Expert Report Prepared for:
The Association of American Railroads

Assessment of European Railways:
Characteristics and Crew-Related Safety

By:

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Contents

I. Overview and Key Findings ................................................................. 3
   A. Oliver Wyman Introduction .......................................................... 3
   B. Key Findings ............................................................................. 3

II. Comparison of US and European Railroads ........................................... 9
   A. Network Overview ...................................................................... 14
   B. Freight Characteristics ............................................................... 16
   C. Operating Complexity .................................................................. 20
   D. Country Profiles ......................................................................... 24
   E. Summary ..................................................................................... 38

III. European Rail Safety Analysis .............................................................. 41
   A. Safety Data Analyzed .................................................................... 45
   B. Overall Significant Accident Rates ............................................... 46
   C. Investment and Accident Rates .................................................... 49
   D. Recent Crew Transition and Accident Rates ................................... 52
   E. Eastern European Accident Rates ............................................... 52
   F. Summary ..................................................................................... 60

Appendix A. European Advanced Safety Technology .................................. 62
Appendix B. Safety Analysis Definitions and Reporting ............................... 69
Appendix C. Data Sources ..................................................................... 74
I. Overview and Key Findings

A. Oliver Wyman Introduction

With offices in 50+ cities across 27 countries, Oliver Wyman is a leading global management consulting firm that combines deep industry knowledge with specialized expertise in strategy, operations, risk management, organizational transformation, and leadership development. The firm’s 3,000 professionals help clients optimize their businesses, improve their operations and risk profile, and accelerate their organizational performance to seize the most attractive opportunities.

Oliver Wyman’s Rail Practice employs the largest and most experienced staff in the world dedicated to the rail industry and is widely recognized as the premier management consultancy to state-owned and private freight and passenger railroads. It has carried out major strategic, operational, and financial planning and evaluation assignments for major rail operators and infrastructure providers in Europe, as well as railroads in North America, South America, Africa, and the Pacific Rim. Oliver Wyman’s European rail experience includes work for public and private entities in Germany, France, Italy, UK, Poland, Finland, Hungary, and the Czech Republic, among others. Many of Oliver Wyman’s assignments for its rail clients include evaluating infrastructure, equipment, and operations activities for both passenger and freight railways. Oliver Wyman staff members are leading experts in safety and train crew management and network planning and operations.

B. Key Findings

On March 14, 2016, the Federal Railroad Administration (FRA) issued a Notice of Proposed Rulemaking (NPRM) (Docket # FRA-2014-0033), in which it proposes regulations establishing
minimum requirements for the size of train crews depending on the type of operation. A minimum requirement of two crew members is proposed for all freight railroad operations (with certain exceptions).

Oliver Wyman was asked to analyze the FRA’s approach with regard to data on European railroad operations in the February 18, 2016 Regulatory Impact Analysis (RIA) that the FRA prepared to support the NPRM. Specifically, Oliver Wyman 1) assessed the FRA’s assertions that European rail operations are not “comparable” to US rail operations; and 2) analyzed European safety data to determine if one-person crews are as safe as two-person crews – an analysis the FRA did not carry out.

Oliver Wyman’s key findings include the following:

- In the RIA, the FRA asserts that European railroads are neither relevant nor comparable to US railroads. Oliver Wyman’s analysis found however that the interconnected standard gauge European network serves an economy approximately as large as the United States in terms of GDP. The rail network is as large as or larger in terms of route-kilometers than that of the United States, and has a train density (daily trains operated per route-kilometer) approximately twice that of the United States. The European network also has a greater percentage of passenger trains, which are intermixed with and operate at higher speeds than freight trains, and multiple freight and passenger operators sharing infrastructure, making for a more operationally complex network. Freight traffic in Europe also has a level of diversity similar to that of freight traffic in the United States, including mix of commodities, mix of dangerous and non-dangerous goods, and mix of train types (unit train, mixed carload

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merchandise, and intermodal) – including a significant number of retarder-equipped hump yards to handle carload traffic.

