Chicago Transit Authority Train Collides with Bumping Post and Escalator at O'Hare Station
Chicago, Illinois
March 24, 2014

Accident Report

NTSB/RAR-15-01
PB2015-103738

National Transportation Safety Board

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Railroad Accident Report

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National Transportation Safety Board

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2015. ***Chicago Transit Authority Train Collides with Bumping Post and Escalator at O'Hare Station, Chicago, Illinois, March 24, 2014.*** **Railroad Accident Report NTSB/RAR-15-01. Washington, DC.**

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Abbreviations and Acronyms

APTA	American Public Transportation Association
ATC	automatic train control
CCM	computer cam magnetic
CTA	Chicago Transit Authority
DOT	US Department of Transportation
FAID	Fatigue Audit InterDyne Model
FAST	Fatigue Avoidance Scheduling Tool
FMP	fatigue management program
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
MAP 21	Moving Ahead for Progress in the 21st Century Act
NTSB	National Transportation Safety Board
PTC	positive train control
PED	personal electronic device
RTA	Regional Transit Authority
SEPP	Security and Emergency Preparedness Plan
SMS	Safety Management System
SSPP	System Safety Program Plan
TBTC	transmission-based train control

Executive Summary

About 2:49 a.m. on March 24, 2014, Chicago Transit Authority train No. 141 collided with the bumping post near the end of the center pocket track at O’Hare Station. The lead car rode over the bumping post and went up an escalator at the end of the track. The escalator provided public access to enter O’Hare International Airport from the platform in the station, but no one was using it at the time of the accident. About 50 people were on the train at the time of the accident. Thirty-three injured passengers and the injured train operator were taken to the hospital. The estimated damage was $11,196,796. The accident occurred in an underground station that was not impacted by weather conditions.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the train operator to stop the train at the appropriate signal due to falling asleep as a result of fatigue, which was the result of the challenges of working shiftwork, circadian factors, and acute sleep loss resulting from her ineffective off-duty time management. In addition, Chicago Transit Authority failed to effectively manage the operator’s work schedule to mitigate the risk of fatigue. Contributing to the severity of the accident was Chicago Transit Authority’s failure to identify the insufficient stopping distance and inadequate speed restriction at the center pocket track at O’Hare Station.

1 Factual Information

1.1 Accident Narrative

About 2:49 a.m. on March 24, 2014, Chicago Transit Authority (CTA) train No. 141 collided with the bumping post near the end of the center pocket track at O'Hare Station.[1] The lead car rode over the bumping post and went up an escalator at the end of the track. (See figure 1.)[2] The escalator provided public access to enter O'Hare International Airport from the platform in the station, but no one was using it at the time of the accident. About 50 people were on the train at the time of the accident. Thirty-three passengers and the train operator were taken to the hospital with injuries. The estimated damage was $11,196,796. The accident occurred in an underground station that was not impacted by weather conditions.

Figure 1. Damaged train No. 141 resting on the escalator.

The train operator went on duty at 8:40 p.m. on March 23, 2014. Ten minutes later, she began the first of her five scheduled round trips between O'Hare and Logan Square Stations.[3] She told investigators she was not sleepy when she began her shift. Until the accident, each trip had been normal; there were no distractions inside or outside the cab. She left Logan Square Station on the return trip of her fourth round trip at 2:23 a.m.

[1] A *pocket track* is an auxiliary track where trains can be parked off of the main tracks. At O'Hare Station, the pocket track was used for boarding and unloading passengers interchangeably with the main tracks.

[2] A *bumping post* is an attenuating mechanical stop placed at the end of a track. If the longitudinal load exceeds the strength of the bumping post, the bumping post will fail.

[3] Normally, the train operator would have made three round trips on the schedule she was working. However, on the day of the accident, there was construction on the Blue Line (one of CTA's eight train routes) that prevented the full round-trip schedule from O'Hare Station to Forest Park Station.

At Harlem Station (about 10 minutes from O'Hare Station), the operator turned the cab's heater off because she was too warm and was feeling drowsy. "I believe it (the heater) took a toll on my body as far as making me tired," she told National Transportation Safety Board (NTSB) investigators. As the train entered O'Hare Station, the train operator fell asleep. She told investigators:

> I was operating normal up until I reached O'Hare Terminal. I was tired. I didn't get any sleep the day before, and I might—I have—I became sleepy, and I nodded off into the terminal at O'Hare.

Train No. 141 continued to travel into the station. Two other trains were already occupying track 1 and track 2, the two outside tracks. Train No. 141 was diverted from track 1 to the center pocket track through the interlocking switches. The aspects of the block signals indicated the tracks had been lined for train No. 141 to travel and berth into the center pocket track. The train traveled through the station with no braking or manipulations of the master controller.[4] (See figure 2.)

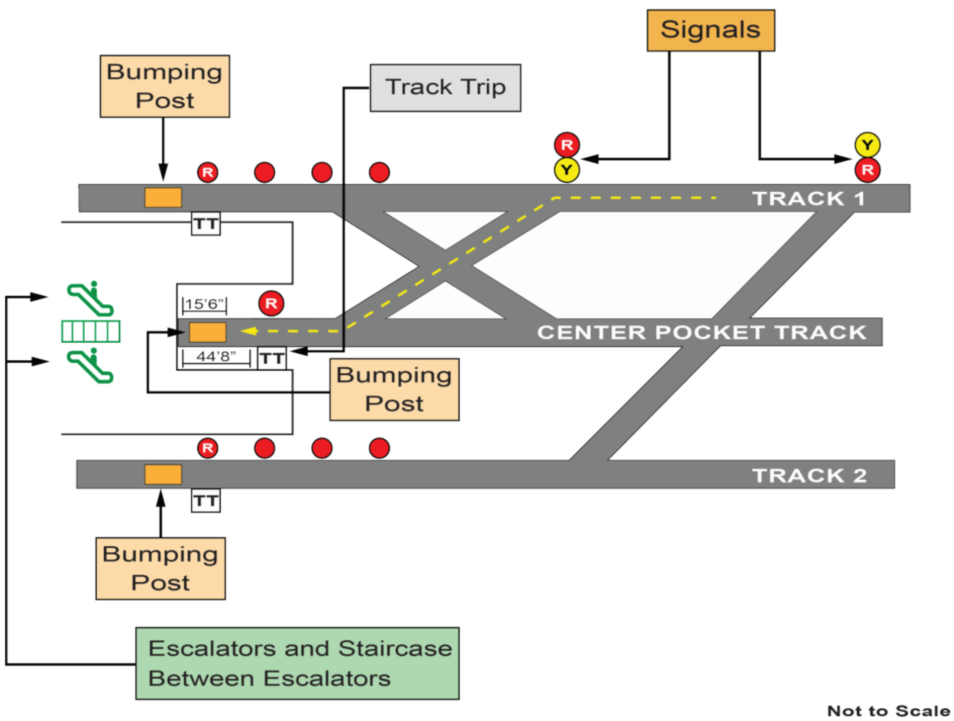

Figure 2. O'Hare Station.

A permanently positioned track trip was installed 29 feet 2 inches from the bumping post and about 44 feet 8 inches south of the end of the center pocket track.[5] The track trip was bolted

[4] The master controller is used to control both propulsion and braking. It is a mechanism that allows the train operator to control the functions of the train with one lever.

[5] A *track trip* is a device positioned near the rail that automatically stops a train when the device is struck. It is known by several different names.

to the concrete floor near the west rail and was always in the "up" or "tripping" position. Adjacent to the track trip, single-aspect wayside signals on each side of the track displayed a red aspect requiring the train operator to stop the train. In the event the train did not stop before passing the red signal, the track trip was designed to make contact with a side trip switch—located on the truck (set of wheels and axles) of the transit car at track level—and activate the braking system.

As the train approached the red signal, a speed command to lower the train's speed to 0 mph automatically went to the operator's control system. As the train passed the red signal, the track trip mechanically initiated full dynamic and full friction braking on the train.[6] Meanwhile, the action of the train hitting the track trip woke the train operator. She immediately moved the master controller into the braking position to apply the dynamic and friction brakes. Postaccident data showed the train's speed was about 23 mph approaching the bumping post. Neither the automatic command nor the train operator's actions engaged the brakes before the train hit the end of the platform. The track trip at track level had a strike mark on its white paint. (See figure 3.) The switch on the lead car, which would come in contact with the track trip, had signs of white paint transfer.

Figure 3. Strike marks on the track trip's white paint.

[6] *Dynamic brakes* convert the electric motors powering the train to generators, which slow the train by making it hard to rotate the train's axle. *Friction brakes* are mechanical brakes that slow the train by pressing a device against a component attached to the train's axle, making the axle hard to turn.

The lead car struck the bumping post near the end of the track and continued onto the concrete platform and up the escalator. The front truck on the first car were raked out from under the car and remained on the tracks where the concrete platform began. The wreckage under the car and against the concrete platform not only contained the wheels and axles but also the track bumping post structure. Part of the undercar propulsion electronic group was damaged when the car slid over the concrete platform.

1.2 CTA Blue Line

The Blue Line—one of eight train routes operated by CTA—runs from O'Hare Station on the north end through downtown Chicago, including Logan Square, to the Forest Park Station on the south end. Due to construction, the CTA was only operating trains between O'Hare and Logan Square, a route that was comprised of 10 stations at the west end of the Blue Line and about 10 miles with a trip time of 25 minutes each way. (See figure 4.)

Figure 4. This map shows the stations along the Blue Line.

O'Hare Station has three tracks for transporting passengers; a manual interlocking routes trains on one of the three tracks.[7] Blue Line trains normally operate with four or eight cars.

When trains entered O'Hare Station, the track on the right was track 1; the middle track was the center pocket track; and the track on the far left was track 2.

[7] A manual interlocking is operated by an operator who is at the station.

The bumping post near the end of the center pocket track was destroyed by the impact. All three tracks had similar bumping posts before the end of the tracks. (GWE 1985) (Figure 5 shows the destroyed bumping post; Figure 6 shows a similar bumping post installed on track 2.)

Figure 5. Destroyed bumping post.

