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October 2016

TRAIN BRAKING

DOT's Rulemaking on Electronically Controlled Pneumatic Brakes Could Benefit from Additional Data and Transparency

Accessible Version

GAO-17-122

GAO Highlights

Highlights of GAO-17-122, a report to congressional committees

October 2016

TRAIN BRAKING

DOT's Rulemaking on Electronically Controlled Pneumatic Brakes Could Benefit from Additional Data and Transparency

Why GAO Did This Study

In May 2015, DOT issued a final rule requiring certain trains hauling flammable liquids to equip with ECP brakes. This rule has met opposition from many industry stakeholders. The Fixing America's Surface Transportation Act requires DOT to test ECP brakes and reevaluate the economic analysis supporting the ECP brake requirement and includes a provision for GAO to review the potential costs and benefits of ECP. This report examines views on costs railroads may realize in meeting the ECP brake rule, the potential business benefits, and how DOT and the railroad industry estimated safety benefits.

GAO reviewed rulemaking documents; interviewed 13 rail experts selected based on published work and suggestions from the National Academies of Sciences; interviewed DOT officials and representatives of the seven largest railroads in North America; interviewed industry stakeholders, including the Association of American Railroads and compared DOT's estimates and modeling efforts against federal criteria and GAO standards for internal control.

What GAO Recommends

GAO recommends that DOT acknowledge uncertainty in its revised economic analysis of ECP brakes, collect data from railroads on their use of ECP brakes, and publish additional information about ECP brake modeling. DOT disagreed with the recommendations, stating that GAO did not provide sufficient evidence. GAO believes it had sufficient evidence and stands by the recommendations, as discussed in this report.

View GAO-17-122. For more information, contact Susan Fleming at (202) 512-2834 or flemings@gao.gov.

What GAO Found

DOT based estimates of the business benefits of electronically controlled pneumatic (ECP) brakes on limited data, in part, because railroads that have used ECP brakes to date have shared limited data on their use. ECP brakes provide an electronic brake signal instantaneously throughout the train, allowing train cars to brake faster than with conventional air brakes. In supporting the May 2015 rule requiring the use of ECP brakes on certain trains hauling flammable liquid, the Department of Transportation (DOT) estimated the potential business benefits of ECP brakes, including reduced fuel consumption, reduced wear on wheels, and improved operational efficiencies. Industry stakeholders claim that DOT overestimated benefits. Seven of 10 experts GAO interviewed who commented on such benefit estimates said that DOT's estimates of business benefits, such as reduced fuel consumption, were based on experiences that may not be representative. DOT also estimated benefits to railroads from improved operational efficiency (e.g., the ability to return to speed sooner after braking), while industry stakeholders stated that poor reliability of ECP brakes will greatly limit any such benefits; however, only two out of five railroads provided GAO extensive quantifiable data to support these claims. DOT's use of limited data adds uncertainty to the estimates that DOT did not always acknowledge in the rule and its supporting analysis. By acknowledging uncertainties and in the future requiring railroads to collect and provide DOT more data on ECP brake use, DOT could improve its estimates and public confidence in those estimates, and use the data to determine the extent to which the ECP brake rule is meeting its objectives.

DOT and an industry association each conducted computer-based modeling and additional analysis to estimate the potential safety benefits of ECP brakes, but took different approaches based in part on different assumptions of how the brakes affect what happens in a derailment. DOT's analysis supporting its final rule found that the improved braking performance of ECP brakes can reduce the number of cars in a derailment that puncture and release their contents by almost 20 percent compared to other braking technologies. DOT published two reports and explanatory details in the final rule to document this approach. The industry association's analysis and modeling, using a different approach and assumptions, found ECP brakes provide a "marginal" safety benefit. GAO found DOT's modeling lacked transparency as the information published may not be sufficient to enable an independent third party to replicate it. For example, DOT did not report complete details on specific inputs, such as how the model applied the brake force to tank cars. One researcher attempted to replicate the analysis and told GAO he was unable to do so, citing limited information. Best practices identified by the Office of Management and Budget state that modeling results published by federal agencies should be supported by transparent data to facilitate third-party review. By providing more information about the modeling, DOT could help stakeholders and the public better understand the analysis and the extent to which the model's results hinged on DOT's choices and assumptions. This increased understanding could in turn increase confidence in the ECP brake requirement.

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Abbreviations

AAR	Association of American Railroads
ASLRRA	American Short Line and Regional Railroad Association
CP	Canadian Pacific
DOT	Department of Transportation
DP	distributed power
ECP	electronically controlled pneumatic
EOT	end of train
FAST Act	Fixing America's Surface Transportation Act
FRA	Federal Railroad Administration
HHFT	high-hazard flammable train
HHFUT	high-hazard flammable unit train
mph	miles per hour
NAS	National Academies of Sciences
NS	Norfolk Southern Railway
NTSB	National Transportation Safety Board
OMB	Office of Management and Budget
PHMSA	Pipeline and Hazardous Materials Safety Administration
PTC	positive train control
RIA	regulatory impact analysis
RSI	Railway Supply Institute
TEDS	Train Energy and Dynamics Simulator
TOES	Train Operation and Energy Simulator
TTCI	Transportation Technology Center, Inc.
UP	Union Pacific

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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October 12, 2016

The Honorable John Thune
Chairman
The Honorable Bill Nelson
Ranking Member
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Bill Shuster
Chairman
The Honorable Peter A. DeFazio
Ranking Member
Committee on Transportation and Infrastructure
House of Representatives

In recent years freight rail shipments of crude oil—a flammable liquid—have increased greatly in the United States. For example, according to the Energy Information Administration, the number of barrels of oil hauled by rail climbed from 1.4 million in April 2010 to 12.8 million in April 2016.[1] If a train transporting such liquids in tank cars derails—which can happen due to a number of reasons, including a broken rail, broken train wheels, and train handling—the contents, if released, can catch fire. For example, in June 2016 a train hauling crude oil derailed in Oregon, leading to a fire that lasted 14 hours. While there were no fatalities as a result of this derailment, some severe derailments can lead to fatalities and environmental damage. For example, in July 2013 a crude oil train derailed in Lac-Mégantic, Quebec, Canada, resulting in 47 fatalities.

In May 2015, the Pipeline and Hazardous Materials Administration (PHMSA), in coordination with the Federal Railroad Administration (FRA)—both within the Department of Transportation (DOT)—issued a final rule requiring, among other things, that railroads equip certain trains

[1]More recently, however, there have been decreases in crude oil shipments by rail for a number of reasons, including smaller price differences between domestic and imported oil, according to the Energy Information Administration. According to the Energy Information Administration, the number of barrels of oil hauled by rail in April 2016 was about 55 percent lower than in April 2015.

hauling flammable liquids such as crude oil and ethanol—called high-hazard flammable unit trains (HHFUT)—with electronically controlled pneumatic (ECP) brakes by 2021 or 2023, when the trains operate at speeds in excess of 30 miles per hour (mph).[2] After those dates, HHFUTs may operate without ECP brakes at speeds of 30 mph or less. To support the rule, DOT conducted computer-based modeling of the potential safety benefits of ECP brakes and estimated potential costs and benefits of the ECP brake requirement in a regulatory impact analysis (RIA).[3]

ECP brakes send an electric signal instantly and simultaneously to each individual train car, allowing for faster brake application than on trains with conventional air brakes. With conventional air brakes, each car receives a braking signal—which moves at close to the speed of sound in emergency braking situations—sequentially through an air pipe instead of simultaneously. Use of ECP brakes can result in shorter stopping times and distances, which in turn, can reduce the frequency of derailments and their severity when they occur—such as by reducing the number and kinetic energy—or energy in motion—of cars that derail, reducing their likelihood to get punctured and release their contents. While analysis of computer-based modeling conducted by DOT estimated that the use of ECP brakes results in almost 20 percent fewer tank cars puncturing in a derailment compared to trains that use multiple locomotives to control speed and braking, modeling conducted by an industry association estimated a much smaller benefit.[4] In addition, ECP brakes can provide business benefits to railroads, including reduced fuel consumption and increased operational efficiencies. However, there is disagreement between DOT and industry participants on the magnitude of these benefits and therefore whether the costs justify the benefits of the technology.

[2]According to this final rule, HHFUT refers to a train comprised of 70 or more loaded tank cars containing Class 3 flammable liquids traveling at greater than 30 mph. Trains transporting crude oil, must equip with ECP brakes by January 2021; trains transporting ethanol must equip with ECP brakes by May 2023. 80 Fed. Reg. 26644, 26645 (May 8, 2015). (49 C.F.R. § 174.310).

[3]DOT, *Final Regulatory Impact Analysis: Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains* (Washington, D.C.: May 2015).

[4]Specifically, the industry association used a different methodology and, thus a different metric to estimate this benefit, concluding that with ECP brakes, less than 2 cars in a 100-car trainset would derail.

Although ECP brakes were first tested and used by freight railroads in the United States in the mid-1990s and railroads supported their development and initial use, the industry is generally opposed to the ECP brake requirement. In May 2015, soon after the rule was issued, the American Short Line and Regional Railroad Association (ASLRRA) and others sued DOT, asserting that DOT's rulemaking lacked sufficient evidence to support the safety justification for requiring ECP brakes. These lawsuits were subsequently consolidated into one case.[5] At the same time, the Association of American Railroads (AAR) filed an administrative appeal challenging the rule, stating that ECP brakes would impose unreasonably high costs and that DOT did not accurately estimate safety benefits. DOT denied the appeal in November 2015.

The Fixing America's Surface Transportation Act (FAST Act), enacted in December 2015, requires DOT to enter into an agreement with the National Academy of Sciences (NAS) to physically test ECP brakes—in contrast to the computer-based modeling DOT conducted during the rulemaking process—and objectively measure the performance of ECP brakes in emergency braking applications, including their effect on stopping distance and the number of cars that derail and are punctured, compared to other braking systems.

The FAST Act includes a provision for us to review the potential costs as well as the business and safety benefits of ECP brakes.[6] This report examines: (1) the views of DOT and selected experts and stakeholders on the costs to railroads to implement and operate with ECP brakes in response to the requirement; (2) the potential operational effects and business benefits railroads may realize from ECP brakes; and (3) how DOT and industry estimated the potential safety benefits of ECP. The Act requires DOT to incorporate the results of the physical testing and this GAO evaluation to update the costs and benefits of ECP brakes in the regulatory impact analysis (RIA) that supported the final rule, and if based on the updated RIA, DOT does not find that the ECP brake requirements are justified, the Secretary must repeal the requirement.[7] The lawsuits

[5] *American Petroleum Institute v. United States of America*, Case No. 15-1131, (D.C. Cir. 2015).

[6] Pub. L. No. 114-94, § 7311(a), 129 Stat. 1312, 1601 (Dec. 4, 2015).

[7] Pub. L. No. 114-94, § 7311(c), 129 Stat. 1312, 1603.

against DOT regarding the ECP brake requirement are on hold pending DOT's efforts in response to these FAST Act requirements.

In order to examine the views of DOT and selected experts and stakeholders on the costs to railroads to implement and operate with ECP brakes in response to the requirement as well as the potential operational effects and business benefits, we reviewed key rulemaking documents related to DOT's ECP brake requirement such as the notice of proposed rulemaking (proposed rule), final rule,[8] RIA,[9] public comments filed by industry, and AAR's administrative appeal. We compared DOT's efforts to estimate the potential costs and benefits of ECP brakes against criteria for conducting regulatory analysis of costs and benefits from the Office of Management and Budget's (OMB) *Circular A-4*.[10] We also compared these efforts to GAO's *Standards for Internal Control in the Federal Government*.[11] We also selected 13 experts in freight rail safety and braking by reviewing literature related to ECP brakes, receiving recommendations from staff with the National Academy's Transportation Research Board, and reviewing the names and qualifications of members of relevant Transportation Research Board freight-rail committees to identify those knowledgeable on specific topics related to ECP brakes. We conducted in-depth interviews with these experts using a semi-structured interview guide. Prior to each interview, we provided each expert with summary information about the estimates and views of DOT and AAR on the potential costs and benefits of ECP brakes. During our interviews, we asked questions related to these potential costs and benefits, specific estimates made by AAR and DOT, and the rationales and data supporting those estimates, among other issues. We conducted a content analysis of responses to identify themes in responses. Not all of the 13 experts provided definitive responses to each question as some experts were unfamiliar with certain topics. As a result, for each area where experts commented on particular topics, our universe of responses varied. For all discussion of expert views in this report, we characterize

[8]80 Fed. Reg. 26644, 26645 (May 8, 2015).

[9]DOT. *Final Regulatory Impact Analysis Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains* (Washington, D.C.: May 2015).

[10]Office of Management and Budget, *Circular A-4* (Washington, D.C.: Sept. 17, 2003).

[11]GAO, *Standards for Internal Controls in the Federal Government,* GAO-14-704G (Washington, D.C.: September 2014).

responses to questions that did not provide a strong response as "neutral." See appendix II for a list of these experts and appendix III for expert responses to selected questions. We also interviewed officials from DOT, the National Transportation Safety Board (NTSB), and industry stakeholders, including representatives from AAR, ASLRRA, the Railway Supply Institute (RSI), and other industry associations all seven class I freight railroads, four class II and III railroads suggested by ASLRRA based in part on those that were interested in meeting with us, two shippers of crude oil suggested by RSI based in part on those that were interested in meeting with us, and the two manufacturers of ECP brakes.[12] These expert and stakeholder interviews are not generalizable. We also interviewed representatives from two selected railroads in Australia suggested by DOT, one rail expert in South Africa, and two in Australia regarding railroad experiences using ECP brakes in these countries. We selected these countries given their breadth of experience with ECP brakes compared to other countries. We did not independently assess the technological reliability of ECP brakes. In addition, to determine how DOT and industry estimated the potential safety benefits of ECP brakes, we reviewed documents related to the modeling conducted by DOT and AAR and compared the efforts against criteria for conducting such modeling, including OMB's *Circular A-4*, and National Academies of Science's (NAS) guidance on principles and practices for conducting statistical analyses by federal agencies.[13] Although DOT's modeling of ECP brakes was not a statistical analysis, we believe that certain parts of this guidance applies to DOT's work.[14] We also asked the 13 experts about the modeling efforts of both DOT and AAR, including questions about the overall approaches taken and specific assumptions used. Finally, we interviewed the railroads industry organization, and

[12]Freight railroads are classified by operating revenues. Class I railroad carriers include those having annual carrier operating revenues of $467 million or more. Class II railroad carriers are those having annual carrier operating revenues of less than $467 million but in excess of $37.4 million. Class III railroad carriers are those having annual carrier operating revenues of $37.4 million or less. 49 C.F.R. § 1201.1-1. The Class I railroads are BNSF Railway, Canadian National, Canadian Pacific, CSX Corporation, Kansas City Southern, Norfolk Southern, and Union Pacific.

[13]National Research Council of the National Academies, *Principles and Practices for a Federal Statistical Agency,* fifth ed. (Washington, D.C.: 2013).

[14]More specifically, we believe that parts of that guidance regarding data collection, openness about data limitations and the methods and assumptions used, and review by third parties, are relevant to other types of analyses such as DOT's.

other stakeholders described above. We did not independently validate DOT's and the railroad industry's modeling and related analysis of ECP brakes. See appendix I for more information on our scope and methodology.

We conducted this performance audit from September 2015 to October 2016 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Freight rail shipments of crude oil and ethanol have increased greatly in recent years despite very recent declines. According to DOT, crude oil and ethanol—another flammable liquid—make up about 68 percent of all flammable liquids transported by rail and are commonly shipped in large quantities either by a manifest train, which includes blocks of different types of rail cars transporting different commodities, or by unit train, which transports only one commodity at any given time. The crude oil and ethanol tank cars hauled by railroads are usually not owned by railroads but by the shippers themselves, such as oil companies or by rail car leasing companies.

The rate of train accidents and derailments, including those incidents where trains were hauling hazardous materials, has declined in recent years. For example, according to DOT, the derailment rate of hazardous materials trains fell from about 60 per million carloads in 1995 to about 36.3 per million carloads in 2015. However, the increase in shipments of crude oil poses safety and environmental concerns. If tank cars carrying flammable liquids derail, they are at risk of releasing their contents when punctured, a circumstance that can lead to fires and contamination of surrounding lands and waterways, causing environmental damage and other effects. In recent years, there have been a number of train accidents resulting in the release of flammable liquids. For example, in an extreme example, in Lac-Mégantic, Quebec, Canada, a train hauling crude oil derailed in 2013, leading to 47 fatalities. In 2013, a freight train hauling crude oil derailed near Aliceville, Alabama; DOT estimated that 630,000 gallons of crude oil entered navigable waters, destroying several acres of wetlands and forest.

The type of braking used to slow down and stop a train can affect both the likelihood and severity of train derailments. Conventional air brakes were first developed and used by railroads in the late 1800s. In trains with conventional air brakes, an air pipe runs the length of a train from the locomotive to the last car or to another locomotive at the end of the train. An air compressor on each locomotive charges each car via the air pipe. When the train's engineer applies the brakes, a reduction in air pressure in an air reservoir in the locomotive is sensed by the first car via the connected air pipe. The car applies brakes in approximate proportion to the reduction in air pressure and vents its brake valves, signaling a reduction in air pressure to the next car. This process is repeated for each car until the signal reaches the end of the train. Because each car receives this signal sequentially at slightly slower than the speed of sound, depending on the length of the train, it can take a number of seconds for the car farthest from the locomotive to receive the signal. As each car receives this signal, it applies pressure to a brake cylinder, which, in turn, applies the brake shoes to the wheels. Because cars receive this signal sequentially, cars closer to the front of the train begin braking before cars behind them do so. This can cause cars to buckle as they are pushed from cars behind them that have not yet received the brake signal.

Other technologies, including two-way end-of-train (EOT) devices and distributed power (DP), are frequently used by U.S. railroads in conjunction with conventional brakes to provide improved braking performance or other benefits.

