

Positive Train Control (PTC): Overview and Policy Issues

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Summary

The Rail Safety Improvement Act of 2008 (RSIA08) requires implementation of positive train control (PTC) on railroads which carry passengers or have high-volume freight traffic with toxic- or poisonous-by-inhalation hazardous materials. PTC is a communications and signaling system that has been identified by the National Transportation Safety Board (NTSB) as a technology capable of preventing incidents caused by train operator or dispatcher error. PTC is expected to reduce the number of incidents due to excessive speed, conflicting train movements, and engineer failure to obey wayside signals. It would not prevent incidents due to trespassing on railroads' right-of-way or at highway-rail grade crossings, where the vast majority of rail-related fatalities occur, and might not work well in some passenger terminal areas.

Under RSIA08, PTC is required on about 60,000 miles of railroad track. The Federal Railroad Administration (FRA) estimates full PTC implementation will cost approximately \$14 billion. Progress among railroads in installing and operating PTC is mixed: a few large freight and commuter railroads show substantial progress while many others show much less progress. Federal funding provided thus far includes about \$2 billion in loans and grants, mostly for commuter lines. After freight and commuter railroads raised concerns about their ability to meet the December 31, 2015, deadline in RSIA08, Congress extended the deadline by three years to December 31, 2018, or up to two years beyond that for certain qualifying railroads (P.L. 114-73). A July 2018 FRA report indicates that possibly all railroads will seek to qualify for an extension beyond the December 31, 2018, deadline, mostly for completing testing of their PTC systems.

PTC uses signals and sensors along the track to communicate train location, speed restrictions, and moving authority. If the locomotive is violating a speed restriction or moving authority, on-board equipment will automatically slow or stop the train. A more expansive version of PTC, called communications-based train control (CBTC), would bring additional safety benefits plus business benefits for railroad operators, such as increased capacity and reduced fuel consumption. However, CBTC is not currently being installed by any U.S. railroad, due to the additional cost and the challenge of meeting implementation deadlines.

In addition to funding requests for maintaining the PTC systems, Congress may be confronted with issues related to interoperability and barriers to market entry as railroads work toward implementing PTC.

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Introduction

Following several high-profile train incidents, Congress passed the Rail Safety Improvement Act of 2008 (RSIA08; P.L. 110-432), which mandated positive train control (PTC) on many passenger and freight railroads by December 31, 2015. The law does not describe PTC in technical terms, but defines it as a risk mitigation system that could prevent train incidents by automatically stopping trains when a collision or derailment is imminent.

After freight and commuter railroads raised concerns about their ability to meet the 2015 deadline, Congress extended the deadline by three years to December 31, 2018, or up to two years beyond that for certain qualifying railroads (P.L. 114-73). As of July 2018, it appears that all railroads will seek qualification for extending the deadline.¹

While PTC promises benefits in terms of safety, its implementation entails substantial costs and presents a variety of other policy-related issues. These include the interoperability of individual railroads' systems, access to sufficient radio spectrum to support PTC, the possibility that PTC could be a barrier to market entry, and the suitability of PTC to passenger terminal environments.

Rail Safety and PTC

The United States railroad network comprises both freight and passenger operations. The seven largest operators by revenue, known as the Class I freight railroads, own about two-thirds of the nation's 140,810 miles of trackage (see **Figure 1**).² These companies include BNSF, Union Pacific (UP), Norfolk Southern (NS), Kansas City Southern (KCS), Canadian Pacific (CP), Canadian National (CN), and CSX Transportation (CSXT). Most of the remaining trackage is controlled by Class II or regional freight railroads; Class III or short-line railroads; state and local government agencies; and Amtrak, the federally owned passenger operator.

In many situations, both passenger and freight railroad companies operate over track owned by other railroads. This may occur under orders issued by the federal Surface Transportation Board or under voluntary agreements between carriers. Amtrak also has the right to operate trains using its own equipment over freight lines.³

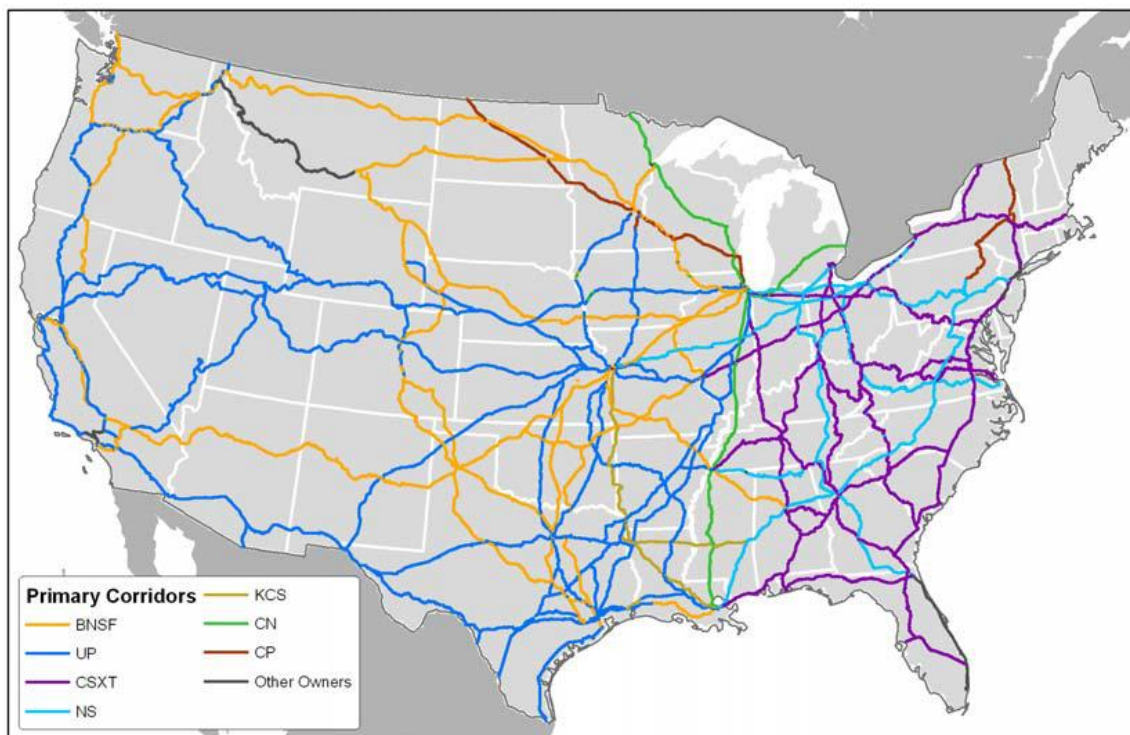
The majority of freight railroad lines have a single track with passing sidings at various locations to allow trains to pass. Trains may operate in either direction along a track. High-volume corridors may have multiple tracks that typically operate in a single direction to increase both operating capacity and safety.⁴

¹ Federal Railroad Administration, *Railroads' Progress Toward Implementation of Positive Train Control Systems*, July 1, 2018, p. 4.