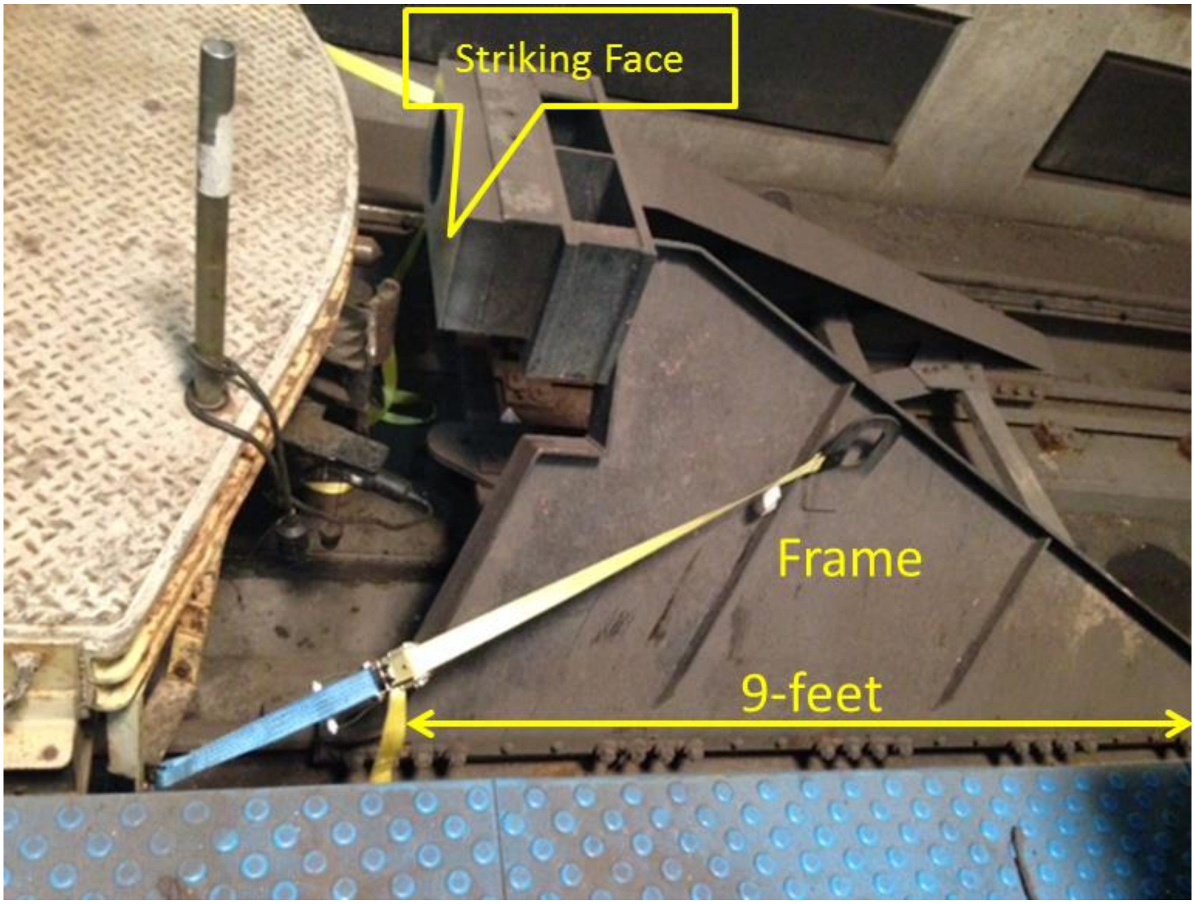

Figure 6. This bumping post is similar to the one destroyed on the center pocket track by the impact.

A postaccident examination of the accident site showed that the bumping post on the center pocket track was installed with the striking face about 13 feet from the end of the rail and 15 feet 6 inches to the concrete platform edge. The distance from the striking face of the bumping post to the end of the frame was 9 feet.

1.2.1 Signal Design

The Blue Line signals operate on a fixed-block, audio frequency track circuit system that provides cab signal controls for the entire length of the line. If an operator passes a nonpermissive signal, such as the wayside signal with the red aspect adjacent to the track stops in the pocket track, the track trip will automatically trigger the train's brakes when the train travels over it. The system will stop trains—but only after they have passed into the restricted block beyond the red signal or after they have passed over a track trip. As stated above, the signal and track trip were 29 feet 2 inches from the bumping post and about 44 feet 8 inches from the end of the pocket track.

The cab speeds of CTA trains are fixed at 0 mph, 15 mph, 25 mph, 35 mph, and 55 mph. A loss of cab signal, a train exceeding the cab speed, or a downgrade in cab speed—which can take up to 4 seconds for the onboard automatic train control (ATC) system to recognize—will result in an audible alarm in the cab. When the alarm is sounded, the train operator must apply brakes within 2.5 seconds or the train will automatically brake until the train is stopped. On the center pocket track, the cab speed control was set at 25 mph until just before the train reached the signal and track trip, at which time it reduced to 0 mph. The train involved in the accident never exceeded 25 mph, so the train's automatic speed control was not activated until the train reached the red signal and the track trip.

At O'Hare Station, tracks 1 and 2 were protected with a series of block signals and track stops. Each block signal had a track circuit associated with it, and train speeds were downgraded from 25 mph to 15 mph to 0 mph as the train passed successive block signals in its approach to the end of the track. In contrast, the center pocket track did not have these features; it had a single track circuit signaled for 25 mph and 0 mph about 68 feet before the wayside signal. All three tracks had a bumping post near the end of the track. Ahead of the bumping post, there was a fixed track trip and a red signal. As stated above, if a train passed the red signal, the track trip activated full dynamic and full friction braking on the train. However, in this accident, there was not enough time or distance for the onboard ATC to respond with automatic braking before the train struck the bumping post near the end of the track.

1.3 Station Design

Original signal prints and design drawings dated March 1980 for the Track End Buffer Construction Specification (bumping post) on track 1, the center pocket track, and track 2 stated:

> The criteria to be used for design purposes shall be that an eight-car train could strike the buffer at a speed of 15 mph.

As discussed above, the speed on the center pocket track was set to 25 mph—despite being specified as 15 mph in the original design specifications. Conversely, tracks 1 and 2 were designed with a speed code of 15 mph as designed.

Original design documents showed the face of the bumping post not to exceed 13 feet from the end of the track for the pocket track. However, the bumping post locations for tracks 1 and 2 are shown as 60 feet ±.

The bumping post specifications included energy friction shoes.[8] However, NTSB investigators contacted a former project manager associated with the original construction, who recalled that when the bumping post was installed in the center pocket track there was not enough room to add the energy friction shoes on the rail behind the post supports. Because of that, the construction workers tightened the fasteners that attach the bumping post to the center pocket track with more force than they used on the other two tracks. Investigators were unable to find evidence of an analysis that showed tightening the fasteners was the appropriate method for addressing the lack of room and absence of the energy friction shoes. Energy friction shoes were installed on tracks 1 and 2. See figure 7 for a depiction of the friction shoes fastened to the rail on track 2.

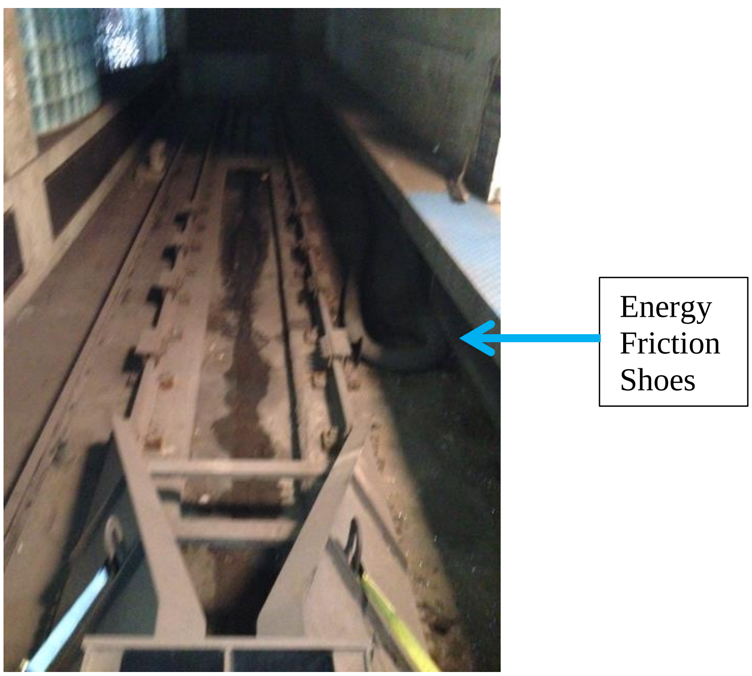

Figure 7. Energy friction shoes fastened to the rail on track 2.

[8] Energy friction shoes are devices fastened onto the top of the rail. If a train hits a bumping post and slides against the energy friction shoes, the shoes add resistance (friction) that assist in slowing the train.

1.4 Accident Train Information

All eight cars involved in the March 24, 2014, accident were 2600 Series cars originally manufactured by the Budd Company between 1981 and 1987 and rebuilt by Alstom between 1999 and 2002.[9] These cars were equipped with dynamic, friction, and track brakes. Dynamic brakes use electromotive force in the traction motors to stop the train. The friction brake system consists of discs and calipers that apply retarding force. The track brake is a component on the car that will drop down onto the top of the rail. The friction between this component and the top of the rail creates a retarding force. Penalty (automatic) brake applications are caused by excessive speed without a response by the operator; the brakes would activate until the train came to a complete stop. If the operator applied the brakes fully, the dynamic brake and the disc brake system would engage fully regardless of the speed. If the operator activated the emergency brakes, the dynamic brake and the friction brakes would become fully engaged, and a track brake would apply pressure to the top of the rail regardless of the speed.

In this accident as a result of the track trip, the 0 mph speed command from the signal near the end of the track started the penalty application with dynamic braking. The track trip activated immediately after the signal command. The track trip added friction braking to the already fully applied dynamic braking. However, there was insufficient time and distance for the brakes to apply and exert retarding forces to stop the train before colliding with the bumping post.