- The FRA asserts that: “It is also apparent that railroads in these countries can be considered to be industrial type railroads servicing one origin and one destination only.”² The FRA’s conclusions, however, are based on a review of a small sample of European rail operators and thus these findings are skewed based on what is only a very small segment of European rail activity. Most of the legacy rail operators (i.e., national railroads prior to liberalization), as in the United States, operate a full range of unit train, intermodal trains, and carload manifest trains. Many of the smaller operators that have started service since liberalization do operate point-to-point unit trains, but have joined the legacy carriers and entered into the carload manifest and intermodal business as well. In Europe the ownership of the track is divorced from the operation of the trains and thus unlike the United States, one must look not at the individual operating companies, but at the full network to really grasp the operating environment. In Germany alone there are over 200 freight operators and over 100 passenger operators sharing a common network that accounts for nearly 25 percent of European train-kilometers.

- “FRA also found that most of these foreign operations would meet the requirement in one of the exceptions of the proposed rule (due to their size).”³ This assertion is only true if the FRA dismisses its own proposed rule that such trains must not exceed a maximum speed of 25 mph (42 kmh). If these operators were restricted to such speeds, the European network would grind to a halt. These varied operating companies primarily operate on the high-density

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² Ibid., p. 19.
³ Ibid., p. 21.
European mainline network, not, as implied by the FRA, only on the low-density branch line
feeder network.

- Most European railroads operate with one-person crews. Countries with one-person crews
  account for 94.1 percent of European train activity (train-kilometers). Many railroads in
  Western Europe have operated with one-person crews since shortly after World War II. As
  the railroads were rebuilt and electrified, many countries implemented one-person crews to
  alleviate manpower shortages, take advantage of electric and diesel locomotive technology
  (no longer requiring a fireman), and to more economically compete in a shorter haul, truck-
  competitive marketplace. Implementation of advanced train control technology has not been
  a prerequisite for the adoption of one-person crews in Europe. Indeed, despite the
  predominance of one-person crews, the EU has no plans to install advanced train control
  technology (ERTMS) on 75 percent of its network. (By comparison, the US will install
  positive train control on at least 60 percent of its network.)

- There is no argument that European freight trains are shorter than those operated in the
  United States, in large part because of the high density of trains operated and the desire to
  keep block sizes shorter to better accommodate close spacing of freight and passenger trains
  and provide greater network fluidity. However, shorter block sizes and a greater number of
  interlockings mean that there are far more signals per route-kilometer, and Europe’s train
  density – double that of the US – means more traffic control transactions (signal indications
  and dispatcher communications) as well. Thus, in most European countries, a higher
  workload is handled safely and efficiently by a single person in an environment where the
tolerance for error is far less than in the United States (where larger slow-moving freight trains and limited passenger traffic are the norm).

- In the RIA, the FRA states that it is aware of international one-person crew operations, but asserts that “There are no safety data available to account for the safety record of one-person crews. …These data are not readily available.”\(^4\) We do not understand why the FRA was unable to secure this data, since it is publicly available, and we have included links to the data in this report (see Appendix C). Based on an analysis of this data, one-person crew operations typically experience lower levels of significant accidents than two-person crews in Europe.

  Additionally, Western European railways with one-person crews have lower accident rates than Eastern European railways (both one-person and two-person), which may reflect higher levels of investment in infrastructure. To adjust for the different accident rates observed between Eastern and Western Europe, and because five of the six remaining two-person crew operations are in Eastern Europe, Oliver Wyman also conducted an analysis comparing one-person versus two-person crews in Eastern Europe. For most types of accidents and overall significant accidents, there is no statistically significant difference between one-person and two-person crews in these Eastern European countries.

- The FRA asserts that “A second crew member could be instrumental in limiting the damages and injuries after an accident takes place.”\(^5\) Oliver Wyman examined the economic impact and the number of fatalities in Eastern Europe for one-person and two-person crews and

\(^4\) Ibid., p. 19.
\(^5\) Ibid., p. 6.
concluded that there was no discernible difference in the magnitude of accidents based on crew size. Furthermore, the number of employee fatalities appears to be significantly higher for two-person crews than for one-person crews, although statistically we could not confirm this. The FRA asserts that “In rare instances, having a second crew member aboard may result in an additional injury or fatality if a serious accident occurs,” but based on Oliver Wyman’s analysis of Eastern European data, exposing two crew members to a field operating environment may actually lead to greater fatalities.