² U.S. Department of Transportation, "National Transportation Statistics," http://www.bts.gov/publications/national_transportation_statistics/html/table_01_01.html.

³ See CRS Report R42512, *Passenger Train Access to Freight Railroad Track*, by John Frittelli.

⁴ Cambridge Systematics, *National Rail Freight Infrastructure Capacity and Investment Study*, Final Report, September 2007, p. 25, http://www.aar.org/~media/aar/Files/natl_freight_capacity_study.ashx.

Figure I. National Network of Class I Railroads

Source: Cambridge Systematics, Inc., National Rail Freight Infrastructure Capacity and Investment Study, September 2007.

Notes: This map shows the Class I railroads in the United States. Not all lines shown are subject to the PTC implementation mandate.

Signal Systems

For safety purposes, train dispatchers and signals along the track provide the engineer with the authority to travel on a certain track segment to prevent collision with other trains. Some long stretches of track in remote areas use only one main line without any signalization. This is called “dark territory,” comprising about 40% of the North American rail network.⁵ In this case, railroads rely on communications with dispatchers to provide authority. Dispatchers are also responsible for assigning priority when more than one train requires use of a particular segment of track.

On signaled track, track is separated into blocks by trackside or overhead signals that indicate to an engineer whether the train can proceed (and at what speed) or must stop before it enters the next block. Given the long stopping distance required by trains, a prior signal actually informs the engineer about the indication on the next signal. This system is called automatic block signal (ABS), and is generally the most sophisticated signal system used by freight railroads where PTC has not been installed. Since 1947, it has been required for freight trains traveling 50 or more miles per hour (mph) and passenger trains traveling 60 mph or more.⁶ Railroads have different

⁵ Institution of Railway Signal Engineers, *Introduction to North American Railway Signaling* (Omaha: Simmons-Boardman, 2008), p. vii.

⁶ Codified today at 49 C.F.R. 236.

operating rules regarding how and under what circumstances the conductor must call out signals to the engineer.

Intercity and commuter passenger trains often incorporate additional features in their signal systems. A “cab signal” system relays external signal information to control displays inside the engineer’s cab via an electric current that travels along the rails and is picked up by a receiver on the locomotive. The cab signal is helpful when fog, sun, or track curvature hinders or delays visual sighting of wayside signals. It also increases track utilization, as the engineer can adjust train speed in between signals. An “automatic train stop” (ATS) or an “automatic train control” (ATC) system can override the engineer’s control of a train if a wayside signal indication is not acknowledged by the engineer. These devices are installed along the tracks, and trip a train’s brakes when an engineer fails to respond to a wayside signal. Cab signals, ATS, and ATC were developed beginning in the early 1900s, and have been required by federal regulations since 1947 for passenger trains traveling over 79 mph (see text box).

A Brief History of Major Legislative and Regulatory Developments

Congress has been interested in automatic train control for over a century. In 1906, Congress directed the Interstate Commerce Commission (I.C.C.)—the Federal Railroad Administration’s (FRA’s) predecessor in federal regulation of rail safety—to investigate and report on the use of and necessity of devices for the automatic control of railway trains, and to recommend such legislation as the agency deemed advisable (H.J.R. 153, 34 Stat. 838). In the Transportation Act of 1920 (41 Stat. 498), Congress authorized the I.C.C. to mandate the installation of ATS or ATC devices. In 1922, the I.C.C. ordered the installation of these devices on 49 railroads on segments of track totaling about 5,000 miles.⁷ In 1937, Congress enacted the Signal Inspection Act (50 Stat. 835), which required railroads to obtain I.C.C. permission for any modification to their signal systems. In 1947, the I.C.C. ordered any railroad operating at a speed of 80 or more mph (i.e., passenger trains) to install ATS, ATC, or cab signal systems on its lines.⁸ In its 1947 report, the I.C.C. noted that ATS or ATC was then in use on over 14,100 miles of track, while cab signals were in use on over 8,100 miles.⁹ The report estimated that its order would require such devices on an additional 27,156 miles of track.¹⁰

The National Transportation Safety Board’s (NTSB’s) first recommendation regarding automatic train control was issued to the FRA in 1970 after its investigation of a collision of a commuter train with a work crew train in Darien, CT, in 1969.¹¹ It recommended that the FRA “study the feasibility of requiring a form of automatic train control at points where passenger trains are required to meet other trains.”¹² In 1976, the congressional Office of Technology Assessment issued a report requested by Congress on the use of automatic train control devices in rail transit systems.¹³ In 1983, the FRA proposed a number of changes to signal and train control requirements, but in issuing its final rule, citing the 1947 I.C.C. threshold of 80 mph for installation of ATS, ATC, or cab signal devices, it determined that there was no compelling argument to either lower or raise the 80 mph speed threshold.¹⁴ In 1990, the NTSB placed automatic train control on its initial “Most Wanted List of Transportation Safety Improvements.”¹⁵ Congress directed the FRA to issue a progress report on positive train control in The High-Speed Rail Development Act of 1994 (P.L. 103-440). In 1997, after investigation of an accident between a commuter train and an Amtrak train in Silver Spring, MD, that killed eight commuter passengers, the NTSB recommended that the FRA require the installation of a positive train separation control system for all tracks where commuter and intercity passenger railroads operate.¹⁶ The FRA responded in 1998 to the NTSB’s recommendation by stating, in part,¹⁷

Current regulations create incentives for installation of these systems by authorizing higher train speeds. However, signal-based technology is expensive, and passenger operators cannot achieve significant increases in safety on the lines that they utilize absent parallel investments by freight operators (which are often the owners and/or dominant users of the line on which passenger trains operate). The answer to this problem is more affordable technology and commitments for joint action by freight and passenger service providers. It is important that we avoid any burden on passenger service providers that would result in service cutbacks and diversion of passengers to less safe forms of transportation.

In 2004, the FRA submitted a cost-benefit analysis of PTC at the request of Congress.¹⁸ That study showed that as of 2004, the costs of PTC outweighed the direct safety benefits, but the agency’s letter to Congress stated, “we believe PTC will be more affordable in the future.”¹⁹

⁷ 69 I.C.C. 258 (Order No. 13413), “In the Matter of Automatic Train-Control Devices,” decided June 13, 1922.

⁸ 268 I.C.C. 547 (Order No. 29543), “Appliances, Methods, and Systems Intended to Promote Safety of Railroad Operation,” decided June 17, 1947; 12 *Federal Register* 4683, July 15, 1947.

⁹ 268 I.C.C. 552.

¹⁰ 268 I.C.C. 559.

¹¹ Railroad Accident Report, *Head-on Collision between Penn Central Trains N-48 and N-49 at Darien, CT, August 20, 1969* (NTSB/RAR-70/03).

