were trapped by their arms and legs between the inside wall of the bus and the seats. A 14-year-old female passenger was ejected and found

[80] Channel 2 is a nonrepeated channel used in the city as a command channel.

trapped between the bus's left side and the muddy creek bed. A 16-year-old male and an 18-year-old female were pinned between the bottom of the seat and several seat cushions that came apart. The 14-year-old male who drowned was trapped between the left side of the bus and a seatback and found face down in the muddy water. The incident commander noted that extrication of passengers from the accident bus was difficult because of the rescuers' lack of knowledge of school bus construction and extrication methods. For instance, because the Jaws of Life device was too large to fit between the bus seats, hack saws were used to cut off seat legs entrapping victims. In addition, when the firefighters attempted to poke holes in the roof with their pick axes, they were hampered by the reinforced roof construction required for school buses.

The incident commander said that as patients were brought up the bank and to a park 150 to 200 yards north of the accident, they were assessed and assigned to a caregiver (firefighters, doctors, and nurses or residents of neighboring houses). The most critically injured (six student passengers) were transported by helicopter to the area trauma center approximately 20 miles away. Others were transported by a medic unit to area hospitals.[81]

In all, it took about 1 1/2 hours (2:06 p.m. until about 3:40 p.m.) to transport all the surviving patients. At least three times during the incident, the incident commander went in person to each sector commander to determine whether additional resources were needed. According to the incident commander, delays in requesting additional medic units were the result of communication problems between the incident commander and dispatch due to the terrain and distance from the repeater. A call for three medic units from three surrounding communities came just short of 1 hour from the time of original request, which was not received by dispatch.

The Omaha City Fire Department and other agencies involved in the emergency response conducted a postaccident critique the week after the accident. Participants agreed that the response was timely (given the rural area) and that the local fire and rescue agencies had adequate resources to handle the situation, but that the communications system needed upgrading.

Tests and Research

ECU Testing

The accident school bus's ECU was removed on January 7, 2002, with the assistance of a technician from Thomas Built. A Safety Board investigator hand-carried the unit to Bendix Commercial Vehicle Systems (Bendix) in Elyria, Ohio, where it was tested on January 9. The testing indicated no current system faults but did reveal a number of fault codes determined by Bendix personnel to have originated during the vehicle assembly process. These fault codes resulted from the ECU's having been originally configured as a six-channel system with traction control. When used in the accident bus,

[81] Saint Joseph Hospital, nine students and the busdriver; Methodist Hospital, five students; Nebraska Health System, seven students; Emmanuel Medical Center, five students and one adult; and Douglas County Morgue, two students and one adult.

which required a four-channel system without traction control, the ECU registered faults as it searched for the extra sensors and traction control. (The accident bus's ECU, which was never replaced, was included in National Highway Traffic Safety Administration [NHTSA] recall 00V-232. The recall is discussed in further detail in appendix B of this report.)

Accident Reenactment and Simulation

Witness statements and Safety Board observations on scene indicated that the Seward bus driver might have perceived one of the three oncoming Norfolk buses as having crossed the centerline and veering into his lane and that he steered rapidly to the right in response. To test this theory, Safety Board investigators obtained an exemplar vehicle—a Thomas Built school bus that was nearly identical to the accident bus in all pertinent features—and videotaped a "driver's eye view" during several westbound passes over the West Papillion Creek Bridge. These passes were conducted at roughly the same time of day as the accident; weather conditions and traffic volume were also similar, and the driver maintained speeds consistent with those reported by witnesses to the accident. The videotape confirmed visual observation of the existence of a visual phenomenon that might have been sufficient to cause the school bus driver to mistakenly believe that one of the approaching motorcoaches was crossing over into his lane.

Further, a simulation study was developed to examine the conditions associated with two-lane/large vehicle traffic in this construction area. The simulation, which was developed using the Human Vehicle Environment (HVE) system[82] and the Simulation Model Non-linear (SIMON),[83] Engineering Dynamics Corporation Simulation of Automobile Collisions (EDSMAC4),[84] and Engineering Dynamics Corporation General Analysis Tool (EDGEN)[85] software programs, approximated the Seward bus driver's view. The Seward bus positions were matched to the physical evidence and the buses' witness-estimated speeds of 40 mph. Spacing of the oncoming Norfolk buses was based on the Norfolk drivers' statements. The Norfolk buses were positioned close to the centerline, but still within their lane. The Seward bus driver's potential view was simulated to include the roadway changes in alignment, the relative movement of the three approaching buses, and similar ambient light conditions.

To animate the accident bus's roll and vault, the simulation employed calculations of the bus's travel. Factors such as the location of the bus at final rest, the point at which the railing posts were no longer damaged, and the distance from which the bus dropped were used to calculate the bus's forward speed as it left the bridge at about 14 mph. During the 1.7-second drop, the bus rolled between 180 and 270 degrees. Thus, the data from the

[82] The HVE system simulates vehicle and occupant kinematics.

[83] SIMON allows users to simulate the response of one or more vehicles to driver inputs and environmentally related factors. SIMON was used to model the approach of the Seward and three Norfolk buses to the accident site.

[84] EDSMAC4, fourth revision, permits simulation of single- or multiple-vehicle crashes. EDSMAC4 was used to animate the bus's initial crash with the guardrail.

[85] EDGEN is a three-dimensional kinematics spreadsheet that uses positions and velocities of vehicles or objects to determine the time required to travel between each location. EDGEN was used to animate the bus's impact with the bridge rail and subsequent rollover and vault.

animation of the bus's movements during the vault showed that the bus had rotational and vertical accelerations that were stopped quickly when the left side of the bus struck the creek bed. When the bus hit the creek bed, it had rotational acceleration and large vertical accelerations from the ground that were exerted laterally on the bus's sides.

Guardrail Crash Testing

Safety Board staff reviewed the results of at least five crash tests[86] conducted in 1979 by the Southwest Research Institute for the FHWA that involved school bus collisions with guardrail-type barriers. In the crash tests reviewed, the buses impacted the barriers at angles of 13.8 to 17.5 degrees and at speeds of 57 to 61 mph.

In the tests conducted using W-beam guardrail, the bus rolled over the guardrail and twist. The buses in these tests initially rolled over the barrier, and the top of the bus just behind the driver made contact with the barrier. Due to the flat surface behind the guardrail, the buses continued along the rail and the posts. As the buses continued to roll to an upright position, the rail severely penetrated the top of the roof, completely cutting it from one side to another, just above the rear axle.

Two additional crash tests were conducted with three-beam rail,[87] with steel block-outs and steel posts. In the first test, a full height, solid block-out[88] was used. The bus rolled over but stayed on the proper side of the barrier, sliding to rest after a 90-degree roll. The front tire that initially contacted the barrier separated from the wheel. In the second test, the bottom third of the block-out was cut away in a triangular piece, reducing the roll of the barrier. The bus rolled about 30 to 45 degrees initially and then returned to an upright position, also staying on the proper side of the barrier.

Two additional crash tests used a SERB design, consisting of a three-beam rail with a block-out having a mechanical spacer (metal rod), which allowed movement (roll) at both ends of the spacer, and a cable attached to wood posts. In one crash test, the bus did not roll as much and was safely redirected in an upright position. In the second test, the bus was loaded to replicate students; it was redirected, but rolled onto its side.

Toxicological Information

Blood samples were obtained from the driver upon admission to the trauma center at approximately 5:20 p.m. (3 1/4 hours after the accident). Samples retained by the hospital and the DCSO were forwarded to the Civil Aeromedical Institute, Oklahoma City, Oklahoma, which performed toxicological testing at the request of the Safety Board.

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[86] The Southwest Research Institute conducted the tests as part of an evaluation for the self-energy restoring barriers (SERB) study.

[87] A guardrail typically has two ridges that protrude outward. A three-beam guardrail has three ridges that protrude outward and is about 50 percent higher.

[88] Section of guardrail post mounted between the post and the rail to prevent a vehicle's wheel from snagging the posts.

Results of alcohol testing were negative. Screening tests for amphetamines, marijuana, cocaine, phencyclidine, benzodiazepines, barbiturates, antidepressants, antihistamines, meprobamate, methaqualone, and nicotine were also negative. Morphine, administered postaccident, was detected in the blood sample.

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 upon the effect of highway design and vehicle handling characteristics upon driver performance, the adequacy of work zone safety and management, the occupant safety of interior bus surfaces, the lack of emergency preparedness of students, and the visibility of emergency signage and exit door levers.

Exclusions

Toxicological Impairment

The results of postaccident testing of the accident driver for the presence of alcohol and 12 drugs, including illicit and common licit drugs with known performance-impairing effects, were negative. The final toxicological analysis from the Civil Aeromedical Institute laboratory indicated the presence of morphine; however, this could be attributed to postaccident administration of the drug for the serious injuries sustained by the driver.

Sleep Loss and Fatigue

According to the accident bus driver's self-reported routine, he normally obtained about 7 1/2 hours' sleep nightly. On the night before the accident, he reportedly obtained about 7 hours' sleep, an amount that is not significantly less than usual. He went to bed an hour later than usual, but slept about 30 minutes beyond his normal waking time. This 1-hour shift in his routine resulted in a 25-hour (lengthened) day. It is well-accepted in the scientific sleep community that in free-running wake/rest cycles, during which individuals are deprived of the usual cues as to time of day, individuals default, on average, to a 25-hour day, suggesting that such a change is physiologically tolerable, if not optimal.[89] In general, studies have concluded that most individuals tolerate such a change very well with no increased sleepiness.

Investigators spoke with numerous witnesses who had accompanied the driver throughout the morning of the accident. None reported any indication that the driver appeared drowsy. Moreover, the relatively short duration of the trip—and the fact that he had returned to driving after a reasonable period of having been off-duty (while the students participated in the competition)—provides no evidence to indicate that fatigue was a factor in this accident. The Safety Board therefore concludes that the accident bus driver was not impaired due to drugs, alcohol, or fatigue.

[89] See, for example, J. Aschoff, "Circadian Rhythms: General Features and Endocrinological Aspects," ed. D.T. Krieger, *Endocrine Rhythms* (New York: Raven Press, 1979) 1-61.

Weather

According to weather reports for the local area, winds were westerly, gusting to 20 mph on the day of the accident. The large profile of a school bus such as the accident vehicle, coupled with gusting winds, can account for an added degree of difficulty in maintaining one's lane, especially if crosswinds exist. In this case, however, the winds were westerly and witness reports, both specific to the time of the accident and earlier in the day, indicate that the accident bus driver displayed a persistent rightward bias in his alignment of the bus within the lane of travel, irrespective of the direction of travel or wind direction. Accordingly, it appears unlikely that the winds were responsible for the accident bus driver's inability to maintain his lane. The Safety Board therefore concludes that the weather was not a factor in this accident.

Mechanical Condition of Bus

The primary postaccident examination of the Thomas Built school bus occurred on October 19, 2001, about 6 days after the accident. All vehicle systems that could have caused or contributed to the accident were examined: engine and transmission, brakes, tires, and steering.