- *Two-way end-of-train (EOT) devices:* Two-way EOT devices include two pieces of equipment linked by radio that initiate an emergency brake application signal from the front locomotive to the rear of the train; the signal then activates an emergency air valve at the rear of the train within one second. According to DOT, a two-way EOT device is more effective than conventional air brakes alone because the rear cars receive the emergency brake signal more quickly.

- *Distributed power (DP):* DP systems use multiple locomotives positioned at strategic locations in the train (generally at the rear) and connected by radio signal to provide additional power and train control in certain operations. If a DP locomotive is located at the rear of the train, it can initiate braking from the rear (with the brake signal moving forward using the same air pipe) at the same time braking is initiated from the head locomotive. (See fig. 1.)

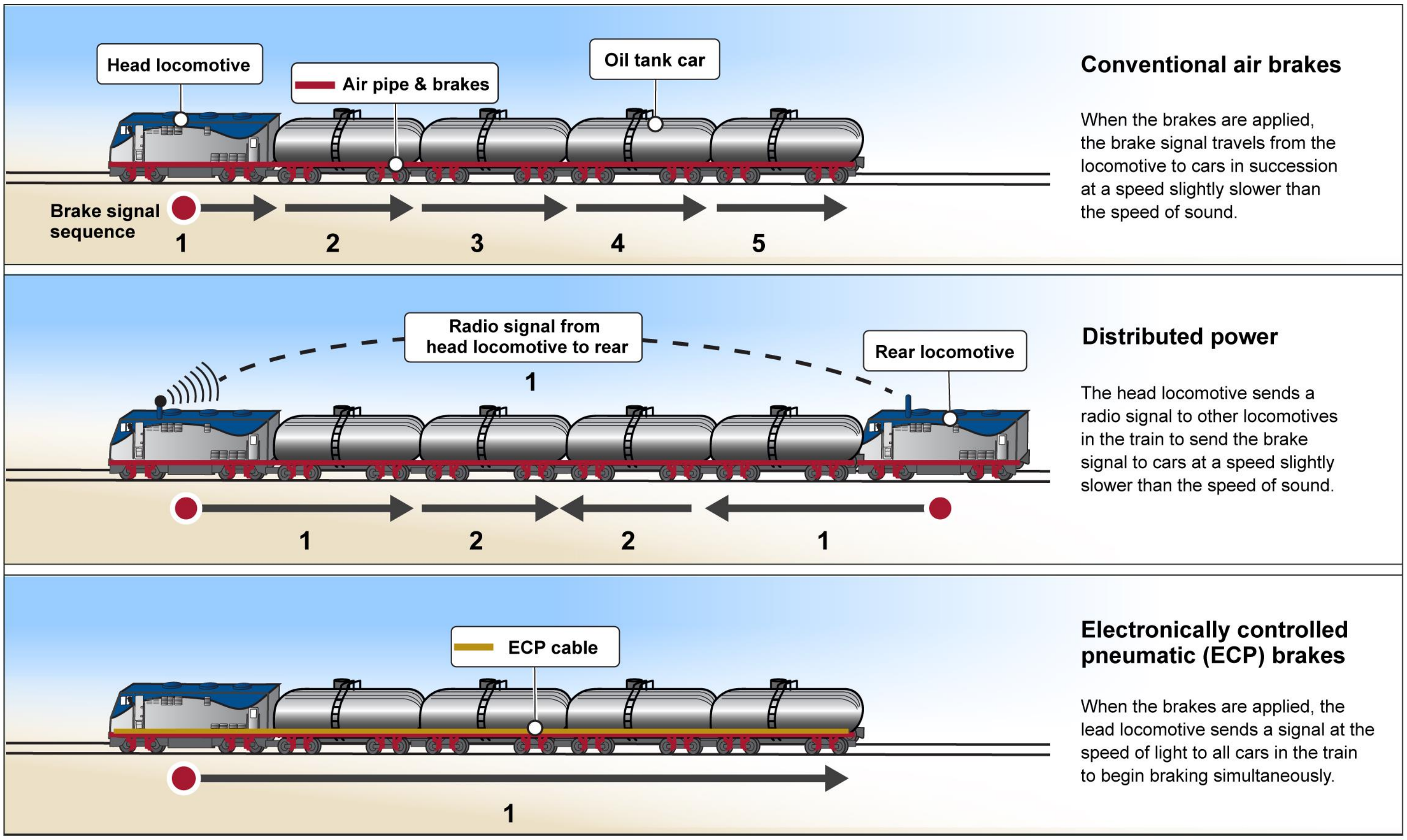
- *Dynamic braking:* Dynamic braking, which uses motors in the locomotive to control speeds, is often used to control speed on trains with conventional air brakes to improve the train's handling and reduce fuel consumption during normal operations. While dynamic brakes can be used instead of the conventional air brakes on the train to control speed, by regulation, dynamic braking cannot be used as a substitute for a train's conventional air brakes.[15] According to DOT, while dynamic braking may be used to control train speed, dynamic brakes do not apply in a way that quickly slows or stops a train in an emergency.

ECP brakes use an instantaneous electric brake signal, but like conventional brakes require air pressure components to apply the brakes. This signal is transmitted at the speed of light via a cable running the length of the train (with connections between cars through inter-car connectors). As a result, all cars on the train receive the brake signal at the same time and instantaneously after the brake application. ECP brake systems can be either overlay, in which the ECP brake system is overlaid on top of the existing conventional air brake system, allowing the train to operate in either ECP or conventional mode; or stand-alone, in which the train can only be operated in ECP mode. Overlay systems allow for ECP-equipped cars to be hauled by a locomotive not equipped with ECP brakes, providing flexibility to railroad operations. In addition, FRA regulations incorporate AAR standards that require ECP brakes to be interoperable with those of different manufacturers.[16] This interoperability means, for example, that a locomotive equipped with ECP brakes from one manufacturer can haul cars equipped with ECP brakes from another.

[15] 49 C.F.R. § 232.109(j)(1).

[16] 49 C.F.R. § 232.603. At this time, there are two manufacturers of ECP brakes.

Figure 1: Brake Signals on Trains with Conventional, Distributed Power (DP), and Electronically Controlled Pneumatic (ECP) Brakes



Source: GAO analysis of information from the Department of Transportation (DOT). | GAO-17-122

Because all cars on the train receive the brake signal instantaneously, ECP brakes not only reduce the braking time and distance through quicker brake application, but also reduce the forces that occur during braking when individual cars push and pull against one another (known as "in-train forces"). According to DOT, the effect of ECP brakes in reducing the stopping distance of a train and reducing in-train forces reduces the occurrence of and severity of derailments. Specifically, if a train stops faster because of ECP brakes, fewer cars may derail. And if fewer cars derail, fewer will be subject to the various forces and objects of impact (such as a rail or another train car) which can puncture the cars and release their contents. Therefore, according to DOT, ECP brakes can reduce the severity of derailments and their consequences.

According to DOT, ECP brake manufacturers, and others, ECP brakes have other features that can provide operational benefits to railroads:

- *Graduated release*—Trains with ECP brakes are able to reduce the level of braking force after a brake application is made. With conventional air brakes, the level of braking force cannot be reduced without first completely releasing the brakes, which can lead to unplanned stops to replenish the air supply. Graduated release allows trains to follow safe speed limits and avoid unnecessary stops.

- *Shorter restarting times after stops*—With conventional air brakes, each car's air reservoir must be refilled and the brakes reset after a brake application. Because ECP brakes do not reduce the air pressure in the air pipe to transmit the brake signal, the air pipe maintains its pressure and continues to supply the reservoirs during braking applications, eliminating the need for refilling after brake applications. As a result, trains with ECP brakes can start moving more quickly after complete stops than trains with conventional air brakes.

- *Possible elimination of power braking*—Trains with conventional air brakes may have to apply more braking than is needed ahead of a speed restriction, such as a curve. Because conventional air brakes do not have the graduated release feature, the engineer may power the locomotive while the brakes are applied in order to maintain an optimal speed. This combination of power and braking can waste fuel and put additional wear on the brakes and wheels.

- *Real-time monitoring*—ECP brake systems allow train crews to electronically monitor the effectiveness of brakes on each individual car and the system provides real-time information on the performance of the entire braking system, allowing for improved diagnostics.

In recent years, DOT has taken action regarding ECP brakes, and a number of North American freight railroads have used them in limited cases, as shown in figure 2. Railroads in the United States began testing and operating with ECP brakes as early as 1995. Union Pacific (UP) started using ECP brakes in limited operations in 1995. In 2007, FRA granted a waiver to some railroads allowing them to operate trains with ECP brakes on a limited basis for longer distances between brake inspections than required by FRA regulations for trains with conventional air brakes—3,500 miles for trains using ECP brakes compared to 1,000 for trains using conventional brakes.[17] In 2008, FRA published a final rule that adopted the 3,500-mile distance between brake inspections for trains using ECP brakes.[18] In 2010, FRA issued a new waiver to BNSF Railway (BNSF) and Norfolk Southern (NS), allowing them to jointly operate a train with ECP brakes for 5,000 miles between brake inspections. Those railroads jointly operated an ECP-equipped train from January 2015 to June 2016 under this waiver. However, despite the benefits of ECP brakes that DOT described in its final rule, four of the five class I railroads that have used ECP brakes no longer do so, and as of June 2016, only one class I railroad operates trains with ECP brakes.[19]

As discussed earlier, DOT recently issued a final rule that, among other things, requires HHFUTs operating at speeds in excess of 30 mph to be equipped with ECP brakes by 2021 (for trains hauling crude oil) or 2023 (for trains hauling ethanol).[20] In order to support this requirement, DOT estimated the potential costs and benefits of the ECP brakes requirement and analyzed the results of computer-based modeling of the brakes' potential safety effects. Following the issuance of the final rule, AAR filed an administrative appeal against the rule while the American Petroleum Institute, UP, ASLRRA, and others filed lawsuits. The administrative appeal stated, among other things, that the rule failed to take into account challenges railroads have faced with using ECP brakes, such as equipment failures resulting in operational delays, underestimating the potential costs associated with railroads' implementing ECP brakes in response to the requirement, and overestimated ECP brakes' potential benefits. ASLRRA's lawsuit claimed that DOT did not have substantial evidence to support the requirement.[21] DOT denied the administrative appeal stating that it reasonably justified the requirement. These lawsuits

[17]Or 1,500 miles for extended haul trains. 49 C.F.R. § 232.213.

[18]73 Fed. Reg. 61512 (Oct. 16, 2008).

[19]We will discuss the reasons why railroad officials told us they have reduced their use of ECP brakes, including operational and reliability problems, later in this report.

[20]DOT enacted this rule to reduce the consequences and, in some instances, reduce the probability of accidents involving trains transporting large quantities of flammable liquids. In addition to the ECP brakes requirement, this rule also includes standards for safer tank cars designed to be less likely to puncture during a derailment, among other requirements. 80 Fed. Reg. 26644, 26645 (May 8, 2015).

[21]ASLRRA Statement of Issues, Case No. 15-1131 (D.C. Cir. 2015).

were later consolidated and suspended pending ongoing additional analysis of ECP brakes.

Specifically, the FAST Act, enacted in December 2015 requires DOT to enter into an agreement with NAS to test ECP brakes and, based on the results of this testing and this GAO evaluation, re-estimate the costs and benefits of the ECP brake requirement.[22] The Act requires the Secretary of DOT, by December 2017, either to determine the ECP brakes are justified based on the updated RIA or to repeal the ECP brakes requirement.[23]

[22]Pub. L. No. 114-94, § 7311(a)(b), 129 Stat. 1312, 1601.

[23]Pub. L. No. 114-94, § 7311(c)(2), 129 Stat. 1312, 1603.

Figure 2: Timeline of Electronically Controlled Pneumatic (ECP) Brake Milestones

1994

Burlington Northern Santa Fe Railway (BNSF) began to test and research electronically controlled pneumatic (ECP) brakes.

1995

Union Pacific (UP) operated ECP brakes on intermodal trains between Chicago and Los Angeles.

2000

November 2000 – CSX Transportation (CSX) began operating with ECP brakes on one coal train between Corbin, KY, and Stilesboro, GA.

2006

FRA commissioned a report on ECP brakes by Booz Allen Hamilton, which provided information on the potential costs and benefits of ECP brakes.

2007

March 2007 – FRA granted a waiver to BNSF and Norfolk Southern Railway (NS) to allow trains equipped with ECP brakes to travel up to 3,500 miles — instead of the normal 1,000 or 1,500 — without a brake inspection.

October 2007 – NS started using ECP brakes on a coal train on a Pennsylvania route.

2008

NS added ECP brakes to four total trains (two coal routes in Virginia, and two coal routes between West Virginia and North Carolina); discontinued use on the two trains between WV and NC because the power plant closed down.

January 2008 – BNSF began operating two coal trains with ECP brakes from Wyoming to Alabama; discontinued one in 2012 and the other is still in service.

September 2008 – Canadian Pacific (CP) began operating with ECP brakes on two coal trains in British Columbia; discontinued use in November 2012.

October 2008 to August 2009 – UP operated ECP brakes on a train from Long Beach, CA, to Mesquite, TX

October 2008 – The Department of Transportation (DOT) issued a Final Rule establishing ECP brake standards and encouraging railroads to adopt ECP brakes by allowing them to use trains with ECP brakes to travel longer distances between required inspections.[a]

2009

August 2009 – UP operated ECP brakes on a train between Oakland, CA, and Seattle, WA.

2010

May 2010 – FRA granted BNSF and NS another waiver allowing them to jointly operate an ECP-equipped train to travel up to 5,000 miles without a brake inspection.

2014

August 2014 – DOT published a Notice of Proposed Rulemaking regarding railroad tank car requirements and ECP brakes.[b]

2015

January 2015 – FRA granted an extension to the 2010 waiver and NS and BNSF began jointly operating a train with ECP brakes between Wyoming and Georgia.

May 2015 – DOT issued a Final Rule on tank car safety requiring, among other things, ECP brakes on certain trains hauling flammable liquids such as crude oil by 2021 or 2023 depending on what they haul.[c]

June 2015 – The Association of American Railroads (AAR) filed administrative appeal against the rule, citing challenges freight railroads in the US have faced with ECP brakes and problems with DOT's estimates of the potential safety benefits.

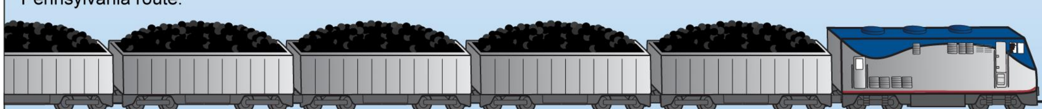
June 2015 – The American Petroleum Institute, the American Short Line and Regional Railroad Association, and others filed suit against the rule.

November 2015 – DOT denied the administrative appeals; AAR then filed suit against DOT.

December 2015 – The Fixing American's Surface Transportation Act enacted, requiring DOT to conduct testing of a tank train equipped with ECP brakes. Based on test results, DOT must update the analysis that supported its final rule and then re-issue its rulemaking if it determines that the potential benefits of ECP brakes justify the costs; if not, it should eliminate the ECP brakes requirement. Lawsuit is on hold pending this re-evaluation.[d]

2016

June 2016 – BNSF ceased all ECP operations, including train operated jointly with NS.



Notes:
a. 73 Fed. Reg.61512 (Oct. 16, 2008)
b. 79 Fed. Reg. 45016 (Aug. 1, 2014)
c. 80 Fed. Reg. 26644, 26645 (May 8, 2015)
d. Pub. L. No. 114-94, § 7311, 129 Stat. 1312, 1601 (Dec. 4, 2015)

Source: GAO. | GAO-17-122

Railroads in some other countries currently use ECP brakes with the same equipment that is used by U.S. railroads, though some under different operational conditions than those in the United States.[24] For

[24]For example, some of these railroads have used ECP brakes on coal trains running in closed loop operations, meaning that sets of train locomotives and cars are kept together and run on dedicated track such as that between a mine and a port. According to DOT, many U.S. railroad operations are closed loop operations though not on dedicated track.

example, some railroads in Australia began using ECP brakes on coal or iron ore unit trains as early as 2005. In addition, as shown in figure 2, in Canada, Canadian Pacific (CP) used ECP brakes on a coal route in British Columbia from 2008 to 2012. Also in Canada, the Quebec Cartier Mining Railway in Quebec began using ECP-equipped trains in 1998 on an iron ore unit train and continues to operate one. Transnet (formerly known as Spoornet)—a railroad in South Africa—began revenue service of one coal train equipped with ECP brakes in 2000 and converted its entire fleet of coal trains to ECP brakes by 2009.

Many railroads in the United States are also currently working to meet a statutory requirement to install positive train control (PTC).[25] PTC is a communications-based system designed to prevent certain types of rail accidents caused by human factors, including train-to-train collisions, trains entering established work zones—which could cause roadway worker casualties or equipment damage—and derailments caused by exceeding safe speeds. The Rail Safety Improvement Act of 2008 first required certain freight and passenger railroads to fully implement PTC by December 31, 2015.[26] Based on a review of selected railroads, we found in September 2015 that most of these railroads would not implement PTC by that deadline.[27] The Positive Train Control Enforcement and Implementation Act of 2015, enacted in October 2015, extended the implementation deadline to December 31, 2018 while providing authority to FRA to grant up to two one-year deadline extensions to individual railroads, if they meet certain thresholds for implementation progress.[28] According to FRA, as of February 3, 2016, six passenger railroads and one freight railroad plan to fully implement PTC in 2016, three passenger and one freight plan to in 2017, 13 passenger and seven freight plan to in 2018, one passenger plans to in 2019, and three passenger and three freight plan to in 2020.

[25] 49 U.S.C. § 20157.

[26] Pub. L. No. 110-432, §104, 122 Stat. 4848, 4857 (Oct. 16, 2008).