¹² NTSB Recommendation R-70-20.

¹³ Office of Technology Assessment, *Automatic Train Control in Rail Rapid Transit*, May 1976.

¹⁴ NPRM, 48 *Federal Register* 11882, March 21, 1983; Final rule, 49 *Federal Register* 3374, January 26, 1984.

¹⁵ National Transportation Safety Board, Office of Public Affairs, “NTSB unveils new ‘Most Wanted List,’” press release, June 23, 2011, p. 1, <http://www.nts.gov/news/2011/110623.html>.

Rail-Related Fatalities

Most rail-related fatalities are caused by pedestrians trespassing on railroad tracks or motor vehicles being hit at grade crossings. Train derailments and collisions, which PTC is designed to prevent, cause relatively few fatalities. Over a 10-year period ending in February 2016, there were 7,695 rail-related fatalities: 58% were due to trespassing (4,458 fatalities), 37% occurred at grade-crossings (2,838 fatalities), 2% were railroad workers (181 fatalities), and 1% were railroad passengers (75 fatalities). Only a portion of these passenger deaths were due to train derailments or collisions.²⁰

Although preventing grade-crossing incidents is not specifically addressed in the PTC mandate of RSIA08, this could be achieved technically within the PTC framework by installing sensors at crossings that would engage the brakes of an oncoming train if a crossing gate is not working properly or if a vehicle is detected on the tracks.²¹ While this may require further investment on the part of the railroads and may not be implementable by the deadline, it may offer more significant gains in terms of safety than train collision prevention alone. Once PTC is implemented, Congress has requested the FRA to study the effectiveness of PTC technology in preventing grade-crossing incidents.²²

Train Incidents and PTC Legislation

While most railroad incidents are minor, several high-profile incidents led Congress to mandate PTC. In 2005, a train carrying chlorine gas was improperly diverted onto a side track by a manual switch left in the wrong position. Another train was parked on the side track. As a result of the collision, chlorine gas was released from one derailed car, killing nine people and forcing the evacuation of 5,400 people within a mile radius of the incident for two weeks. This incident occurred in dark territory. It was among the factors leading to introduction of the Federal Railroad Safety Improvement Act of 2007 (H.R. 2095, S. 1889) in the 110th Congress, which would have mandated implementation of PTC in specific circumstances.

In 2008, the head-on collision of a Metrolink commuter train and a Union Pacific freight train in Chatsworth, CA, led to 25 fatalities and over 100 injuries. That crash occurred on a section of track on which no cab signal, ATS, or ATC system was installed, leaving the commuter train engineer completely dependent on his sightings of the wayside signals. Reportedly, the cost of also equipping freight locomotives with automatic signaling technology was one reason a new system had not been installed.²³ The cause of the accident was determined to be negligence by the

¹⁶ NTSB, Safety Recommendation R-97-9 through -21, August 28, 1997; see also Safety Recommendation R-97-013.

¹⁷ Safety Recommendation History, NTSB Safety Recommendation R-97-013.

¹⁸ U.S. Congress, House Committee on Appropriations, *Conference Report on the Consolidated Appropriations Resolution*, to accompany H.J.Res. 2, 108th Cong., 1st sess., 2003, H.Rept. 108-10 (Washington: GPO, 2003), pp. 1286-1287.

¹⁹ Letter from Betty Monro, Federal Railroad Administration Acting Administrator, to Senator Robert Byrd, August 17, 2004, http://www.fra.dot.gov/downloads/safety/ptc_ben_cost_report.pdf.

²⁰ Two percent (143 fatalities) occurred for other reasons. FRA safety data (as of February 2016); <http://safetydata.fra.dot.gov/officeofsafety/default.aspx>.

²¹ Fred Coleman III, Ronald W. Eck, and Eugene R. Russell, "Railroad-Highway Grade Crossings," TRB Conference Publication, Washington, DC, January 2000.

²² Fixing America's Surface Transportation Act (FAST Act, P.L. 114-94, §11404).

²³ "Train Crash's Roots Run Deep; Decades-old Decisions by Metrolink Gambled on Passenger Safety, According to Experts and Documents," *Los Angeles Times*, December 12, 2008.

commuter train engineer—it is believed he missed a red signal while texting. PTC was specifically identified by the NTSB as a technology that could have prevented Chatsworth and other similar incidents by providing a safeguard against human error.²⁴

The Chatsworth accident on September 12, 2008, expedited the legislative process, and the bill mandating PTC was signed into law October 16, 2008, as the Railroad Safety Improvement Act of 2008 (RSIA08). RSIA08 requires “each Class I railroad carrier and each entity providing regularly scheduled intercity or commuter rail passenger transportation” to implement PTC on all segments or routes of railroad tracks that (a) carry frequent passenger or commuter service, or (b) carry more than 5 million gross tons of freight per year and also are used for transporting toxic-by-inhalation hazardous materials (TIH).²⁵ At the time the law was signed, this mandate covered approximately 70,000 miles of railroad track.

During the FRA rulemaking process, it became apparent that rail companies could change the routes of trains carrying TIH to avoid the PTC requirement on some track segments. A Senate bill was introduced to forgo mandatory PTC implementation on lines that will not be transporting passengers or hazardous materials by the end of 2015.²⁶ This was estimated to eliminate the PTC mandate on 10,000 of the 70,000 track-miles initially covered. The bill was not enacted, but the FRA approved such a change in its amended final rule, effective July 13, 2012.²⁷ The American Short Line and Regional Railroad Association proposed several changes to the FRA final rule, including eliminating the PTC requirement for trains traveling less than 20 miles on PTC-required track and extending the deadline for Class II and III railroads to employ PTC-equipped locomotives until 2020. The FRA approved these changes in an amended final rule.²⁸

In the 112th Congress, bills to delay the PTC implementation deadline were considered in both houses of Congress. As approved by the Senate, the Moving Ahead for Progress in the 21st Century Act (MAP-21; S. 1813) would have allowed the U.S. Department of Transportation (DOT) to extend the December 31, 2015, deadline for any railroad in one-year increments until December 31, 2018, if it deemed full implementation infeasible and if the railroad had made a good-faith effort to comply. The bill would have allowed use of Railroad Rehabilitation and Improvement Financing (RRIF)²⁹ for PTC implementation. The American Energy and Infrastructure Jobs Act of 2012 (H.R. 7), which was adopted by the House Transportation and Infrastructure Committee but was not approved by the House of Representatives, would have extended the deadline for PTC implementation to December 31, 2020, and would have allowed railroads to adjust TIH routes until 2020 to reduce the extent of track affected by the PTC mandate. The bill also would have allowed railroads to implement alternative strategies on track that does not transport passengers where the “alternative risk reduction strategy that would reduce the risk of release of poison- or toxic-by-inhalation hazardous materials to the same extent the risk of a release of poison- or toxic-by-inhalation hazardous materials would be reduced if positive train control were installed on those tracks.”³⁰ While the provision would have allowed

²⁴ National Transportation Safety Board, *Collision of Metrolink Train 111 With Union Pacific Train LOF65-12 Chatsworth, California*, RAR 10/01, September 12, 2008.