Engine and Transmission. The Cummins ECM did not have the capability to record data related to the precrash operation of the vehicle such as speed, rpm, and braking,[90] information that would have been useful in determining what may have occurred just prior to the accident. The investigation was similarly hindered by the Allison, Mode 3060, transmission ECU's lack of recording abilities.

Steering. The steering linkage was intact, and the wheels moved slightly when the bent steering wheel was turned. The heavy crush in the left-front corner of the coach impeded the linkage from moving. The steering gearbox was found to be without defect.

Tires. The like-new tires had adequate tread depth. The only tire for which the air pressure could not be checked was the right-rear-inside dual wheel, which had been torn open during the accident, causing a total loss of air. The other five tires had air pressures between 100 to 110 psi, which is in the normal range.

Brakes. The right-rear push-rod stroke was measured at 3/4 inch. A 3/4-inch push-rod stroke is very unusual, if not impossible, for a type 30 brake unless the brakes are dragging. The cracked right-rear drum most likely impeded the stroke and resulted in this measurement. Although vehicle damage prevented examination of the brakes, the automatic slack adjusters are likely to have been working properly on the relatively new bus with an odometer reading of fewer than 15,000 miles.

Further, although the Bendix ABS ECU had been recalled and should have been replaced nearly a year earlier, the Lincoln Truck Center's inspection of the vehicle in September 2000 (see appendix B) did not reveal any chafed speed sensor wiring, which

[90] Of the four major engine manufacturers (Detroit, Cummins, Mack, and Caterpillar), Cummins is the only one that manufactures an ECM unable to record these parameters.

would have indicated a false ABS activation that can lead to a total loss of braking at low speeds. Postaccident testing also revealed no system faults. Consequently, though brake defects cannot be totally ruled out, the Safety Board found no evidence that the braking system had a role in this accident. The Safety Board therefore concludes that evidence does not indicate that the mechanical condition of the accident bus contributed to the accident.

Emergency Response

The Omaha Fire Department had a current standard operating procedure for handling multiple, casualty, mass casualty, and disaster incidents. The policy was well-documented and appeared sufficient for handling such events within Douglas County as long as the incident occurred within radio contact. However, because of the Omaha accident's rural location and site beneath a bridge, 49 feet below the highway, communications between the incident commander and other agencies and officers on the scene were hampered. Communication via radio required the radio to be held as high as possible, while standing at the crown of the bridge above the scene. At any other location, the radio could not access the repeater, severely limiting inbound and outbound transmissions.

The resulting communications failure prevented the incident commander from establishing a staging area for emergency vehicles at 164th and California Streets, just north of the incident, and, as a result, blocked travel lanes and contributed to about 1/2 mile of roadway congestion. Further, requests for three medic units from three surrounding communities were delayed almost an hour from the time of the original radio transmission because dispatch did not receive the first transmission. The Safety Board therefore concludes that, although not detrimental to the emergency response efforts on behalf of the accident victims, communications were inadequate and resulted in a less than optimal emergency response. According to the Director of Omaha's 911 services, the equipment necessary to upgrade its communications system has been purchased and is now being installed; anticipated use by all departments is scheduled for spring 2004.

Driver's Qualifications

At the time of the accident, the 22-year-old driver was licensed and met all requirements to be a school bus driver in Nebraska. He had more than 2 years' experience as a busdriver and 2 years' experience driving a dump truck in intrastate commerce. Although he had two prior speeding convictions, neither involved commercial motor vehicles, and both sufficiently predated his employment as a school bus driver that one could assume they did not reflect the accident bus driver's operating tendencies at the time of the accident. Every witness interviewed by the Safety Board during this accident investigation who knew the accident bus driver and had ridden with him before, spoke favorably of the busdriver's performance. None provided any information that would call into question his usual judgment and skill in performing the duties of a school bus driver.

Further, in this accident, the busdriver either failed to maintain his lane or appears to have taken evasive action to avoid a collision or the perceived threat of a collision.

Neither scenario suggests a general lack of experience as the root cause of the accident. Most likely, the significant event, actions taken to avoid oncoming traffic, had more to do with road design than with experience. The Safety Board therefore concludes that the accident bus driver's qualifications neither caused nor contributed to this accident.

Accident Discussion

This analysis of the accident sequence focuses on the human performance aspects of the accident bus driver's behavior in interaction with the work zone's roadway geometry. Two possible accident scenarios have emerged from an evaluation of the factual information collected during this investigation: the accident bus struck the guardrail when the driver took evasive action to prevent either a *perceived* or an actual frontal collision with an approaching motorcoach. The contributing components of the speed limit in the work zone and of the driver's unfamiliarity with the accident vehicle will also be discussed.

Ability of Driver to Maintain Lane

The handling characteristics of the transit-style accident bus may have affected the driver's ability to maintain his lane. The accident bus differed from the driver's regular route bus, which was a conventional-type school bus, in several important respects. They affected the maneuverability of the bus, and in particular, the timing of steering inputs by the driver in order to effect control. Greater anticipation and earlier initiation of a turn is necessary for a conventional bus than for a transit-style bus to attain the same turning radius. Further, the right-front corner of the transit-style bus is aft of the driver's visual field; consequently, a driver who is experienced generally, but has limited experience driving this type of bus, must make extensive use of the mirror on the right side of the bus to align the vehicle and judge its right-side clearance. This difference changes the driver's visual scan patterns and imposes greater visual demands and a more complex cognitive workload, as the driver strives to sense and integrate spatial cues. As the driver entered areas where the lateral alignment was more critical (for instance, on curves), the increased complexity of the roadway might have drawn his attention to the view ahead, reducing the frequency and/or duration of glances to the right mirror. Given the increased need for active maneuvering in such situations, it is not surprising that witnesses reported the driver drifted onto the right shoulder. With experience, drivers typically develop an intuitive sense of their vehicle's spatial envelope, learning to gauge the width of their vehicle and to extrapolate the spatial arrangement of obstructions in their forward view. However, this driver had very limited recent experience operating a bus of this design. Consequently, his ability to judge the vehicle's spatial proximity to the bridge rail was probably limited, a factor that was compounded by the series of slight curves on the approach to the bridge.

The placement of the front (steering) axle probably compounded the driver's spatial uncertainty because it altered the required timing of steering inputs to maneuver the accident bus, compared to his regular route bus, and may have resulted in less skilled steering responses, due to the driver's limited familiarity with the steering and handling characteristics of the transit-style bus. Although the accident bus driver was able to recall the previous trip from Seward to Omaha, he did not recall the incidents en route, during which he drifted onto the shoulder. The rumble strip should have served as a salient warning to the driver, providing him feedback that the bus had drifted onto the shoulder, but the observations of his misalignment in the lane suggest that any warning provided by the rumble strip failed to have a discernible or lasting impact on his behavior.

The Safety Board has found during investigations of other school bus accidents[91] that most school transportation administrators usually try to assign drivers to a single bus, perhaps recognizing the value of the driver's familiarity with the particular features and idiosyncrasies of that vehicle. When a bus undergoes repairs—or in this case, the trip itinerary necessitates a specially designated vehicle, thereby requiring that the driver use a bus with which he or she is less familiar—drivers may underestimate the potential risks of the vehicle's handling characteristics.

The Safety Board therefore concludes that the accident bus driver's unfamiliarity with the accident vehicle, which differed both in its perceptual demands and in its handling characteristics from his regular route bus, may have contributed to his inability to accurately judge the lateral distance to the guardrail, bridge rail, and oncoming vehicle and to his inability to properly steer the bus through the work zone.

This accident demonstrates the tragic consequences of underestimating key operational differences among buses. Therefore, the Safety Board will inform the National Association of State Directors of Pupil Transportation Services (NASDPTS) of the circumstances of this accident so that the association can, in turn, encourage its members to review their practices regarding assignment of drivers based upon familiarity with the bus, recurrent training, and "check rides" for drivers who are assigned a bus that fundamentally differs from the type of bus upon which they developed their skills.

Possible Impingement on Accident Vehicle's Travel Lane

Although the persistent, rightward bias of the vehicle in its lane demonstrates the driver's unfamiliarity with the accident bus, it is insufficient to explain the circumstances of this accident. Additional evidence regarding the roadway geometry of the work zone and handling characteristics of the larger vehicles suggests that the driver's inability to accurately judge the lateral distance to the bridge rail was not solely responsible for this accident and that drivers traveling in both directions may have crowded each other's lanes.

[91] For example, see (a) National Transportation Safety Board, *Motorcoach Loss of Control and Overturn, New Mexico State Route 475, March 2, 1999,* Highway Accident Brief NTSB/HAB-01/01 (Washington, DC: NTSB, 2001); (b) National Transportation Safety Board, *Bus Crashworthiness Issues,* Highway Special Investigation Report NTSB/SIR-99/04 (Washington, DC: NTSB, 1999), case studies of school bus accidents that occurred in Buffalo, Montana (HWY-98-M-H022), on March 10, 1988, and Flagstaff, Arizona (WRH-96-F-H014), on August 14, 1996; and (c) National Transportation Safety Board, *Mayflower Contract Services, Inc., Tour Bus Plunge From Tramway Road and Overturn Crash Near Palm Springs, California, July 31, 1991,* Highway Accident Report NTSB/HAR-93/01 (Washington, DC: NTSB, 1993).

Figure 23 shows the width of the lane lines, the widths of the buses, and the direction of off-tracking[92] as the first Norfolk bus approached the accident bus, based on a simulation of the accident.