1.4.1 Postaccident Inspection

Supervised by NTSB investigators, the undercar propulsion electronic group from car 3061 was removed after the accident and sent to CTA's repair facility in Skokie, Illinois. A qualified electrician removed the propulsion card. (See figure 8.) The visibly undamaged U20 chip was put onto a new card, but no data could be retrieved. The only data that could be recovered was from the trailing cars.

The data indicated there was a power supply interruption or extreme vibration—which was entered into the data as an "event 98"—on the trailing cars. This typically happens during a collision. The data showed that before the event 98 occurred the train cars were in coast mode, traveling about 25 mph. When the event 98 occurred, the train was in dynamic braking mode and was traveling about 23 mph.

Car 3061's master controller handle was found in the B3 position during the initial postaccident inspection. During interviews, the train operator stated that she tried to move the controller to B4 when she realized the situation.[10] The train operator carried a key for the master controller that was inserted into the control stand and could be put into positions for forward, off, and reverse. The key was found in the forward position after this accident.

[9] These were older cars that were not equipped with event recorders.

[10] Master controller position in B3 means that dynamic service brakes were applied; the B4 position means that full dynamic and friction brakes are applied.

Figure 8. The card rack, which recorded the event data, was within the undercarriage and was damaged in the crash.

1.5 Personnel Information

1.5.1 Sleep/Wake/Work and Health History

The train operator was assigned to the extra board, meaning that she could be called upon to work any shift throughout the day. When a regularly assigned employee was off sick or on leave, the employee's shift was filled by employees from the extra board.

The train operator told investigators that on the night of the accident she did not feel tired at the beginning of her shift at 8:40 p.m. During the accident trip, she started to feel tired after leaving Rosemont Station, as she neared the O'Hare Station. (The travel time between those stations is about 4-5 minutes). She told investigators that staying awake during the midnight shift was sometimes difficult—with the most challenging time for her to remain alert being between 2:00 a.m. and 3:00 a.m. The train operator said:

> You know, my body has to adapt to staying up all throughout the night, you know, adjust to the schedule. But it's mainly just doing those trips back and forth, and once you get to the last one, you know, you tend to get tired on the last trip.

The train operator's work and rest schedule during the 3 days leading up to the accident is presented in table 1.

Table 1. The Train Operator's 72-Hour Sleep/Wake History.

Day	CTA Job	Duty Times	Activities at Home	Sleep
Thursday March 20	Flagging[a]	7:30 a.m-3:30 p.m.	Arrived home between 5:00 p.m.-5:30 p.m. Ate, relaxed.	Slept from about 11:00 p.m. Thursday to 10 a.m. Friday
Friday March 21			Ate breakfast, relaxed at home. Departed for work at 6:30 p.m. and arrived at 7:30 p.m.	
Friday March 21	Train Operator	On duty Friday 8:40 p.m. to Saturday 6:17 a.m.		
Saturday March 22			Arrived home about 9:00 a.m. Showered; played flag football until noon. Left for work about 4:00 p.m.	Told investigators she napped “maybe 50 minutes” sometime between 12:00 p.m. and 4:00 p.m.
Saturday March 22	Train Operator	Arrived at CTA at 5:22 p.m., missing her 4:55 p.m. report-for-duty time because she overslept. Was rescheduled to another shift; on duty 6:40 p.m. to 2:25 a.m. Sunday		
Sunday March 23			Arrived home around 4:00 a.m. Stayed at home. Left for work at 6:30 p.m.	Told investigators she slept soon after arriving home [about 4:00 a.m.] until about 2:00 p.m-3:00 p.m. (*See paragraph and table immediately below.*)
Sunday March 23	Train Operator	On duty at 8:40 p.m. Scheduled to work until 5:46 a.m.		
Monday March 24	Train Operator	2:49 a.m. Accident at O’Hare Station		

[a] “Flagging” jobs are assigned to train operators on the extra board. Instead of operating a train, the employees are assigned to a maintenance crew working on or near the tracks. The operating employee provides protection for the workers from approaching trains.

The train operator told investigators that on March 23, the day before the accident, she slept from shortly after arriving home, about 4:00 a.m., until 2:00-3:00 p.m. However, when investigators examined her personal electronic device (PED), voice, text messages, and data usage records for March 23, 2014, they found that she had not slept as long as she had reported. (See table 2).

Table 2. Select Personal Electronic Device Activity on March 23, 2014.

Time	Activity
10:45 a.m.	Outgoing call
10:46 a.m.	Text message sent
11:04 a.m.	Text message sent
11:05 a.m. -12:0 p.m.	Numerous text messages sent and received
12:07 p.m. - 2:30 p.m.	No phone or text message activity
2:31 p.m.	"Data Usage" (e.g., accessing the Internet/applications)

The train operator's PED records showed no activity—incoming or outgoing calls, text messages, or data usage—at the time of the accident.[11] Postaccident toxicological tests were negative for alcohol or illicit drugs.[12]

Additional Information

- The train operator told investigators that she needed 6-8 hours of sleep to feel rested.
- The week before the accident, the train operator worked 55.7 hours, which included one double shift.
- The day of the accident was the 12th consecutive calendar day she had worked.
- She told investigators her commute time to work is from 90 minutes to 2 hours. She often arrived at work early, sometimes as much as 30 minutes before her shift.

The 25-year-old train operator had a pre-employment physical in 2013. In her CTA medical records, the train operator said she was in generally good health and was taking no medications. She told investigators her overall health was good, and her vision and hearing were normal. She said she had a cold about a week before the accident, but she did not take any prescription or nonprescription medications. She said she did not have any chronic medical conditions. Although she said she snores, she indicated on her medical history that she did not have any sleep disorders. Other factors—being young, female, and not having hypertension—placed her in the low-risk category for obstructive sleep apnea.

1.5.2 Train Operator's Operating Experience

The train operator began working at the CTA as a flagman on April 1, 2013. In December 2013, she began training to become a train operator. She successfully completed the training program and became a qualified train operator on January 24, 2014.

[11] Current CTA policy (CTA 2009) dictates that PEDs are not allowed in the cab of the train.

[12] Title 49 *Code of Federal Regulations* (CFR) Part 655. The substances tested for include: marijuana, cocaine, opiates, amphetamines, phencyclidine and alcohol.

The train operator training program had 17 days of formal training that consisted of: 7 days of classroom training, which included details about the operator's duties and responsibilities, radio communication, blocks and interlocking, signals, and troubleshooting; 8 days of field training, including railcar familiarization, towers, coupling, and troubleshooting; and 2 days of training on 5000 series rail cars.[13] Students were required to pass written tests and score 100 percent on the signal identification test.

After classroom training, transit operator trainees spent 10 days operating passenger trains under supervision.

The train operator told investigators that her training was very positive. She said the most challenging parts of her training were learning the signal system and troubleshooting minor mechanical issues with the vehicles. She had primarily worked on the Blue Line (where the accident happened) and occasionally on the Pink Line.

1.5.3 Employee Discipline

The train operator received a written warning on February 1, 2014, because she "fail(ed) to make station stop." During her postaccident interview, the train operator told NTSB investigators the incident (that resulted in the warning) happened on the last trip of her shift when she dozed off and failed to stop properly at a station platform. "I was a new operator. I panicked because I slid out, and I just proceeded on (as) normal to the next station."

On March 22, 2014, the train operator arrived late and missed the start of her 4:55 p.m. shift. She was reassigned to work the 6:40 p.m. shift. During postaccident interviews, the train operator explained that she had overslept and had left her home too late. When the accident happened, the train operator had not yet been interviewed by a CTA manager concerning her tardiness, so it did not appear in her personnel file.

CTA subsequently notified the train operator by mail that she was being discharged as a result of the March 24, 2014, accident at O'Hare Station.

1.5.4 CTA's Method of Scheduling Work

CTA administrative managers have varied responsibilities, including overseeing payroll and scheduling for regular and extra board employees. They also approve time off and sick days for the trainmen, flagmen, customer service representatives, and assistants. At the time of the accident, administrative managers were not required to take fatigue awareness training.[14]

At CTA, every 6-9 months there was a "pick" process by which employees were assigned new work schedules. Based on seniority, employees either worked regular schedules (about 80 percent of employees) or were included in the extra board (about 20 percent of employees).

[13] Troubleshooting refers to minor mechanical issues that can be addressed by a train operator.

[14] Since the accident, CTA has required all managers—including administrative managers—to take fatigue awareness training. CTA managers have met that requirement.

When an employee with a regular work schedule was off (for instance, due to illness or training), the employee's shift was filled by an extra board employee.

CTA had an "a.m." extra board and a "p.m." extra board. Employees on the a.m. extra board worked assignments that began as early as 4:00 a.m. Employees assigned to the p.m. extra board would usually be assigned to shifts starting about noon. After 4:30 p.m., employees could contact the clerk to receive their next assignments. (The upcoming assignments would not begin until after midnight that next day).

Work assignments for employees working regular schedules were typically 8-9 hours long, 5 days a week, and they were given at least 8 hours off between assignments. According to the contract agreement with Amalgamated Transit Union Local 308, employees could not be assigned to work more than 13 hours straight. However, employees could volunteer to work overtime.[15] This sometimes resulted in employees working consecutive or double shifts—for instance, two 8- or 9-hour shifts back-to-back. (After working a double shift, the operators were required to have 8 hours off before the start of their next assignment.) Those who volunteered for overtime after working a single shift had fewer than 8 hours off between assignments. (The work/rest policy has changed since the accident. See the *Postaccident Actions* section of this report.)

CTA did not limit the overtime employees could work in a given week.[16] In fact, between February 28 and March 11, the train operator had worked 12 consecutive days that included working on her 2 scheduled days off. The administrative manager told investigators, "The only time we would consider not giving someone (overtime) is if we feel that it's not safe for them to continue to double every day." That decision was made by the manager at that work location. A clerk whose duties included observing the employees could alert a manager. The manager could then examine the payroll to see the total number of hours the employee had worked.[17]

After finishing her assignment early in the morning 4 days before the accident (March 19), the train operator asked to work another shift later that day for the overtime. Aware the train operator had just worked 7 consecutive days, the clerk suggested the train operator not work another shift and instead take her day off as scheduled. The operator followed the clerk's suggestion. She took the rest of March 19 off and returned to work at 7:30 a.m. the following day.