²⁵ P.L. 110-432, §104.

²⁶ S. 301, 112th Congress.

²⁷ Federal Railroad Administration, “Positive Train Control Systems Amendments (RRR),” 76 *Federal Register* 52918, August 24, 2011. See also 78 *Federal Register* 5767, January 28, 2013, and 79 *Federal Register* 49693, August 22, 2014.

²⁸ Federal Railroad Administration, “Positive Train Control Systems,” 75 *Federal Register* 2704, January 15, 2010.

²⁹ Railroad Reinvestment and Improvement Funding (RRIF) provides direct federal loans and loan guarantees up to a total of \$35 billion to improve or develop new rail equipment and facilities and refinance outstanding debt.

³⁰ H.R. 7, §8401, p. 805.

flexibility on the part of the railroads, alternative safety measures might interfere with the goal of interoperability and could raise costs for smaller railroads that might need to conform to multiple safety systems. The final version of the 2012 surface transportation bill, signed by President Obama on July 6, 2012, as P.L. 112-141, did not change existing law concerning PTC.

The derailment of a Metro-North commuter train in the Bronx, NY, on December 1, 2013, renewed calls for PTC implementation. Four passengers died and 60 to 70 passengers were injured in this derailment. The train traveled at 82 mph over a straight section of track with a 70-mph speed limit, but then derailed as it entered a curve with a 30-mph speed limit. According to one report, although this section of Metro-North's network was equipped with a cab signal/ATS/ATC system, Metro-North's version of this system was designed to prevent collisions with other trains, and did not restrict speeds when no other trains posed a danger (as was the case with the derailed train). In other words, the backup safety signal system was designed strictly to ensure train separation and did not include a speed control element. Other commuter railroads (New Jersey Transit and Southeastern Pennsylvania Transportation Authority, for example), as well as Amtrak on the Northeast Corridor, had a system that would have restricted train speed in this instance.³¹ The FRA ordered Metro-North to add speed control to its signal system and to station a second crew member with train control duties at certain locations until it did so.³²

The commuter rail incidents at Chatsworth, CA, and the Bronx, NY, revealed significant disparities among signal system capabilities deployed by commuter operators. While these two incidents intensified calls for PTC installation, neither railroad had fully deployed long-standing signal technology that could also reduce the risk of collisions and derailment.

On May 12, 2015, an Amtrak train derailed at a curve in Philadelphia, killing eight passengers. The train was travelling at 106 mph, while the curve had a speed limit of 50 mph. The NTSB's May 2016 report determined that the engineer had been distracted by dispatch calls about a nearby train being hit by projectiles and likely thought the train had traveled beyond the curve, where the speed limit is 110 mph.³³ The NTSB noted that PTC would have prevented this incident. Amtrak had not installed automatic train control technology on this portion of track based on a risk analysis. It has since installed PTC on all segments of the Northeast Corridor that it owns, including the segment on which this incident occurred.

At an NTSB forum on PTC held February 27, 2013, BNSF Railroad, Amtrak, the Alaska Railroad, and Metrolink Commuter Railroad were identified by an FRA official as the only railroads that were perhaps on schedule to meet the December 31, 2015, deadline.³⁴ One topic of discussion at the forum regarded the allowances the FRA was making in implementing PTC because of the deadline.³⁵ The complexity of testing the numerous subsystems, spectrum availability in urban areas, and "back office" software interoperability were some of the difficulties that the railroads identified.

The Positive Train Control Enforcement and Implementation Act of 2015 (P.L. 114-73), enacted October 29, 2015, extended the deadline for PTC implementation from December 31, 2015, to

³¹ "Spuyten Duyvil: Why? A Safety Expert Weighs In," *Railway Age*, December 5, 2013.

³² FRA, Emergency Order 29, Notice No. 1, December 6, 2013.

³³ <http://www.nts.gov/news/events/Pages/2016-Amtrak-BMG.aspx>.

³⁴ NTSB, *Forum—Positive Train Control: Is It on Track?*, February 27, 2013. Witness presentations and a webcast of the forum are available at <http://www.nts.gov/news/events/2013/ptc/presentations.html>.

³⁵ Described as "shortcuts" by a former FRA official; see testimony of Grady C. Cothen, Jr., NTSB, *Forum—Positive Train Control: Is It on Track?*, February 27, 2013, available at <http://www.nts.gov/news/events/2013/ptc/presentations.html>.

December 31, 2018. The three-year extension was thought necessary after most freight railroads and commuter railroads stated that they would not be able to meet the 2015 deadline.³⁶ Congress also allowed the 2018 deadline to be extended up to another two years, provided that a railroad's modified implementation schedule was approved by the FRA and it had installed all the necessary PTC hardware and acquired the necessary radio spectrum by December 31, 2018. Two accidents resulting in passenger fatalities, the December 18, 2017, derailment of an Amtrak passenger train near DuPont, WA, on track owned by the regional transit agency, and the February 4, 2018, crash between an Amtrak train and a stationary freight train on South Carolina track owned by CSX Corp., occurred in locations where PTC installation was in progress but the system was not yet operational.

The Basics of PTC

PTC is defined in federal law as a “system designed to prevent train-to-train collisions, over-speed derailments, incursions into established work zone limits, and the movement of a train through a switch left in the wrong position.”³⁷ The federal government has imposed no specific technical requirements, allowing railroads to adopt whatever PTC systems seem best suited to their particular needs. However, all PTC systems share certain characteristics, including use of radio communication to provide in-cab signals to the train engineer and the ability for the dispatcher to stop a train in an emergency.³⁸

Most U.S. railroads currently are implementing what is referred to as an “overlay-type” system, in which the sensors, signals, and transponders are installed over existing track.³⁹ The network operating center sends one-way communication in the form of speed restrictions and moving authorities to a train as it passes over a transponder embedded in the track. This information requires integration with existing signals, switches, sensors, and other wayside infrastructure. The network operating office does not track real-time train location, but rather receives notice whenever a train passes the wayside infrastructure. **Figure 2** illustrates PTC hardware and communication pathways in an overlay-type system architecture.