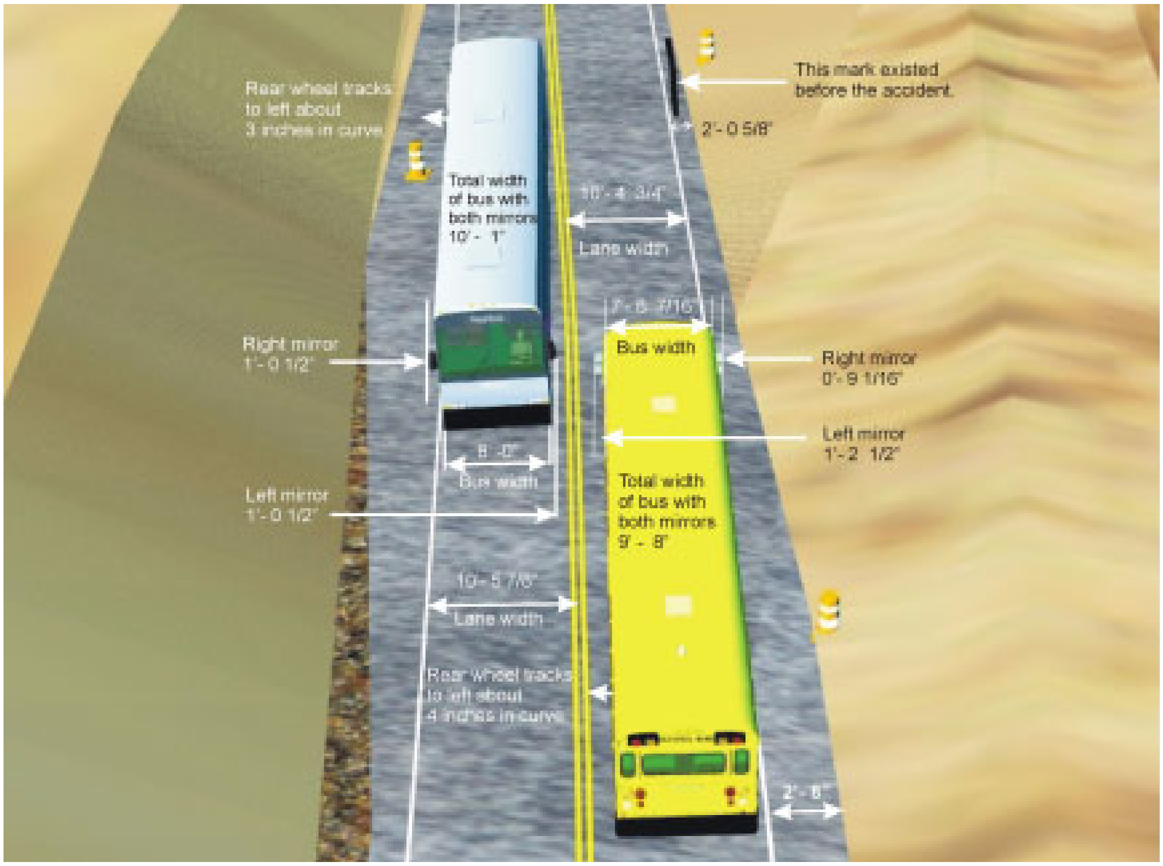

Figure 23. Bus and lane widths (Norfolk bus, top left, and accident bus, lower right).

Data from the Safety Board's simulation study indicated that on this curve, at speeds of about 40 mph, the Norfolk bus would have off-tracked about 3 inches; in other words, the drive axle tires would have been about 3 inches closer to the edgeline than the front tires. Similarly, on this curve, the accident bus would have off-tracked about 4 inches, and the rear tire would have been closer to the centerline than the front tires.

When one considers the width of the eastbound and westbound lanes (each about 10 1/2-feet wide) and the widths of the bus bodies with drivers' side mirrors (about 9 feet

[92] Off-tracking refers to the tendency of a long vehicle's rear tires to follow a different path from the vehicle's steering tires. As a vehicle goes around a turn at low speeds, the rear tires of the vehicles track inside the front tires. This phenomenon is similar to that of a bus at an urban intersection where the front tires are perhaps 10 feet or more from the curb at the start of the turn but the rear tires come very close to the curb as the bus turns. As speed increases and the radius of the turn becomes greater, the amount of off-tracking declines. At higher speeds in a turn, the vehicle begins to slip at the rear tires, and the rear tires track outside the front tires.

wide), along with an additional 3 to 4 inches of off-tracking for each bus, clearly both lanes were almost fully occupied. Further, if the Norfolk bus was near the centerline to avoid the dirt embankment on the right, the accident bus may have been driven near the edgeline on the outside of the curve.

As the accident bus approached the guardrail and bridge, the simulation indicates that, if the right side of the bus was near the edgeline, the operator would have had to steer the bus to the left about 70 degrees[93] to avoid striking the guardrail. The rear of the bus tracked inside the front by about 4 inches at 41 mph. For the accident bus driver's to avoid going across the lane and striking the second Norfolk bus, the accident bus would have had to track about 5 to 8 inches toward the guardrail. During this corrective right steer,[94] the bus struck the guardrail and then the bridge rail.

Although the roadway might have been wide enough to permit the second Norfolk bus and the accident bus to pass one another on a straightaway, given the off-tracking, overhang, and turning radii characteristics of the two vehicles, it may not have been wide enough for either driver to maneuver his vehicle through the series of curves at the speeds at which the vehicles were traveling. The Safety Board concludes that the roadway geometry in the work zone resulted in extremely tight tolerances on driver performance, which may have been exceeded when the second Norfolk bus and the accident bus approached the West Papillion Creek Bridge. The Safety Board further concludes that although it cannot be determined whether the driver of the oncoming Norfolk bus encroached upon or crossed the centerline, the narrowness of travel lanes in the work zone relative to the space occupied by the buses left the accident bus driver little room for error.

Perceived Threat of Frontal Collision by Accident Vehicle Driver

The extremely tight tolerances on the drivers' performance due to the roadway geometry, coupled with the size and handling characteristics of the vehicles, which would have made it difficult for the two buses to have safely passed one another, support the theory that the school bus left the roadway as its driver took evasive action to avoid a frontal collision with the approaching Norfolk bus. Yet the testimony of a witness who regularly drove U.S. 6 and noted that it *appeared* that oncoming vehicles were impinging on the lane of travel, even when this was not the case, supports the theory that the driver took evasive action to avoid the perceived threat of a frontal collision. Drivers who regularly travel the route may adjust their interpretation of the visual scene to reflect this experience, developing the confidence and experience that ensures safe passage. Drivers, such as the accident bus driver, who had never traveled the work zone in that direction, lack the benefit of this learning and are likely to react based upon their initial impressions.

[93] Equivalent to a radius of about 500 feet.

[94] To follow the tiremarks, the bus required about a 175- to 290-degree right steer in SIMON after the 70-degree left steer. At 175 degrees or more right steer, the bus would have followed a curve radius of about 150 feet. Above 175 degrees, the bus would have followed about the same radius as at 40 mph but would have yawed and side-slipped. Above 175 degrees, the bus would have rolled over after a quarter of a turn. The steering input may have been reduced slightly due to the right-rear tire dragging along the face of the guardrail.

The Safety Board's videotape of the accident bus driver's potential view captured the dynamic interplay between the roadway characteristics (especially vertical and horizontal alignment), vehicle characteristics (in particular, the relative speeds and changes in acceleration of approaching vehicles), and visual phenomena that may have affected the driver's actions, including interposition,[95] linear perspective,[96] and motion parallax.[97]

Naturally occurring visual distortions can affect a drivers' ability to accurately perceive an object's location in three-dimensional space, especially beyond a distance of 66 feet (20 meters), in which monocular visual cues predominate as the eye-brain visual system works to develop a three-dimensional representation of the spatial environment. Such distortions may also be compounded when the viewer, the target, or both, are in motion.

The Safety Board's simulation further supports the theory that the accident driver may have experienced a visual illusion of the approaching bus impinging his travel lane. Figure 24 shows frames from the simulation that depict the driver's potential view and the occurrence of this illusion.

[95] Interposition of objects provides spatial information because objects that are further away can be obscured by closer objects in the same visual path. Interposition is a monocular cue of relative spatial location.

[96] Linear perspective refers to the monocular visual spatial cue in which parallel lines in a perspective image appear to converge toward a single point at the most distant location in the image (the horizon or infinity). Nearby objects will also appear larger than similar objects at a distance; due to size constancy (the recognition that it is the perception that changes with distance, rather than the real size of the object); consequently, an observer perceives this change as one of distance. Additionally, the apparent shape of an object changes to reflect a change in spatial orientation or distance from the observer (that is, a rectangular door appears as a trapezoid shape as it is opened away from the observer); due to shape constancy (the recognition that the object retains its original shape, while it is our perception of it that changes), this feature provides spatial information.

[97] Motion parallax refers to the differences in apparent angular velocity of objects, when the viewer and/or the image are in motion. The apparent velocity is inversely proportional to real distance, that is, nearby objects appear to move (or pass) rapidly by, while those at a distance move/pass much more slowly. Consequently, this dynamic monocular cue permits one to judge distance to an object when the object and/or the observer are in motion. However, when both the object and the observer are in motion, the accuracy of judgments of distance is diminished.

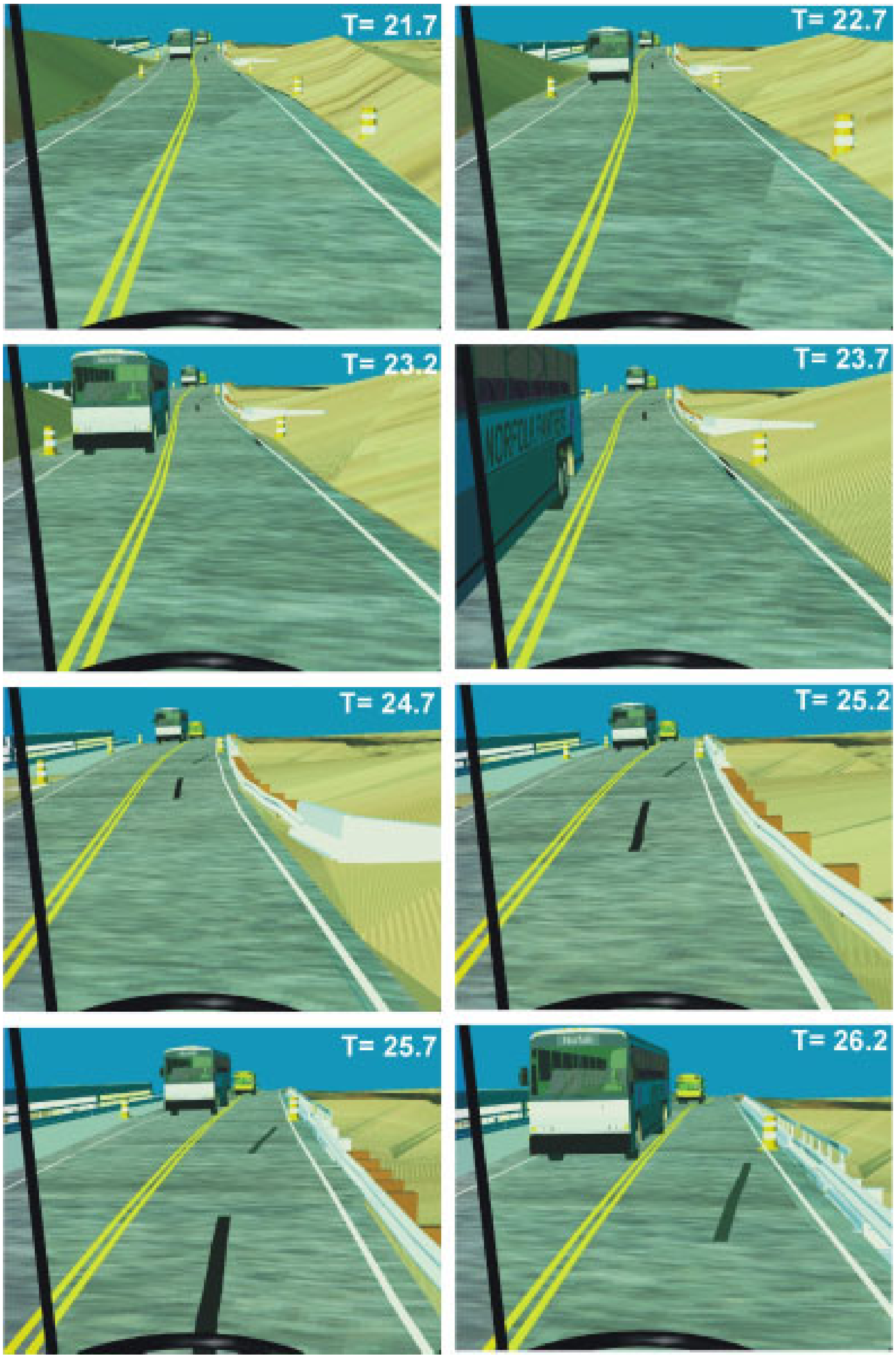

Figure 24. Simulation of the accident bus driver's potential view.