In Oliver Wyman’s experience, safe train operations have more to do with what is in front of a locomotive, rather than what it is pulling. Most European railroads have used single-person crews on freight trains for decades, predating advanced train control technology. They use single-person crews despite the fact that Europe has twice the train density, far more passengers sharing the network with freight, and far more control transactions per route-kilometer – and yet suffers no reduction in crew-related safety.

6 Ibid., p. 5.
II. Comparison of US and European Railroads

Trends in both the US and abroad are driving the increased use of single-person train crews. There is a long history of technological improvements in the rail industry that have led to productivity gains and set new standards for safety. The use of single-person crews is widespread internationally, for both freight and passenger trains, and on rail networks similar to the United States in size and complexity. The use of single-person crews on the majority of the European rail network is one such example.⁷

In the FRA’s “Train Crew Staffing: Notice of Proposed Rulemaking, Regulatory Impact Analysis” (RIA) of February 18, 2016, the FRA reviewed average train length and train weight for a small sample of European rail operators in Sweden, Norway, Denmark, and the UK. The review did not include large rail networks such as those of Germany and France, which account for a large share of total European rail traffic – and which have one-person crews (Exhibit II-1). In fact, 94.1 percent of all European rail traffic (train-kilometers) is moved by one-person crews.⁸

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⁷ Throughout this document, a “one-person crew” means one person in the cab of the locomotive, without regard to whether, in the case of passenger service, there is an additional rail employee in the passenger section of the train (i.e., a conductor).
⁸ Information on crew size is based on Oliver Wyman’s direct knowledge of rail operators, interviews, and public data, supplemented with a survey of 12 countries where crew size was unknown.
Based on this review of a small sampling of operators, the FRA concluded that “It is clear that US rail industry operations are different from the railroads that have one-person operations in Europe….For the most part, foreign train operations are not comparable as train lengths, territory, and infrastructure are not as heavy or complex. It is also apparent that railroads in these countries can be considered to be industrial type railroads servicing one origin and one destination only.”

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9 Eurostat and Oliver Wyman analysis.
Oliver Wyman undertook a much more extensive analysis of available and recent data on the overall European rail network and individual national networks, which provided a more detailed and accurate picture of both rail operations and rail safety performance. Because rail services in Europe freely operate across borders, a proper analysis will consider the European Economic Area (EEA) as a whole, and on this basis, the EEA is comparable to the US rail network in terms of network size and density. European railroads on the networks of the 28 EEA countries (Exhibit II-2) operate a wide variety of services, both within their national territories and internationally (cross-border). The latter can involve changes in safety systems, electrification, and operating rules, and requires the use of complex interoperable equipment and multiple train control systems.

Similar to US freight railroads, European railroads provide intermodal, unit train, and carload manifest services for an extensive array of commodities (including dangerous goods) and serve a wide range of origins and destinations over varying distances. And because operations in Europe are now decoupled from infrastructure ownership, dozens of small “new entrant” and large legacy freight operators (e.g., DB Schenker Rail, SNCF) run trains simultaneously on mixed passenger-freight corridors and offer high-frequency services, meaning that operations are higher density than is the case for much of the US rail network. On a per-kilometer basis, European rail networks also are more complex, with a greater number of junctions, interlockings, turnouts, and train movements.

11 The European Economic Area (EEA) includes all 28 European Union Member States (of which 26 have railroads) plus Norway. Switzerland, while not an EEA member, is accorded the same rights and is part of Europe’s international rail system. The European Railway Agency and Eurostat compile rail statistics for the EU, Norway, and Switzerland. Thus, “Europe” and “EEA” as used in this report refer to all 28 countries for which data has been compiled and analyzed.
The FRA also asserts that “Most of these foreign operations would meet the requirements in one of the exceptions of the proposed rule, (due to their size).” The FRA appears to be referring to its specific exceptions for “Class III” freight railroads, i.e., short lines with less than 400,000 employee work hours per year.