[27] GAO, *Positive Train Control: Additional Oversight Needed As Most Railroads Do Not Expect to Meet 2015 Implementation Deadline,* GAO-15-739 (Washington, D.C.: Sept. 4, 2015).

[28] The Positive Train Control Enforcement and Implementation Act of 2015 was enacted as section 1302 of the Surface Transportation Extension Act, of 2015, Pub. L. No. 114-73, §1302, 129 Stat. 568, 576 (Oct. 29, 2015).

DOT, Stakeholders, and Experts Have Mixed Views on Effects of ECP Brake Requirement on Railroad Costs

DOT and Railroad Industry Disagree on Costs, Using Differing Estimates on the Extent to which the Fleet Must be Equipped

DOT and AAR disagree on the extent to which railroads will need to equip locomotives and tank cars and train staff in response to the ECP brake requirement; this disagreement is central to the large difference in their respective estimates of costs to the industry, as seen in table 1.[29] DOT's analysis found that railroads and shippers can respond to the requirement by equipping about 2,500 locomotives and 60,000 tank cars with ECP brakes and using them for HHFUT service and not for other services. DOT noted that railroads and shippers typically manage certain fleets for specific purposes, such as fleets of distributed power locomotives.[30] For example, CSX equipped some locomotives to operate on the Northeast Corridor, where locomotives operate over Amtrak's Advanced Civil Speed Enforcement System, an early form of PTC. Moreover, DOT's RIA found that most shippers' fleet managers have the responsibility to know in advance if their tank cars will be operated in unit train service or not. In addition, according to DOT, large oil companies typically ship their products in unit trains.

AAR and other industry participants, however, argue that DOT oversimplifies U.S. railroad operations in which crude oil and ethanol trains move between multiple origins and destinations and not often by unit train. AAR added that efficient railroad operations require railroads to be flexible in their operations; as a result, railroads move their locomotives around throughout their entire network based on business needs and do not dedicate specific locomotives to specific routes or services; consequently, railroads cannot dedicate locomotives and tank

[29] All costs in table 1 and in the related discussion are estimated over 20 years at a discount rate of 7 percent.

[30] 80 Fed. Reg. 71952, 71965-71966. (Nov. 11, 2015).

cars equipped with ECP brakes to HHFUT service. AAR states that railroads and shippers will need to equip about 20,000 locomotives and 133,000 tank cars with ECP brakes and train most staff. A representative of one oil company that provides crude oil tank cars to freight railroads for shipment said that, in order to meet the ECP requirement, it expects that it will need to equip all its tank cars that haul crude oil with ECP brakes because when it provides those cars to a railroad for shipping, it does not know whether or not the cars will be part of a HHFUT. However, according to DOT officials, HHFUTs are a contract service and not a random assembly of cars.

Six out of the eight experts who commented on equipping fleets with ECP brakes, said that railroads could operate a dedicated fleet of HHFUTs, with four of those six experts adding that doing so would create manageable logistical challenges. (See appendix III for expert responses to selected questions.) In addition, three of these six experts also cited examples of railroads successfully installing other technologies on a small portion of their fleet.[31] However, the remaining two experts who commented on this issue said that because railroads do not always haul flammable liquids like crude oil in unit train service, railroads would not be able to equip only a small portion of their fleet with ECP brakes.[32]

In addition, there is disagreement among DOT and the railroad industry on the extent to which class II/III railroads will be affected by the ECP brake requirement. The final rule states that it reduces the regulatory burden on small railroads that may not have the capital to invest in ECP brakes and DOT stated to us that the rule “specifically excludes” the operations of small railroads. The rule requires HHFUTs to be equipped with ECP brakes when they operate at speeds of over 30 miles per hour.[33] According to DOT, the majority of Class II/III railroads do not haul flammable liquids at speeds over 30 mph, and therefore, the ECP brake

[31]For example, one expert cited railroads successfully installing cab-signaling equipment on only certain locomotives in their fleet. Cab-signaling equipment transmits information on a railroad track to the engineer in a locomotive.

[32]For example, one expert pointed to examples of railroads being unable to equip a technology on a small portion of their fleet because crude oil and ethanol locomotives need to retain the flexibility to accommodate various destinations depending on the location of the buyer.

[33]49 C.F.R. § 174.310.

requirement will not affect their operations. In addition, DOT's analysis concluded that all tank cars equipped with ECP brakes will have overlay systems, allowing those cars to be hauled in conventional brake mode by locomotives not equipped with ECP brakes or not travelling faster than 30 mph. However, ASLRRA representatives told us that many class II/III railroads may be affected by the rule by having to work with ECP-equipped trains because they receive crude oil and ethanol trains from class I railroads and do not always travel under 30 miles per hour. Representatives with all four class II/III railroads we met with said that they may be affected by the ECP requirement. A representative with one such railroad, for example, said that they may need to equip their locomotives with ECP brakes to haul tank cars equipped with ECP brakes it receives from class I railroads. However, to the extent that these trains are equipped with overlay brakes, the railroad should be able to operate them in conventional mode. According to DOT, these concerns are unfounded as small railroads are unaffected by the rule

Table 1: Estimated Costs over 20 Years (2015 to 2034) to the Railroad Industry of the Requirement for Electronically Controlled Pneumatic (ECP) Brakes

Type of cost	Department of Transportation's estimate	Association of American Railroads' estimate
Equipping locomotives with ECP brakes	$79.9 million – Railroads will need to equip about 2,500 locomotives.	$1,766 million – Railroads will need to equip 20,000 locomotives.
Equipping tank cars with ECP brakes	$373.2 million – About 60,000 tank cars will need to be equipped.	$1,037 million – About 133,000 tank cars will need to be equipped.
Training railroad employees on ECP brakes	$39.9 million - 51,500 railroad employees will need training.	$239 million – About 78,000 (almost all employees) will need training.
Total	**$493 million**	**$3,042 million**

Source: GAO analysis of information from the Department of Transportation and Association of American Railroads. | GAO-17-122

Note: All costs are discounted at a rate of 7 percent. The use of a 7 percent discount rate is in line with guidance from the Office of Management and Budget for agencies when determining the net present value of proposed regulations. In the RIA supporting the final rule, DOT estimated costs and benefits of the rule, including requirements unrelated to ECP brakes, from 2015 to 2034.

The primary costs to industry in meeting DOT's ECP brake requirement include equipping locomotives, equipping tank cars, and training staff. DOT estimated costs over a 20-year period from 2015 to 2034, and all costs discussed below are over that time period, discounted at a rate of 7 percent, in line with guidance from the Office of Management and Budget (OMB). As shown in the table above and discussed below, DOT provided single-point cost estimates. Not only is there a great discrepancy between DOT and industry views on the extent to which the industry will have to equip and train staff in response to the ECP brake requirement, there is also disagreement on the per-unit costs to equip locomotives, among other things.[34]

- *Locomotives:* DOT estimated a total cost to railroads of almost $80 million to equip their locomotives. Based on forecasts for rail traffic for crude oil and ethanol, DOT estimated that 633 HHFUTs will need to be equipped with ECP brakes. With four locomotives per train,[35] DOT also estimated that railroads will equip a total of 2,532 locomotives (about 10 percent of the current class I fleet) at an average cost of $49,000 each.[36] DOT also assumed that railroads would purchase 2,532 bypass cables at $1,000 each[37] and incur an initial asset management cost to manage the new ECP system of about $435,000. AAR, as discussed earlier, states that railroads will need to equip most of their locomotives with ECP brakes. Therefore, AAR estimates that railroads will equip 20,000 existing locomotives with ECP brakes, or 83 percent of the current class I fleet, at an upgrade cost of $88,300 each.[38] AAR assumes that all locomotives that will be equipped with ECP brakes will be retrofitted, and therefore the total cost would be greater than DOT's estimate.[39] Experts we interviewed had limited views of the specific costs of equipping locomotives. One of the two experts who commented on specific cost estimates said that the cost is likely somewhere between DOT's and AAR's estimates, and the other said that DOT's estimate was reasonable.

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[34]Although DOT's rulemaking documents that make such estimates underwent public review and comment, industry efforts did not undergo similar review.

[35]DOT's RIA states that DOT "conservatively assumed four locomotives per HHFUT even though only three are necessary to power the train."

[36]DOT arrived at this estimate by estimating industry purchases of new locomotives of 1,000 per year and assuming that 20 percent of locomotives would be retrofitted with ECP brakes at a cost of about $79,000, while 80 percent would be new locomotive purchases at an additional cost of about $40,000 for ECP brakes.

[37]DOT included bypass cables as part of the locomotive estimate in the event that a non-ECP-equipped locomotive is placed on an ECP-equipped train. These cables allow the ECP cable bypass those locomotives and provide the ECP brake signal to tank cars behind those locomotives.

[38]The industry report making this cost estimate does not provide the basis for the estimate.

[39] Also, in contrast to DOT, AAR did not assume it would cost less to equip each new locomotive than to retrofit them.

- *Tank Cars:* Similar to the estimates for locomotives, DOT and AAR disagree on the extent to which tank cars will need to be equipped with ECP brakes. As discussed earlier, tank cars are usually owned by shippers or car-leasing companies. Based on forecasts of traffic of crude oil and ethanol as well as comments from the Railway Supply Institute (RSI)—an industry association representing builders of rail cars, among other entities—DOT estimated that about 60,000 tank cars will be equipped with ECP brakes. Based on data from RSI, DOT estimated that the cost to equip each tank car would be a weighted average cost of about $7,600.[40] DOT also estimated $1 million for cables for 1,266 buffer cars[41] and $27.2 million in maintenance costs. Furthermore, DOT reduced the estimated costs by $9.7 million because it expects that ECP brakes will increase railroad productivity, resulting in railroads using fewer tank cars. We discuss potential operational effects of ECP brakes later in this report.

  AAR, on the other hand, assumed that more tank cars would need to be equipped with ECP brakes (about 133,000) at an average cost of about $7,700.[42] In addition, a study conducted by Oliver Wyman for AAR[43] assumed a cost of $10 million to equip buffer cars with ECP brakes and $68 million in maintenance costs. And, as we will discuss later, AAR questions that ECP brakes will increase railroad operational efficiencies and, as a result, did not assume a reduction in tank cars.

- *Training:* Based on data on shipment of commodities, DOT determined that approximately 68 percent of the total ton-miles were

[40]DOT based this estimate on input from RSI leading DOT to assume that one-third of the fleet of cars with ECP brakes would be on newly constructed cars and two-thirds would be on existing cars retrofitted with ECP brakes.

[41]Buffer cars are cars placed between locomotives and rail cars hauling hazardous materials. These cables would allow railroads to use buffer cars unequipped with ECP brakes on ECP-equipped trains. DOT assumed that HHFUT’s would use two buffer cars each.

[42]AAR’s cost estimate for tank cars does not distinguish between new construction and retrofits.

[43]Oliver Wyman, *Assessment of the Enhanced Braking Requirements in the Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains Final Rule of May 1, 2015* (June 12, 2015; New York, NY).

on routes with crude or ethanol unit trains.[44] Therefore, DOT estimated that 68 percent of total crews, minus the small percentage of employees who are already trained, or a total of about 51,500, would need ECP brake training. AAR, however, stated that railroads would have to train about 78,000 employees, or almost all engineers, conductors, and carmen, as they cannot dedicate crews specifically to HHFUTs with ECP brakes. They also estimated higher wage rates and more days to complete training.[45] None of the 13 experts we interviewed were able to provide views on the specific costs to train employees.

DOT and Railroad Industry Disagreed on Challenges in Installing of ECP Brakes in Response to ECP Brake Requirement

As with the costs of ECP brakes, stakeholders also expressed differing opinions on the extent to which installation of ECP brakes, in response to the DOT requirement, will pose challenges to railroads. Representatives from only one of the seven selected class I railroads cited potential technical challenges related to the installation of ECP brakes. However, six of the seven stated that ECP brake installation could create potential challenges for PTC implementation because PTC-braking processes would need to be updated. For example, representatives from one class I railroad told us that integrating ECP brakes with PTC will require a significant amount of time to allow for both software and hardware changes to PTC, which they anticipate will interfere with time frames for PTC implementation. DOT, however, stated that the ECP brake requirement will not affect PTC implementation because the implementation of PTC on affected routes is required by statute prior to 2021, when ECP brakes will first be required.[46] Furthermore, according to DOT officials, trains equipped with both PTC and ECP brakes can stop with greater certainty in less distance, thereby increasing rail network

[44]The RIA does not specify the years that DOT used data from to make this 68 percent estimation.

[45]DOT based the wage rates on AAR publications and staff attending NS and BNSF training to determine the amount of training needed. AAR's public comments on the ECP brakes proposed rule filed with DOT do not specify how it estimated wage rates.

[46]The Rail Safety Improvement Act of 2008 first required certain railroads to fully implement PTC by December 31, 2015. Pub. L. No. 110-432, §104, 122 Stat. 4848, 4857. Since then, the Positive Train Control Enforcement and Implementation Act of 2015, enacted in October 2015, extended the implementation deadline to December 31, 2018 while providing FRA authority to grant up to two one-year deadline extensions to railroads. Pub. L. No. 114-73, §1302, 129 Stat. 568, 576.

capacity, reducing equipment wear and tear and related maintenance, and improving fuel efficiency.[47]

Of the nine experts who commented on ECP brake installation, five said that installing ECP brakes could be a challenge to railroads, largely citing potential capacity constraints in the shops that would conduct installations.[48] Of the remaining four experts, three said that installation of ECP brakes will not pose any challenges, and one was neutral and did not provide a strong view either way. However, of the eight experts who commented on the potential interaction between ECP brake and PTC installations, only two thought ECP brake installation would cause difficulties with PTC implementation, citing potential difficulties in updating PTC- braking processes.[49]

Some Business Benefits Are Likely from ECP Brakes; However, Limited Data Make It Difficult to Determine Magnitude

[47]DOT officials also stated that ECP brakes and PTC are unrelated technologies and that while their integration can provide operational benefits, one is not dependent on the other. ECP equipped trains can operate safely on PTC equipped lines, and PTC equipped lines do not interfere with ECP braking systems

[48]Four of the five cited limited shop capacity; three of those four believed that shops would already be constrained by installing PTC. The remaining expert of the five stated that whenever there is a new requirement, it takes some time for shops to adjust to the change.

[49]The remaining six experts said ECP would not pose a challenge to PTC installation.

Views on the Reliability of ECP Brakes Drives Disagreement on Potential Operational Effects

There is disagreement on the reliability of ECP brakes and the extent to which railroads can achieve operational—or business—benefits from ECP brakes. DOT expects that because ECP brakes enable trains to start faster after stops, ECP brakes will increase railroad operational efficiencies, resulting in improved utilization of tank cars and a reduced quantity of tank cars in HHFUT service. According to DOT in the final rule, ECP brakes are a reliable and "proven technology" and "concerns related to maintenance and repair issues that arise during normal operations will be resolved through adequate training of operating crews and maintenance personnel." DOT officials noted that the reliability of ECP brakes has improved in recent years. In addition, representatives for both ECP brake manufacturers stated that ECP brakes have become more reliable over time. One of them told us that reliability continues to improve over time; for example, that manufacturer is now developing new ways to address failures with ECP brakes' inter-car connectors.[50] We did not identify any additional, credible third-party data on the reliability of ECP brakes in the United States. In addition, crosstalk[51] was a problem, but according to DOT officials and representatives from the two ECP brake manufacturers, the issue has been addressed. Furthermore, according to DOT, certain features of ECP brakes, such as graduated release, will improve operations as they enable railroads to run trains closer together and to operate for longer distances between brake inspections.[52]

AAR representatives, however, told us that there will be only minimal operational benefits that are outweighed by operational burdens and that reliability issues will cause network disruptions. Representatives we interviewed from all five Class I railroads that have used ECP brakes stated that poor reliability would prevent them from achieving any operational efficiencies. These representatives confirmed that their railroads stopped or reduced their ECP brakes operations in part due to challenges related to their reliability. For example, one railroad representative said that the railroad stopped using ECP brakes after

[50] We did not identify any additional, credible third-party data on the reliability of ECP brakes in the United States.

[51]Crosstalk occurs when a signal from a train interrupts the signal of an ECP-equipped train, causing the train to go into emergency mode and stop.

[52]Trains with conventional air brakes are required by FRA regulations to stop for brake inspections every 1,000 miles (49 C.F.R. § 232.207) and every 1,500 miles for long haul trains. (49 C.F.R § 232.213).

experiencing reliability problems including crosstalk and issues with the ECP inter-car connectors that connect the ECP cable down the length of the train. Another railroad official said that problems such as issues with the ECP cable and inter-car connectors resulted in delays that caused network disruptions; this railroad said that failures on ECP-equipped trains resulted in delays that lasted an average of about 7 hours compared to less than 2 hours on trains with conventional air brakes given the additional time needed for repairs.[53] Of the class I railroads we interviewed that have used ECP brakes, only two railroads were able to provide us with data on these reliability problems; the rest instead provided anecdotal support.

Generally experts we interviewed thought that while ECP brakes have experienced reliability challenges, their reliability should improve over time. Six of the 8 experts who commented on reliability-cited problems that railroads have experienced with ECP brake use to date, including some of those noted above. One of these six experts also noted that freight railroads are always looking to improve their efficiency and the fact that most U.S. railroads that have used ECP brakes stopped doing so indicates that they may be unreliable.[54] However, many international railroads continue to use ECP brakes in some of their operations, and some have expanded their use. The remaining two experts did not believe that ECP brakes have been unreliable. More than half the experts we interviewed (8 of the 13) said the reliability should improve over time as the technology continues to mature and railroads gain more experience with ECP brakes; three of these experts added that improved reliability could lead to efficiency improvements.

Representatives we interviewed from other countries with experience operating trains equipped with ECP brakes found them to be reliable. Representatives of two Australian railroads and one South African expert said ECP brakes are more reliable than conventional air brakes. AAR representatives noted that unlike in the United States, railroads in Australia and South Africa are running closed loop operations[55] and keep

[53]We did not independently validate these data.