The simulation shows that the first Norfolk bus may have been on a tangent line headed toward the accident bus as the two buses met at a curve,[98] thus the accident bus driver has no indication of where the Norfolk driver will turn as he gets to the curve or how much of the roadway the Norfolk bus will occupy. In addition, as the second and third Norfolk buses pass into a curve and a depression in the roadway prior to crossing the bridge, they appear to cross the centerline because the centerline visually "disappears" into the depression.

Both buses are about 9 feet wide with driver's side mirrors; on the 10 1/2-foot-wide lanes, the slight off-tracking of the buses leaves little room for error in the curve, especially if the Norfolk bus is near the centerline. If the Norfolk buses impinge on the centerline or cross slightly into the other lane, the perception that the Norfolk buses are crowding the accident bus is exacerbated. The illusion of crowding is supported by the second Seward bus driver's statement that the accident bus was traveling close to the right side of the road.

Physical evidence collected during the accident investigation further supports the theory that the accident bus driver feared a frontal collision with the Norfolk bus. (See figures 25 and 26.) In the simulation, as the accident bus driver approaches the west end of the concrete barrier toward the pavement edge, the W-beam tapers gradually, coming closer to the edgeline. During the accident bus's first sideswipe along the W-beam, it is near the shoulder and must be steered hard left to avoid striking the guardrail with the front of the bus and then hard right for the rear tire to strike the guardrail. By rubbing the guardrail with the rear tire, the bus may have turned more than the driver planned, and corrective steering did not occur before the bus broke through the bridge rail.

[98] The curve radius is 1,500 feet, based on the Safety Board's mapping.

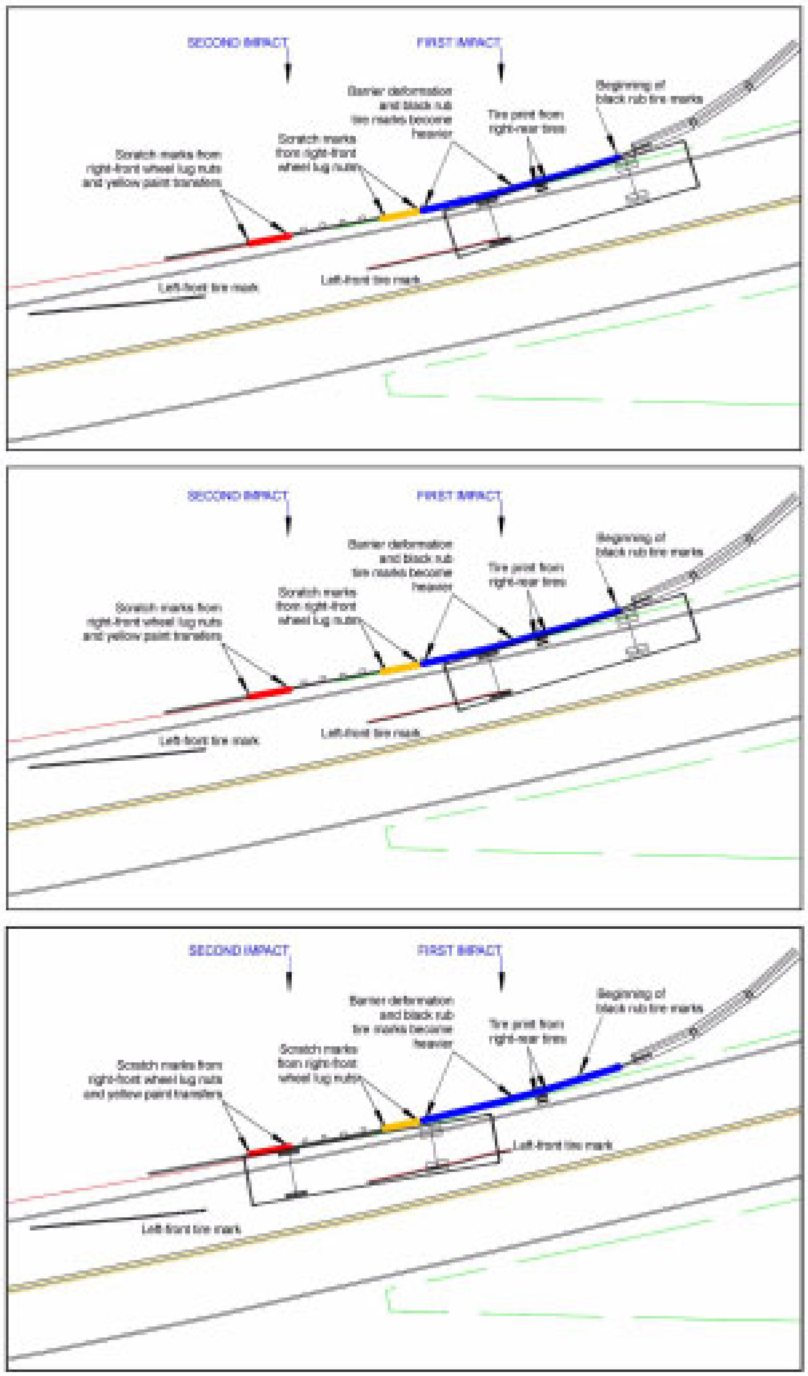

Figure 25. School bus impacts to guardrail in relationship to accident sequence.

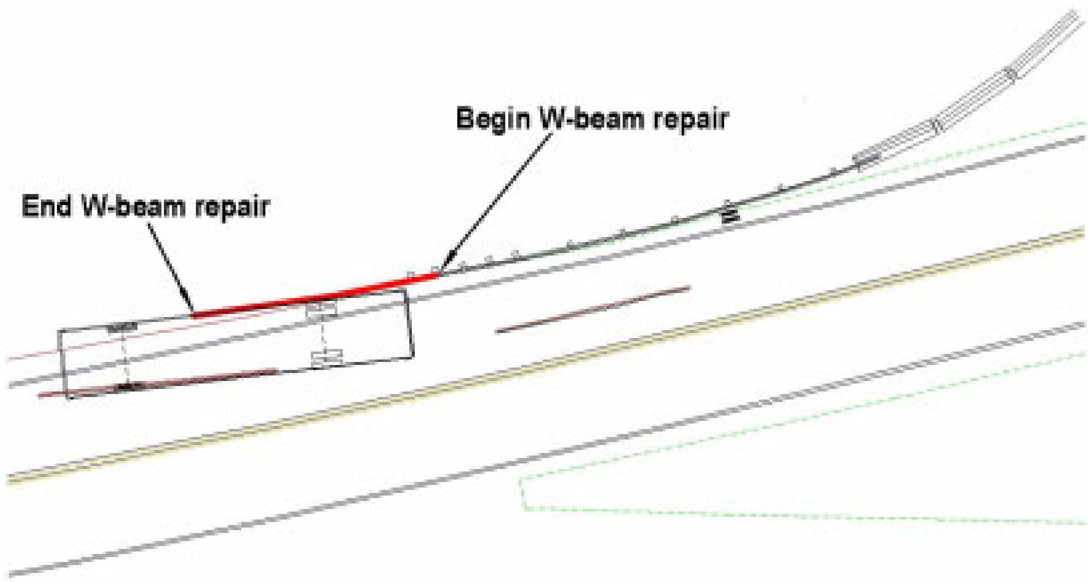

Figure 26. School bus impacts to guardrail in relationship to repair area.

The only way that the rear of the bus could have initially struck the guardrail without the front of the bus striking the guardrail first was for the bus to have been steered right and for the rear of the bus to have off-tracked inside the front of the bus. The theory that the right-rear tire initially struck the guardrail is supported by the physical evidence of tire smear found on the guardrail and the tire print matching the right-rear tire found in the soil between the edge of the pavement and the guardrail. The simulation also shows that the accident bus must steer hard to the right to avoid hitting the second Norfolk bus with its left-front side, even though the tire mark indicates that the left tire is about 4 feet, 10 inches, from the centerline. The Seward driver is forward of the tire and oversteers.

In both the videotape of the driver's view and the simulation, the third Norfolk bus appears to be further to the right of the centerline in the accident bus's lane, due to the simultaneous change in vertical and horizontal alignment at the end of the bridge, and may have led the accident bus driver to exacerbate his tendency to oversteer. This distortion was also noted as the two preceding Norfolk buses approached the accident site.

These visual distortions, together with the accident bus driver's unfamiliarity with the bus and his relative position to the tires, the width of the buses relative to the width of lanes, and a small amount of off-tracking, combined to create the difficult situation that the driver encountered as he neared the edgeline in this curve. As the simulation's potential view demonstrates, a collision with the second Norfolk bus appears to be imminent and evasive action appears to be necessary. The Safety Board concludes that the roadway geometry in the work zone created a visual phenomenon that caused the accident bus driver to perceive the oncoming Norfolk bus as impinging upon its lane, regardless of whether it did or not.

Because of the seriousness of his injuries, the accident bus driver stated that he could not recollect his perceptions at the time immediately preceding the accident. DCSO and Safety Board investigators interviewed a large number of witnesses who were in a position to observe the buses as they passed. Those witness reports were consistent with the types of visual phenomena discussed in this section.

The driver of an automobile immediately behind the accident bus told investigators that the motorcoach appeared to cross the centerline, thereby partially obstructing the accident bus's lane of travel. Passengers on the school bus immediately behind that automobile provided similar recollections of having seen the oncoming motorcoach impinge upon the school bus's lane of travel. Of note, a driver who preceded the accident bus over the bridge told investigators that he observed the second motorcoach in the eastbound convoy cross the centerline by several feet and then correct its alignment less than a mile from its approach to the bridge.

Witness statements indicate that the accident bus driver took action to avoid a real or perceived hazard. According to the driver of the second Norfolk bus that entered the curve from the opposite direction, he observed a look of terror on the accident bus driver's face as the accident sequence unfolded. Yet students on the accident bus, whose view outside was obstructed by their uniforms that hung in the windows, described the early experience of the accident sequence (up to the point of the guardrail strike) as similar to having drifted onto the shoulder and activating the "rumble strip." This initial experience did not alarm the students, perhaps because they had experienced a similar sensation earlier in the trip, with no untoward consequences. Similarly, the benign nature of the driver's previous contacts with the rumble strip explains why the noise or kinesthetic sensation reported by the students just before the accident would, in and of itself, not have startled or frightened the accident bus driver. Instead, the accident bus driver, whose view outside the bus was unobstructed, was probably alarmed by something that he *saw*.