[15] CTA estimates that up to 10 percent of their employees request overtime. Overtime pay is time and a half.

[16] A CTA employee can work overtime by either working on their scheduled day off or by working a double shift. The latter is more common.

[17] If CTA decides not to give the employee overtime work, the employee can file a grievance with the union.

1.6 Oversight

1.6.1 Federal Transit Administration

Overview

The Federal Transit Administration (FTA) oversees rail transit safety as described in 49 CFR Part 659 Rail Fixed Guideway Systems; State Safety Oversight. The regulation requires states with rail fixed guideway systems to designate an oversight agency. Part 659 requires the state oversight agencies to establish, oversee, and ensure compliance with rail safety and security practices. Rail transit agencies are required to develop and implement a written system safety program plan (SSPP), and the state oversight agencies are required to review and approve these plans. The state oversight agency is required to conduct an on-site review of the transit agency's implementation of the system safety plan and propose recommendations resulting from its review. If a state does not meet the requirements of Part 659, the FTA may withhold up to 5 percent of funding for the FTA's program for urbanized areas.

The FTA requires each state to designate a safety oversight agency to perform on-site safety and security reviews of rail transit fixed guideway systems once every 3 years. The Regional Transit Authority (RTA) was Illinois' designated safety oversight agency for the CTA. Following each review, a report documents the methodology, observations, and results of RTA's triennial review of CTA. RTA completed its most recent triennial review of CTA in May 2010. Previous reviews were conducted in 2007, 2004, 2001, and 1998. The most recent review was started in 2013 and was in progress at the time of the accident.

1.6.2 CTA Management Oversight

1.6.2.1 System Safety

The CTA SSPP dated April 2013 was in effect at the time of the accident, and was reviewed by NTSB investigators.

CTA's Safety Department is led by the chief safety and security officer. The chief safety and security officer reports to the authority's president. The Safety Department develops, maintains, and annually reviews the SSPP. When revised, SSPP's are submitted to the RTA for review and approval. According to the plan, CTA's "Safety (Department) has the responsibility to implement, oversee, and maintain a safety management system that ensures that risks are identified and controlled, minimized or eliminated."

According to the plan, the responsibilities of the Safety Department are emergency preparedness, construction and engineering oversight, industrial hygiene, inspections and investigations, data analysis and audit, safety training and observations, safety communications, fire protection, and regulatory compliance. The safety responsibilities of other departments—including rail transportation, rail maintenance, infrastructure, and administrative—are outlined in the SSPP. The SSPP describes committees through which the

Safety Department coordinates with other departments, such as the Rail Operations and Rail Maintenance Committee.

Hazard Management Process

CTA's hazard management process is based on the FTA *Hazard Analysis Guidelines for Transit Projects* and CTA's risk matrix and described in the agency's SSPP. However, CTA did not identify insufficient stopping distance and inadequate speed restriction as hazards at the O'Hare Station. The plan aims to ensure the hazard management process includes all elements of the rail system, including equipment, procedures, people, the environment and the interactions between these elements.

CTA identifies hazards through inspections, audits, employee observations, as well as incidents and near misses. In addition, customer service representatives relay passenger concerns and employees may convey their concerns through SafeLine, a telephone hotline for submitting anonymous safety issues. CTA uses a hazard assessment process to determine which safety risks rise to the level of a hazard. When a potential hazard is identified, CTA calculates the risk by determining the probability it will result in an accident, and determining the severity of the accident, should it occur. According to CTA, eliminating the risk may involve a single step or a multi-level process that may include, but is not limited to:

- Eliminating the source or activity that created the risk
- Altering design
- Providing safety devices or protective equipment
- Enhancing or initiating employee training

The Safety Department maintains a hazard log for each department that is submitted to the RTA each quarter. The log enables CTA to evaluate the effectiveness of mitigation efforts and re-evaluate the probability that the hazard will result in another accident.

Rail System Modifications and Configuration Management

The SSPP describes a process to monitor safety for rail system modifications. System modifications may include a remodel or rehabilitation of a facility and changes in the operating environment. The SSPP states:

> All proposed capital project changes to existing facilities must be submitted…to the Infrastructure department, for evaluation.
>
> (The Transit Operations Department), is responsible for overseeing the design and construction planning for rail facility modifications and verifying that planned construction or engineering work on the rail right-of-way meets all CTA safety requirements.

> For identified capital projects, Safety (and Security department is responsible for the) Safety and Security Certification Plan. The safety certification process ensures that the new or rehabilitated facilities are safety-certified and incorporate all the safety and security requirements prior to being placed in passenger operations.
>
> For smaller projects that are not integrated in the Safety Certification Program…Transit Operations monitors the changes on the rail system.[18]

The chapter about modifications focused on rail facility and rail vehicle modifications. Those processes were formalized so that when modifications were made, new hazards would be identified. During postaccident interviews, investigators asked if CTA would perform a hazard analysis if an operating scheme was modified. The CTA chief transit safety officer said:

> So moving ahead, we discussed that yesterday, as well. Any changes to procedures and SOPs [standard operating practices] that affect the system would be elevated to the Configuration Management Control Committee.[19]

At the time of the accident, CTA only looked at configuration management on projects costing $1 million or more, a policy that has changed since this accident. CTA provided investigators with the configurations management policy. (CTA 2014) The new policy says “all changes to CTA critical systems” will be processed through the Management of Change Committee. CTA provides specific guidelines to determine if the system element change is critical.

Safety Certification

Safety certification presents an opportunity to identify hazards during construction and into operation, but the CTA only obtains safety certification for projects costing $100 million or more. CTA’s chief engineer for infrastructure was asked if there were any discussions that might change the criteria for safety certification and if a dollar amount should be part of those criteria. He said that the CTA had recently hired a consultant to better structure its contract requirements so that the contracts would incorporate safety certification, even on projects that do not reach the $100 million criteria. He also said that all of the designs for small and medium projects would now be routed through the CTA Safety Department for a safety review. The review would include the Operations Department, giving the user an opportunity to provide comments on the design.

[18] The Infrastructure, Transit Operations, and Safety and Security Departments are led by a chief officer who reports directly to the CTA president.

[19] *Configuration management* is the detailed process for approving changes in a system whether the changes are to a facility or the equipment. The process involves recording, updating all systems, and, most importantly, identifying potentially new hazards or negative consequences of the changes. It is also known as change management.

The SSPP describes a process to verify the safety and security of a newly built or renovated facility. According to the program plan, the safety certification process is used when new stations are added, new railcars are purchased, and rail lines are extended.

For a project subject to the safety certification process, a safety and certification plan is developed. The certification process begins with the design stage and continues through the start of revenue operations. Steps in the certification process include establishing safety design criteria; verifying conformance with specifications; and performing testing, training, and emergency response coordination.

Regulatory Compliance and Investigations

The CTA Safety Department ensures compliance with federal and state regulations. It coordinates with RTA, the American Public Transportation Association (APTA), and FTA during safety audits and triennial reviews. The CTA develops corrective action plans to resolve the findings of FTA, RTA, and APTA audits and tracks the progress of the corrective actions. However, rail transit agencies are not required to accept APTA's recommendations. APTA is a consensus-based advocacy organization made up of public transportation organizations and acceptance of the group's audit findings and guidelines is voluntary.

If neither the NTSB nor RTA investigates an incident, the CTA Safety Department investigates the incident and develops corrective actions plans to address its findings. If either the NTSB or RTA investigates an incident, the CTA prepares corrective action plans to address the findings and recommendations of the investigation.

1.7 Postaccident Actions

1.7.1 Federal Transit Administration

On June 12, 2014, the FTA issued *Safety Advisory 14-2, Verification of Rail Vehicle Safe Stopping Distances in Terminal Stations*. (FTA 2014) This safety advisory asked transit agencies to review and verify that stopping distances are adequate in terminal stations (the stations at the ends of a rail transit line). The FTA also directed state oversight agencies (such as RTA) to confirm that transit agencies had complied.

1.7.2 Chicago Transit Authority

Signal System

Following the accident and before trains carrying passengers were again allowed to enter the center pocket track, CTA signal personnel downgraded the speed code command applications from 25 mph to 15 mph through the O'Hare interlocking to O'Hare Station.

The designed braking or deceleration rate was 5.3 miles per hour per second (mph/s) for this equipment.[20] CTA calculated the required stopping distance to be 78 feet. A few weeks after the incident, the CTA conducted a series of braking tests at the CTA's test track in Skokie, Illinois. The CTA determined that the braking distance associated with train (track trip) stop activation was insufficient. As a result, the standard braking distance when the track trip is activated was increased to 100 feet—including a safety factor. Once this change in distance was made, the CTA implemented further restrictive measures at O'Hare and other terminal stations on April 16, 2014. These restrictive measures included reducing the cab speed in the pocket track to 0 mph and forcing trains entering the pocket track to stop before reaching fixed track trips.

Further improvements on tracks 1 and 2 were commissioned on June 10, 2014. These improvements included the reconfiguration of the block signals to act as timed signals. The timed signals would allow trains to approach the normal berthing location under a maximum cab speed of 15 mph, but a train's braking system would be activated if an operator failed to begin braking from the 15 mph maximum speed to accomplish a normal station stop at the berthing marker. The pocket track continues to be operated with a 0 mph speed cab signal while CTA completes its design for a new timed signal in advance of the normal berthing location.

Furthermore, the CTA engineering department has done an analysis of rail terminals where the track terminates similar to the O'Hare Station. The purpose of this inspection was to determine if the conditions at another terminal could lead to a similar incident if a train operator failed to reduce speed before reaching the normal berthing point.