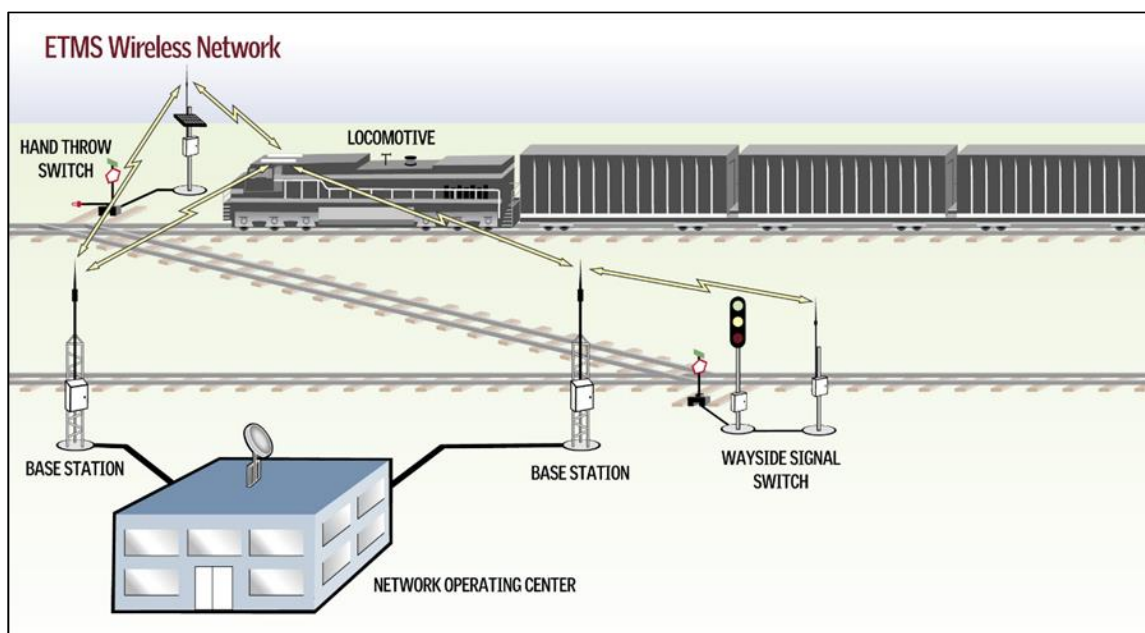
³⁶ Government Accountability Office, *Positive Train Control: Additional Oversight Needed as Most Railroads Do Not Expect to Meet the 2015 Implementation Deadline*, GAO-15-739, September 4, 2015.

³⁷ 49 C.F.R. §236.

³⁸ Federal Railroad Administration, *The North American Joint Positive Train Control (NAJPTC) Project*, Research Results, April 2009, p. 2.

³⁹ Jeff D. Young, Lisa C. Wilson, and Denise E. Lyle, *Interoperable Electronic Train Management System (I-ETMS) Positive Train Control Development Plan (PTCDP)*, Union Pacific Railroad, Norfolk Southern Railway, and CSX Transportation, Inc., FRA-2010-0060-0002, June 1, 2011.

Figure 2. Example PTC System Architecture



Source: Meteorcomm LLC, ETMS Wireless Network, 2011.

Note: Meteorcomm supplies communication equipment for the Electronic Train Management System (ETMS), which several large freight companies are planning to implement. This diagram shows a two-way communications-based PTC system, although most railroads are installing one-way systems that comply with the law.

Communication between wayside infrastructure, transponders, and trains is delivered through analog radio signal. Wireless communication options that provide greater data transfer capability, such as Wi-Fi, are not currently practical. Equipment on the train receives information from transponders to alert the train operator to current and upcoming signals, movements, and work zones. The train has equipment capable of superseding train engineer authority, so that the PTC system can slow or stop the train to prevent incident in the event of human error.

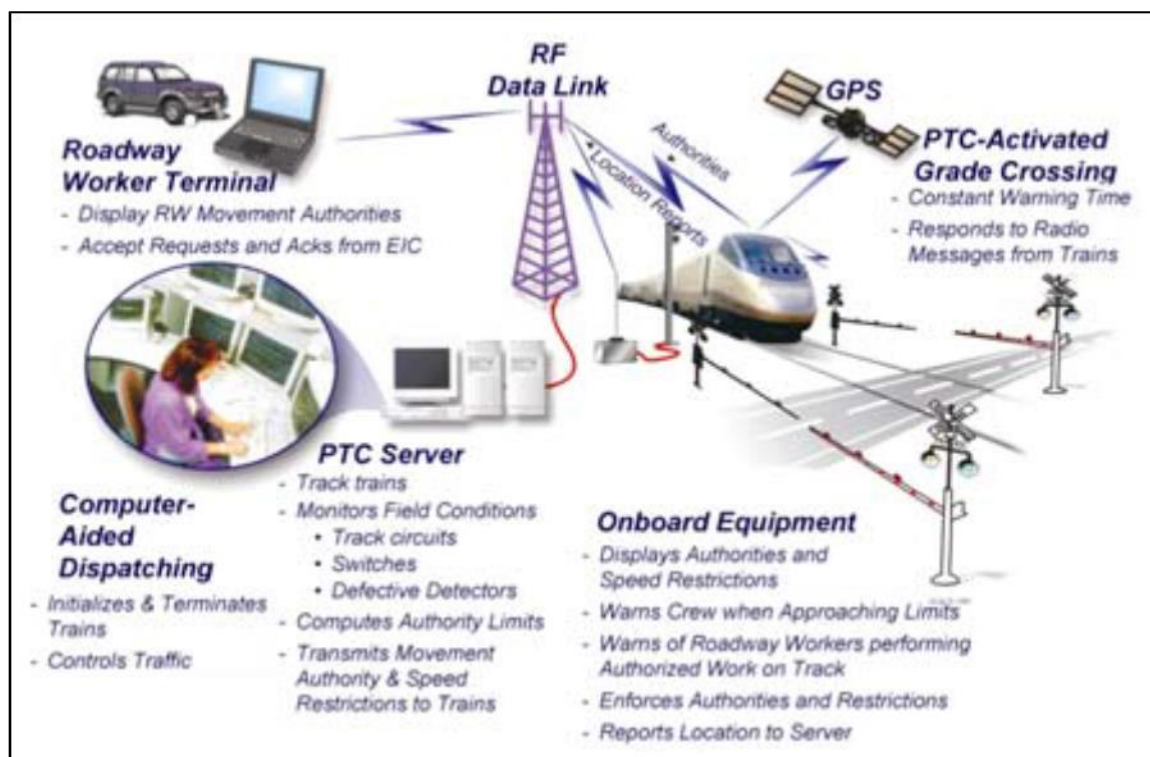
A more expansive variant of an overlay-type system is communications-based train control (CBTC). CBTC is a more sophisticated computer-aided dispatching framework which requires train information to be sent to a central location, which then disseminates the information to all entities in the network.⁴⁰ In this architecture, Global Positioning System (GPS) is used to track train location and speed, with other instrumentation providing location and speed coverage when the GPS cannot locate a signal. These additional components provide greater precision as well as system redundancy in the event of failure. Similarly, GPS and radio communication similar to cell phone technology can be used to identify work zone locations along specific lengths of track. CBTC is based on digital rather than analog technology, facilitating interoperability among systems used by different railroads.