[54]However, many international railroads continue to use ECP brakes in some of their operations.

[55]Closed loop operations involve sets of train locomotives and cars being kept together and run on dedicated track such as that between a mine and a port.

their locomotives and cars together, not moving cars around, making their operations better suited for ECP brakes. Furthermore, some railroads in these countries use standalone ECP brake systems; while both DOT and AAR anticipate that the U.S. industry will likely use ECP overlay systems to meet the ECP brake requirement. A representative from one Australian railroad and a South African rail expert stated that ECP overlay systems tend to be less reliable because the existence of two braking systems creates additional complexity and introduces additional components that are subject to failure.

Potential Business Benefits Include Fuel Savings and Operational Efficiencies; DOT and Stakeholders Disagree over Extent

In estimating the benefits of ECP brakes, DOT estimated business and safety benefits. In terms of business benefits, DOT estimated a total of about $254 million, resulting from reduced fuel usage, reduced wheel wear, and savings from fewer required brake inspections that according to DOT in the RIA, generally take trains out of service for about 3 hours, among other things, as shown in table 2.[56] DOT estimated business benefits over a 20-year period from 2015 to 2034, and all benefits discussed below are over that time period, discounted at a rate of 7 percent, in line with guidance from the Office of Management and Budget (OMB). According to DOT, these benefits would be achieved incrementally, beginning in 2017, as railroads start to equip trains with ECP brakes. As shown in table 2, DOT estimated all business benefits as single values and did not estimate a range of potential benefits. The full benefit would be achieved once railroads equip all required trains with ECP brakes. If railroads meet the requirement deadlines, DOT determined that railroads would start to achieve full benefits in 2021 for crude oil trains and in 2024 for ethanol trains. Additionally, to the extent each ECP-brake-equipped train generates benefits, railroads would realize more benefits proportionate to the number of trains equipped. Although AAR did not conduct its own estimates of the potential business benefits of ECP brakes, as it did with costs, it raised concerns with many of DOT’s benefit estimates.[57]

[56]All benefits in table 2 and in the related discussion are estimated over 20 years at a discount rate of 7 percent.

[57]DOT estimated a benefit of $8.3 million for set out relief—the benefit of FRA regulations’ allowing trains equipped with ECP brakes to continue operating with a certain number of defective cars. 49 C.F.R. § 232.609(d). Trains equipped with conventional brakes are unable to do so. Because of the small size of this potential benefit compared to others, we do not discuss this in detail as we do with other potential business benefits.

Table 2: Estimated Business Benefits over 20 Years (2015 to 2034) to Railroad Industry of Electronically Controlled Pneumatic (ECP) Brakes Requirement

Benefit	Department of Transportation's (DOT) estimate
Fuel savings	$121.1 million
Brake inspections savings	$51.5 million
Locomotive savings	$49.9 million
Reduced wheel wear savings	$23.4 million
Set out relief[a]	$8.3 million
Total	**$254.2 million**

Source: GAO analysis of information from DOT. | GAO-17-122

Note: All benefits are calculated with a 7 percent discount rate. The use of a 7 percent discount rate is in line with guidance from the Office of Management and Budget for agencies when determining the net present value of proposed regulations. In its Regulatory Impact Analysis supporting the final rule, DOT estimated costs and benefits of the rule, including requirements unrelated to ECP brakes, from 2015 to 2034.

[a]Trains equipped with conventional brakes are required to stop and set-out defective cars for repair. Due to self-monitoring capabilities of ECP brakes, Federal Railroad Administration (FRA) regulations allow ECP trains to continue operating with a certain number of defective cars. 49 C.F.R. § 232.609(d).

In the final rule, DOT estimated that use of ECP brakes would result in 2.5 percent fuel savings for railroads, leading to a benefit of about $121 million[58] based on CP's and other railroads' experiences with ECP brakes and the price railroads paid for fuel per mile travelled in 2013.[59] In the proposed rule, DOT had estimated fuel savings of 5 percent based on Booz Allen Hamilton's *ECP Brake System for Freight Service, Final Report*.[60] In the final rule, DOT recognized that the 5.4 percent fuel savings CP realized from 2008 to 2011 was over "advantageous terrain" and therefore reduced the potential savings to 2.5 percent in the final rule. According to DOT officials, this was a conservative approach, and DOT

[58]As noted in the above table, this and the other benefits discussed here are over 20 years and discounted at 7 percent.

[59]According to the 2006 Booz Allen Hamilton report provided to FRA, railroads can obtain fuel savings from ECP brakes due to the graduated brake release component of ECP brakes, the elimination of power braking, and the reduction of unnecessary train stops and starts. Booz Allen Hamilton, *ECP Brake System for Freight Service, Final Report* (August 2006).

[60]Booz Allen Hamilton, *ECP Brake System for Freight Service, Final Report* (August 2006).

based this reduction in part on fuel savings data from other railroads, including BNSF. However, AAR stated more recently that the updated savings estimate of 2.5 percent is not supportable because railroads have not been able to quantify any fuel savings from ECP brakes. Representatives from three of the five class I railroads that have used ECP brakes told us that they have been unable to attribute any fuel savings to ECP brakes. One railroad that provided us data on its analysis of fuel savings concluded that it had not realized any statistically significant fuel savings. Representatives of two class I railroads that have used ECP brakes added that while they expect some fuel savings with ECP brakes, they expect the savings to be minimal because other technologies, such as dynamic braking, already provide similar benefits. Five of the seven experts who commented on fuel savings had concerns with DOT's approach to estimating fuel savings, with four of them stating that more or better data would have been beneficial. Of the remaining two experts, one did not have any concerns with DOT's fuel savings estimate and one was neutral.

DOT estimated a benefit to railroads of $51.5 million based on FRA regulations allowing ECP-equipped trains to travel up to 3,500 miles,[61] instead of 1,000 or 1,500 miles required for trains with conventional air brakes, without stopping for brake inspections required by FRA regulations.[62] DOT noted that Transportation Technology Center, Inc.—an AAR subsidiary—reported in 2014 that permitting 3,500 miles between brake inspections can result in about 50 fewer inspections per year per train and savings between $220 and $300 per car per year. However, a report written by industry consultancy Oliver Wyman for AAR says that even if trains stop less frequently for brake inspections, they must stop for other regular-servicing events, such as refueling and crew changes, limiting this benefit. No representatives of any of the five class I railroads that have used ECP brakes that we interviewed provided any data to verify whether there are any potential savings from reduced required brake inspections. One representative said that their railroad has not seen any operational benefit from less frequent inspections given the reliability problems with ECP brakes. DOT stated that regular-servicing

[61]49 C.F.R. § 232.607(b).

[62]Trains with conventional air brakes are required by FRA regulations to stop for brake inspections every 1,000 miles. (49 C.F.R. § 232.207) and every 1,500 miles for long haul trains (49 C.F.R. § 232.213).

events occur regardless of a train's braking equipment type and that such servicing stops are quicker than the 1 to 2 hours needed to conduct a brake test. Eight out of the 11 experts who commented on this issue said that railroads would achieve a benefit from reduced brake inspections, despite other stops. For example, one expert noted that crew change stops take as little as 5 minutes to complete, much less than the 3 hours DOT stated in the RIA brake that inspections generally take. The remaining three experts were neutral and believed both arguments were valid.

DOT estimated a benefit of $49.9 million in locomotive savings based on the estimate that railroads will need 150 fewer locomotives to operate crude oil and ethanol HHFUTs due to operational efficiencies from using ECP brakes compared to conventional air brakes.[63] According to DOT, ECP brakes provide operational efficiencies to railroads due to the ability to maintain an optimal speed, the ability to run longer trains due to improved handling of trains with ECP brakes, and reduced need for inspections, among other reasons. As discussed earlier, AAR questions that ECP brakes will increase operational efficiencies. However, a representative with a railroad labor union said that ECP brakes can potentially increase a railroad's network capacity due to improved stopping distances.

DOT estimated a benefit of $23.4 million in wheel wear savings in part based on data from CP. Wheel wear savings can result from ECP brakes providing more uniform braking and better train handling. While DOT's estimate in the proposed rule was much higher, AAR commented to DOT that railroads' use of dynamic braking has already reduced wheel wear, limiting the potential benefit provided by ECP brakes. Additionally, CP's experience with reduced wheel wear was based on limited operations over advantageous terrain; as a result, in the final rule, DOT reduced its original estimate by 75 percent to $23.4 million. The Oliver Wyman report also noted that while CP reported some reductions in wheel wear, BNSF reported increased wear and tear; however, the report did not quantify these savings or increases. While representatives of only one of the five class I railroads that has used ECP brakes that we interviewed said they expected wheel savings, only one provided us with any relevant

[63]DOT estimated that railroads would eventually operate crude oil and ethanol unit train service with 149.7 fewer locomotives.

quantified data. Six of eight experts who commented on DOT's approach to estimating savings from reduced wheel wear expressed concerns. For example, one expert stated that DOT should not have included any benefit for wheel savings based on one particular railroad's experiences with ECP brakes, and two other experts also noted that better data would have helped DOT address the variability in this potential benefit. Of the remaining two experts, one did not have concerns with DOT's estimate and the other was neutral.

Limited Data Available to DOT and Uncertainty in Potential Business Benefits and Operational Effects of ECP Brakes Make Assessing Estimates Difficult

DOT officials said they used credible data to estimate the benefits of ECP brakes; however, the data were limited as railroads have not consistently collected and shared data on their use of ECP brakes to DOT. According to DOT, the railroad industry shared limited data to support its claims and only provided anecdotal information on the reported limited benefits and reliability issues that they state have prevented them from realizing the benefits of ECP brakes. As a result, DOT has had limited opportunity to date to present a realistic range of scenarios to support its estimates. FRA granted waivers to some railroads in recent years that allowed them to operate with ECP brakes. These waivers required that the railroads regularly collect and provide to FRA data on their use of ECP brakes, including data on reliability and wheel wear. According to FRA officials, they did not receive any data from these railroads. However, two of the waivers were superseded by FRA's 2008 ECP rule, and DOT told us that data from the remaining waiver would not have been received in time to inform the 2015 rule.

We found that the five railroads that have used ECP brakes collected limited operational data, limiting DOT's opportunity to use such data in its estimates. For example, as discussed earlier, while representatives with all five class I railroads we interviewed that have used ECP brakes cited poor reliability, which they stated would affect the potential operational benefits they could achieve, only two provided us with extensive quantifiable data, such as the data on the average time of stops on ECP-equipped trains discussed earlier. Additionally, only two of the five railroads provided us data on fuel consumption, and only one provided data on wheel wear. Representatives with two of the five railroads that have used ECP brakes that we interviewed said that they did not collect extensive data because they used ECP brakes in normal rail service and not in a controlled testing environment.

AAR, in its administrative appeal, stated that while it had presented its concerns with recent railroads' experiences with ECP brakes, including reliability issues, in its comments to the proposed rule, DOT did not incorporate that information in the final rule.[64] Representatives of AAR added that DOT did not contact freight railroads that have used ECP brakes to work with the freight railroads or to obtain current information and data on experiences since 2010. However according to DOT, NS and BNSF did not provide data but were in constant contact with FRA regarding their waivers to operate with ECP brakes with less frequent inspections. In addition, DOT officials stated that while the railroad industry provided limited data to support the concerns or recent experiences reported in comments to the proposed rule, DOT had sufficient, credible data to develop its benefit calculations.

We also sought data from other potential sources and received either limited or no data. For example, although both ECP brake manufacturers we interviewed cited potential business benefits of ECP brakes, neither provided us with any quantifiable data on such benefits. In addition, we found that international railroads we interviewed had collected limited data on the benefits of ECP brakes. While a South African railroad expert stated that fuel savings from using ECP brakes were a 5 percent improvement over the fuel cost for conventional brakes, this expert did not provide any quantified benefit for wheel savings. In addition, a representative from one railroad in Australia asserted that ECP brakes provide benefits, including fuel savings and improved operations, but acknowledged that the railroad had not collected any data to quantify these benefits.

Experts we interviewed cited limitations to DOT's business benefit calculations due to the lack of data. Seven of 10 experts who commented on fuel or reduced wheel-wear savings expressed concerns that benefits were based on experiences that may not be representative or were lacking in quantitative data to support DOT's initial or revised estimates. For example, six of the experts suggested that DOT would have benefited from additional data on fuel consumption to estimate fuel savings or from estimating fuel savings as a function of terrain, among other things, to address variability.[65] Out of the remaining three experts, one was not

[64]As noted above DOT did adjust some estimates, including fuel savings, in the final rule based on comments from AAR.

[65]These experts stated that DOT could take steps to obtain better data on fuel savings, such as by comparing ECP-equipped to conventional trains running on various types of terrain, but one acknowledged that this would be resource-intensive.

concerned about the estimates for fuel or reduced wheel wear savings and the other two were neutral.

When conducting regulatory analyses, including cost-benefit analyses, agencies are required by OMB's *Circular A-4*[66] to use the best reasonably obtainable scientific, technical, and economic information available. *Circular A-4* also states that agencies should use sound and defensible values and procedures to estimate benefits and costs. Furthermore, OMB's guidance states that to address uncertainty, agencies could present results from a range of plausible scenarios and, if possible, any available information that addresses the likelihood of those scenarios.

Limitations in data, such as fuel or reduced wheel-wear savings resulting from the use of ECP brakes as cited by some of the experts we interviewed, created uncertainty in DOT's estimates that is not always acknowledged in the RIA. Since DOT had limited data on railroads' experiences with ECP brakes, it introduced an additional level of uncertainty into many of its estimates and assumptions beyond the uncertainty inherent in any estimate. For example, there is uncertainty in estimating operational efficiencies, given limited data on the reliability of the technology. Similarly, as discussed above, although DOT provided single point estimates of the potential costs of the ECP brake requirement, there is inherent uncertainty in these estimates, as reflected by the great discrepancy between DOT's and industry's views on the per-unit costs to equip locomotives and the extent to which the industry will have to equip and train staff, among other things. Although OMB's guidance, as noted earlier, suggested federal agencies could address uncertainty by providing a range of possible scenarios, estimates for business benefits in the RIA are single point and do not reflect a range of possible outcomes. The acknowledgment of uncertainty in certain estimates in the RIA could help increase confidence in those estimates and address stakeholder concerns.

Looking ahead, better data on railroad experiences with ECP brakes could help DOT determine the effects of the ECP brakes requirement and the extent to which DOT's ECP brake requirement met its goals. The

[66]Office of Management and Budget, *Regulatory Analysis, Circular A-4* (Washington, D.C.: revised Sept. 17, 2003).

Standards for Internal Controls in the Federal Government[67] states that federal agencies should review policies and procedures for effectiveness in achieving their objectives and to determine if efforts—such as a regulation—are designed and implemented appropriately. These standards also state that quality information should be used to make informed decisions,[68] and such data should be reasonably free from error and bias; as a result, it is important for any data DOT collects to be reliable. According to the 2015 final rule requiring ECP brakes, PHMSA and FRA made regulatory decisions within the rule based upon the best currently available data and information. The final rule further notes that the agencies will continue to gather and analyze additional data related to ECP brakes. Executive Order 13610[69] urges agencies to conduct retrospective analyses of existing rules to examine whether they remain justified and whether they should be modified or streamlined in light of changed circumstances, including the rise of new technologies. Consistent with its obligations under Executive Order 13610, the rule states that PHMSA and FRA will retrospectively review all relevant provisions in this final rule, including industry progress toward ECP implementation. Similarly, as we have reported in the past, retrospective analyses of regulations can help inform Congress and others about ways to improve the design of regulations and can be used by agencies to help determine the extent to which the expected costs, benefits, and goals of a regulation are being realized.[70] A retrospective analysis of the ECP brake requirement after it is in effect could help determine if the goals of the requirement are being met.

Such data collection and retrospective analyses could help DOT determine the extent to which the expected costs, benefits, and goals of the regulation are being realized and could inform any future actions DOT may take regarding ECP brakes. For example, in the proposed rule, DOT proposed requiring ECP brakes on all high-hazard flammable trains, which it defined as a train comprised of 20 or more cars of a flammable

[67]GAO, *Standards for Internal Controls in the Federal Government,* GAO-14-704G (Washington, D.C.: September, 2014).

[68]GAO-14-704G.

[69]*Exec. Order No. 13,610,* 77 Fed. Reg. 28469, *Identifying and Reducing Regulatory Burdens* (May 14, 2012).

[70]GAO, *Reexamining Regulations: Opportunities Exist to Improve Effectiveness and Transparency of Retrospective Reviews*, GAO-07-791 (Washington, D.C.: July 16, 2007).

liquid such as crude oil and ethanol,[71] a larger scope than the requirement that 70-or-more-car HHFUTs equip with ECP brakes in the final rule.[72] If DOT decides to encourage or require the use of ECP brakes on other trains in the future, a retrospective analysis of key data inputs used for the existing rule could help DOT improve its estimates of potential costs and benefits.

DOT and AAR Conducted Modeling of ECP Brake Safety Benefits; Limited Transparency Hinders Understanding of How Modeling Informed DOT's Estimation

DOT and AAR Used Different Methodologies to Estimate ECP Brakes' Safety Benefits; Both Have Limitations

According to DOT, the potential safety benefit of ECP brakes is in reducing the stopping distance of a train as well as the in-train forces (the forces of individual cars pulling and pushing against one another). As a result, according to DOT, the use of ECP brakes can reduce the impact when trains derail, and reduce the number of cars that may derail, puncture, and release their contents. DOT and AAR used different computer-based engineering models and related analysis to assess the effects of ECP brakes compared to DP, EOT, and conventional brake systems in reducing the severity of derailments.[73] For the final rule, DOT

[71]In the proposed rule, DOT defined a high-hazard flammable train as a train comprised of 20 or more cars of a class 3 flammable liquid such as crude oil and ethanol. 79 Fed. Reg.45016, 45075 (Aug. 1, 2014).