The driver of the second approaching Norfolk bus stated that the first indication of a serious problem that he noted was when the accident bus driver abruptly "jerked" his steering wheel to the right. This action is inconsistent with a realization that his bus was aligned too far to the right; it is, however, consistent with the belief that a collision with oncoming traffic was imminent. An abrupt steering maneuver in either direction would suggest that the driver sought to avoid a hazard that he believed existed in the roadway ahead. The Safety Board therefore concludes that the accident bus driver's behavior at the time of the accident was consistent with anticipation of a frontal collision.

The accident bus driver's action was consistent with the curriculum for school bus driver certification in the State of Nebraska, which advises drivers to reduce their speed and move to the extreme right of the roadway if an approaching (passing) vehicle is in their lane. Under most conditions, the guidance provided to Nebraska school bus drivers is appropriate and prudent advice; the severity of a potential run-off-road accident is typically less than that of a full-impact, head-on collision, or even a glancing impact, given the lack of a crush zone forward of the driver in the transit-style bus. The guidance contained in the busdriver training curriculum is general in nature and not intended to take into account all possible scenarios, such as the potential for a head-on collision while crossing a bridge. Even in this instance, in which the bus fell from the bridge, injuring 27 passengers and killing 4, a head-on collision with the Norfolk bus would have exposed passengers on both buses to possibly more serious risk of injury. Furthermore, depending on the following distances and speeds maintained by other vehicles in the two convoys and their drivers' attentiveness, subsequent collisions might have ensued, further increasing the magnitude of the accident.

The Norfolk drivers insisted that the second Norfolk bus never crossed out of its own lane. These four witnesses, who were traveling eastbound, would have viewed the scene from a different perspective than the accident bus driver and may not have experienced the perceptual illusion experienced by westbound vehicles. The Norfolk drivers provided the only testimony to refute the theory that the Norfolk bus had come close to or crossed the centerline. The Safety Board concludes that even though all witnesses traveling eastbound on U.S. 6 insisted that the motorcoach maintained its lane, most witnesses who were traveling westbound insisted otherwise; therefore, it cannot be unequivocally determined whether the Norfolk bus encroached upon the westbound lane, creating a potential collision hazard.

Highway Design and Driver Performance

Whether the motorcoach truly presented a collision hazard for the school bus or only appeared to, the fact remains that the tolerances on the drivers' performance left little or no room for error. The narrow lane width, coupled with the lack of a shoulder on the bridge, left the drivers with no option in the event that they anticipated a collision risk. Moreover, the rapid closing speed of the two vehicles and the limited sight distance that resulted from the series of curves would have necessitated very fast reaction by one or both drivers.

AASHTO[99] notes:

> When drivers use a highway designed to be compatible with their capabilities and limitations, their performance is aided. When a design is incompatible with the capabilities of drivers, the chance for driver errors increases, and crashes or inefficient operation may result.

In other words, a driver's performance is not independent of the roadway design. An apparent driver error is an indicator that the compatibility of the roadway design must be evaluated with respect to drivers' capabilities and limitations. If a representative segment of the population exhibits a particular limitation, highway engineers have the responsibility to mitigate that limitation through effective highway design. The functional aspects of highway design that most directly affect human behavior under these circumstances are discussed below.

[99] American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets*, 4th ed. (Washington, DC: AASHTO, 2001) 46.

Roadway Width

Lane(s) must be sufficiently wide to permit the widest of vehicles that may legally travel the roadway to be maneuvered in a manner that does not interfere with the ability of others to do the same. Lanes must be wide enough to permit all normal maneuvers *and* to provide ample options in the event of foreseeable problems. Human performance varies with differences in skill, experience, and other factors. A roadway that does not accommodate such differences—and does not account for an appropriate degree of variability in performance—will promote unsafe conditions. In the case of U.S. 6, the lane shifts and reduction of lane width for the temporary routing of traffic resulted in heavy trucks and buses being routed on 10 1/2-foot-wide lanes through two sets of reverse curves at the lane shifts. When two of these wider vehicles met on this narrowed section—especially in the lane shifts—their drivers confronted actual clearance hazards or the perception of a hazard.

Horizontal and Vertical Alignment

Roadway geometry affects what drivers are able to see. Effective roadway design provides drivers with an ample view ahead and also minimizes deceptive visual phenomena that may cause drivers to misperceive what they see. When features of the roadway geometry interfere with the accurate perception of the roadway and other vehicles, the likely result will be a misperception of the spatial relationships among the driver's vehicle and other vehicles and structures in the immediate environment. Because the consequences of such misperceptions can be severe, it is essential to avoid or mitigate the effects of roadway geometries that give rise to visual misperceptions. The Safety Board concludes that the combination of the west lane shift on U.S. 6 and the 10.5-foot lanes and the crest vertical curve on West Papillion Creek Bridge presented drivers with a complicated visual situation that could cause them to misjudge clearances and distances.

Speed

Speed is inversely related to sight distance requirements and to the amount of time available for a driver to respond to roadway conditions. Reducing speeds increases drivers' time to acquire and assess information about the roadway conditions ahead and, in turn, permits them to more effectively plan and execute actions needed to control their vehicle. Speed is also a critical factor in motion-induced visual illusions. Reducing speed may lessen the degree of an illusion (or completely eliminate the illusion), while simultaneously providing the driver with more time to evaluate what he or she sees and to potentially recognize the visually deceptive phenomenon.

While a posted speed of 45 mph might seem relatively slow compared to a freeway speed limit, at this location it means that the closing speed between opposing vehicles is 90 mph or 132 feet per second. Although speed limits in work zones are generally determined by engineering judgment, various factors, such as roadway geometry, traffic density and type, recovery zones, and positive barrier separation must be considered when making these determinations. However, it appears that narrow lanes, the lane shifts, the absence of a positive barrier between opposing lanes of traffic, the absence of a buffer space between the construction activity area on the bridge, and the two-way operation of commercial vehicles were not considered in combination when NDOR assigned a 45-mph work zone speed limit to the U.S. 6 project. The Safety Board concludes that the work zone speed limit was too high for existing conditions.

Preparation

Consistent use of markings and signage and consistent rules for traffic flow (for example, vehicles keep right or vehicles in a rotary have the right of way) promote drivers' expectancy and facilitate error-resistant behavior. Work zones frequently incorporate features that are admittedly deficient, yet inevitable, and, fortunately, only temporary. Improving drivers' ability to anticipate the conditions ahead and their required response(s) is vital. Building upon previous learning is preferred over introducing extensive signage, markings, and channelization devices to prepare drivers for a work zone, since such devices greatly increase the visual complexity of the construction scene and maximize cognitive workload and the potential for distractions. When it appeared to the Seward bus driver that a frontal collision was imminent, he acted in a manner that was consistent with the training he had been provided—to steer to the right. Yet the unanticipated absence of a right shoulder left him no room to maneuver. Mere signs warning of potential hazards are a poor substitute for proper geometric design, because they increase visual and cognitive complexity and rely on drivers to change their behavior, rather than perform in a manner that is familiar to them. Nevertheless, they are essential when other means to mitigate risk are unavailable. In this accident situation, drivers were presented with hazardous roadway geometry and no options for recovery, as well as a lack of warnings or other means to alert them to the problems ahead. The Safety Board concludes that poor traffic controls and hazardous roadway geometry left drivers ill-prepared to anticipate danger and to respond properly to any problems encountered.

Even if NDOR could not have avoided the inherent hazardous roadway geometry associated with the work zone, it could have designed the work zone to compensate for those hazards by not only reducing the work zone speed limit, but by providing drivers with additional information. For instance, NDOR could have added "Road Narrows"[100] signs that are intended for use in advance of a transition on two-lane roads where the pavement width is reduced abruptly to a width such that two cars cannot pass safely without reducing speed. Clearly, with the narrow lane widths, large commercial vehicles were forced to pass each other within inches.

Failsafe Design

When a driver errs—or equipment fails (or whatever is at the root of a mishap)—highway design should minimize the consequences. A center barrier and positive lane separation reduce the likelihood of frontal collision when a driver loses control or makes an error in lateral guidance. Similarly, lateral barriers help to deflect vehicles away from hazardous roadside obstructions. In this accident, nothing was in place to prevent a vehicle from crossing the centerline of the narrow road or to assure drivers that oncoming traffic would maintain its lane. Further, no positive means existed to prevent off-roadway

[100] MUTCD, 1988 edition, as revised 1993, page 2C-20.

excursions, especially on the bridge. The Safety Board concludes that the segment of U.S. 6 where the accident occurred required relatively "perfect" performance, especially by drivers of large, commercial vehicles. Not only were these demands unattainable, but when the driver failed, measures in place to minimize the consequences were inadequate.

In the sections that follow, shortcomings in the work zone's design, geometry, traffic control plan, and maintenance are discussed further from an engineering and regulatory perspective.

Work Zone Issues

As noted in the preceding section, the construction work zone provided a challenging driving environment. Although the U.S. 6 project has been completed, the potential exists for more accidents on U.S. 6 and on other roads where, as noted earlier, driving requires "perfect" performance and inadequate measures are in place to minimize the consequences.

Adequacy of State and Federal Requirements for Traffic Control Plans

The FHWA requires a temporary traffic control plan for all Federal-aid projects,[101] such as the one underway at the accident site. According to AASHTO,[102] a traffic control plan is an essential part of the overall project. A carefully developed traffic control plan should contribute significantly to the safe and efficient flow of traffic, as well as to the safety of the construction workers, and have enough flexibility to accommodate unforeseen changes in work schedule and traffic patterns.

According to NDOR, the "generic"[103] traffic control plan chosen for this construction project had been in place since the project began in March 2000. This generic plan was insufficient to have incorporated a detailed geometric design for TLTWO, including site-specific elements such as lane shifts, or to have addressed the use of the south side of the West Papillion Creek and railroad bridges for construction work areas.

While the geometry of the tapers for the lane shifts met the guidelines in the MUTCD, the reverse curve condition near the east end of the West Papillion Creek Bridge and the 10 1/2-foot lanes resulted in an awkward geometric condition that appears inconsistent with the MUTCD,[104] which states, "Frequent and abrupt changes in geometrics such as lane narrowing, dropped lanes, or main roadway transitions that require rapid maneuvers, should be avoided." Further, this lane shift on a TLTWO with 10 1/2-foot lane widths and little or no shoulders could cause drivers to have difficulty

[101] Title 23 CFR 630.1001, *Federal-Aid Policy Guide*.

[102] *A Policy on Geometric Design of Highways and Streets,* page 301.

[103] A "generic" traffic control plan is not site-specific and consists of standard diagrams of signing and traffic control measures necessary to accommodate common types of work zone traffic.

[104] MUTCD, 1988 edition, as revised 1993, page 6B-2b.

remaining within their traffic lane, and specifically, could cause them to encroach on the centerline while approaching the bridge deck. Heavy vehicle operators would be especially prone to this since their vehicles can be 9 or more feet wide.