The Surface Transportation Board also defines a Class III railroad as generating less than $38.06 million per year in revenues. It is true that there are many small “new entrant” rail operators in Europe that would meet the definitions of a Class III railroad in terms of work hours and revenues (just as in the United States) but in terms of train-kilometers, the majority of traffic

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is still handled by rail operations that are equivalent to Class I and Class II US railroads — just as in the United States (Exhibit II-3).

Furthermore, small rail operators in Europe are not like Class II short lines, which generally maintain their own low-speed Class 2 track (under 25 mph), and operate over short distances — typically hauling traffic to/from specific customers for interchange with the Class I railroads. Small rail operators in Europe instead have access to and operate over the entire European rail network — both domestically and cross-border. And where the FRA would exempt Class III US railroads from the two-person crew requirement where a rail operation “would take place at speeds not exceeding 25 mph,” many small European rail operators run trains on mainline networks that exceed this speed limitation (and require operators to maintain strict schedules or

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16 Proposed Rules,” Federal Register, op. cit. Note that heavy-grade operations (over steep mountains or hills) would not be exempted.
incur penalties). Maximum running speeds for freight – no matter the size of the operator – can reach 90 to 120 kmh, equivalent to 56 to 75 mph.\(^{17}\) They also operate extensively on lines over which passenger trains run as well, which the FRA has identified as a factor (presumably negative) in considering future approvals of one-person crew operations.

All of these factors combine to create an agenda of operating work events and decision points for European train crews – regardless of rail operator size – far greater than those facing train crews in the United States. In addition, safety issues routinely impact thousands of more lives than in the US, due to the close proximity of freight and high-density passenger services on the European rail network.

**A. Network Overview**

As shown in Exhibit II-4, the interlinked EEA-28 rail network serves a market that in total generates a slightly larger GDP than the United States. Operators on the standard gauge portion of the network have slightly shorter lengths of haul (freight train-km) and train sizes are shorter, but the overall network as a whole has three times the density (in train-kilometers), due to large numbers of passenger trains.

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\(^{17}\) Troche, Gerhard, “High-speed rail freight: Sub-report in efficient train systems for freight transport,” Centre for Research and Education in Railway Engineering at the Royal Institute of Technology Stockholm (Railway Group KTH), 2005, p. 11.
### Exhibit II-4: Overview of European and US Rail Networks, 2014

<table>
<thead>
<tr>
<th></th>
<th>Total Europe (EEA-28)</th>
<th>European Standard Gauge</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP, US$ billions</td>
<td>19,541</td>
<td>17,064</td>
<td>17,419</td>
</tr>
<tr>
<td>Route-kilometers</td>
<td>231,370</td>
<td>201,470</td>
<td>151,399</td>
</tr>
<tr>
<td>Total train-km, millions</td>
<td>4,317</td>
<td>3,968</td>
<td>1,233</td>
</tr>
<tr>
<td>Total train density, trains per day</td>
<td>51.1</td>
<td>54</td>
<td>22.3</td>
</tr>
</tbody>
</table>

In addition, total train density on the rail networks of the EEA-28 is much higher on a daily basis than in the United States (Exhibit II-5). Freight train density is comparable in a number of countries as well, including large economies such as Germany, Austria, and Poland. Train density is a far more important metric than train size in relation to safety considerations, since what is in front of the train (e.g., signals, objects on track, presence of other trains) dictates the train crew’s safety decisions far more than what is behind the cab. It is important to recognize as well that in the US environment, in most cases the train crew cannot directly observe more than the first 30 or 40 cars, which is about the average length of European freight trains.