[72]60 Fed. Reg. 26644 (May 8, 2015).

[73]DOT did not measure the potential benefits of ECP brakes in preventing derailments as part of this modeling. Rather, DOT estimated this safety benefit in a separate analysis based on a review of historical derailments due to train-handling issues and estimated a potential derailment prevention benefit of ECP brakes of $0.8 million.

found that on trains with ECP brakes, a weighted average of 19.7 percent fewer cars will puncture in a derailment compared to on trains with DP. Based on the results of this analysis, DOT estimated the monetary safety benefits of ECP brakes. In analyses conducted to respond to DOT's final rule, AAR found that on trains with ECP brakes, fewer than two cars in a 100-car trainset will reach the point of derailment compared to conventional air brakes and DP. These two different approaches were based in part on different assumptions about how and to what extent ECP brakes can mitigate derailments.

To estimate the safety benefit of ECP for the final rule, DOT used the LS-DYNA model—a system of equations based on the laws of physics widely used in multiple industries, including the rail industry—to simulate derailments to determine what happens to tank cars once they leave the track in a derailment and are subject to forces of impact.[74] (See fig. 3.) Sources of impacts can include other cars, segments of rail, and other objects. Specifically, through a series of calculations using the LS-DYNA model in trains equipped with ECP brakes, DP, and conventional brakes, and other inputs,[75] DOT determined the likelihood of cars puncturing in a derailment. This methodology applied variables such as speed, train length, and friction between the tank car and the ground, then applied a force to trains to initiate a derailment in 414 simulations. Specifically, those 414 simulations included 18 scenarios for 23 different combinations of speed, train length, and braking system. DOT then performed

[74]To accelerate obtaining public input and development of the final rule's ECP brakes requirement, DOT conducted less extensive modeling to support the proposed rule than it did for the final rule. For the proposed rule, DOT estimated the number of tank cars that would puncture in trains equipped with ECP brakes, conventional brakes and DP and EOT systems, and estimated, using the Train Energy and Dynamics Simulator (TEDS) and LS-DYNA simulations, the extent to which each alternative braking system could reduce kinetic energy—or the energy of trains in motion-relative to conventional brakes. DOT also used public input obtained in response to this preliminary modeling to refine and extend the modeling it conducted for the final rule. For example, in response to AAR comments, for the final rule DOT estimated puncture risk at different locations of derailment in the trainset, in addition to derailments at the head-end of the trainset.

[75]DOT contracted with Sharma and Associates (Sharma), a railroad engineering consultant, to perform the simulations and related calculations, while DOT conducted the additional analysis based on the simulations to arrive at the ECP weighted average effectiveness rate. Sharma adapted the LS-DYNA model to perform these simulations for DOT. Sharma provides railway mechanical and infrastructure engineering consulting services to such clients as FRA, AAR, railroads and transit agencies, rail car builders, and rail-car component manufacturers.

calculations based on the simulation results and data about the distribution of derailment locations along the length of trains[76] to determine the weighted average rate of 19.7 percent fewer cars puncturing in a derailment on trains with ECP brakes compared to those with DP.[77] According to DOT, this analysis is rooted in the laws of physics that govern how objects move, gain energy due to the movement, and lose speed and energy due to impacts with other moving or stationary objects.

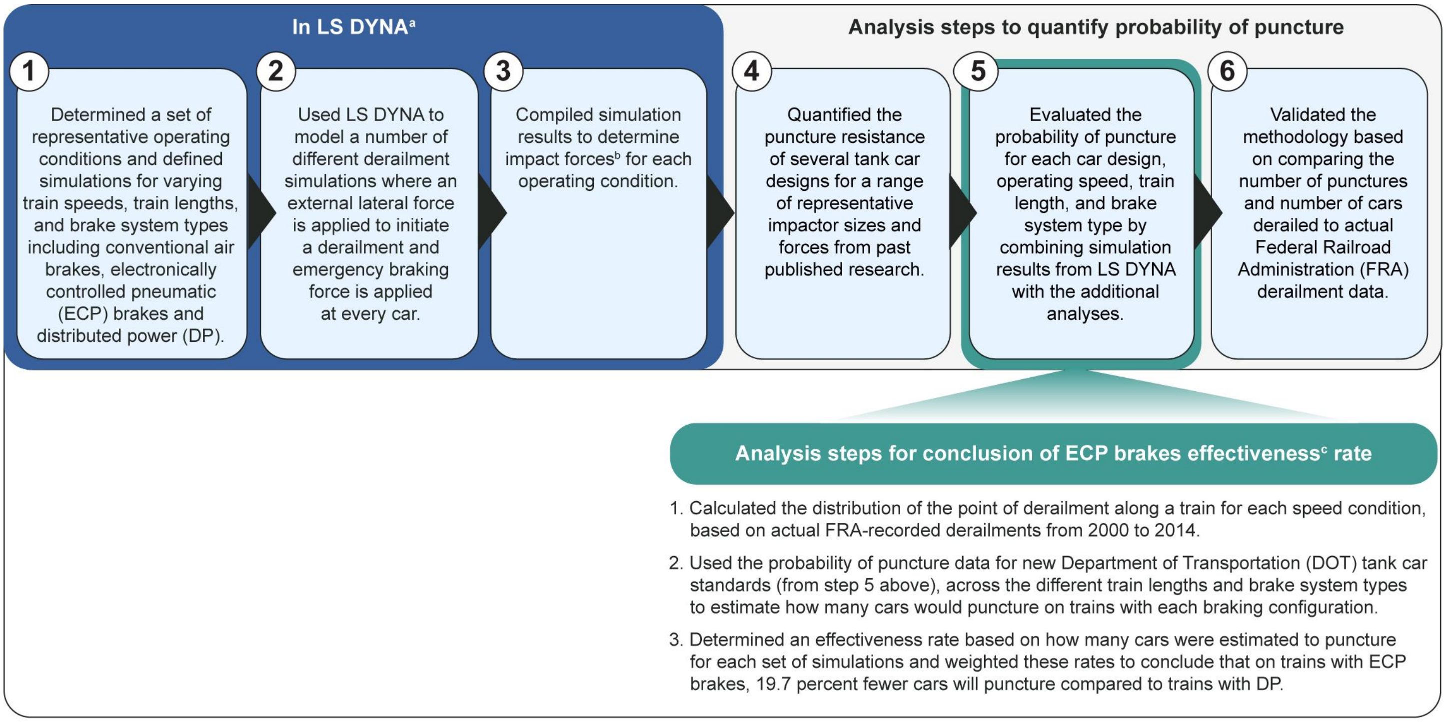
DOT officials also told us that the assumptions as well as the analysis of the modeling results were approached in a conservative manner so as not to overestimate the effectiveness of ECP brakes. For example, DOT ensured that the effect of ECP brakes was measured separately from the safety benefit of the new tank car design also required by the May 1, 2015, rule and officials told us that this factor contributed to the conservativeness of the modeling estimates.[78]

[76]DOT used FRA derailment data of trains hauling all commodities from 2000 to 2014.

[77]Based on previous analysis and experience, DOT assumed that the effect of DP and two-way EOT systems would be similar in the modeled scenarios, and thus, treated those systems similarly for the purposes of the modeling. AAR assessed the systems separately.

[78]The rule requires that new cars constructed after October 1, 2015, used to transport Class 3 flammable liquids in an HHFT, meet the standards for the DOT 117 or 117P tank cars. These standards are aimed at improving crashworthiness and include, among other things, changes to required puncture resistance of the tank shells. 60 Fed. Reg.26644 (May 8, 2015).

Figure 3: Department of Transportation's (DOT) Modeling Key Steps



Source: GAO analysis of information from DOT. | GAO-17-122

[a]LS-DYNA is a software package used in various industries to simulate transportation scenarios, among other things. FRA contracted with Sharma & Associates to perform all the LS-DYNA analysis and subsequent calculations in the blue boxes. FRA performed additional analysis steps, as shown, to identify the ECP effectiveness rate.

[b]Impactors are objects that may hit the tank car, such as broken rails, and thus may result in a puncture and subsequent release of tank car contents. In general, a smaller, more rigid impactor increases the probability of puncture.

[c]The ECP brakes' effectiveness calculations assumed that a DOT 117 specification tank cars would be used. Specifically, this tank is the new design proposed by DOT in the final rule to minimize the risks associated with the transportation by rail of ethanol and crude oil by high-hazard flammable unit trains (HHFUT). The effectiveness of ECP brakes and other braking systems was evaluated independently of, and subsequent to, these changes to the tank car design so as to minimize the ECP brakes effectiveness rate.

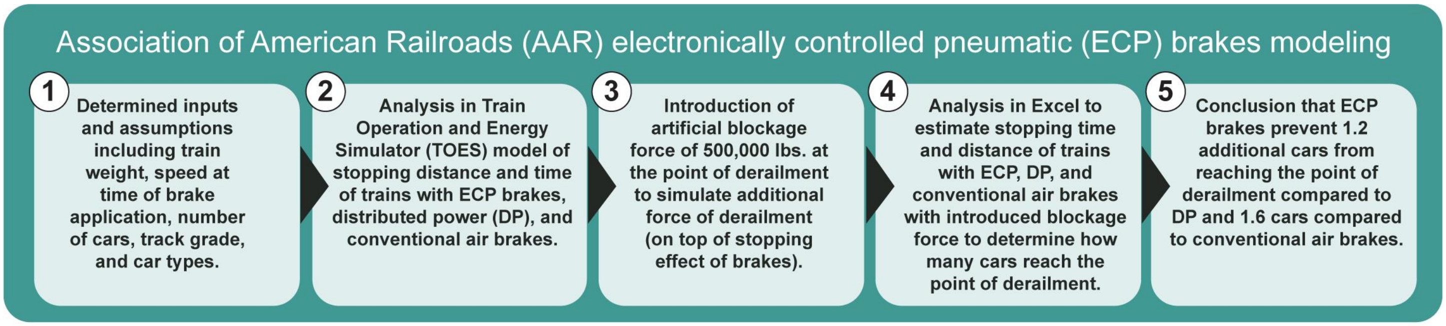
The Transportation Technology Center, Inc. (TTCI), a subsidiary of AAR, used the Train Operation and Energy Simulator (TOES)[79] to model the potential effects of ECP brakes in response to DOT's final rule. AAR used a different approach than DOT as it attempted to determine how many cars reach the point of derailment and not the reduction in the number of cars that puncture. This AAR approach (see fig. 4) ran 420 simulations incorporating different speeds and derailment locations, among other variables. AAR concluded from its modeling that ECP brakes provide a "marginal" benefit;" specifically, on 100-car trains, fewer than two fewer cars will reach the point of derailment with ECP brakes compared to DP or conventional air brakes. Unlike DOT's modeling with LS-DYNA, AAR's modeling did not simulate a derailment. Instead the model factored in the estimated additional force that would be created in a derailment, which slows down a train, to approximate stopping distances, which AAR then applied to each simulation result used to estimate how many cars would reach the point, or location, of derailment.[80] While, according to AAR representatives, it is likely that any car reaching the point of derailment would derail, this analysis does not assume that to be the case. According to AAR representatives, the number of cars reaching the point of derailment was all that they needed to model to understand the benefits of ECP brakes, as discussed later in this section. Based on its calculations, AAR estimated that on a 100-car trainset, 1.2 fewer cars will derail on a train with ECP brakes as compared to DP, and 1.6 fewer compared to conventional brakes. Unlike DOT's approach, AAR's did not estimate the probability of cars' puncturing in a derailment.[81]

[79]AAR developed TOES in 1990 to perform a range of train dynamics simulations. TOES, which is a proprietary model for AAR and its member railroads, models dynamics of trains on the track, such as speed and kinetic energy, rather than derailments. According to AAR, TOES has been continuously maintained, upgraded, and validated since then, and the most recent version was released in February 2015.

[80]AAR estimated a blockage force of 500,000 pounds using event recorder data from three recent real-world derailments.

[81]As a side effort, separate from the rulemaking docket, AAR conducted additional analysis to assess the probability of a derailment occurring that would result in greater than 100 gallons releasing. This analysis found that the effect of ECP brakes in preventing cars from releasing their content in a derailment is marginal—about 1.2 percent in a sample scenario where four cars derailed. However, the findings are not directly comparable to DOT's conclusion of a 19.7 percent reduced puncture rate because the methodology is different.

Figure 4: Overview of Association of American Railroads' (AAR) Modeling



Source: GAO analysis of AAR information. | GAO-17-122

Of the 11 experts who commented on DOT's and AAR's modeling efforts, eight described potential limitations with both DOT's and AAR's modeling, including the lack of real-world data on ECP brakes or physical testing to support results.[82] For example, one expert stated that DOT's modeling could have benefited from additional simulations[83] and one expert stated that AAR's modeling may not incorporate the effects of all types of derailments and their causes. The remaining three experts who commented on DOT's and AAR's modeling efforts leaned towards one or the other approach as more appropriate, but acknowledged they did not have enough background in the specific type of modeling conducted to make a definitive statement.

In addition, seven of the 13 experts we interviewed thought that both DOT and AAR could have bolstered their modeling efforts by performing physical tests to affirm the results while six did not mention physical testing.[84] For example, one expert thought that stakeholders could measure the stopping distance of ECP brakes versus other braking systems on a test train equipped with monitoring devices to measure

[82]ECP manufacturers and most international railroads that have used ECP brakes stated there were safety benefits, but they did not have specific data on the extent to which the brakes could prevent or mitigate derailments.

[83]As previously discussed, DOT's modeling was based on a series of simulations of derailments to estimate the effect of ECP brakes.

[84]We did not ask a question specifically about physical testing. One of these seven thought physical testing was ideal, but likely not realistic at the time of the rulemaking. The remaining six experts did not specifically mention physical testing, but did state that more specific historical derailment data would have been useful to incorporate into each model.

speed. According to DOT officials, DOT did not perform physical testing of ECP brakes for the rule, because it would not have yielded the breadth of results that DOT obtained from the hundreds of simulations it ran, particularly compared to the high cost of conducting a single physical test. In addition, DOT officials said a single test derailment would add only one data point, whereas the simulations yielded hundreds of points of information. Officials told us that conducting physical testing is more expensive and time consuming by orders of magnitude than running computer simulations. Pursuant to the FAST Act, DOT is developing an agreement with NAS to conduct physical testing of ECP brakes that will provide additional data about the safety effects of ECP brakes compared to other advanced braking technologies. Specifically, the physical testing is to measure the performance of ECP brake systems relative to DP and EOT devices, including differences in the number of cars derailed, the number of cars punctured, the measures of in-train forces, and the stopping distance.[85] DOT officials stated that the Department plans to adhere to the time frame within the Act to complete this testing,[86] but as of July 2016, DOT was developing the agreement with NAS and therefore did not provide us with any details of the planned testing.

AAR expressed concerns with DOT's approach, including its overall methodology and more specific issues. AAR told us that derailments are very complex and that DOT's modeling did not sufficiently account for these complexities and the number and variability of parameters involved in derailments. That is why, according to AAR representatives, its model focused on estimating a train's stopping distance to determine how many cars reach the point of derailment and did not go as far as to model a derailment and what happens to cars once they derail.[87]

AAR also stated in its administrative appeal to DOT's final rule that DOT presented its 19.7 percent estimate of fewer cars puncturing without providing needed additional detail, such as the results of all simulations or the margin of error to show a range of scenarios. AAR added that DOT's

[85]Pub. L. No. 114-94, §7311 (b)(3), 129 Stat. 1312, 1602.

[86]The Act requires DOT to transmit a report to Congress on the results of this testing by June 4, 2017. Pub. L. No. 114-94, § 7311(b)(1)(B). 129 Stat. 1312, 1602.

[87]Experts also had some concerns with AAR's methodology. For example, three experts of the eight who commented disagreed with the process AAR used to determine the additional force that would be created in a derailment.

estimate was based on a flawed statistical approach that used small samples of modeling results, did not consider variation in modeling results, and did not account for the margin of error in the results. Only one of the 11 experts who commented on DOT's presentation of an average without additional detail agreed that DOT's presentation was appropriate, while five experts disagreed and five were neutral. For example, one expert who disagreed with the use of an average as an estimate said DOT could have run more advanced analyses to better quantify the uncertainty.

While DOT acknowledged in its response to the administrative appeal that some uncertainty surrounds the 19.7 percent estimate, as in any simulation result, it added that FRA selected a rigorous engineering approach, rather than a statistical one, that by design did not quantify uncertainty because they wanted to model the physical benefits of ECP brakes under realistic operating conditions rather than random variations. Similarly, DOT officials told us that it was inappropriate for them to calculate and report on confidence intervals because the results of their simulations reflect carefully selected operating scenarios and were not intended to represent the universe of all possible derailments. DOT officials agreed that derailments are complex but stated they took a rigorous approach to modeling them and that, to minimize uncertainty in the results, the 19.7 percent weighted average reflects 414 simulations over different operating conditions.[88] For example, DOT officials said that ECP brakes were shown to provide better performance than conventional brakes over each simulation at different speeds at the time of derailment, not just at one point. Results from all 414 simulations and data on the distribution of the point of derailment along train lengths in actual derailments, factored into the calculation of the 19.7 percent weighted average.