The construction planning for this project allowed the contractor to use the south sides on both the West Papillion Creek and railroad bridges for construction work space. On both bridges, construction traffic and equipment had access to U.S. 6. Construction equipment and personnel were moving about in the 24±-foot-wide work space available on the southern half of the bridges. Directly adjacent to this work space, the north sides of the bridges were carrying two-directional traffic flow at a posted speed limit of 45 mph. This condition afforded the possibility for numerous traffic conflicts[105] between the construction work space area and the two-way traffic space, with little or no buffer space. For example, eastbound traffic could crowd the centerline due to drivers' concern about the construction activity on their right in an area where westbound drivers were also crowding the centerline to avoid the bridge wall on their right.

The fact that conflicts could occur was demonstrated on May 15, 2001, when an unattended off-the-road earth moving truck rolled out of the work space on the west side of the West Papillion Creek Bridge, traversed both lanes of U.S. 6, and collided with the barrier transition at the northeast corner of the bridge.

According to NDOR and its general contractor, the use of TLTWO "sort of evolved." No consideration was given to construction of a temporary retaining wall to avoid the "lane shift" in the temporary two-lane roadway where the crash occurred. In fact, the implementation of TLTWO was not part of the traffic control plan, but part of a field application by NDOR's construction supervisor and contractor.

Further, contrary to FHWA guidance,[106] no consideration was given to physically separating the opposing flows of traffic, even though it was not possible to see from one end of the TLTWO to the other due to the crest vertical curve near the crash site, and U.S. 6 to the east of the project was a six-lane divided highway. In addition, no consideration was given to portable concrete barriers or other separation for the project work spaces on the bridges to protect construction workers and road users.

The traffic volume history in table 3 (earlier in this report) shows significant increases in traffic on U.S. 6 over the past several years. It also shows that heavy trucks constituted at least 3 percent of that traffic. This information alone should have prompted NDOR traffic and construction engineering staff to include provisions in the traffic control plan to separate the opposing flows of traffic through the work areas and to accommodate the movement of large vehicles.

[105] Traffic conflicts are conditions that place roadway users (pedestrian and vehicular) in positions in which they may interfere with each other. Conflicts are "near-miss" traffic crashes and are therefore predictors of traffic crashes. Institute of Transportation Engineers, *Traffic Engineering Handbook,* fifth edition (Washington, DC: 1999), page 201.

[106] Title 23 CFR 630.1010, Part 5(i).

A well-engineered and detailed traffic control plan, designed by experienced traffic and safety engineering staff, could have made the construction activity area safer and probably more efficient for traffic flow. Such a plan could have either eliminated the traffic lane shifts existing on U.S. 6 at the time of the crash or provided smoother transitions for the lane shifts. It could also have required a buffer between the work areas on the bridge and the through traffic lanes, thereby permitting wider lanes by reducing the potential for encroachment on the through traffic's lane by construction activity and traffic. The Safety Board therefore concludes that the absence of a site-specific traffic control plan for the U.S. 6 construction project allowed hazardous traffic conflicts to develop in several areas of the project, especially on and near the West Papillion Creek and railroad bridges. The Safety Board further concludes that the decision to construct the lane shift near the east end of the West Papillion Creek Bridge and to allow a construction work area with no buffer space on the south side of the West Papillion Creek Bridge created a hazardous geometric condition that contributed to the accident. The Safety Board will inform AASHTO of the circumstances of this accident, so that AASHTO can, in turn, inform its members and urge them to emphasize traffic safety and management in their construction work zones.

Traffic Operations During Construction

NDOR relied upon its district construction engineer, project manager, and project assistants to ensure that the contractor complied with the "generic" traffic control plan. None of these NDOR employees had specific or general training in traffic engineering. Further, the ATSSA training that these employees reportedly received did not include the depth of traffic operations and safety engineering training necessary to manage and make traffic engineering control decisions for a large construction project. NDOR acknowledged that traffic engineering office staff did not periodically inspect work zones or monitor traffic accident experience in work zones. The general contractor's project management personnel also had no training in construction work zone safety. It contracted with a "safety consultant," but this person's duties related to workers' occupational safety, not traffic safety or operations.

NDOR conducted random, statewide work zone traffic control reviews annually, as required by FHWA policy. In 1999, a team of FHWA and NDOR engineers traveled approximately 2,000 miles in 4 days to review some 50 Nebraska work zones.[107] Merely traveling 2,000 miles in 4 days would require about 33 hours (at an average driving speed of 60 mph). Assuming 12-hour workdays, with no breaks, would leave only 15 hours to inspect 50 projects, about 18 minutes per project. Such figures call into question the thoroughness of the FHWA-required inspections and the accuracy of the resulting statistics.

A subsequent FHWA-NDOR work zone review on July 26, 2001, rated the work zone on U.S. 6 (West Dodge Road) as "fair" for 2001. The inspection report mentioned only minor signage discrepancies; it failed to mention the following instances of nonconformance with FHWA policy and MUTCD guidelines:

[107] Study of Work Zone Crashes in Nebraska prepared by FHWA and NDOR, August 1999.

- Operation of the TLTWO in an area where road users could not see from one end of the operation to the other and the posted speed limit was 45 mph.
- Lack of traffic control training for the individuals apparently responsible for monitoring the safety effectiveness of the traffic control plan.
- Failure to monitor reported traffic accidents in the work zone.
- Failure to document the lack of a buffer space and barriers between the work and traffic space on the bridges.
- Failure to document the May 15, 2001, damage to the barrier caused by the earth moving truck and the barrier's subsequent inadequate "repair."

Traffic control needs and safety hazards in construction work areas can change frequently as a project progresses. A feature that might not have been hazardous one day can become a danger the next day. Properly trained and vigilant construction supervision personnel can correct hazardous conditions or request assistance from the State traffic engineering office or from AASHTO. In this instance, construction engineering and supervision personnel with training in traffic engineering and work zone traffic control would probably have recognized that this project did not comply with MUTCD guidelines and other traffic safety guidance.

Also key to effective work zone management is monitoring the work area's traffic accident experience so that potential hazards can be corrected. But work zone traffic accident records can be monitored effectively only if reports are acquired in a timely manner, directly from local and State traffic law enforcement agencies. Waiting for the reports to be sent to the State through normal channels can take months, a delay that renders them almost useless for the timely identification of hazards.

The *Federal-Aid Policy Guide* contains more stringent guidelines for work zone safety and monitoring than does the MUTCD. The *Federal-Aid Policy Guide* requires that "construction zone accidents and accident data *shall* [emphasis added] be analyzed and used to continually correct deficiencies which are found to exist on individual projects…," while the applicable MUTCD guideline states, "When *warranted* [emphasis added], an engineering analysis should be made (in cooperation with law enforcement officials) of all accidents occurring within the temporary traffic control zones."

The Safety Board concludes that because inspections of U.S. 6 required and evaluated by the FHWA and executed by NDOR personnel were inadequate, several hazardous conditions either developed, were left uncorrected, or both. The Safety Board believes that the FHWA should incorporate into the MUTCD the stricter criteria on work zone safety and management contained in the *Federal-Aid Policy Guide, 23 CFR 630J, Subchapter G-Engineering and Traffic Operations, Part 630-Preconstruction Procedures, Subpart J-Traffic Safety in Highway and Street Work Zones*, to include continuously monitoring traffic accident experience in work zones to detect and correct safety deficiencies existing in individual projects. Further, the traffic accident reports necessary to accomplish this should be obtained monthly, directly from local traffic law enforcement agencies. The Safety Board also believes that the FHWA should require its divisional offices to participate in the States' work zone safety inspections and diligently monitor and evaluate the results of those inspections in conformance with the *Federal-Aid Policy Guide, 23 CFR 630J, Subchapter G-Engineering and Traffic Operations, Part 630-Preconstruction Procedures, Subpart J-Traffic Safety in Highway and Street Work Zones.* The Safety Board further believes that NDOR should initiate a program to obtain work zone traffic accident reports from law enforcement agencies monthly and analyze these data to aid in identifying and eliminating hazards as they develop.

Maintenance of Bridge Approach and Barrier Systems

Neither the AASHTO, MUTCD, nor FHWA policy documents contain guidance on the maintenance of existing traffic safety features (such as traffic barriers) in construction work zones. Yet these safety features may be even more important in work zones than in the normal operational environment. Because some States, including Nebraska, require contractors to maintain the roadway facility during construction, the need for guidance or standards to which a facility must be maintained is particularly critical. In this case, the contractor had supposedly repaired the barrier system struck by the earth moving vehicle, but not to any accepted standard of performance. The repair resulted in the W-beam not being secured at its west end, and, therefore, it lacked the strength provided by tension from another structure. This allowed the W-beam to act like a "swinging door" and be pushed aside when it was struck by the school bus.

The approach angle for the Seward school bus to the guardrail was about 6 degrees—40 percent less than the angle at which crash tests are usually conducted. The Seward bus was traveling at a speed of about 40 mph[108] when it struck the barrier. This reduction in speed, from standard crash testing at a speed of 60 mph, represents a decrease in energy by 2.25 times. Given this lower angle of impact and lower speed, the school bus is more likely to have been redirected safely had it struck a barrier that met design and performance guidelines. However, it may have been redirected into the path of the opposing buses.

The Safety Board therefore concludes that had the barrier system struck by the accident bus been repaired to its original design and strength, the bus would probably have been deflected back into its lane and its departure from the bridge avoided. The Safety Board further concludes that NDOR and the contractor failed to adequately maintain the barrier system on the northeast corner of the West Papillion Creek Bridge, as required by the construction contract, and this failure contributed to the severity of the accident. Highway engineers, States, and contractors use both the *Federal-Aid Policy Guide* and the MUTCD in determining the safe design and operation of highway work zones. However, as demonstrated by this accident, both guides are not always utilized. NDOR representatives did not use the *Federal-Aid Policy Guide* in designing the U.S. 6 work zone. Although the *Federal-Aid Policy Guide* contains a requirement that contractors maintain traffic safety systems during construction, the MUTCD does not. To ensure the safe design and operation of work zones, the MUTCD and *Federal-Aid Policy Guide* must

[108] The bus fell vertically into the creek in about 1.7 seconds; when combined with the vertical velocity due to gravity of about 38 mph, the bus's forward speed was determined to be about 40 mph.

provide consistent advice. The Safety Board believes that the FHWA should include in the *Manual for Uniform Traffic Control Devices* a requirement that, for roadways under construction, traffic safety features (such as barrier systems) be maintained at an equivalent or better level than existed prior to construction.

Occupant Safety

The primary area of impact on the school bus was the top-left roof section of the bus body. The primary crush points occurred at the bus's left-front roof corner, adjacent to the driver's compartment, and the left-rear roof corner, which sustained the most significant deformation. Buckling of the roof was evident, along with wrinkles in the metal "skin" of the body. Intrusion into the bus body occurred, resulting in compromised survival space for the occupants due to roof deformation and subsequent deformation of the overhead luggage racks (see figure 27), although intrusion was not directly correlated to the level of passenger injury. Two passengers seated at the front of the bus (rows 1 and 3) sustained fatal injuries due to blunt-force trauma. In addition, passengers seated in row 5 and forward sustained either serious or fatal injuries, while those seated rearward of row 5, with the exception of a fatality in row 13 caused by blunt-force trauma, sustained injuries ranging from minor to serious. Thus, those seated at the front of the bus sustained higher levels of injury, in general, than those seated toward the rear of the bus. Such damage and corresponding injury patterns are not unexpected in a 49-foot fall.