In addition to the O'Hare Terminal, the following terminal stations have similar signal, track trip, and bumping post configurations and were modified as follows:

- At Midway Terminal Station, a 0 mph cab speed was implemented in all three tracks on April 16, 2014, as a result of further brake rate testing. Design and installation of a timed signal is now underway. The modification is expected to be completed by the end of 2015.
- At Linden Terminal, a 0 mph cab speed was implemented in the east pocket track. Design and installation of a timed signal should be completed in the first part of 2015.[21]
- At Cottage Grove, the permanently located track trips in the two pockets were moved 100 feet from the bumping post, and the 0 mph cab signal speed was removed and replaced with a 15 mph speed. With a 100-foot side trip braking distance, a train traveling at 15 mph will stop before reaching the bumping post, based on updated side trip braking test results. This work was completed in November 2014.

[20] When designing signal location and calculating stopping distances for new installations at the time of the accident, the CTA used a derated brake rate of 3.5 mph/s instead of the 5.3 mph/s for a greater safety margin.

[21] CTA has installed temporary provisions at both Linden and Midway. Trains are forced to come to a complete stop before reaching the berthing markers.

Work and Rest Cycles

Following the accident, the CTA instituted the following changes to the work and rest cycles of train operators:

- Set a maximum of 12 hours of actual train operations duty (including layover times at terminals and other nondriving rail duties, which was not included in the duty hours prior to the accident) for rail operations employees in a 14-hour time period. Previously, there was no maximum.
- Increased the minimum time of rest between shifts from 8 to 10 hours.
- Required all rail operations employees to take at least 1 day off in any 7-day period. Previously, there was no limit.
- Limited the number of hours that operators with less than 1 year of experience can operate a train to 32 a week (with no limit on other duties). As they do now, these employees work other related duties during the remainder of their work hours. Previously, there was no limit on the number of hours new operators could operate a train.
- The CTA has also revised their employee education and training on fatigue.

2 Analysis

2.1 Introduction

The following analysis discusses the operator's fatigue, the station design and location of the track trip, the signal system, the status of the event recorders on transit equipment, and the oversight role of the FTA.

Specifically, the following safety issues are discussed in greater detail:

- operator fatigue
- identification of station hazards
- the need for standardized event recorders on transit vehicles
- the need for signal systems that stop a train before it reach obstructions or other trains, such as transmission-based train control
- clarification of FTA's oversight role in transit safety

NTSB investigators examined the train involved in the accident and found no preexisting mechanical conditions related to the crash. Although she was a fairly new employee, the train operator was familiar with operating trains at the O'Hare Station. The results of the operator's drug and alcohol tests were all negative. The operator's PED records did not show any use while she was operating the train. The accident occurred in an underground station that was not impacted by weather conditions. The NTSB concludes that none of the following were factors in the accident: (1) mechanical condition of the train, (2) operator experience operating transit trains, (3) PED use while operating the train, (4) alcohol or drug use, or (5) weather.

2.2 Operator Fatigue

The train operator told investigators that she fell asleep as she was entering the O'Hare Station. "I became aware once I came in contact with the track trip," she said during interviews.

2.2.1 Inverted Work Schedule/Shift Work

Although the train operator was assigned to the extra board and did not work a regularly scheduled shift, most of her assignments required that she work during the nighttime hours. In the week before the accident, six of her seven start times began at night between 7:30 p.m. and 9:00 p.m., and she went off duty in the early morning—usually between 5:00 a.m. and 6:00 a.m. Such inverted schedules, which are the opposite of normal wake/rest schedules, have been shown to degrade the quality and quantity of sleep. (Tepas and Carvalhais 1990) Research has also shown that inverted schedules are associated with shortened sleep lengths and degraded performance. (Ohayon and Others 2010)

The one exception to the train operator working the night shift the week before the accident was March 20 when she worked from 7:30 a.m. to 3:30 p.m. While those daytime work hours are consistent with normal wake/rest routines, working that schedule likely negated her progress in adapting to her typical, nighttime work schedule. That is, as a result of working a daytime shift, her circadian rhythms could have changed back to a daytime schedule.[22] However, adjusting back to a nighttime schedule—which she had worked during the 3 days leading up to the accident—can take 1 week or longer.[23]

According to the National Sleep Foundation, many people who work a nighttime schedule—even on a regular basis—experience sleep disturbances and associate excessive sleepiness. However, those who irregularly work at night have additional challenges adjusting to this type of schedule. Studies, as well as accidents investigated by the NTSB, have shown a prevalence of operator fatigue on the first and second night following a transition from a daytime to nighttime work schedule. At the time of the CTA accident, the train operator was working on her third consecutive night shift. Additionally, during the week before the accident, she had worked four straight nighttime shifts before working a daytime shift. Research has shown the cumulative effects of working night shifts even in the short term. Specifically, the relative risk of having an accident increases over four consecutive night shifts as compared with the accident risks associated with working an equal number of day shifts. (TCRP 2002)

2.2.2 Circadian Rhythms / Time of Day

The accident occurred at 2:49 a.m.—a time of day that coincides with a circadian low—making the train operator more prone to fatigue and causing a decrease in attention and performance. In a normal circadian rhythm, the human body naturally sleeps to refresh its capabilities for normal physical and cognitive performance during the time between about midnight and 6:00 a.m.; the window of circadian low generally occurs between 3:00 a.m. and 5:00 a.m. People who are awake during the window of circadian low are less alert, have degraded performance, and are susceptible to the effects of fatigue. Circadian desynchronization—being awake when one typically sleeps or being awake during the early morning hours when the body is inclined to sleep—can lead to sleepiness and fatigue. (Kecklund and Akerstedt 1995) Therefore, the time of day that the train operator was operating the train made her more vulnerable to the effects of fatigue and at a higher risk for having an accident.

2.2.3 Cumulative Sleep Loss

The train operator told investigators that she needed 6 to 8 hours of sleep each day to feel rested.[24] In the 24 hours before the accident, the train operator had no more than a 6 hour 45 minute opportunity for uninterrupted sleep; it is unclear if she slept during a 2 hour 23 minute period when she was not using her PED later that afternoon. However, 2 days before the accident

[22] Circadian rhythms affect patterns of brain activity, hormone production, cell generation, and other biological activities linked to a 24-hour cycle.

[23] The difference in relative risk between the day and night shift is pronounced after the first shift and the onset of sleep debt.

[24] The National Sleep Foundation maintains that adults typically need 7-9 hours of sleep a night.

(after completing the prior day's shift at 6:17 a.m. Saturday), her only sleep period was a 50-minute nap in the afternoon. She had spent a large portion of her off-duty day commuting to and from work and playing sports. The day before (Friday), she woke at 10:00 a.m. and had not slept for more than 26 hours until her nap on Saturday.[25] During the 2 1/2 days (63 hours) leading up to the accident, the most the train operator could have slept was about 10 hours, although it was probably less. After several days of sleep deprivation, a person incurs a "sleep debt" that causes the impairment from sleep deprivation to be compounded. (Van Dongen and Others 2003) The NTSB concludes the train operator was experiencing the effects of a cumulative sleep debt, which contributed to her falling asleep.

2.2.4 Sleep Opportunity

In the 3 days leading up to the accident, the train operator had two off-duty periods, ranging from 12 hours to 26 hours. Two days before the accident (Saturday), she went off duty about 6:00 a.m. and was scheduled to work at 4:50 p.m. the same day. Shortly after she got home on Saturday morning, she left to play flag football for a few hours. When she got home, she took a 50-minute nap, and then she left for work. (She had departed late for work and missed the start of her scheduled assignment). The following day (Sunday), she got home from work about 4:00 a.m. and had 16 hours off until her next shift started Sunday night. The train operator had an opportunity for adequate sleep; however, her longest opportunity for sleep was 6 hours 45 minutes. There was also a period of about 2 hours 23 minutes in the early afternoon when she was not using her personal electronic device. However, it is not known what she was doing at that time. Even if she had taken a nap during that time, her total amount of sleep that day would have been in the range of what she said she normally requires (6 to 8 hours per day), but likely not a sufficient amount of sleep to compensate for the sleep debt she incurred the previous 2 days.

The NTSB notes that because of the circadian influence on sleep, there is an important distinction between having the opportunity to sleep and the amount of actual sleep someone obtains when there is an opportunity. In one sleep study, people who slept 8 hours when they went to bed at 11:00 p.m. would only sleep 6 hours if they went to bed at 3 a.m.; they would sleep only 4 hours when they went to bed at 11 a.m.—even though they had been kept awake all night. (Akerstedt and Gillberg 1986) So even if the train operator had tried to get enough sleep, circadian forces may have prevented her from being adequately rested because of the time of day that she would have tried to sleep.

The NTSB concludes that the train operator was impaired by fatigue at the time of accident due to the challenges of working shiftwork, circadian factors, sleep deprivation, and failing to get adequate sleep during her off-duty time.

[25] The train operator reported sleeping from 11:00 p.m. Thursday night to 10 a.m. Friday morning. This 11-hour sleep period, which far exceeds her normal 6 to 8 hours, is indicative of "recovery sleep" and suggests that she was not getting the sleep she required.

2.2.5 Hours of Service in Rail Transit Systems

There are no federal hours of service regulations in the rail transit industry. Each company institutes its own policy governing on- and off-duty requirements for employees, with some transit agencies maintaining policies requiring only 6 hours off between shifts. (FTA 2006). In 2006, the majority of transit companies required 8 hours off between the end of a train operator's shift (including overtime) and the beginning of the employee's next shift (including overtime). In 2014, a new APTA recommendation required a minimum of 10 hours off between scheduled work assignments as a new standard for hours of service for rail transit operators.[26] However, compliance with the APTA standard is voluntary. A Transit Advisory Committee for Safety (TRACS) working group that includes many transit companies is convening in 2015 to examine the need to establish government regulations on hours of service for transit agencies.

At the time of the accident, CTA employees working regular shifts were given at least 8 hours off between the completion of their last shift and the start of their next shift. Work assignments for those working regular schedules typically were 8-to-9 hours long, 5 days a week. Under CTA's agreement with Local 308, employees were not permitted to be assigned to work beyond 13 hours.[27]

This agreement, however, did not always apply to those working overtime. Up to 10 percent of CTA's employees requested overtime work. Employees working overtime may work on their scheduled days off and work back-to-back shifts. In the latter case, those who work consecutive shifts may have fewer than 8 hours off before the start of their next work assignment. CTA imposed no limit on employees working double shifts in a given week.