Differing views on what happens to a train and its cars in a derailment can in part explain the differing results of DOT's and AAR's modeling

[88]According to DOT, the LS-DYNA modeling enabled analysts to quickly measure complex dynamics in many operating scenarios, and the calculation of puncture risk was based on laws of physics relating to the effects of speed and kinetic energy. As a result, the uncertainty of the methodology stems from the extent to which actual operating conditions differ from the representative operating scenarios selected for the modeling, rather than random statistical variations. To mitigate that uncertainty, DOT measured 18 scenarios for each of 23 reasonable combinations of speed, train length, and brake type combinations, or a total of 414 simulations.

approaches. Specifically, while DOT and AAR agree that a range of causes can lead to a derailment, such as broken rails and operator mishandling, they differ with regard to the magnitude by which the braking configuration affects train forces. DOT states in its RIA that ECP brakes affect the physics of trains in ways that can mitigate derailment severity beyond stopping time and distance. Additionally, DOT, in its denial of AAR's administrative appeal, states that these benefits reduce the severity of a derailment above and beyond the reduction in stopping distance and time, reducing the potential for a car to puncture in a derailment. DOT, in the denial, adds that AAR's model, however, did not capture a large portion of the potential benefits of ECP brakes—for example, their ability to reduce in-train forces when the brakes are applied.[89] DOT officials stated that, as a result, the LS-DYNA simulations used to support the 19.7 percent weighted average inherently include the beneficial effects of reduced in-train forces. In contrast, AAR stated in its appeal that ECP brakes only affect the reduction of kinetic energy in a moving train and the resulting effect on stopping distance and time and not what happens in or after a derailment, such as the potential of rail cars to puncture.

Both of the current ECP manufacturers told us or stated in written documentation that ECP brakes reduce in-train forces. One manufacturer said in written responses that its customers also anecdotally spoke to decreased derailment risks, while the other stated that it is conducting a review of DOT's modeling of ECP brakes' safety benefits, but would not be making the results public. Additionally, 6 of the 10 experts who commented on the effect of ECP brakes post-derailment stated that ECP brakes are unlikely to have much impact on what occurs after cars leave the track, but three of these six experts could not rule out such effects. Of the remaining four experts, three stated that ECP brakes could affect train dynamics besides stopping distance, such as in-train forces, and one was neutral.

The extent to which ECP brakes provide improved safety benefits than conventional air brakes and DP is dependent in part on the benefit of ECP brakes in providing a faster brake signal and brake application.

[89]As previously described, in-train forces represent the various types of forces, such as pulling and compressive forces, that are inherent in train dynamics. According to FRA and AAR, excessive in-train forces can break equipment, cause a rail to turn over, or cause a car to climb a rail, all of which can lead to derailments.

While DOT and AAR agree that ECP brakes provide a faster braking application than conventional brakes, they disagree on the extent to which ECP brakes do so. As discussed earlier, the braking signal with ECP brakes is instantaneous, while it travels at slightly less than the speed of sound with conventional air brakes. Once cars receive that signal, it takes additional time for the brakes in each car to be applied. AAR representatives stated that ECP brakes provide a benefit of about 2 seconds in faster brake application on a 100-car train compared to conventional air brakes, which they said is not sufficient to prevent severe "pile-ups" of cars in most derailment circumstances. On the other hand, DOT officials stated the braking application is much quicker on trains with ECP brakes as the signal vents to the brakes more directly than on trains with conventional air brakes. DOT provided an ECP manufacturer's data to show that full brake application on the last car in a 110-car train with ECP brakes is about 8.5 seconds faster than on a train with conventional air brakes.[90] Representatives of both ECP brake manufacturers we interviewed said that ECP brakes provide significantly faster braking application than conventional brakes; specifically, one provided testing data and stated that full brake application on a 150-car train with ECP brakes is about 15 seconds faster compared to conventional air brakes. Two out of the 4 experts who commented on the speed of the brake signal and brake application said that both are faster with ECP brakes; two stated that ECP brakes affect the signal only and not the full brake application.[91]

Incomplete Information on DOT's Modeling Approach Used to Support Final Rule Limits Ability to Replicate It

We found that DOT's approach with the LS-DYNA model and related analysis lacked transparency and the information provided to support the ECP brake requirement was not sufficiently thorough and transparent to enable a third party to reproduce a portion of the modeling methodology. Best practices identified by GAO and OMB highlight that modeling results published by an agency, particularly those that support stated monetary costs and benefits, should be supported by validation processes and transparent review. If an agency is responsible for disseminating such

[90]DOT did not report on a quantified braking speed improvement of ECP brakes relative to conventional brakes and DP in its RIA or final rule. However, this is accounted for in the LS-DYNA modeling.

[91]We did not ask a specific question about braking speed and so gathered incomplete responses.

information, a high degree of transparency regarding data and methods facilitates reproducibility by third parties.[92] Additionally, NAS guidance states that agencies can promote greater confidence in results by facilitating review by qualified third parties, and by providing as much information as possible about the methods, assumptions and inputs.[93] Our past work has also stated that successful validation by third parties enhances the credibility of simulations by offering assurance that they are sufficiently clear and complete to enable successful reproduction of the results.[94] Seven of the ten experts who commented on third-party reviews said that third-party reviewers should be provided with specific assumptions, inputs and calculations into models; the remaining three discussed reviews more generally and did not specifically comment on the need for this documentation.

DOT published two letter reports outlining the LS-DYNA modeling of ECP brakes conducted by Sharma and Associates[95] along with additional explanatory details in the RIA. Taken together, these documents represented the information provided to the public about the modeling process DOT used to support the ECP brake requirement.[96] These documents provide many pages of general information on DOT's

[92]Office of Management and Budget, *Regulatory Analysis,* Circular A-4 (Washington, D.C.: revised Sept. 17, 2003).

[93]National Research Council of the National Academies, *Principles and Practices for a Federal Statistical Agency, fifth ed.* (Washington, D.C.: 2013).

[94]GAO, *Defense Transportation: Opportunities Exist to Enhance the Credibility of the Current and Future Mobility Capabilities Studies*, GAO-05-659R, (Washington, D.C.: Sept. 14, 2005).

[95]One report was issued in 2014 to support the proposed rule. Sharma & Associates, Inc. *Objective Evaluation of Risk Reduction From Tank Car Design & Operations Improvements* (July 2014.) DOT published the 2014 report on August 26, 2014, after it published the proposed rule on August 1, 2014. DOT published another report in 2015 to support the final rule's projected safety benefits. Sharma & Associates, Inc., *Objective Evaluation of Risk Reduction From Tank Car Design & Operations Improvements – Extended Study* (March 2015.). Based on public comments made by industry stakeholders to the proposed rule, DOT made some changes to its modeling approach, such as by including additional simulations.

[96]DOT stated that it also made presentations at numerous industry meetings about the DOT and Sharma modeling processes where it provided sample calculations.

modeling process[97] and some specific information, such as sample calculations. However, the information DOT published about the model is limited and would not necessarily allow independent third parties to replicate the analysis. Because DOT did not provide some of the specific data and information underlying its modeling efforts and analysis, in a situation where little real-world information about the benefits of ECP brakes exists, the public may not have reasonable assurance as to DOT's projected safety benefits, limiting confidence in DOT's overall findings.

For example, in the 2015 letter report to support the final rule's projected safety benefits, DOT reported on the average, minimum and maximum values of the number of cars that derailed in the simulation for each braking system but did not report on all simulation results.[98] In addition, DOT did not report full details on specific inputs such as how the brake force was applied to the tank cars throughout the simulations. DOT stated that these can be easily estimated from the information provided and that further, this data is readily available to AAR and industry from AAR's TOES simulations. However, AAR documented in its appeal to the final rule that it was unable to identify how the brake force was used, among other things. DOT also did not provide information on all the calculations used in the LS-DYNA model. We also found that the letter reports did not always provide full information about how the simulations were conducted.[99] For example, DOT noted in the 2015 letter report that many assumptions relevant to operating conditions "reflect the preferences of the analyst" without detailing what those assumptions were and how they were made. Officials told us that even though these assumptions were not specifically listed in the letter report, they were un-biased, and an experienced modeler could make any such assumptions without affecting the end results of the modeling. Specifically, DOT officials stated that these preferences address the selection of options related to LS-DYNA execution and output processing and that other analysts could choose differently, but that their results would not differ meaningfully from DOT's

[97]The 2015 letter report provides information that Sharma and DOT used to validate the methodology internally, including graphs overlaying data from actual derailments and simulation results on the number of cars that derail and puncture, and data from FRA derailment investigations versus derailment speed.

[98]Sharma & Associates, Inc., 2015.

[99]We asked DOT if it had information pertaining to its assumptions and calculations beyond what it made publicly available. DOT provided us with a brief excerpt of this information.

results, provided the preferences are scientifically reasonable and kept constant throughout the analysis.

DOT officials also told us that the information provided in the letter report and rulemaking documents suffices to enable outside experts to recreate the modeling, test the assumptions, and understand the results. For example, DOT said, the charts and values presented in the letter report would enable an experienced modeler to reproduce the calculations of the number of cars punctured. DOT stated that the government-industry Advanced Tank Car Collaborative Research Project[100] is using a methodology similar to DOT's ECP brake analysis to evaluate the benefits of alternative car designs. DOT told us that as part of this effort, an industry expert ran several tank-car derailment simulations using a method similar to the one described in DOT's documentation, and similarly extracted forces from these simulations. Based on these simulations and available braking-force data from AAR's TOES simulations, DOT stated that knowledgeable third parties can easily recreate its methodology without additional information and that while the keyword files have been requested by AAR, they are not essential to recreating the simulations. However we found, and DOT and others acknowledged, that LS-DYNA is a broad program used for a range of applications. In addition, one expert we interviewed stated that because derailments are so complex to model, different approaches to modeling them are still being refined by stakeholders. As a result, more detailed information, including specific inputs and calculations, would lend transparency to DOT's specific approach using LS-DYNA to model derailments. Moreover, we found and one expert stated that the keyword files could provide information on how DOT customized LS-DYNA to model specific types of train movements in a derailment. These files are typically used to set various parameters in simulations and with the number of inputs used to model derailments, including speed, braking force, and friction, among others, the combination of key inputs can be in thousands with various permutations.

We also found that independent experts may not be able to reproduce DOT's work based on the information publicly provided.[101] AAR

[100]This effort leverages participation from industry, academia, and government and seeks to understand the parameters that affect tank car derailments and safety, among other things.

[101]We did not attempt to independently replicate this analysis.

representatives stated, and their comments to DOT's rulemaking docket indicate, that they believe they were not provided with sufficient information to replicate DOT's process. Additionally, the two experts we interviewed who commented specifically on DOT's review process thought that its process was not sufficiently formal or rigorous,[102] and one expert with experience using LS-DYNA added that it is not possible to replicate DOT's efforts with the amount of information DOT provided. This expert, who is involved in the aforementioned government-industry tank-car-modeling effort, told us that this group's efforts to replicate the DOT analyses resulting from the LS-DYNA modeling were unsuccessful due to a lack of information. Specifically, this researcher said that more information was needed in order to replicate the LS-DYNA modeling, such as, for example, how the braking, coupler, and wheel-rail lateral constraint force assumptions were applied in the model.[103] Preferably, he said that keyword files would be provided so that other researchers could independently run and evaluate the simulations. This researcher added that such information may help address some concerns raised with the modeling.

DOT Estimated Several Hundred Million Dollars in Safety Benefits Based on Modeling Results, but Some Assumptions May Have Been Oversimplified

Based in part on its estimate that 19.7 percent fewer cars will puncture in a derailment compared to trains with DP or two-way EOT devices, DOT estimated that by reducing the release of flammable liquids in derailments, ECP brakes will provide safety benefits of $215.3 million (for addressing lower-consequence events[104]) or $358.4 million (for addressing lower-consequence events as well as higher-consequence events[105]) over the 20 year period from 2015 to 2034.

[102]The other 11 experts did not comment specifically on this issue.

[103]The coupler forces are those transmitted by the pushing and pulling of the couplers that connect adjacent cars within a trainset. The wheel-rail lateral constraint forces are the lateral (side) forces produced by the wheel and rail interaction with side-to-side movement.

[104]The lower-consequence events look at the projected damages that might occur if the rate and size of future accidents were similar to the existing United States' safety record.

[105]According to the RIA, such higher-consequence events are characterized by large-scale property damage and multiple fatalities. While there have not been any higher-consequence accidents in the U.S., DOT argues in the RIA that such events are possible and therefore, it was necessary to examine their potential. The higher-consequence events estimate is an estimation of how many of these higher-consequence events might occur in absence of the final rule and an estimation of expected damages from them.

More specifically, DOT used data on derailments of crude oil and ethanol trains from 2009 to 2013[106] to predict the number of derailments over 20 years from 2015 to 2034. DOT also took into account the estimated percentage of cars that would be equipped with ECP brakes in each year, future crude oil and ethanol rail traffic estimates based on data from RSI, and the 19.7 percent estimated reduction in punctures from ECP braking to determine how many gallons spilled use of ECP brakes would avoid. Based on the costs of recent releases from derailments and pipeline spills, DOT estimated that the cost of each gallon released (and therefore, the benefit per gallon spilled that ECP brakes help avoid) to be $200, taking into account clean up, environmental, and other costs.[107]

According to AAR, railroads, and some experts we interviewed, some of DOT's assumptions used to monetize these estimated safety benefits may have been oversimplified or not accurate. For example, to project benefits, DOT used a constant derailment rate (of 0.011 per thousand carloads) over the 20-year forecast period. This is because DOT found the derailment rate for crude oil and ethanol trains to be nearly constant for the 5 years preceding the final rule despite an overall declining trend in the rate in recent years. (For example, DOT reported in the final rule that the derailment rate for all commodities fell about 38 percent between 1995 and 2012 to 0.037 per thousand carloads.) DOT argued that the derailment rate has leveled out in recent years and that it is not realistic to expect sharp decreases in the rate to continue indefinitely. However, AAR stated that DOT's assumption of a constant derailment rate is based on a very small sample and may inflate benefit estimates as the derailment rate for trains hauling crude oil or ethanol declined by more than half between 2000 and 2014. Nine out of the 11 experts who commented on the derailment rate disagreed with the use of a constant derailment rate. Three of these nine experts noted that DOT should have used a

[106]DOT used data from FRA's Incident Database—which collects data on railroad accidents—and the Surface Transportation Board.

[107]These estimates exclude the values of deaths and injuries. DOT estimated the costs of released product by applying a monetary value to each gallon spilled. This implicitly assumes that costs per gallon are in direct proportion to the volume of product spilled, but DOT intended for the value to reflect an average, recognizing the number may be declining with respect to the volume spilled due to economies of scale in cleanup costs.

derailment rate that reflects historical data.[108] Of the remaining two experts who commented on the use of a constant derailment rate, one expert stated that DOT's use of a constant derailment rate was reasonable and the other was neutral.

In addition, AAR and some experts we interviewed expressed concerns with DOT's use of a $200 cost per gallon estimate used to calculate benefits. Specifically, AAR stated that DOT's estimated cost per-gallon average of $200 is 10 to 18 times higher than costs reported by its member railroads. The Oliver Wyman report provided to AAR said that DOT's average is high because it included one extreme case—a 2010 pipeline spill—that is a possible outlier. The report added that this case was a high-consequence event; therefore, its costs should not have been included in DOT's estimate of the costs of low-consequence events.[109] Five out of the eight experts who commented on this issue disagreed with DOT's inclusion of one high- consequence event, with two stating that including one outlier could skew the results. The remaining three experts thought DOT's use of the high-consequence event was appropriate.

As discussed earlier, there can be uncertainty in many variables that are used to estimate benefits, and OMB guidance says that when conducting cost and benefit estimates, agencies should take into account such uncertainty. While crude-oil rail traffic, in particular, has increased significantly in recent years, it has experienced a more recent decrease. As reported by the Energy Information Administration, the volume of crude oil transported by rail depends on many factors, including but not limited to production volumes, price differences across crude oil types, and availability of pipeline infrastructure. As discussed earlier, after years of sharp increases, the amount of crude oil hauled by rail decreased significantly from March 2015 to 2016. DOT based benefits on a single forecast for shipments of crude oil over 20 years and a single value for fuel prices and did not provide a range of potential benefits based on potential variability. To the extent that actual fuel prices are higher or lower than DOT estimated, this benefit may be larger or smaller than

[108]For example, one expert explained that using a constant rate could overstate benefits, and another expert added that DOT could have incorporated both a constant and declining derailment rate and presented a range of potential benefits depending on the derailment rate.

[109]According to AAR, if this one case were removed from DOT's analysis, the average cost per gallon spilled estimate would be only $110, instead of the $200 DOT used.

estimated. Similarly, should future traffic in crude oil by rail be significantly lower (or higher) than DOT forecasted, the actual benefits of ECP brakes may be significantly lower (or higher). Similarly, to the extent that the derailment rate for crude oil and ethanol trains continues to fall and does not remain constant, as DOT assumes, the realized benefits of ECP brakes may be lower than expected. However by basing estimates on one forecasted derailment rate, DOT's analysis does not acknowledge this uncertainty.

Conclusions

Increases in shipments of flammable liquids such as crude oil and in recent years ongoing concerns regarding tank car safety suggests that DOT's 2015 rule requiring HHFUTs to equip with ECP brakes could not only provide potential operational—or business—benefits to railroads but also safety benefits by reducing the severity of tank car derailments. Although freight railroads in the United States supported initial development and use of ECP brakes, with the issuance of the rule, AAR and other industry participants have stated that the costs do not justify the benefits of the technology and are strongly opposed to this requirement. In opposing the requirement, AAR has stated that DOT overestimated the benefits and underestimated the costs of ECP brakes.

Given that equipping HHFUTs with ECP brakes has sparked a highly polarized debate between the railroad industry and DOT, it is critical that DOT's analysis supporting the ECP brake requirement be based upon the best data possible. However, because those railroads that have had experience with ECP brakes (both in the United States and in other countries) have shared limited data on their use of ECP brakes, DOT may have been hampered in its efforts to estimate the potential effects of ECP brakes, including their potential benefits. Railroads provided limited data in part because some of them operated ECP trains in normal rail service and did not attempt to collect data on their operational effects. Subsequently, the limited data on railroads' experiences with ECP brakes contributed to the uncertainty in DOT's estimates of potential business benefits. Similarly, some variables included in the estimates of costs and safety benefits also introduced a level of uncertainty to DOT's estimates. For example, DOT's estimate for the potential safety benefits of ECP brakes is based on a single forecast of future oil by rail traffic over the next 20 years. However, recent decreases in oil by rail demonstrate the uncertainty inherent in future estimates of traffic that DOT did not reflect in its analysis.