Figure 27. Deformation to luggage racks (as viewed facing rearward).

School buses are designed to meet *Federal Motor Vehicle Safety Standards* for roof strength, joint strength, and occupant safety, and they have been largely successful in protecting school bus passengers. According to the School Bus Information Council, school bus deaths occur at a rate of 0.01 per 100,000 passenger miles as compared with 0.94 per 100,000 passenger miles for passenger cars.[109] Further, according to NHTSA, school bus occupant fatalities averaged only nine per year from 1992 to 2002.[110]

Despite their success in protecting school bus passengers, these standards were not developed with extreme accident scenarios in mind. As a NASDPTS position paper[111] states,

> It is difficult, if not impossible, to develop ways to protect school bus occupants in catastrophic crashes, such as those involving trains and heavy trucks. The crash forces in those crashes are so great that any reasonable structural design cannot maintain the integrity of the vehicle, which is one critical component of occupant crash protection.

It can be argued that the Omaha accident, which combined a fall of 49 feet and an impact into a creek bed, also constitutes a scenario in which crash forces are so great that compliance with a performance standard cannot reasonably provide complete occupant protection.

The extreme circumstances of this accident make it difficult to determine the causes of the passenger injuries. Therefore, the Safety Board concludes that because of the difficulties in identifying the passenger locations and orientations at impact after the roll and 49-foot drop, it cannot be determined whether improvements in the accident bus's body would have mitigated the severity of the passengers' injuries.

Although this accident was unusually severe, the deformation characteristics, intrusion patterns, and loose seat cushions are similar to conditions found in previous accidents investigated by the Board. The Safety Board investigated a school bus accident in Conasauga, Tennessee,[112] in which a school bus was struck on the passenger side by a locomotive traveling 51 mph. In the Conasauga accident, the Safety Board found that sidewall components, such as the overhead storage racks, seatframes, and sidewalls, were not designed to be energy-absorbing, and these structures could cause injury to occupants during their lateral movement in a side-impact collision. As a result, the Safety Board issued Safety Recommendation H-01-40 to NHTSA:

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[109] Information obtained on September 23, 2003, from <http://www.schoolbusinfo.org>.

[110] U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics & Analysis, *Traffic Safety Facts 2002: School Transportation-Related Crashes*, DOT HS 809 615 (Washington, DC: NHTSA, 2002).

[111] National Association of State Directors of Pupil Transportation Services, *History of School Bus Safety—Why Are School Buses Built As They Are?* (The Plains, Virginia: NASDPTS, 2000).

[112] National Transportation Safety Board, *Collision of CSXT Freight Train and Murray County School District School Bus at Railroad/Highway Grade Crossing, Conasauga, Tennessee, March 28, 2000,* Highway Accident Report NTSB/HAR-01/03 (Washington, DC: NTSB, 2001).

H-01-40

> Develop and incorporate into the *Federal Motor Vehicle Safety Standards* performance standards for school buses that address passenger protection for sidewalls, sidewall components, and seatframes.

NHTSA responded that it is conducting a research program addressing sidewall occupant protection on buses, and on July 16, 2002, the Safety Board classified Safety Recommendation H-01-40 "Open—Acceptable Action." The Safety Board understands that NHTSA has issued a contract to perform this research, which should be completed in November 2004.

The Safety Board also investigated a school bus accident in Central Bridge, New York,[113] during which the seat cushions came loose during impact, and the Board subsequently concluded that the school bus passengers, whether lap belt-restrained or unrestrained, may have sustained more severe injuries because the seat cushion bottoms were unlatched. As a result, the Safety Board made Safety Recommendation H-00-29 to NHTSA:

H-00-29

> Modify the *Federal Motor Vehicle Safety Standards* to include the requirement that school bus seat cushion bottoms be installed with fail-safe latching devices to ensure they remain in their installed position during impacts and rollovers.

NHTSA responded that it plans to address this issue when the agency upgrades the *Federal Motor Vehicle Safety Standards* for the next generation of school buses, and on August 6, 2002, the Safety Board classified Safety Recommendation H-00-29 "Open—Acceptable Response." Because enhanced performance for sidewalls, sidewall components, seatframes, and seat cushion fixation are critical for occupant safety in many accident scenarios, the Safety Board urges speedy action on these recommendations.

[113] National Transportation Safety Board, *School Bus and Dump Truck Collision, Central Bridge, New York, October 21, 1999,* Highway Accident Report NTSB/HAR-00/02 (Washington, DC: NTSB, 2000).

Emergency Preparedness of Students

Although State and Federal law require twice-yearly school bus evacuation drills for *all* students who ride school buses, that was not the practice in the Seward School District; very few of the students on the accident bus had received such training.[114]

On-scene inspection of the forward and aft roof hatches showed that the latches to open them were in the closed position, and student passengers indicated that they kicked open or kicked out the emergency hatches rather than attempting to open them as designed. Although the students interviewed did not specifically state that they acted out of panic in their opening of the roof hatches, in previous accidents[115] investigated by the Safety Board, motorcoach passengers have reported a general sense of panic because they did not know what to do or how to get out of the bus. As a result, the Safety Board made safety recommendations concerning pretrip safety briefings for motorcoach passengers to the U.S. Department of Transportation, American Bus Association, and United Motorcoach Association (UMA).[116]

[114] As stated earlier in the report, Safety Board interviews with student passengers revealed that only one student had received school bus emergency evacuation training while in high school and that only four students had received any form of school bus emergency evacuation training in either elementary or middle school. According to the Seward School District's transportation supervisor, although two evacuation drills are conducted each school year, none of the accident bus's passengers had received such training because most of them rode buses only for special events. The director added that Seward's school buses only pick up students who live outside the city limits, noting that friends or family normally drive students who live inside the city limits to school.

[115] National Transportation Safety Board, *Selective Motorcoach Issues,* Special Investigation Report NTSB/SIR-99/01 (Washington, DC: NTSB, 2001).

[116] The American Bus Association stated that it had informed its members of the Safety Board's recommendations to provide pretrip safety briefings and to train drivers in conducting them, prompting the Safety Board to ask for more detailed information and, pending receipt of that information, to classify Safety Recommendations H-99-13 and -14 "Open—Acceptable Response" on October 29, 2001. The UMA took aggressive action, making available to its members a safety briefing video and written script (for use on buses without video equipment) and also developing and distributing driver training materials through the UMA's Bus and Motorcoach Research and Education Institute. Consequently, on November 16, 1999, the Safety Board classified Safety Recommendation H-99-17 "Closed—Acceptable Action" and Safety Recommendation H-99-18 "Closed—Acceptable Alternate Action." The U.S. Department of Transportation stated that it believed the UMA's actions on Safety Recommendations H-99-17 and –18 were sufficient to fulfill the intent of Safety Recommendations H-99-7 and –8 to require and set standards for pretrip safety briefings, prompting the Safety Board to express its concerns that the UMA's actions may not be indicative of the entire motorcoach industry. On January 7, 2003, the Safety Board classified Safety Recommendations H-99-7 and –8 "Open—Acceptable Response," pending receipt of information on the U.S. Department of Transportation's efforts to promote industry best practices on this issue. According to a Federal Motor Carrier Safety Administration official, as a result of an August 2003 conference call and a September 2003 meeting on these recommendations, a Government-industry working group will produce informational cards covering topics such as emergency exits.

The circumstances of this accident demonstrate that pretrip safety information may be critically important for students who ride school buses sporadically, since they may be less familiar with the bus's general layout and escape routes than regular riders. The Safety Board therefore concludes that had the Seward School District conducted emergency evacuation drills and demonstrations for all students, the passengers' ability to open emergency exits and evacuate the vehicle in an emergency would have been greatly improved. The Safety Board will inform NASDPTS of the circumstances of this accident, so it can, in turn, inform its members of the difficulty the students had in identifying and opening the emergency exits and of the need to conduct pretrip safety briefings prior to every school-related activity trip.

The Seward students' lack of emergency evacuation training is not atypical. According to a December 2003 survey of State Directors of Transportation conducted by the NASDPTS,[117] only 15 States require that students who ride buses for extracurricular functions receive pretrip safety information and only 9 States require physical demonstration of the operation of emergency exits. Despite the Federal recommendation in Guideline 17 that operators conduct pretrip briefings on the location and operation of emergency exits and the adoption of that recommendation in *National School Transportation Specifications and Procedures,* the NASDPTS survey shows that most schools do not conduct pretrip briefings before every school-related activity trip, and few States have adopted this practice. Therefore, the Safety Board believes that the NASDPTS should prepare a report that can be used by the State Directors to influence their States to require pretrip briefings before school-related activity trips on school buses or school-chartered buses and subsequently assist the States in developing criteria for such briefings, to include training all students regarding the location and use of emergency exits.

Obscured Emergency Exit Levers and Signage

On-scene examination of the emergency exits revealed that the 2-inch lettering above the emergency door exit and side windows was partially blocked by the overhead luggage racks. The lettering was further obscured by the students' hats, instruments, and backpacks piled on top of the overhead racks. Because of these hidden overhead warnings, several students interviewed stated that they were unaware of these emergency exit windows and knew only about the side and rear emergency exit doors. The Safety Board therefore concludes that some emergency exit levers and signage were obstructed and not clearly visible and may have hindered the evacuation of the bus after the accident. The Safety Board believes that Thomas Built should ensure that all emergency signage is visible in school buses equipped with overhead luggage racks.

[117] As of December 17, 2003, 42 States had responded to the survey.

In addition, the investigation revealed that, following the accident, the first aid kit was blocking the emergency lever and instructions for the front-loading door. As installed by the manufacturer, Thomas Built, the kit would not have blocked the emergency exit lever or instructions for the front-loading door. The first aid kit likely shifted during the accident impact, not surprising given the bus's 49-foot fall from the bridge.

School Bus Extrication Issues

The incident commander noted that the rescuers' lack of knowledge concerning school bus construction and extrication techniques hindered extrication efforts. Because of reinforced construction on school buses, methods for extricating passengers from school buses differ significantly from methods for extricating passengers from lighter vehicles, necessitating specific training. The President of the International Association of Fire Chiefs told Safety Board investigators that he was unaware of a national standard for providing school bus extrication training and that the need for such training is determined by the States. The training director for the Nebraska Fire Marshal's Office told investigators that he was unaware of any States that provide such training, given its specialized nature and budgetary constraints. However, school bus extrication training is readily available through courses and videos available from a variety of vendors and equipment manufacturers. The Safety Board concludes that had the rescuers received school bus extrication training, rescue efforts would probably have proceeded more efficiently. Therefore, we are requesting that the International Association of Fire Chiefs inform its members of the circumstances of the Omaha accident and encourage participation in such training. In addition, the Safety Board believes that the Omaha Fire Department should provide its emergency responders with school bus extrication training.