Employees working regular 8- or 9-hour shifts with the same on-duty start time each day typically have the opportunity to get enough sleep between work assignments. However, in certain circumstances—such as working overtime followed by an off-duty period of 8 or fewer hours—receiving adequate sleep likely is not achievable. To be able to sleep for 8 hours, an employee's off-duty time must be appreciably greater than 8 hours to accommodate commuting, family time, and self-care activities (for example, eating and grooming).[28] The NTSB maintains that CTA's practice (and that of other transit companies) of allowing employees who work overtime to return to work after having 8 or fewer hours off between shifts does not give the employees the opportunity to receive enough uninterrupted sleep to be fully alert and operate safely.

Following the accident at O'Hare Station, the CTA initiated changes to some of their scheduling and service planning policies. One of the changes was increasing the minimum rest time between shifts from 8 hours to 10 hours for rail operations employees. The NTSB

[26] The standard also stated that rail transit systems shall not schedule a train operator in a shift that has an overall elapsed time from start to finish of greater than 16 hours, with no more than 14 hours of work in the aggregate.

[27] Several other rail transit systems had similar overtime policies.

[28] One week before the accident, the train operator worked back-to-back shifts totaling 15 hours, followed by 8 hours off duty before beginning a new shift.

recognizes that increasing the rest time from 8 hours to 10 hours appears to be an improvement. However, the NTSB notes that for some employees, such as the CTA train operator whose commute time each way to work was 1 hour or more, a 10-hour off-duty period would not be a sufficient amount of time to achieve 8 hours of sleep. The NTSB, therefore, encourages the CTA to monitor the effectiveness of this policy, and if necessary, revise it to ensure that it provides employees with a legitimate opportunity to receive adequate rest.

CTA Overtime Scheduling

After finishing a shift that began at 8:10 p.m. on Tuesday, March 18, and ended at 5:46 a.m. on Wednesday, March 19, the train operator requested an overtime assignment later that same day. The CTA clerk was aware the train operator had just worked 7 consecutive days and suggested that she not work another shift that day. The CTA may decline employees' overtime requests if CTA believes it is not safe for them to work additional hours. Even though the train operator did not work overtime Wednesday, March 19, she began her next assignment 26 hours later, which allowed her to continue working Thursday, March 20. A CTA administrative manager told investigators, "The only time we would consider not giving someone [overtime] is if we feel that it's not safe for them to continue to double every day." That decision is made by the manager at that work location. A clerk, whose duties include observing the employees' general fitness, may initially alert a manager. The manager can then examine the payroll and see the number of hours the employee has worked. The CTA has no specific criteria determining when a clerk should alert a manager about an employee's work schedule.

The train operator had worked on each calendar day during the 11 days immediately prior to the accident. The majority of those assignments were night shifts. During this period, she was also granted overtime assignments on the 2 days that were normally her scheduled days off. Moreover, this was not the first time she had worked such a schedule for an extended amount of time. Investigators noted that earlier that same month, the train operator had worked 12 consecutive days – including working overtime on her two scheduled days off.

The NTSB is concerned that the CTA did not decline overtime when it resulted in the train operator working as much as 12 consecutive days and nights. Further, the NTSB believes that personnel who are in a position to grant overtime based on an employee's work history should have a background in identifying factors that lead to fatigue; however, not all CTA clerks and managers had received fatigue training.

Following the accident, CTA made changes to the agency's fatigue and awareness training. The changes include having rail operators repeat their fatigue and awareness training; integrating an online Transportation Safety Institute course for all new rail employees and as a refresher course for all safety-sensitive position supervisors and managers; training 25 CTA instructors to deliver a fatigue course; and reviewing the content of CTA's current fatigue training to address shift work. The NTSB concludes that CTA's changes to education and training on employee fatigue are a first step toward making all CTA operating employees and managers aware of the effects of fatigue.

2.2.6 Fatigue Management Programs and Safety Recommendations

The NTSB has long advocated fatigue education for employees and managers in all modes of transportation. The NTSB notes, however, that fatigue education alone is not sufficient to prevent incidents and accidents caused by fatigue. Rather, fatigue education should be one component of a comprehensive fatigue management program (FMP). The goal of FMPs is to mitigate human fatigue, thereby reducing the probability of incidents and accidents caused by human error. Consequently, the NTSB has previously recommended that transportation companies develop fatigue management plans.[29]

An FMP helps manage fatigue in an operational environment. Managing fatigue requires a complete risk assessment; creation and execution of a plan to eliminate or mitigate risks using risk reduction measures or controls (such as strategic work scheduling and opportunities for napping); and educating and encouraging employees to proactively manage their fatigue risks.

A typical FMP addresses the following areas: scheduling policies and practices; attendance; employee education on fatigue management, medical screening and treatment; personal responsibility during non-work periods; task/workload issues; rest environments; and commuting and/or napping. The FMP should be (1) developed through a collaborative process that involves operators and other employees; (2) readily available for inspection and auditing; (3) clearly documented and reviewed on a regular basis.

According to a 2006 survey by the FTA, only 24 percent of the transit agencies reported that fatigue management is addressed in their SSPPs. (FTA 2006)

Fatigue Management and the Rail Safety Improvement Act of 2008—Congress enacted the Rail Safety Improvement Act of 2008 following the September 12, 2008, head-on collision between a passenger train and a freight train in Chatsworth, California. Under the law, passenger and freight railroads had to develop fatigue management plans as a means of reducing accidents, incidents, injuries, and fatalities.[30] The plans—due within 4 years of the law's enactment—had to include methods for managing and reducing the fatigue of railroad employees in safety-related positions.[31]

Although the law did not apply to rail transit agencies, the requirements for fatigue management plans that address employee scheduling—which are particularly relevant to this accident—include:

- innovative scheduling practices

[29] The NTSB has also made recommendations in the highway, railroad, and aviation modes to establish ongoing programs to evaluate, report on, and continuously improve FMPs implemented by operators (NTSB Safety Recommendations H-08-14, R-12-07, A-06-11, and A-08-45) (NTSB 2012) (NTSB 2008a) (NTSB 2008b) (NTSB 2006).

[30] Smaller properties may be granted a waiver by the FRA.

[31] The first two elements of the Fatigue Management Plan include employee education and training on the physiological and human factors that affect fatigue, as well as strategies to reduce or mitigate the effects of fatigue, based on current scientific and medical research; and opportunities for identification, diagnosis and treatment of medical conditions that may affect alertness or fatigue.

- work and rest cycles
- increased consecutive days off for employees
- changes in shift patterns
- appropriate scheduling practices for various types of work
- other aspects of employee scheduling that would reduce employee fatigue and cumulative sleep loss

Scheduling Practices for Transit Employees

The NTSB has previously recommended the incorporation of science-based principles into the creation of work schedules.[32] The NTSB is aware that biomathematical models of fatigue and performance are currently used in transportation industries—including aviation and railroads—to help predict fatigue due to work schedules. Biomathematical models consider the relationships among working hours, sleep, and employee performance. In the NTSB accident report, *Collision of BNSF Coal Train With the Rear End of Standing BNSF Maintenance-of-Way Equipment Train in Red Oak, Iowa, April 17, 2011* (NTSB 2012), the NTSB noted some general limitations regarding the use of these models. These included the fact that the models have been calibrated to represent a population average rather than real-time fatigue levels of specific individuals; the model's inability to account for individual differences (such as operating experience, age, sex, and health); and the models limitations for considering all factors affecting fatigue including differences in workload (mental or physical), operating environments (such as lighting, temperature, noise levels) and other factors such as time pressures or monotony.

The FRA has supported the implementation of biomathematical models in the passenger and commuter train industry.[33] The models allow a company to control crewmembers' fatigue and fatigue risk in crew planning and operation. For instance, passenger and commuter railroads are required to take steps to mitigate fatigue among train crews on-duty between 8:00 p.m. and 4:00 a.m. In the rail transit industry, however, only 14 percent of the agencies surveyed had used analyses (which did not include biomathematical models) to assess the impacts of work schedules on operational safety. (FTA 2006) Therefore, the NTSB concludes that transit agencies and the FTA have underutilized science-based tools—such as biomathematical models—to assess and manage the risks of operator fatigue in their work scheduling practices. Therefore, the NTSB recommends that the FTA develop a work scheduling program for rail transit agencies that incorporates fatigue science—such as validated biomathematical models of fatigue—and provides for the management of personnel fatigue risks and implement the program through the state safety oversight program. Establish (through the state safety oversight program)

[32] In 1999, the NTSB issued an intermodal safety recommendation (I-99-1) to the US Department of Transportation regarding science-based hours-of-service regulations. This safety recommendation letter can be found at http://www.ntsb.gov/safety/safety-recs/_layouts/ntsb.recsearch/Recommendation.aspx?Rec=I-99-001.

[33] Title 49 CFR Part 228, Subpart F. On August 12, 2011, FRA published its final rule providing new limitations for passenger train employees, based on the limitations in the Hours of Service laws as it existed prior to 2008. The regulation adds a requirement to analyze employee work schedules with fatigue modeling tools, and consecutive-days limitations that recognize the difference between work during daylight hours and work during nighttime hours.

scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements.

The competency of work schedule managers

The NTSB is concerned that personnel in the railroad industry assigned to prepare work schedules may not be adequately prepared to schedule work assignments that help employees mitigate fatigue. A 2010 FRA report examined the job tasks and knowledge, skills, abilities and other characteristics needed to perform the job of a work schedule manager in the railroad industry. (FRA 2010) The results pointed to a need for training in understanding how work scheduling affects employee health, safety, and performance. Specifically, the study found significant gaps (between subject matter experts and actual schedule managers) were apparent in terms of knowledge of sleep physiology, human factors, and shift work training programs, again addressing the health and safety components of shift work.

The study concluded, in part:

> Additional schedule management training is needed to aid work schedule managers in understanding how the design of work schedules can have an impact on employee health, safety, and performance. The incumbents interviewed were fully capable of maintaining work schedules and making minor changes to scheduling to account for absenteeism, turnover, or overtime needs. However, they may not be qualified to identify problems in the schedule design and/or make changes to the system to address those problems. The majority of the training that schedulers receive is currently on-the-job, often involving a short-term mentorship with another scheduler in their organization. There is very little standardized training even within organizations.