Furthermore, we found the information DOT publicly provided on the modeling it conducted to estimate the potential safety benefits of ECP brakes lacked the transparency that could allow for a third-party reviewer to replicate the analysis. As a result, the public and industry stakeholders may have limited confidence in DOT's projected safety benefits. OMB guidance indicates that agencies should, in assessing the costs and benefits in support of a RIA, use the best reasonably obtainable data—such as data that DOT collected from some railroads though to a limited extent—to address uncertainty in its cost and benefit estimates and be fully transparent so that the results can be independently validated. The 2015 FAST Act requires DOT to physically test ECP brakes[110] and update the RIA it used to support the 2015 ECP brakes final rule. This requirement is an opportunity for DOT to include its own "real world" experience with ECP brakes through this physical testing and address some of the data limitations, uncertainties, and lack of transparency that may have contributed to the lack of confidence in the ECP brake requirement.

Recommendations

As DOT, in response to the FAST Act, conducts additional evaluation and analysis of ECP brakes and updates the regulatory impact analysis, the Secretary of Transportation should direct FRA and PHMSA to:

- Take into account, in the updated RIA conducted in response to the FAST Act, potential uncertainty in key variables and assumptions, such as, but not limited to, fuel prices and future rail traffic of crude oil and ethanol, discuss this uncertainty, and present ranges of possible scenarios.

- Create a plan to collect data from railroads' ongoing and future operational experiences using ECP brakes. The plan should include details on how the agency will work with railroads to collect this data, ensure that such data are reliable, and analyze these data to conduct a retrospective analysis of the ECP brakes requirement that could help inform any potential future actions regarding ECP brakes.

- If, based on its updated analysis, DOT promulgates a new rule on the applicable ECP brake system requirements, require that freight railroads, once they equip with ECP brakes in response to the

[110]Pub. L. No. 114-94, §7311 (b)(3), 129 Stat. 1312, 1602.

requirement, collect and provide data to FRA on their ongoing operational experience with ECP brakes.

- Publish information—including data inputs, formulas, and results of all simulations and assumptions regarding DOT's use of the LS-DYNA model used and related analyses to support the 2015 final rule—that would allow a third party to fully assess and replicate the analysis.

Agency Comments

We provided a draft of this report to NTSB and DOT for review and comment. NTSB did not have any comments. DOT provided a written response (see app. IV) as well as technical comments that we incorporated as appropriate. In the written letter, DOT stated that it believed that we did not provide sufficient and appropriate evidence to justify our findings and conclusions and that it disagreed with our recommendations.

We appreciate DOT's comments, however we believe that our findings and conclusions, as well as our recommendations, are well supported and justified. As part of our work—conducted in response to a requirement in 2015's FAST Act—we assessed DOT's efforts to estimate the potential cost and benefits of ECP brakes against government standards and guidance from GAO, OMB and other entities. DOT states that our approach generates “unwarranted doubt” about DOT's ECP brake rule. We disagree. We believe we conducted and presented our work in a fair and balanced manner. Our work examines the views of DOT and selected experts and stakeholders on the costs to railroads to implement and operate with ECP brakes in response to the requirement and information on the potential operational effects and business and safety benefits railroads may realize from ECP brakes. To the extent that the report presents industry or expert concerns about DOT's estimates of the potential costs and benefits of ECP brakes, we provided the basis for their doing so, as well as DOT's perspective on the estimates. Where relevant we also provided contrary expert views.

DOT also states that we present DOT's views side-by-side with those of selected experts and the railroad industry in a manner that suggests that either side could be correct. We provided estimates and information from DOT and industry side-by-side as doing so improves the presentation of our report compared to presenting, for example, all of DOT's estimates followed by information on all of industry's estimates and views. Furthermore, our review was not designed to determine if any such estimate was “correct,” and the report does not at any point assert that any DOT or industry estimate is "correct." When providing DOT and industry estimates of the potential costs and benefits of ECP brakes, we provide a description of the estimates, as well as concerns about the estimates raised by the experts we interviewed, along with the federal standards and guidance for developing cost benefit analyses.

DOT adds that while its analyses were fully vetted during the rulemaking process and underwent critical evaluation, we do not make any statements about whether industry assertions were similarly vetted. We agree with DOT that industry's published work on ECP brakes did not undergo a similar rigorous review process as DOT's analysis—for example DOT's proposed rule was published and open to public review and comment—and have made note of this in our report. In addition, we did not use findings from expert interviews to solely inform our recommendations. Instead we based our recommendations on information collected from multiple sources, including expert interviews, our review of key documents such as DOT's RIA, and our analysis of DOT's efforts against criteria for conducting such analyses.

DOT also states that we did not present information it provided during our audit work in which it refuted industry's and experts' assertions. We believe that we have appropriately noted DOT's response to industry's and experts' statements where relevant; we do so in additional places in our final report in response to technical comments DOT provided on the draft report. Specific concerns DOT raised in its letter include:

- <u>Effect of the rule on smaller railroads</u>: DOT stated that we did not make clear that the rule specifically excludes small railroads. We recognize that in the rule, DOT attempts to reduce the burden on small railroads that may not have the capital available to install ECP brakes by only requiring ECP brakes on HHFUTs operating at speeds in excess of 30 miles per hour. However, representatives of ASLRRA told us that they believe that it is possible that class II/III railroads may receive tank cars for shipment from class I railroads that are equipped with ECP brakes, potentially requiring them to operate with ECP brakes. This outcome could be the case if such cars are equipped with standalone, and not overlay, ECP brakes. We have added DOT's views to our report.

- <u>Availability of information regarding DOT's efforts</u>: DOT expressed concern with the comment of one expert we interviewed that DOT did not make certain information about its modeling of ECP brakes publicly available and notes that it made such information available in the letter reports published as part of the rulemaking. In our draft report, we acknowledged that DOT published information about its ECP modeling in two letter reports but found that some relevant information—including some modeling assumptions, inputs, and outputs—was not included in the published reports. Based on our review of documentation provided by DOT and publicly available, we continue to believe that the two letter reports detailing the modeling conducted by Sharma and Associates for DOT, and the results of that modeling, do not contain detailed information on all inputs and assumptions in the model as well as all outputs such as the results of all simulations included as part of the model. We believe such information is necessary to allow third parties to independently and adequately review DOT's modeling efforts and assess its conclusions.

- Foreign railroads' experience: DOT also states that it disagrees with industry assertions that the use of ECP brakes by international railroads "is not relevant." Our draft report noted the perspective of industry association representatives that some foreign railroads' operations are "better suited for ECP brakes" and discussed ways in which foreign railroads that use ECP brakes differ operationally from U.S. railroad. The draft report did not cite industry as asserting that such experiences are "not relevant." DOT also states that some foreign railroads have expanded their use of ECP brakes, and we now note this. DOT also states in its letter how many U.S. railroads have similar operations to such foreign railroads, and we also now note this in our report.

- Comparison of safety benefit calculations: DOT also stresses that its modeling efforts, and those conducted by industry, answer different questions. We agree and have added additional language to make this distinction more clear.

DOT also comments that it cannot determine the specific concerns raised by experts regarding DOT's modeling of ECP brakes because we provided insufficient or incompatible statements. Specifically, DOT stated that we did not elaborate on what basis some experts stated that they believed DOT oversimplified its analysis and that it is not correct for one expert to have said that DOT could have used a "more rigorous statistical analysis" as DOT's modeling and related analyses were not statistical analyses. We agree that the modeling effort DOT used was an engineering-based model and not a statistical model, and note that in our report. While we deleted a reference to expert views that DOT could have used a "more rigorous statistical analysis" as that was not the purpose of DOT's work, we continue to believe DOT should publish more information regarding its modeling, as discussed below.

While DOT disagrees with all four of our recommendations, we believe that all are relevant and well justified by our analysis. Specifically:

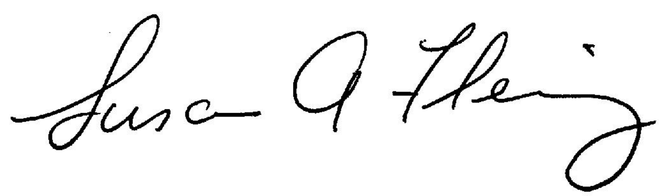
- We recommended that DOT, in updating its RIA, take into account potential uncertainty in key variables and assumptions. The limited data that railroads provided to DOT—based on our review and as asserted by DOT—introduce a level of uncertainty in DOT's estimates. Generally speaking, the more the data used to support such estimates are high-quality, the less uncertainty there may be. However, as we note in our report, DOT has not recognized this uncertainty. For example, the fact that shipments of crude oil by rail have fallen sharply since DOT completed its RIA may affect the estimates for benefits to the extent that this recent decline affects the forecast for future shipments of crude oil by rail. We believe that DOT should recognize this uncertainty. Furthermore, our justification for this recommendation is primarily based on data that DOT received from railroads, on what DOT reported in rulemaking documents, and on clear criteria from OMB and others for conducting such analyses, and not solely on the views of industry or experts we interviewed.

- We recommended that DOT: (1) create a plan to collect data from railroads' future and ongoing experiences using ECP brakes, and (2) require railroads to collect and provide such data if DOT promulgates a new rule on the applicable ECP brake system requirements. We believe that the receipt of additional ECP brake operational data from railroads could improve DOT's estimates of the costs and benefits. While DOT, during the course of our audit work, maintained that it had sufficient and credible data to support its regulatory impact analysis, DOT also agreed that the railroads shared limited data with the agency. As stated above, we believe that more quality data based on railroads' real-world experiences can lead to better estimates. In its letter responding to a draft of this report, DOT states that it looks forward to receiving additional operational data from railroads and expects that such data will confirm its earlier findings of the potential benefits of ECP brakes. Based on this statement, we believe that DOT agrees with the intent of our recommendations regarding collecting additional data. We believe that by implementing our two recommendations regarding the collection of operational data, DOT can better ensure that it will receive and benefit from such data.

- We recommended that DOT publish additional information regarding its computer-based modeling and related analysis of ECP brakes that would allow a third party to fully assess and replicate the analysis. We continue to believe that DOT provided incomplete information regarding its modeling and related analyses of the potential safety benefits of ECP brakes. We recognize DOT's efforts in developing and conducting the modeling of ECP brakes. However, because the letter reports and accompanying information in the regulatory impact analysis supporting the final rule do not include all relevant information on inputs, assumptions, and the results of all modeling simulations, we continue to believe that it is important for DOT to publish such information, which could increase the public's and industry's confidence in DOT's efforts.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Transportation, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-2834 or flemings@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix V.



Susan Fleming
Director, Physical Infrastructure Issues

Appendix I: Objectives, Scope, and Methodology

To determine the views of the Department of Transportation (DOT) and selected experts and stakeholders on the costs to railroads to implement and operate with electronically controlled pneumatic (ECP) brakes in response to the requirement we reviewed and analyzed key rulemaking documents including the notice of proposed rulemaking,[1] final rule,[2] regulatory impact analysis (RIA),[3] public comments filed by the Association of American Railroads (AAR) and other industry participants, including freight railroads, an administrative appeal filed by AAR against the rule, a study on ECP brakes conducted by consultancy Oliver Wyman on behalf of AAR,[4] and DOT's denial of AAR's administrative appeal. We analyzed these key documents to determine key cost estimates for railroads to respond to the ECP requirement, data and assumptions used to support cost estimates, and key differences in cost estimates made by DOT and AAR. Although DOT's rulemaking documents that make such estimates underwent public review and comment, industry efforts did not undergo similar review such as public comment. We did not independently assess the technological reliability of ECP brakes.

We also identified a list of 13 relevant experts in freight rail transportation, rail safety, rail braking, and rail modeling, to interview. We determined these experts based on recommendations from staff with the National Academy's Transportation Research Board, a review of published literature on ECP brakes, and a review of members and their qualifications on relevant freight rail committees of the Transportation Research Board. Staff with the Transportation Research Board reviewed our draft list of experts and provided additional suggestions. The group of experts included one South African expert and two Australian experts familiar with the use of ECP brakes in those countries. We selected these two countries based on our review of the use of ECP brakes in foreign countries and our conclusion that outside of the United States and

[1] 79 Fed. Reg. 45015 (Aug. 1, 2014).

[2] 80 Fed. Reg. 26644 (May 8, 2015).

[3] DOT, *Final Regulatory Impact Analysis:* Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains (Washington, D.C.: May 2015).

[4] Oliver Wyman, *Assessment of the Enhanced Braking Requirements in the Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains Final Rule of May 1, 2015* (June 12, 2015; New York, NY).

Canada[5] these are the two countries where ECP brakes have been the most widely used. We interviewed these 13 experts using a semi-structured interview guide that we developed. This guide included questions on specific ECP brake cost estimates of DOT and the railroad industry,[6] rationales for those estimates, and key differences between DOT and industry estimates. Not all experts were able to answer all questions as, for example, some had limited knowledge or opinions about certain issues. Prior to each interview, we provided each expert with information on key cost estimates by DOT and AAR, including key assumptions and data used to support those estimates as well as supporting information such as key rulemaking documents. Officials with the Federal Railroad Administration (FRA) and AAR reviewed relevant portions of this summary information to help ensure its accuracy. Once we completed the interviews, we conducted a content analysis of these responses to determine themes in responses to questions about DOT's and AAR's cost estimates.

Furthermore, we interviewed all seven North American class I freight railroads[7] as well as four class II and III railroads as recommended by the American Short Line and Regional Railroad Association (ASLRRA) based on those interested in meeting with us, as well as two shippers of crude oil as suggested by the Railway Supply Institute (RSI) based on those interested in meeting with us. We also interviewed staff with FRA and the Pipeline and Hazardous Materials Safety Administration (PHMSA), industry associations including AAR, ASLRRA, RSI, and the American Petroleum Institute, and one railroad labor union—the Brotherhood of Locomotive Engineers and Trainmen—as well as two manufacturers of train ECP brakes.[8] These expert and stakeholder interviews are not

[5]As both Canadian Pacific and Canadian National railroads are considered North American class I railroads, we interviewed these two Canadian railroads as well.

[6]In this case, "the industry" refers to estimates put together by the AAR as well as those included in the Oliver Wyman report.

[7]Freight railroads are classified by operating revenues. Class I railroad carriers include those having annual carrier operating revenues of $467 million or more. Class II railroad carriers are those having annual carrier operating revenues of less than $467 million but in excess of $37.4 million. Class III railroad carriers are those having annual carrier operating revenues of $37.4 million or less. 49 C.F.R. § 1201.1-1. The Class I railroads are BNSF Railway, Canadian National, Canadian Pacific, CSX Corporation, Kansas City Southern, Norfolk Southern, and Union Pacific.

[8]One of these manufacturers opted to provide written responses instead of participate in an interview.

generalizable. We also interviewed two selected railroads in Australia based on recommendations from DOT. During these interviews we discussed the costs of ECP brakes—including the costs that railroads that have used ECP brakes to date have experienced—as well as other issues.

In order to review what is known about the potential operational effects and business benefits railroads may realize from ECP brakes, we reviewed the rulemaking and other key documents described above. We reviewed these documents for estimates of business benefits, data used to support these estimates, key assumptions behind these estimates, and key industry arguments against DOT's estimates. We analyzed these documents to determine key disagreements on the potential business benefits of ECP brakes between DOT and the railroad industry. We also reviewed key DOT-rulemaking documents, in particular the regulatory impact assessment used to support the final rule, to determine how DOT estimated the potential benefits of ECP brakes. We identified criteria for conducting such cost-benefit analyses including OMB's *Circular A-4*[9] and GAO's *Standards for Internal Controls in the Federal Government*,[10] and compared DOT's efforts against these criteria.

We also interviewed the 13 experts discussed above regarding the potential business benefits of ECP brakes and key areas of disagreement in estimates between DOT and the railroad industry. As noted above, we used a semi-structured interview guide for these interviews and conducted a content analysis to analyze their responses. As with costs, we put together a summary table of key benefit estimates and key differences between DOT and industry views, and provided this summary table along with supporting documentation to each expert prior to each interview. Once we completed the interviews, we conducted the content analysis of these responses to determine themes in responses to questions about DOT's and AAR's estimates and views of business benefits. Finally, we interviewed the railroads, industry associations, and others described above regarding the potential business benefits of ECP brakes.

[9]Office of Management and Budget, *Circular A-4* (Washington, D.C.: September 17, 2003).

[10]GAO, *Standards for Internal Controls in the Federal Government,* GAO-14-704G (Washington, D.C.: September 2014).

To determine how DOT and industry estimated the potential safety benefits of ECP brakes, we reviewed the key rulemaking documents described above, as well as documentation specific to engineering modeling and related analyses used by both DOT and AAR to estimate the potential safety benefits of ECP brakes. DOT contracted with Sharma and Associates to conduct modeling using LS-DYNA. The Transportation Technology Center, Inc. (TTCI)—an AAR subsidiary—conducted modeling using the Train Operations and Energy Simulator (TOES). Key documents we reviewed included Sharma and Associates' 2015 letter report,[11] and a TTCI report detailing its modeling effort.[12] We compared DOT's efforts against criteria for conducting such modeling, including OMB Circular A-4, and National Academies of Science (NAS) guidance on principles and practices for conducting statistical analyses by federal agencies.[13] Although DOT's modeling of ECP brakes was not a statistical analyses, we believe that certain parts of this NAS guidance applies to DOT's work.[14] We did not independently validate DOT's and the industry's modeling and related analysis of the potential safety benefits of ECP brakes.