With CBTC, central control automatically tracks the movements of all the trains in the network, sends speed restrictions and movement authorities to individual trains, and checks for potential derailment and collisions (see **Figure 3**). The system uses location and speed information to determine headway distance and the necessary braking distance required to prevent potential

⁴⁰ There are many ways of designing the system architecture to support PTC communication. In the context of railroad operations with dispatchers, a system architecture with central control is the most plausible design.

incidents. Braking distance can be several miles for large freight trains and is dependent on factors such as train speed, reaction time, wheel-rail friction, brakes wear, track conditions, track grading, mass, and mass distribution of the train.⁴¹ All these variables are processed with a complex braking algorithm designed to ensure an emergency stop prior to a collision without excessive speed restriction leading to inefficient operation.

Figure 3. Communication-Based Train Control (CBTC)



Source: Federal Railroad Administration, Research Results, North American Joint Train Control (NAJTC) Project, April 2009.

Note: Two-way data communication and computer-aided dispatch are the primary subsystems that distinguish full CBTC from PTC.

The greater capability of CBTC makes it suitable for very high speed passenger lines, and CBTC is being instituted on some European rail lines for that reason. It has also been adopted by New York City Transit and the Southeastern Pennsylvania Transportation Authority. CBTC also has the potential to allow for driverless trains. However, the system requires seamless communication coverage along the entirety of PTC-equipped track, as temporary communication loss can pose safety risks. The need for constant communication also requires significant investment in either radio towers or fixed transponders. These requirements raise the capital cost, making CBTC more expensive than an overlay-type system.

The CBTC system potentially offers greater business benefits to railroad operators than an overlay-type system. For example, the real-time, two-way communication of train locations combined with speed restrictions and moving authorities can lead to more efficient scheduling, increased capacity, and fuel savings. Nonetheless, U.S. railroads appear to have concluded that

⁴¹ David Barney, David Haley, and George Nikandros, "Calculating Train Braking Distance," This paper appeared at the 6th Australian Workshop on Safety Critical Systems and Software (SCS '01), Brisbane, 2001, pp. 23-29, <http://129.96.12.107/confpapers/CRPITV3Barney.pdf>.

the advantages of communication-based train control are not worth the additional cost of installing it at the present time.

It is important to note that both overlay-type systems and CBTC systems are designed principally to reduce collisions between trains. The systems do not address intrusion into railroad right-of-way. Currently, there is no requirement that they be capable of detecting and notifying trains about crossing-gate failures, vehicles blocking tracks, or trespassers. However, such capabilities could be incorporated into PTC systems in the future.

Implementation

Based on progress reports submitted by railroads to the FRA, the FRA surmises that only four railroads (BNSF and Union Pacific, and the Los Angeles and Philadelphia area commuter railroads) will likely have fully installed the necessary PTC equipment by the end of 2018, but even these railroads would likely need an extension because other railroads operating over their lines would not be fully PTC-compliant.⁴² As of June 30, 2018 (latest data available), PTC was operating on 66% of the freight route miles required to have PTC and 2% of the passenger network.⁴³ PTC was installed and operable on 93% of the freight locomotives and 73% of the passenger locomotives. Among the larger commuter railroads, the FRA deemed that Caltrain, Maryland Area Regional Commuter, and New Jersey Transit were at risk of not qualifying for a deadline extension because these railroads had installed less than 90% of the PTC hardware required (as of June 30, 2018).⁴⁴

Most of the current PTC projects rely on fixed transponders in conjunction with GPS with one-way information communication to the trains to fulfill the baseline PTC requirements. Only a few systems involve two-way communication with real-time information and computer-aided dispatch. The smaller railroad companies and commuter lines, in most cases, are relying on the Class I railroads to implement PTC before investing in their own systems due to the high risk and the cost of developing their own systems.

In the United States, precursors to full PTC capability were developed voluntarily prior to the 2008 mandate. Development of radio-based CBTC systems and coordinated wayside systems used to locate and communicate with trains began in 1983. Although systems developed by the Association of American Railroads and Burlington Northern Railroad achieved technical success, both systems were functional only in fully signalized territory and were deemed not economically viable to deploy on a nationwide scale.

In 1991, Amtrak adopted an automatic train control (ATC) system along the tracks it owns in the Northeast Corridor. That system, as discussed above, repeated signalization in the cab and required the train engineer to acknowledge and enforce the speed limit given by the signals to reduce human error. That system was later upgraded with the Advanced Civil Speed Enforcement System, using transponders to send signals to trains and to enforce speed restrictions and stop

⁴² Federal Railroad Administration, *Railroads' Progress Toward Implementation of Positive Train Control Systems*, July 1, 2018, p. 4.

⁴³ For railroad implementation status and plans, see <https://www.fra.dot.gov/ptc>.

⁴⁴ Federal Railroad Administration, "FRA Publishes Railroads' Quarter 2 PTC Data," <https://railroads.dot.gov/newsroom/fra-publishes-railroads-quarter-2-ptc-data>.

orders.⁴⁵ Amtrak began transitioning to radio-based communication in 2009 to incorporate work zone safety measures required by RSIA08.⁴⁶

In 1999, CSX Transportation began development of a PTC system that uses GPS combined with fixed infrastructure at switching points to provide exact track location information, specifically on parallel lines. This method is particularly useful to improve safety on long stretches of non-signalized track. CSXT is now modifying this architecture to meet the full requirements of PTC. BNSF, Union Pacific, Norfolk Southern, and Chicago's Metra commuter line are planning implementation of similar systems. Norfolk Southern's system is expected to provide for computer-aided dispatch over small segments of track.⁴⁷

Overseas Experience

Passenger train incidents overseas with train control systems already installed may provide lessons for implementation of PTC in the United States. After a deadly commuter train derailment in Japan in 2005, an audit found that the maximum speed calibrated on many curves to trigger the automatic train control system had been set too high to prevent derailments.⁴⁸ After 40 passengers were killed in a train collision in China in 2011, it was discovered that its train control system had not been sufficiently tested.⁴⁹ Investigations following an overspeed incident in Spain in 2013 that killed 79 passengers found that the train control system had been turned off on a second set of locomotives because it was not functioning properly.⁵⁰ Similarly, the train control system had been turned off on a German commuter locomotive so that it could make up time, which is believed to have contributed to its collision with another train in February 2016.⁵¹

Cost and Benefits

In 2009, the FRA estimated the total capital cost of wayside, on-board, radio, and office equipment necessary for full PTC deployment on all affected railroads to be in excess of \$10 billion. It projected annual maintenance costs of \$850 million.⁵² In recent years, fixed-capital investment by U.S. railroads has been around \$15 billion annually, of which about \$10 billion has been for structures and \$5 billion for equipment.⁵³ The estimated capital cost of meeting the PTC mandate is thus almost equal to the railroads' total capital spending in a single year.