The study recognized that additional research is necessary to identify training and certification needs in specific occupations. The NTSB concludes that identifying the training and certification needs of transit work schedulers would help them develop more effective work schedules for transit employees. Therefore, the NTSB recommends that the FTA identify the necessary training and certification needs for work schedulers in the rail transit industry and require the transit agencies—through the state safety oversight program—to provide additional training or certification for their work schedulers.

Moreover, the NTSB recognizes that several factors—including the way work is planned and scheduled; the time work is performed; and the amount of time worked—can increase the risk of fatigue. (NSW MSAC 2009) The NTSB concludes that work schedulers should have a strong understanding of factors that influence employee fatigue, including working night shifts, length of shifts, unplanned work, emergencies, and commute time to and from work. Therefore, the NTSB recommends that the FTA require (through the state safety oversight program) rail transit employees who develop work schedules to complete initial and recurrent training based on current fatigue science to manage work schedule risks that contribute to operator fatigue.

2.3 Station Design and System Safety

The O'Hare Station was designed and built in the 1980s by the City of Chicago, but there was no documentation showing a safety certification of the station design. Under 49 CFR 659, a safety certification would have been required for this size project if it were done today.

The bumping posts were designed to withstand being struck by an average eight-car train at 15 mph. The bumping posts for tracks 1 and 2 were about 60 feet from the end of track, and they had friction shoes attached to the rail to help slow a striking train. The bumping post on the center pocket track was installed with only 15.6 feet of distance to the end of the track. There was not enough room to equip it with energy friction shoes. The deficiencies of the center bumping post had been previously noted, and construction workers had tried to compensate by tightening the bumping post to the rail so it would not move as easily. To exacerbate the problem, the center pocket track had a maximum speed command of 25 mph, which was inappropriate based on the 15 mph speed commands allowed on tracks 1 and 2. So, not only was the bumping post distance too short, the speed was too high. The NTSB concludes that the design of the center pocket track was not adequate to prevent a train from striking the bumping post near the end of the track.

Since the accident, the CTA has installed additional track trips with more distance to the end of the track at the O'Hare Station. They have also decreased the maximum speed to 15 mph on the center pocket track. Further, as explained in the Postaccident Actions section, the CTA found other locations of terminating tracks with suspect stopping distances and are making modifications.

As explained earlier, the station design and train speeds for the center pocket track created a hazard of trains striking the bumping post. Because the signal and track trip location was too close to the end of the track, the single point failure of an incapacitated operator allowed this accident to happen. Finding existing hazards in a mature transit system can be a challenge. The CTA's System Safety Program required a hazard analysis and design evaluation to be performed only when a modification of either a vehicle or facility was made. However, a robust system safety program should include hazard analysis of existing equipment, facilities, and operations. The CTA's hazard management process did not identify the hazard at the center pocket track at the O'Hare station. Neither the CTA's System Safety Program Plan nor a safety committee identified the hazard at the center pocket track at the O'Hare Station. Therefore, the NTSB concludes that the CTA's System Safety Program did not include a hazard management program sufficient to identify hazards at existing facilities at the time of the accident. Following the accident, the CTA implemented a new *Management of Change Committee* standard operating procedure. According to the procedure, the purpose is to outline how changes to the system are evaluated, approved, and implemented. It applies to existing systems, procedures, and operational processes. The procedure considers if the proposed change may impact the safety of the system and requires a hazard analysis if there is a potential safety impact. The procedure also describes the documentation and approval process for system changes.

2.4 Signal System

2.4.1 Overview

The CTA signal system did not stop trains before they reached a stop signal, even when a track trip was added. A red stop signal sent a 0 mph speed command to an approaching train shortly before it passed the signal. The train's brakes would engage and begin slowing the train as the train passed the red signal. Depending upon the train's speed, a train could strike an obstruction or another train before coming to a stop after passing the signal. When a track trip was used to apply the brakes, trains still did not stop until they passed the red stop signal. In this accident, the train could not stop before hitting the end of the track. Although the distances and speeds were corrected at the O'Hare Station, there were other locations where decelerating trains could pass a red signal and collide with a standing train.

The NTSB has investigated numerous train collisions—most of which could have been prevented if a system had been in place that ensured train separation. (NTSB 2012b) (NTSB 2011) (NTSB 2010) (NTSB 2009) (NTSB 2008c) (NTSB 2008d) The NTSB is a strong advocate of advanced train control systems that will provide a safety net for human performance failures in the operation of trains. These systems can reduce both the number and severity of train accidents caused when an engineer or operator fails to take action to slow or stop a train.

The NTSB has attributed human performance failures to a variety of causes, including fatigue, sleep disorders, use of medication, reduced visibility, and distractions in the operating cab (such as the use of PEDs). Many of these accidents occurred after train crews failed to comply with train control signals, failed to follow operating procedures in nonsignaled (dark) territories, or failed to comply with other specific operating rules (such as returning track switches to normal position after completing their work at railroad sidings).

The urgency of this issue has been highlighted in NTSB investigations, and the NTSB has repeatedly concluded that technological solutions have great potential to reduce the number of serious train accidents by providing redundant systems to protect against human performance failures. These technological solutions include transmission-based train control (TBTC) systems—a term most often used in the rail transit industry—or positive train control (PTC) systems, the term used by freight railroads to refer to the same function as TBTC.[34] Although the names of these advanced train control systems differ, these systems operate similarly.

These advanced train control systems use bidirectional train-to-wayside data communications and train and wayside processors for train location determination. TBTC systems implemented on transit rail properties can implement automatic train protection functions and can also be configured to provide automatic train operation and supervision functions.

On May 28, 2008, at 5:51 p.m. eastern daylight time, Massachusetts Bay Transportation Authority Green Line train 3667 was traveling westbound about 38 mph and struck the rear of

[34] TBTC systems are also referred to as communication-based train control systems.

westbound Green Line train 3681, which had stopped for a red signal. (NTSB 2009) The accident occurred in a suburb of Boston. The operator of the striking train was killed, and one passenger was seriously injured. Four passengers and three crewmembers sustained minor injuries.

On July 23, 2009, as a result of the May 28, 2008, Massachusetts Bay Transportation Authority train collision in Newton, Massachusetts, the NTSB recommended that the FTA:

> Facilitate the development and implementation of positive train control systems for rail transit systems nationwide. (R-09-08)

The FTA responded by organizing a November 2009 meeting with transit train control experts and asking for industry input on implementing PTC. In June 2010, the FTA indicated that it was developing a research proposal on PTC that would recommend actions to FTA. The NTSB classified Safety Recommendation R-09-08 *Open—Acceptable Response*. The FTA has not provided any further updates on its activities in response to Safety Recommendation R-09-08 in the 5 years since the meeting. The NTSB generally expects that actions in response to recommendations can be completed within 5 years after the recommendation was issued. During the 5 years since the FTA meeting, the NTSB has continued to investigate rail transit accidents where a PTC or TBTC system would likely have prevented the accident. The FTA now has legislative authority to require the implementation of a positive train control system, commonly referred as transmission-based train control systems on transit properties. The NTSB recognizes that TBTC systems are most often used on transit properties and is making a recommendation in this report to address this issue. Therefore, Safety Recommendation R-09-08, previously classified "*Open—Acceptable Response*," is now classified "*Closed—Unacceptable Action/Superseded*."

2.4.2 Transmission-Based Train Control

CTA trains receive continuous cab signal indications and speed commands that are displayed in the operating cab. Wayside signals are equipped with trip mechanisms that are in the raised position (de-energized) when a signal is set at stop. If a train advances past a block with the track trip (or train stop mechanism) in the raised position, the trip mechanism will engage a lever located on the underside of a train and activate the braking system of the train. After a brake application is initiated, the train can proceed when two conditions are met: (1) the train speed is 0 mph and (2) the master lever is placed in the B3 dynamic braking position.

Train control systems that supplement wayside signals with in-cab displays and train stop mechanisms—like the one installed on the CTA Blue Line—have existed since the early 1900s. While the components employed by these systems have been upgraded from electromechanical relays to microprocessor-based systems, the means of operation remains the same as originally designed. The CTA signal and train control system provides for automatic enforcement of stop signals, but that only occurs if a train operator fails to comply with a restrictive signal.

The NTSB has repeatedly concluded that technological solutions have great potential to reduce the number of serious train accidents by providing redundant safety systems—which utilize multiple methods for stopping a train—to protect against human performance failures. This includes TBTC, which is most often used by the transit rail industry.

TBTC and PTC systems monitor train operations and enforce a safe braking distance as a train approaches a restrictive signal. If the train operator or engineer fails to operate the train so the train can comply with the restrictive signal, the advanced train control system will assume some control, stopping the train before a signal violation can occur.

The NTSB concludes that a fully implemented TBTC system would have prevented this accident by applying the train's brakes before the train passed the red stop signal. The NTSB recommends that the CTA install a TBTC system, which includes collision avoidance, on all passenger train routes. Also, the NTSB recommends that the FTA require rail transit agencies to implement transmission-based train control systems that prevent train collisions.

2.5 Event Recorders

The accident train was equipped with a fault logger (part of the undercar propulsion electronic group). A fault logger is not an event recorder; however, when a fault is triggered it can capture a limited amount of data. One of these data points is train speed. In this accident, the undercarriage of the lead car—where the fault logger was located—was destroyed and so badly damaged that no information could be retrieved.

CTA has equipped all of its newer rail transit equipment with event recorders that will continuously record data across a broad spectrum, including speed and master controller positions. The event recorders are located in a protected area within the car's body and are not as likely to be destroyed during an accident. As the older cars are replaced, CTA's entire fleet will eventually be equipped with event recorders.