Conclusions

Findings

1. The accident bus driver was not impaired due to drugs, alcohol, or fatigue; further, neither the weather nor the mechanical condition of the accident bus contributed to the accident.

2. Although not detrimental to the emergency response efforts on behalf of the accident victims, communications were inadequate and resulted in a less than optimal emergency response.

3. The accident bus driver's qualifications neither caused nor contributed to this accident.

4. The accident bus driver's unfamiliarity with the accident vehicle, which differed both in its perceptual demands and in its handling characteristics from his regular route bus, may have contributed to his inability to accurately judge the lateral distance to the guardrail, bridge rail, and oncoming vehicle and to his inability to properly steer the bus through the work zone.

5. The roadway geometry in the work zone resulted in extremely tight tolerances on driver performance, which may have been exceeded when the second Norfolk bus and the accident bus approached the West Papillion Creek Bridge.

6. Although it cannot be determined whether the driver of the oncoming Norfolk bus encroached upon or crossed the centerline, the narrowness of travel lanes in the work zone relative to the space occupied by the buses left the accident bus driver little room for error.

7. The roadway geometry in the work zone created a visual phenomenon that caused the accident bus driver to perceive the oncoming Norfolk bus as impinging upon its lane, regardless of whether it did or not.

8. The accident bus driver's behavior at the time of the accident was consistent with anticipation of a frontal collision.

9. Even though all witnesses traveling eastbound on U.S. 6 insisted that the motorcoach maintained its lane, most witnesses who were traveling westbound insisted otherwise; therefore, it cannot be unequivocally determined whether the Norfolk bus encroached upon the westbound lane, creating a potential collision hazard.

10. The combination of the west lane shift on U.S. 6 and the 10.5-foot lanes and the crest vertical curve on West Papillion Creek Bridge presented drivers with a complicated visual situation that could cause them to misjudge clearances and distances.

11. The work zone speed limit was too high for existing conditions.

12. Poor traffic controls and hazardous roadway geometry left drivers ill-prepared to anticipate danger and to respond properly to any problems encountered.

13. The segment of U.S. 6 where the accident occurred required relatively “perfect” performance, especially by drivers of large, commercial vehicles.

14. The absence of a site-specific traffic control plan for the U.S. 6 construction project allowed hazardous traffic conflicts to develop in several areas of the project, especially on and near the West Papillion Creek and railroad bridges.

15. The decision to construct the lane shift near the east end of the West Papillion Creek Bridge and to allow a construction work area with no buffer space on the south side of the West Papillion Creek Bridge created a hazardous geometric condition that contributed to the accident.

16. Because inspections of U.S. 6 required and evaluated by the Federal Highway Administration and executed by Nebraska Department of Roads personnel were inadequate, several hazardous conditions either developed, were left uncorrected, or both.

17. Had the barrier system struck by the accident bus been repaired to its original design and strength, the bus would probably have been deflected back into its lane and its departure from the bridge avoided.

18. The Nebraska Department of Roads and the contractor failed to adequately maintain the barrier system on the northeast corner of the West Papillion Creek Bridge, as required by the construction contract, and this failure contributed to the severity of the accident.

19. Because of the difficulties in identifying the passenger locations and orientations at impact after the roll and 49-foot drop, it cannot be determined whether improvements in the accident bus’s body would have mitigated the severity of the passengers’ injuries.

20. Had the Seward School District conducted emergency evacuation drills and demonstrations for all students, the passengers’ ability to open emergency exits and evacuate the vehicle in an emergency would have been greatly improved.

21. Some emergency exit levers and signage were obstructed and not clearly visible and may have hindered the evacuation of the bus after the accident.

22. Had the rescuers received school bus extrication training, rescue efforts would probably have proceeded more efficiently.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the Nebraska Department of Roads to recognize and correct the hazardous condition in the work zone created by the irregular geometry of the roadway, the narrow lane widths, and the speed limit. Contributing to the accident was the accident bus driver's inability to maintain the bus within the lane due to the perceived or actual threat of a frontal collision with the approaching eastbound motorcoach and the accident bus driver's unfamiliarity with the accident vehicle. Contributing to the severity of the accident was the failure of the traffic barrier system to redirect the accident vehicle.

Recommendations

To the Federal Highway Administration:

Incorporate into the *Manual for Uniform Traffic Control Devices* the stricter criteria on work zone safety and management contained in the *Federal-Aid Policy Guide, 23 Code of Federal Regulations 630J, Subchapter G-Engineering and Traffic Operations, Part 630-Preconstruction Procedures, Subpart J-Traffic Safety in Highway and Street Work Zones*, to include continuously monitoring traffic accident experience in work zones to detect and correct safety deficiencies existing in individual projects. Further, the traffic accident reports necessary to accomplish this should be obtained monthly, directly from local traffic law enforcement agencies. (H-04-01)

Require divisional offices to participate in the States' work zone safety inspections and diligently monitor and evaluate the results of those inspections in conformance with the *Federal-Aid Policy Guide, 23 Code of Federal Regulations 630J, Subchapter G-Engineering and Traffic Operations, Part 630-Preconstruction Procedures, Subpart J-Traffic Safety in Highway and Street Work Zones*. (H-04-02)

Include in the *Manual for Uniform Traffic Control Devices* a requirement that, for roadways under construction, traffic safety features (such as barrier systems) be maintained at an equivalent or better level than existed prior to construction. (H-04-03)

To the Nebraska Department of Roads:

Initiate a program to obtain work zone traffic accident reports from law enforcement agencies monthly and analyze these data to aid in identifying and eliminating hazards as they develop. (H-04-04)

To the Omaha Fire Department:

Provide emergency responders with school bus extrication training. (H-04-05)

To the National Association of State Directors of Pupil Transportation Services:

Prepare a report that can be used by the State Directors to influence their States to require pretrip briefings before school-related activity trips on school buses or school-chartered buses and subsequently assist the States in developing criteria for such briefings, to include training all students regarding the location and use of emergency exits. (H-04-06)

To Thomas Built Buses, Inc.:

Ensure that all emergency signage is visible in school buses equipped with overhead luggage racks. (H-04-07)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

ELLEN ENGLEMAN CONNERS
Chairman

MARK V. ROSENKER
Vice Chairman

JOHN J. GOGLIA
Member

CAROL J. CARMODY
Member

RICHARD F. HEALING
Member

Adopted: February 10, 2004

Mark V. Rosenker, Vice Chairman, filed the following concurring and dissenting opinion on February 11, 2004:

Notation 7610

Vice Chairman ROSENKER, concurring and dissenting:

I agree with my colleagues and the entire report with the exception of a portion of the probable cause. Our staff's proposed probable cause, correctly in my view, identified the primary cause as the accident bus driver's inability to maintain the bus within the lane due to the perceived or actual threat of a frontal collision with the approaching eastbound motorcoach. The majority of the Board instead attributes the cause to the Nebraska Department of Roads. While I fully support that there were significant design and other deficiencies with the work zone, they did not preclude the safe operation of vehicles through the work area, and the work zone accident history undermines ascribing primary cause to the Department of Roads.

Appendix A

Investigation and Public Hearing

The National Transportation Safety Board was notified of the Omaha, Nebraska, accident on October 13, 2001. An investigative team was dispatched consisting of members from the Washington, D.C.; Arlington, Texas; Denver, Colorado; and Gardena, California, offices. Groups were established to investigate human performance; motor carrier operations; and highway, vehicle, and survival factors.

Parties to the investigation were the Federal Highway Administration, Nebraska Department of Roads, Nebraska State Patrol, Douglas County (Nebraska) Sheriff's Office, Elkhorn (Nebraska) Suburban Fire Department, Omaha (Nebraska) Fire Department, Seward (Nebraska) School District, Norfolk (Nebraska) School District, and Thomas Built Buses, Inc.

No public hearing was held.

Appendix B

Recall of Bendix EC-17 Electronic Control Unit

On July 17, 2000, Bendix Commercial Vehicle Systems (Bendix) initiated a voluntary recall of its EC-17 electronic control unit (ECU) due to a number of instances where chafed antilock braking system wheel speed sensor wires had sent a false signal to the ECU, resulting in a partial or total loss of braking at low speeds. By the time Bendix had reported the problem to the National Highway Traffic Safety Administration (NHTSA),[1] several noninjury accidents and a number of other nonaccident low-speed braking losses had already occurred. The ECU mounted on the accident bus was included in the recall.[2]

On August 29, 2000, Thomas Built Buses, Inc., (Thomas Built) sent a letter to all of its dealers advising them of the recall; the letter included the names and addresses of individual customers who owned the affected units. On August 30, Thomas Built sent a separate letter to individual customers affected by the recall, which involved 4,784 Thomas Built buses,[3] advising them to have their vehicles inspected at a Thomas Built authorized dealer.

Because the recall affected approximately 300,000 Bendix ECUs in vehicles of various manufacturers, units were not immediately available to replace all affected units. Consequently, Thomas Built asked its customers to take their vehicles to an authorized dealer to have the prescribed inspection performed. They also advised their customers that repair kits, including the ECU, would be available by November 2000. According to a spokesperson for Thomas Built, as of December 31, 2001, the ECU had been replaced in 4,032 Thomas Built buses.[4] In January 2002, a Bendix spokesperson told Safety Board investigators that the ECUs needed for the approximately 15,000 buses included in the recall became available within about 30 to 60 days of the July 2000 recall letter.

The first week of September 2000, the Seward School District received a "Safety Recall" notice regarding the accident bus, a 2000 Thomas model 1405S. The same week, Seward School District received a call from the Omaha Truck Center[5] requesting that the bus be brought to Lincoln, Nebraska, for an inspection. On September 12, the Seward School District shop foreman and mechanic took the bus to Lincoln Truck Center for the prescribed inspection. No problems were noted with the brake system. According to the

[1] In accordance with 49 *Code of Federal Regulations* Part 573, "Defect and Noncompliance Reports."

[2] NHTSA recall number 00V-232.

[3] Safety Board interview with Thomas Built, March 4, 2002.

[4] Safety Board interview, March 4, 2002.

[5] The Omaha Truck Center is the parent company of the Lincoln Truck Center, a Freightliner dealer in Lincoln, Nebraska, authorized to perform work on Thomas Built buses. The Omaha Truck Center has 10 locations, operating under different local names, including Lincoln Truck Center.

foreman, he was not advised that he would have to return to have the ECU replaced when the component became available.

The Service Manager of the Omaha Truck Center stated[6] that a recall notice had been sent to the Seward School District and that the school district also had been notified by telephone. He did not know why the foreman was not told to return to have the ECU installed. He also related that Omaha Truck Center had one Bendix ECU in stock and theorized that it was probably intended for Seward School District. The Senior Service Manager of the Omaha Truck Center also stated[7] that the Seward School District had been notified by letter and telephone of the recall. He also did not know why the Seward foreman was not told to return to have the ECU replaced. He further stated that the accident bus and been road-tested and inspected and that no problems had been discovered.

[6] Safety Board interview, January 7, 2002.

[7] Safety Board interview, March 1, 2002.