⁴⁵ James Hoelscher and Larry Light, "Full PTC Today with Off the Shelf Technology: Amtrak's ACSES Overlay on Expanded ATC," Proceedings of the 2001 AREMA Conference, Chicago, IL, 2001, http://www.arema.org/files/library/2001_Conference_Proceedings/00022.pdf.

⁴⁶ Federal Railroad Administration, "Positive Train Control Overview," press release, February 2, 2009, p. 1, http://www.fra.dot.gov/rrs/pages/fp_1265.shtml.

⁴⁷ William Vantuono, "Two new technologies ready to roll," *International Railway Journal*, vol. 48, no. 4 (April 2008), pp. 26-28.

⁴⁸ Knight Ridder Tribune Business News, "JR West's new ATS had flaws that would not slow speeding trains," November 1, 2005.

⁴⁹ *International Railway Journal*, "Wenzhou Crash Report Blames Design Flaws and Poor Management," February 2012.

⁵⁰ *International Railway Journal*, "ETCS: A Crucial Factor in Santiago Accident Inquiry," April 7, 2015.

⁵¹ BBC, "Germany Train Crash: Controller Distracted by Computer Game," April 12, 2016.

⁵² Frank D. Roskind, *Positive Train Control Systems Economic Analysis*, Federal Railroad Administration, FRA-2006-0132, Notice No. 1, July 10, 2009, p. 120.

⁵³ Association of American Railroads, *Railroad Facts*, 2016 edition, p. 46.

The four largest railroad companies account for almost all of the estimated 60,000 miles of Class I track that fall under the PTC mandate. In 2017, CSX estimated its cost of installing PTC to be \$2.4 billion, of which \$1.8 billion had been expended through 2016, while as of 2018 Union Pacific estimated its total cost for PTC to be \$2.9 billion, of which \$2.3 billion had been spent by the end of 2016.⁵⁴

Smaller freight companies often share track with the Class I railroads. While this presents interoperability challenges, there is opportunity to use the PTC type approvals from the larger companies' development efforts to save cost. This is also the case with shared passenger rail in the Northeast Corridor. Despite this advantage, the infrastructure cost alone for just two of the five largest transit agencies operating on the corridor, Metro-North in the New York area and the Southeastern Pennsylvania Transportation Authority in the Philadelphia area, has been estimated at \$350 million and \$100 million, respectively.⁵⁵ As the FRA has stated (see text box), the expense of PTC could constrain commuter rail development, diverting commuters to less safe forms of transportation.

Commuter railroads' cost for installing PTC is likely to be borne primarily by state or local governments. However, the federal government has provided assistance. This includes a \$967 million RRIF loan to the Metro-North and Long Island commuter railroads for PTC implementation,⁵⁶ \$382 million in combined RRIF/Transportation Infrastructure Finance and Innovation Act (TIFIA) loans to the Massachusetts Bay Transportation Authority, \$199 million in FY2017 in the FAST Act (P.L. 114-94, §3028), and \$250 million in grants provided in the Consolidated Railroad Infrastructure and Safety Improvement (CRISI) program (funding is not restricted to just commuter railroads). In March 2018, the DOT Inspector General issued a report reviewing how railroads had spent federal funding provided for PTC implementation.⁵⁷

Some shippers believe that since the majority of the investment in PTC will come directly from the railroad companies, these costs will likely be passed to customers. They expect price increases due to the cost of PTC implementation, especially if the rail companies are unable to realize business benefits from the new systems. The Chlorine Institute, a trade organization representing the chlorine industry, expects the railroad companies to raise costs disproportionately for shipments of toxic-by-inhalation hazardous materials (TIH), as concern about the safety of TIH transport is perceived as a source of the PTC mandate.⁵⁸

Safety Benefits from PTC-Preventable Incidents

Based on analysis of past PTC-preventable incidents, the FRA estimated in 2009 that \$90 million in annual safety benefits will be realized after full implementation of PTC.⁵⁹ Safety benefits are calculated by estimating the cost of incidents that are likely to be prevented by PTC, including

⁵⁴ CSX Corporation, *Form 10-K for the fiscal year ended December 30, 2016*, p. 5; Union Pacific, "Positive Train Control," https://www.up.com/media/media_kit/ptc/about-ptc/ (accessed February 6, 2018).

⁵⁵ Jeff Stagl, "PTC: Railroads, suppliers still have a ways to go to meet the 2015 positive train control mandate," *Progressive Railroading*, August 2010.

⁵⁶ <https://www.fra.dot.gov/ptc#>.

⁵⁷ DOT IG, "Federal Funding Support for Positive Train Control Implementation," March 28, 2018.

⁵⁸ The Chlorine Institute, Inc., "Chlorine Institute Asks Federal Rail Administration to Reconsider Positive Train Control Rule Due to Faulty Cost-Benefit Analysis," press release, March 16, 2010, <http://www.chlorineinstitute.org/files/PDFs/2010-03-16%20-%20CI%20PTC%20petition.pdf>.

⁵⁹ Frank D. Roskind, *Positive Train Control Systems Economic Analysis*, Federal Railroad Administration, FRA-2006-0132, Notice No. 1, July 10, 2009, pp. 140-144.

fatalities and injuries, equipment damage, track damage, off-track damage, hazardous material cleanup, evacuations, wreck cleanup, loss of freight, and freight delay. According to a 1999 FRA estimate, between 1987 and 1997 an annual average of 7 fatalities, 22 injuries, \$20 million in property damages, and evacuations of 150 people due to potential hazardous material release could have been prevented by PTC.⁶⁰

Although many serious incidents due to error by train engineers or dispatchers could be prevented by PTC, PTC is expected to prevent less than 2% of the approximately 2,000 railroad collisions and derailments that occur annually. The majority of these 2,000 incidents occur in rail yards and are generally less severe than PTC-preventable incidents.

While the costs and safety benefits are projected with some confidence, there is disagreement regarding the potential business and social benefits of PTC. This makes a full cost-benefit analysis of PTC-related issues difficult. Business and social benefits are expected to come from increased railroad efficiency, reductions in logistical costs, and diversion of freight from truck to rail. However, these benefits are predicated on the functionality of full computer-based train control and not PTC alone. Computer-aided dispatch has the potential to increase capacity and reduce fuel consumption. This can reduce railroad operating costs, lead to faster, less expensive delivery, and induce demand from truck freight. This then may lead to social benefits such as reductions in fuel consumption and truck accidents.