The NTSB has addressed event recorders on transit equipment in previous accidents. In 1996 the NTSB recommended that the FTA:

> (D)evelop, with the assistance of the American Public Transit Association, guidelines for monitoring/recording devices that capture critical performance & event data for rapid rail transit cars and urge transit agencies to install these devices on new and rehabilitated cars. (R-96-46)

On September 4, 1998, the NTSB received a letter from the FTA that included a copy of a report titled, "Event Recorders for Rapid Transit Systems, 1/6/1998, FTA-VA-26-7004-98-1". The FTA also stated that they would provide the report to the transit properties and urge them to install event recorders. On January 6, 1999, the NTSB classified R-96-46 *Closed—Acceptable Action.*

Within a 2-month period in 2001, there were two similar rear-end collisions involving CTA rapid transit trains. (NTSB 2002) The NTSB conducted a special investigation and determined that information from the accidents was missing because of the lack of event recorders on the transit equipment. The NTSB issued the following recommendation to the FTA:

> Require that new or rehabilitated vehicles funded by FTA grants be equipped with event recorders meeting Institute of Electrical and Electronics Engineers Standard 1482.1 for rail transit vehicle event recorders. (R-02-19)

On November 25, 2002, the FTA responded, "There has been no change in our legislative authority to allow FTA to regulate vehicle equipment standards."

The FTA continued to maintain its position that the administration did not have the legislative authority to implement the recommendation. On August 29, 2008, the NTSB classified Safety Recommendation R-02-19 *Closed—Unacceptable Action*.

Moving Ahead for Progress in the 21st Century Act (MAP 21) (P.L. 112-141), signed into law on July 6, 2012, granted the FTA the authority to establish and enforce a new comprehensive framework to oversee the safety of public transportation throughout the United States as it pertains to heavy rail, light rail, buses, ferries, and streetcars. The NTSB concludes that through MAP 21, the FTA has the legislative authority to require equipment standards on transit equipment and can now require event recorders. Therefore, the NTSB recommends that the FTA require that new or rehabilitated rail transit vehicles be equipped with event recorders meeting Institute of Electrical and Electronics Engineers Standard 1482.1 for rail transit vehicle event recorders.

2.6 Oversight

2.6.1 FTA Oversight

Previous NTSB Investigations

On Monday, June 22, 2009, about 4:58 p.m., eastern daylight time, inbound Washington Metropolitan Area Transit Authority Metrorail train No. 112 struck the rear of stopped inbound Metro rail train No. 214. (NTSB 2010b) Nine people aboard train No. 112, including the train operator, were killed. According to emergency response agencies, 52 people were taken to local hospitals. The damage to train equipment was estimated to be $12 million.

The NTSB found that the FTA's lack of statutory authority to provide federal safety oversight contributed to the accident. As a result, the NTSB made the following recommendation to the US Department of Transportation (DOT):

> Continue to seek the authority to provide safety oversight of rail fixed guideway transportation systems, including the ability to promulgate and enforce safety regulations and minimum requirements governing operations, track and equipment, and signal and train control systems. (R-10-3)[35]

[35] This safety recommendation was reiterated as R-11-1.

On December 20, 2010, the NTSB received a response to this recommendation from the FTA. The FTA, in part, stated the following:

> FTA strongly endorses this recommendation. The leadership of DOT and FTA has worked hard to develop a workable safety regulatory framework that will meet the intent of NTSB's recommendation to support stronger safety assurance systems for the Nation's rail transit systems. U.S. rail transit carries more passengers on a daily basis than domestic airlines, Amtrak, or Commuter Rail. Yet rail transit operates in a significantly less regulated environment with regard to safety.

On March 21, 2012, the NTSB received an update on pending legislative authority from the DOT Secretary. The Secretary reported the following:

> Appropriately, the legislation was about implementing an enforceable national rail transit safety initiative, which the FTA has been prohibited from doing since 1964. The Senate Banking Committee unanimously passed legislation that was supportive of the Administration's initiative. During the 112th Congress, the Administration will continue to advocate for Congress to provide FTA with the authority to establish and oversee national rail transit safety standards.

On December 26, 2012, the NTSB acknowledged that the MAP 21 granted the FTA with legislative authority. The recommendation was classified *Closed—Acceptable Action*.

MAP-21

Chapter 5300 of Title 49 United States Code, effective October 1, 2012, describes the new requirements for the FTA, state safety oversight agencies, and transit agencies.[36] Section 5329 directs the Secretary of Transportation to establish "a national public transportation safety plan to improve the safety of all public transportation systems that receive funding under this chapter." The plan must include safety performance criteria for public transportation. Section 5329 authorizes the Secretary of Transportation to conduct inspections, investigations, and audits; make reports; and issue directives with respect to the safety of the public transportation system.

On October 3, 2013, the FTA issued an advanced notice of proposed rulemaking (NPRM) to obtain comments about FTA's proposed national public safety plan requirements from the transit industry.[39] The notice stated:

> FTA is also seeking comment on its intent to propose adoption of the Safety Management System (SMS) approach to guide the development and implementation of the National Safety Program. SMS offers a proactive method for managing safety which enables agencies to identify and resolve safety concerns and challenges before they result in incidents. SMS combines established system safety engineering principles with advanced organizational

[36] Public Law 112–141 [Division B – Federal Public Transportation Act of 2012].

> management techniques, and supports continuous improvement in safety performance through a positive safety culture founded on four key priorities: safety policy, safety risk management, safety assurance, and safety promotion.

On February 27, 2015, the FTA issued a *Federal Register* NPRM announcing the agency intends to implement the requirements of MAP 21. The notice proposes changes to the State Safety Oversight (SSO) program to increase states' oversight responsibilities, have the FTA review and certify each state's SSO program, and allow the FTA to impose financial penalties for states that are not in compliance. Appendix A to the NPRM provides a framework for SMS principles that will be the basis of future NPRMs. According to the NPRM, the FTA will incorporate SMS standards in rulemaking for the National Public Transportation Safety Plan, the Public Transportation Safety Certification Training Program, and the Public Transportation Agency Safety Plans. FTA has maintained they do not have legislative authority to establish minimum requirements for the transit agencies; however, MAP 21 has provided FTA with that authority. The FTA administrator and the DOT secretary have indicated that they welcome the authority to more widely regulate the transit agencies.

3 Conclusions

3.1 Findings

1. None of the following was a factor in the accident: (1) mechanical condition of the train, (2) operator's experience operating transit trains, (3) personal electronic device use while operating the train, (4) alcohol or drug use, or (5) weather.

2. The train operator was experiencing the effects of a cumulative sleep debt, which contributed to her falling asleep.

3. The train operator was impaired by fatigue at the time of accident due to the challenges of working shiftwork, circadian factors, sleep deprivation, and failing to get adequate sleep during her off-duty time.

4. Chicago Transit Authority's changes to education and training on employee fatigue are a first step toward making all Chicago Transit Authority operating employees and managers aware of the effects of fatigue.

5. Transit agencies and the Federal Transit Administration have underutilized science-based tools—such as biomathematical models—to assess and manage the risks of operator fatigue in their work scheduling practices.

6. Identifying the training and certification needs of transit work schedulers would help them develop more effective work schedules for transit employees.

7. Work schedulers should have a strong understanding of factors that influence employee fatigue, including working night shifts, length of shifts, unplanned work, emergencies, and commute time to and from work.

8. The design of the center pocket track was not adequate to prevent a train from striking the bumping post near the end of the track.

9. The Chicago Transit Authority's System Safety Program did not include a hazard management program sufficient to identify hazards at existing facilities at the time of the accident.

10. A fully implemented transmission-based train control system would have prevented this accident by applying the train's brakes before the train could advance past the red stop signal.

11. Through the Moving Ahead for Progress in the 21st Century Act, the Federal Transit Administration has the legislative authority to require equipment standards on transit equipment and can now require event recorders.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the train operator to stop the train at the appropriate signal due to falling asleep as a result of fatigue, which was the result of the challenges of working shiftwork, circadian factors, and acute sleep loss resulting from her ineffective off-duty time management. In addition, Chicago Transit Authority failed to effectively manage the operator's work schedule to mitigate the risk of fatigue. Contributing to the severity of the accident was Chicago Transit Authority's failure to identify the insufficient stopping distance and inadequate speed restriction at the center pocket track at O'Hare Station.

4 Recommendations

4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations:

To the Federal Transit Administration:

> Develop a work scheduling program for rail transit agencies that incorporates fatigue science—such as validated biomathematical models of fatigue—and provides for the management of personnel fatigue risks, and implement the program through the state safety oversight program. (R-15-18)
>
> Establish (through the state safety oversight program) scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. (R-15-19)
>
> Identify the necessary training and certification needs for work schedulers in the rail transit industry and require the transit agencies—through the state safety oversight program—to provide additional training or certification for their work schedulers. (R-15-20)
>
> Require (through the state safety oversight program) rail transit employees who develop work schedules to complete initial and recurrent training based on current fatigue science to identify and mitigate work schedule risks that contribute to operator fatigue. (R-15-21)
>
> Require rail transit agencies to implement transmission-based train control systems that prevent train collisions. (R-15-22)
>
> Require that new or rehabilitated rail transit vehicles be equipped with event recorders meeting Institute of Electrical and Electronics Engineers Standard 1482.1 for rail transit vehicle event recorders. (R-15-23)

To the Chicago Transit Authority:

> Install a transmission-based train control system on all passenger train routes. (R-15-24)

4. 2 Previously Issued Recommendation Reclassified in This Report

Safety recommendation R-09-08, which was issued to the Federal Transit Administration on July 14, 2009, is reclassified "Closed—Unacceptable Action/Superseded" in this report:

> Facilitate the development and implementation of positive train control systems for rail transit systems nationwide. (R-09-08)
>
> The recommendation is superseded by Safety Recommendation R-15-22.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CHRISTOPHER A. HART Chairman	**ROBERT L. SUMWALT** Member
T. BELLA DINH-ZARR Vice Chairman	**EARL F. WEENER** Member

Adopted: April 28, 2015

Appendix–Investigation

The National Transportation Safety Board was notified on March 24, 2014, that a Chicago Transit Authority train had collided with the bumping post near the end of the track at O'Hare Station. The National Transportation Safety Board launched an investigator-in-charge and five team members to investigate the accident.

The Federal Transit Administration, Regional Transit Authority, and Chicago Transit Authority were parties to the investigation.

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