We also interviewed FRA staff as well as staff with Sharma and Associates regarding the TEDS and LS-DYNA modeling and staff with AAR and TTCI regarding TTCI's TOES modeling, and we reviewed studies conducted by the National Transportation Safety Board (NTSB) regarding the potential safety effects of ECP brakes[15] and interviewed key NTSB staff.

[11]Sharma & Associates, Inc., *Letter Report: Objective Evaluation of Risk Reduction from Tank Car Design & Operations Improvements—Extended Study* (March 2015).

[12]Joseph Brosseau, Transportation Technology Center, Inc., *Analysis and Modeling of Benefits of Alternative Braking Systems in Tank Car Derailments*, R-1007 (Pueblo, CO: September 2014).

[13]National Research Council of the National Academies, *Principles and Practices for a Federal Statistical Agency. fifth ed.* (Washington, D.C.: 2013).

[14]More specifically, we believe that parts of that guidance regarding data collection, openness about data limitations and the methods and assumptions used, and review by third parties, are relevant to other types of analyses.

[15] NTSB, *Train Braking Simulation Study: Train Derailment, Opposing Train Struck Derailed Car and Derailed, Fire and Evacuation* (Washington, D.C.: July 2015).

We interviewed the 13 experts discussed above about the potential safety benefits of ECP brakes as well as the modeling efforts conducted by both DOT and TTCI. We assembled a summary table describing each modeling effort, key variables and assumptions, key differences, and key arguments made by DOT and AAR against each other's modeling efforts. We provided this table to each expert prior to each interview. As noted, we used a semi-structured interview guide for these interviews and conducted a content analysis to analyze expert responses and viewpoints on the potential safety benefits of ECP brakes and DOT and TTCI modeling efforts.

We also interviewed the railroads, industry organizations, manufacturers, and others described above regarding the potential safety benefits of ECP brakes as well as the modeling conducted by both DOT and AAR.

Appendix II: List of Selected Experts

• Mehdi Ahmadian	Center for Vehicle Systems and Safety at Virginia Tech University
• Chris Barkan	University of Illinois at Champaign-Urbana
• George Bibel	University of North Dakota
• David Clarke	University of Tennessee
• Philip Daum	Engineering Systems, Inc.
• Steven Ditmeyer	Transportation Technology and Economics (formerly with FRA and Burlington Northern Railroad)
• Steven Kirkpatrick	Applied Research Associates
• Simon Lymbery	Aurizon (Australia)
• Dave van der Meulen	Railway Corporate Strategy (South Africa)
• Bruce Sismey	SNC-Lavalin Australia
• Gerhard Thelen	Retired, Norfolk Southern Corporation
• Elton Toma, Ph.D., P.Eng.	National Research Council, Canada
• Dr. Allan M Zarembski, PE, FASME, Hon. Mbr. AREMA	University of Delaware

Appendix III: Expert Responses to Selected Semi-Structured Interview Questions

GAO analyzed the results of semi-structured interviews regarding electronically-controlled pneumatic (ECP) conducted with 13 experts (listed in appendix II) in train braking technology, safety and operations. The analysis of responses to selected questions is summarized below.

Table 3: Summary of Expert Responses

Question[a]	Agree (Y)	Disagree (N)	Neutral/ Maybe	No Response/ Not Able to Comment
Is one of the methodologies used to model electronically-controlled pneumatic (ECP) brakes—the Department of Transportation's (DOT) or Association of American Railroads (AAR)—preferable for assessing the benefits of braking systems?[b,c]	3	8	0	2
Did DOT take a simplified approach to modeling the dynamics of a derailment?	8	1	2	2
Was it appropriate for DOT to use averages to present the results of its modeling and related analysis?	1	5	5	2
Are ECP brakes likely to only affect kinetic energy dissipation rather than derailment dynamics?[d]	6	3	1	3
Was AAR's process used to estimate the additional force that would be created in a derailment[e] appropriate?	5	3	0	5
Was DOT's cost estimate to equip locomotives reasonable?	1	1	0	11
Will railroads be able to manage high-hazard flammable unit trains as dedicated systems?	6	2	0	5
Could reliability problems be avoided through a larger rollout?	8	0	0	5
Was it appropriate for DOT to use one high-consequence event to estimate the cost per gallon spilled as part of its calculation of ECP safety benefits?	3	5	0	5
Was it appropriate for DOT to use a constant derailment rate as part of its calculation of ECP safety benefits?	1	9	1	2
Does DOT's allowance for reduced required inspections provide a benefit for ECP-equipped trains despite trains stopping for other reasons?	8	0	3	2
Do you have concerns with DOT's approach to estimating fuel savings?	5	1	1	6
Do you have concerns with DOT's approach to estimating wheel savings?	6	1	1	5
Will installation of ECP brakes be a significant challenge for railroads?	5	3	1	4
Will the integration and interaction with ECP and PTC and other technologies be a significant challenge for railroads?	2	6	0	5

Source: GAO Analysis. | GAO-17-122

[a]We do not reproduce the exact wording of the questions we asked experts, paraphrasing them for brevity and clarity.

[b]Twelve of the experts whom we interviewed described themselves as having at least moderate familiarity with computer simulations of train operations; one cited minimal familiarity and did not answer any of the questions related to modeling.

[c]For this question, an "agree" or "disagree" response means that the experts generally leaned, or did not lean, respectively, towards one or the other methodology. Experts that leaned towards one methodology did not necessarily agree with the entire approach taken.

[d]This question asks experts' opinion of AAR's statement that the type of braking system used affects how physics (i.e., kinetic energy dissipation) stop a train prior to the point of derailment, but not what happens after a derailment occurs, such as a puncture to the tank car. If trains equipped with ECP brakes can only affect the former, then their safety benefits may be more limited.

[e]AAR and others refer to this force as a "blockage force."

Appendix IV: Comments from the Department of Transportation

U.S. Department
of Transportation

Office of the Secretary
of Transportation

Assistant Secretary
for Administration

1200 New Jersey Avenue, SE
Washington, D.C. 20590

SEP 22 2016

Susan Fleming
Director, Physical Infrastructure Issues
U.S. Government Accountability Office (GAO)
441 G Street, NW
Washington, D.C. 20548

Dear Ms. Fleming:

The Department of Transportation's (DOT) responsibility as a safety regulator is specific: save lives, prevent injuries, and protect property and the environment. To fulfill this responsibility, we adhere to the rigorous Federal rulemaking process, followed by systematic oversight and enforcement when needed. By law, rulemaking requires thorough cost and benefit analyses; collection and consideration of public input; and revision of proposed regulations as appropriate to reflect public input and reduce burdensome requirements.

DOT's final rule on electronically controlled pneumatic (ECP) brakes resulted from this demanding process, based on conservative assumptions, credible data, and well-respected dynamic models. We collected and fully considered hundreds of comments and testimonies from the public, railroads, brake manufacturers, and numerous organizations during two comment periods. Moreover, it reflects not only FRA expertise, but also the best judgment of professionals throughout DOT and Office of Management and Budget reviewers. The final rule, developed in multiple iterations with many levels of review and comment, yielded the most safety improvement with the lowest burden and cost.

We disagree with many of the draft report findings and statements. The approach GAO used in the draft report generates unwarranted doubt about DOT's rule. GAO's report structure — presenting industry and expert comments side-by-side with Government evidence— suggests either side could be correct. While DOT's analyses were fully vetted through the rigorous and documented rulemaking process, the draft report provides no record that industry assertions underwent similar peer review or critical evaluations. The draft report does not characterize this difference between the analyses. Additionally, the report does not present the information DOT provided GAO during the audit that refutes these industry and expert assertions. Some of our concerns are listed below:

- *Disagreement among DOT and the industry on the rule's effect on smaller railroads.* The rule specifically excludes small railroads' operations; therefore, it cannot increase their costs. GAO did not make clear that the rule's scope is a matter of fact, not opinion, meaning the vague concerns are unfounded.

- *An expert's comment that DOT did not make information available about certain assumptions.* DOT made this specific information available in letter reports published during the rulemaking process and provided them to GAO during the audit. Moreover, DOT used AAR's own design, manufacturing, and performance standards to develop the model. Specifically, inputs to the model are within AAR's Standards and Practices (M-1001) allowable tolerances for brake operations and performance, dimensions and movement limits on couplers, and safe and unsafe trucks (wheel-rail lateral forces).
- *Industry's assertion that foreign railroads' ECP experience is not relevant.* In fact, Australian and South African railroads are expanding their use of ECP braking systems, and they are using the same type of equipment from the same manufacturers that U.S. railroads use. Moreover, many U.S. railroads have closed loop operations similar to the Australian and South African trains, which go back and forth between the same origin and destination without being broken up.
- *Comparison of DOT and industry safety benefit calculations.* The Association of American Railroads' results differed from DOT's because they addressed different questions. DOT answered the question, "After a high-hazard flammable unit train derails, will ECP brakes reduce harm (in terms of tank car punctures) compared to other braking systems?" Industry modeling described the number of cars that would reach the derailment point with different braking systems—a question that does not capture the relationship between train kinetic energy and puncture risk.

In addition, we cannot determine from the draft report what the GAO experts' specific concerns were about DOT's modeling, because GAO presented either insufficient information or incompatible statements. For example,

- GAO states experts had "concerns that DOT may have oversimplified" its computer-based modeling, without elaborating why or to what extent DOT's methodology might be inappropriate to quantify the relative benefits of alternate braking systems with respect to mitigating damage in a derailment.
- GAO cites experts' comment that DOT could improve its derailment modeling with "more rigorous statistical analysis." DOT did not base its modeling on sampling, so statistics have no role. Finite element modeling, the basis for the final rule, uses the laws of physics to generate precise predictions about objects in motion. Statistical analysis estimates a population's attributes from the attributes of samples.

We look forward to industry providing us more operational data about high-hazard flammable unit trains with ECP braking systems. We expect it will confirm our findings derived during the rulemaking process: the physical properties and safety benefits of ECP technology reduce the likelihood of tank car punctures and releases of hazardous material.

We believe GAO did not provide sufficient and appropriate evidence—specifically, it did not present its assessment of industry and expert comments—to justify its findings and conclusions. As a result, we do not concur with the recommendations in the draft. Nevertheless, we will fully consider GAO's final report, consistent with the Fixing America's Surface Transportation Act (FAST Act).

We appreciate the opportunity to respond to the GAO draft report. Please contact Madeline M. Chulumovich, Director, Audit Relations and Program Improvement, at (202) 366-6512 with any questions or if you would like to obtain additional details.

Sincerely,

Jeff Marootian
Assistant Secretary for Administration

Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

Susan A. Fleming, (202) 512-2834 or Flemings@gao.gov

Staff Acknowledgments

In addition to the contact named above, Sharon Silas (Assistant Director), Matt Rosenberg (Analyst in Charge), Namita Bhatia-Sabharwal, David Hooper, Tara Jayant, Delwen Jones, Sara Ann Moessbauer, Madhav Panwar, Malika Rice, and Paola Tena made key contributions to this report.

Appendix VI: Accessible Data

Agency Comment Letter

Text of Appendix IV: Comments from the Department of Transportation

Page 1

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Washington, D.C. 20590

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Sincerely,

Jeff Marootian

Assistant Secretary for Administration

Accessible Text

Accessible Text for Figure 1: Brake Signals on Trains with Conventional, Distributed Power (DP), and Electronically Controlled Pneumatic (ECP) Brakes

Conventional air brakes: When the brakes are applied, the brake signal travels from the locomotive to cars in succession at a speed slightly slower than the speed of sound.

Distributed power: The head locomotive sends a radio signal to other locomotives in the train to send the brake signal to cars at a speed slightly slower than the speed of sound.

Electronically controlled pneumatic (ECP) brakes: When the brakes are applied, the lead locomotive sends a signal at the speed of light to all cars in the train to begin braking simultaneously.

Source: GAO analysis of information from the Department of Transportation (DOT). | GAO-17-122

Accessible Text for Figure 2: Timeline of Electronically Controlled Pneumatic (ECP) Brake Milestones

1994

Burlington Northern Santa Fe Railway (BNSF) began to test and research electronically controlled pneumatic (ECP) brakes.

1995

Union Pacific (UP) operated ECP brakes on intermodal trains between Chicago and Los Angeles.

2000

November 2000 – CSX Transportation (CSX) began operating with ECP brakes on one coal train between Corbin, KY, and Stilesboro, GA.

2006

FRA commissioned a report on ECP brakes by Booz Allen Hamilton, which provided information on the potential costs and benefits of ECP brakes.

2007

March 2007 – FRA granted a waiver to BNSF and Norfolk Southern Railway (NS) to allow trains equipped with ECP brakes to travel up to 3,500 miles —instead of the normal 1,000 or 1,500 — without a brake inspection.

October 2007 – NS started using ECP brakes on a coal train on a Pennsylvania route.

2008

NS added ECP brakes to four total trains (two coal routes in Virginia, and two coal routes between West Virginia and North Carolina); discontinued use on the two trains between WV and NC because the power plant closed down.

January 2008 – BNSF began operating two coal trains with ECP brakes from Wyoming to Alabama; discontinued one in 2012 and the other is still in service.

September 2008 – Canadian Pacific (CP) began operating with ECP brakes on two coal trains in British Columbia; discontinued use in November 2012.

October 2008 to August 2009 – UP operated ECP brakes on a train from Long Beach, CA, to Mesquite, TX

October 2008 – The Department of Transportation (DOT) issued a Final Rule establishing ECP brake standards and encouraging railroads to adopt ECP brakes by allowing them to use trains with ECP brakes to travel longer distances between required inspections.[a]

2009

August 2009 – UP operated ECP brakes on a train between Oakland, CA, and Seattle, WA.

2010

May 2010 – FRA granted BNSF and NS another waiver allowing them to jointly operate an ECP-equipped train to travel up to 5,000 miles without a brake inspection.

2014

August 2014 – DOT published a Notice of Proposed Rulemaking regarding railroad tank car requirements and ECP brakes.[b]

2015

January 2015 – FRA granted an extension to the 2010 waiver and NS and BNSF began jointly operating a train with ECP brakes between Wyoming and Georgia.

May 2015 – DOT issued a Final Rule on tank car safety requiring, among other things, ECP brakes on certain trains hauling flammable liquids such as crude oil by 2021 or 2023 depending on what they haul.[c]

June 2015 – The Association of American Railroads (AAR) filed administrative appeal against the rule, citing challenges freight railroads in the US have faced with ECP brakes and problems with DOT's estimates of the potential safety benefits.

June 2015 – The American Petroleum Institute, the American Short Line and Regional Railroad Association, and others filed suit against the rule.

November 2015 – DOT denied the administrative appeals; AAR then filed suit against DOT.

December 2015 – The Fixing American's Surface Transportation Act enacted, requiring DOT to conduct testing of a tank train equipped with ECP brakes. Based on test results, DOT must update the analysis that supported its final rule and then re-issue its rulemaking if it determines that the potential benefits of ECP brakes justify the costs; if not, it should eliminate the ECP brakes requirement. Lawsuit is on hold pending this re-evaluation.[d]

2016

June 2016 – BNSF ceased all ECP operations, including train operated jointly with NS.

Notes:

[a] 73 Fed. Reg.61512 (Oct. 16, 2008)

[b] 79 Fed. Reg. 45016 (Aug. 1, 2014)

[c] 80 Fed. Reg. 26644, 26645 (May 8, 2015)

[d]. Pub. L. No. 114-94, § 7311, 129 Stat. 1312, 1601 (Dec. 4, 2015)

Source: GAO. | GAO-17-122

Accessible Text for Figure 3: Department of Transportation's (DOT) Modeling Key Steps

In LS DYNA[a]

1. Determined a set of representative operating conditions and defined simulations for varying train speeds, train lengths, and brake system types including conventional air brakes, electronically controlled pneumatic (ECP) brakes and distributed power (DP).
2. Used LS DYNA to model a number of different derailment simulations where an external lateral force is applied to initiate a derailment and emergency braking force is applied at every car.
3. Compiled simulation results to determine impact forces[b] for each operating condition.

Analysis steps to quantify probability of puncture

4. Quantified the puncture resistance of several tank car designs for a range of representative impactor sizes and forces from past published research.
5. Evaluated the probability of puncture for each car design, operating speed, train length, and brake system type by combining simulation results from LS DYNA with the additional analyses.
6. Validated the methodology based on comparing the number of punctures and number of cars derailed to actual Federal Railroad Administration (FRA) derailment data.

Analysis steps for conclusion of ECP brakes effectiveness[c] rate

1. Calculated the distribution of the point of derailment along a train for each speed condition, based on actual FRA-recorded derailments from 2000 to 2014.
2. Used the probability of puncture data for new Department of Transportation (DOT) tank car standards (from step 5 above), across the different train lengths and brake system types to estimate how many cars would puncture on trains with each braking configuration.
3. Determined an effectiveness rate based on how many cars were estimated to puncture for each set of simulations and weighted these rates to conclude that on trains with ECP brakes, 19.7 percent fewer cars will puncture compared to trains with DP.

Source: GAO analysis of information from DOT. | GAO-17-122

Accessible Text for Figure 4: Overview of Association of American Railroads' (AAR) Modeling

Association of American Railroads (AAR) electronically controlled pneumatic (ECP) brakes modeling

1. Determined inputs and assumptions including train weight, speed at time of brake application, number of cars, track grade, and car types.
2. Analysis in Train Operation and Energy Simulator (TOES) model of stopping distance and time of trains with ECP brakes, distributed power (DP), and conventional air brakes.
3. Introduction of artificial blockage force of 500,000 lbs. at the point of derailment to simulate additional force of derailment (on top of stopping effect of brakes).
4. Analysis in Excel to estimate stopping time and distance of trains with ECP, DP, and conventional air brakes with introduced blockage force to determine how many cars reach the point of derailment.
5. Conclusion that ECP brakes prevent 1.2 additional cars from reaching the point of derailment compared to DP and 1.6 cars compared to conventional air brakes.

Source: GAO analysis of AAR information. | GAO-17-122

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