The FRA projects \$4 billion in potential annual business benefits a decade after full PTC implementation. The overlay system without CBTC capability currently planned by the railroads is expected to offer little or no business benefit to the railroads. A possible exception is the role PTC could have in discussions about the appropriate size of train crews. The Class I freight railroads generally run trains with two-person crews, but PTC might facilitate one-person crews. However, the FRA has recently proposed a rule requiring two-person crews.⁶¹ The social benefits of the overlay system are likely to come largely from the anticipated reduction in incidents.⁶²

Policy Issues

Interoperability

The freight rail transportation network has two primary components: the track and the freight service. In some cases, the service is provided by the same company that owns the track. However, since shippers' needs do not correspond to railroads' track ownership, freight operators trade trackage or haulage rights and share revenue from the shipper. FRA regulations require that railroads' PTC systems be interoperable so that any train operating on PTC-equipped track can communicate with the host railroad's PTC system.

Prior to RSIA08, several railroad companies were developing communication-based train control independently for their own business reasons, and were not concerned about interoperability. The federal mandate has required changes in these plans in the interest of interoperability. UP, CSXT, and NS have received FRA "type approvals" for Interoperable Electronic Train Management

⁶⁰ Railroad Safety Advisory Committee, Federal Railroad Administration, *Implementation of Positive Train Control Systems*, Report, August 1999, <https://rsac.fra.dot.gov/meetings/19990908.php>.

⁶¹ 81 *Federal Register* 13918, March 15, 2016.

⁶² Frank D. Roskind, *Positive Train Control Systems Economic Analysis*, Federal Railroad Administration, FRA-2006-0132, Notice No. 1, July 10, 2009, pp. A-1-A-16.

Systems (I-ETMS) in which the PTC system itself is approved for development.⁶³ This makes it likely that the systems installed by these railroads will be highly compatible. BNSF, which has a precursor ETMS system in place, has type approval for that system, which is to be updated to I-ETMS when software becomes available.

Interoperability issues pertain to passenger service as well. In the Northeast Corridor, Amtrak operates on Amtrak-owned track and track owned by regional transit authorities and vice versa. Amtrak began PTC development prior to RSIA08 and has provided the PTC standard and type approval for transit authorities utilizing the corridor. The freight companies and Amtrak are now working to ensure interoperability between their respective systems.

In Europe, achieving interoperability in train control systems has been a decades-long challenge among the different national railroad passenger networks attempting to cross borders.⁶⁴

Avoiding Barriers to Market Entry

There are several ways the PTC mandate could be used as a barrier to market entry for the railroads. First, installing track will now be more expensive due to the need to incorporate PTC wayside equipment, which is expected to add approximately \$50,000 per mile to the \$1 million to \$3 million per mile cost of installing new rail lines. On-board PTC equipment is expected to cost around \$55,000 per locomotive, which represents only a minor increase in the cost of a new \$2 million locomotive but is substantial compared to the \$75,000 cost of used locomotives operated by some short line railroads.⁶⁵ A passenger rail operator providing or proposing service over freight-owned track that otherwise would not be required to install PTC may require the passenger railroad to pay for the cost of installing PTC on the freight locomotives also. In addition to capital costs, operating and maintenance costs will increase as well.⁶⁶ This could be a barrier to both railroad expansion and startup services.

Another barrier to market entry could arise from the need for interoperability and spectrum compatibility. Hypothetically, if two rail networks have different PTC systems because they do not currently share track or services, it may be cost prohibitive to implement a new service over these two lines. Similarly, one company could upgrade or modify its PTC system, forcing further investment by other companies using its track. Also, if the radio spectrum licenses are owned by certain railroads or a consortium of railroads, they could dictate leasing prices to operate necessary PTC systems on that spectrum for a new railroad or service which is not part of the consortium. Control of spectrum and interoperability issues with PTC could be used as tools to prevent new services on existing lines or even using an interoperable spectrum on new lines.

The possibility that PTC could impede competition may be of particular concern for short line and regional railroads which operate on Class I track. Class I railroads have a legal obligation to

⁶³ Letter from Jo Strang, FRA Associate Administrator for Railroad Safety/Chief Safety Officer, to Jeff D. Young et al., Union Pacific Railroad Assistant Vice President, Transportation System, August 26, 2011, FRA Type Approval (FRA-TA-2011-02) for the Interoperable Electronic Train Management System (I-ETMS).

⁶⁴ *International Railway Journal*, “ETCS Progress Still Dogged by Challenges,” March 30, 2016; European Commission Staff Working Document, “Delivering an Effective and Interoperable European Rail Traffic Management System—the Way Ahead,” November 14, 2017; <https://ec.europa.eu/transport/sites/transport/files/swd20170375-ertms-the-way-ahead.pdf>.

⁶⁵ Federal Railroad Administration, “Positive Train Control Systems Amendments (RRR),” 77 *Federal Register* 28285, May 14, 2012.

⁶⁶ Frank D. Roskind, *Positive Train Control Systems Economic Analysis*, Federal Railroad Administration, FRA-2006-0132, Notice No. 1, July 10, 2009, pp. 115-116.

accommodate short line railroads, but in some cases may be reluctant to allow short line trains on their networks.⁶⁷ The president of the American Short Line and Regional Railroad Association issued the following testimony to the Surface Transportation Board:

Differential pricing of certain routes or products by class I carriers ... ha[s] eliminated marginal customers who may be a small railroad's only source of business on its line, effectively putting the small railroad out of business. Some small railroads who want to provide service to new customers meet resistance from connecting carriers whose marketing plans are inconsistent with the small railroad's proposed business.⁶⁸

At this point, concerns that PTC could create barriers to railroad competition are hypothetical, as no specific complaints are known to have been presented to the FRA or to the Surface Transportation Board, which oversees certain rail competition issues.

PTC Requirements Within Passenger Terminals

The September 29, 2016, crash of a New Jersey Transit train beyond its end of line track bumper post in Hoboken, N.J., killing one commuter and injuring more than 100 others, raised discussion of PTC requirements within passenger terminals. The driver of this train apparently fell asleep momentarily as the train reached the end of the platform. Current FRA regulations allow an exception to PTC installation in passenger terminals under certain conditions, one of which is terminals with a maximum train speed of 20 mph.⁶⁹ A February 2018 NTSB board meeting discussing this and a similar incident noted that PTC is not a technology well-suited to a terminal environment, due to the extremely short stopping distances and the inability for trains in tunnels to send and receive GPS signals. The NTSB recommended that the FRA examine other technologies under development that may be able to provide a backup speed check within terminals.⁷⁰

Author Information

John Frittelli
Specialist in Transportation Policy

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Disclaimer

⁶⁷ CRS Report RL34117, *Railroad Access and Competition Issues*, by John Frittelli.

⁶⁸ Richard F. Timmons, *STB Ex Parte No. 677: Common Carrier Obligation Hearing*, American Short Line and Regional Railroad Association, Testimony of Richard F. Timmons, Washington, DC, April 25, 2008, p. 2.

⁶⁹ 49 C.F.R. §236.1019 (b).

⁷⁰ NTSB Board Meeting, "2 Bumping Post Collision Investigations," February 6, 2018; <https://www.nts.gov/news/events/Pages/2018-DCA17SR001-BMG.aspx>.

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