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Note: European data covers all passenger, commuter, and freight operations on the regulated railway networks of each constituent nation. US data, with the exception of total train-km, covers Class I freight railroads only. Total train-km, derived from FRA operational data, covers all railway operations (Class I, passenger, commuter, regional, and short line) in the US. In order to remain consistent across the chart, total train-km was divided by Class I route km to yield a total train density of 22.3. If the total train-km figure were divided instead by 222,932 km, the length of the entire US railway network, the total train density would be 15.1 trains per day, 32 percent lower. Source: World Bank; European Railway Agency; European Commission (Eurostat); Independent Regulators’ Group, Fourth Annual Market Monitoring Report; Association of American Railroads, Analysis of Class I Railroads; Federal Railroad Administration, Operational Data Tables; Oliver Wyman analysis.
B. Freight Characteristics

In addition to the many passenger trains that run on the European network (which include commuter, regional, intercity, and high speed), freight trains carry a wide variety of cargo, including dangerous goods. Freight trains operated include local, general merchandise, and unit trains. Further, many large rail networks carry a substantial share of intermodal traffic (containers, swap bodies, road vehicles, semi-trailers), as shown in Exhibit II-6.

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Evidence of the carload network in Europe is provided by a large number of retarder equipped hump yards in the European network. These facilities are not needed for handling unit train operations. Reported carload data (tonne-kilometers) is limited, but a number of countries report carload traffic to be a quarter or more of total traffic, including Germany, the largest rail freight market in Europe (Exhibit II-7).

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20 Eurostat. Four EEA-28 countries do not report this data. Includes containers and trailers.
Many of the freight trains operating over the European railway network carry dangerous goods (hazardous materials), which make up a sizable portion of the freight handled. Whereas dangerous goods traffic comprises approximately six percent of all freight handled in the United States, it comprises 12 percent of total freight tonnage and 13 percent of total freight tonne-kilometers in Europe. In Europe (as in the US) rail is considered the safer mode of transport and shipment of dangerous goods by rail is often encouraged rather than truck shipment of these goods. And on nearly all networks, these dangerous goods are handled by one-person train crews.

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21 Eurostat, all railroads reporting this data.
In addition, the amount of dangerous goods carried is particularly high in some European countries (Exhibit II-8). Thus, in some areas of the European railway network, the potential for an incident involving dangerous goods can be high.

**Exhibit II-8: Dangerous Goods Moved by Rail and Percentage of Total Rail Freight**

Million tonne-kilometers, 2014

There is no argument that European freight trains are shorter than those operated in the United States, in large part because of the high density of trains operated and the desire to keep block sizes shorter to better accommodate close spacing of freight and passenger trains and to provide greater network fluidity for the passenger trains on the network. However, the shorter block sizes and greater number of interlockings due to more double track and density of trackage create far more signals per route-kilometer. And twice the train density of the United States

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23 Eurostat, Oliver Wyman analysis.
means that European rail operations require far more traffic control transactions (signal indications and dispatcher communications) than is the case in the United States.

The FRA contends that this work should be done in the United States under the “supervision and command of the conductor” due to workload concerns. Yet a far higher workload in Europe is handled safely and efficiently by a single “train driver” in an environment where the tolerance for error is far less than in the United States, given Europe’s high passenger volumes and fast speeds, versus the larger slow-moving freight trains and low passenger train density commonly found in the United States. The FRA lists three primary tasks for a locomotive engineer, and all of these tasks are present in the European operating environment. Yet in a more complex, fast moving operating environment, without assistance from a conductor, the engineer is able to perform satisfactorily and as well as when there are two people in the train crew.

C. Operating Complexity

The European rail operating environment is also more challenging than that of the US, as a far larger number of operators run on most networks. Unlike in the US, where most railroads are shortlines serving a small territory and feeding a few large Class I’s, freight rail operators in Europe can operate virtually anywhere on the network by obtaining the necessary certification as a “railway undertaking” and applying to the relevant infrastructure managers for each country network for train slots. Total active freight and rail operators for countries reporting data are shown in Exhibit II-9.

24 Those three primary tasks are “1) coordinate with the conductor (or dispatcher) on information about the route, stops, delays, or other operation details; 2) ensure that the locomotive is ready to operate by checking for mechanical problems and for adequate levels of fuel, sand, water, and other supplies; and 3) under the conductor’s supervision and command, interpret train orders, signals, and operating rules.” Train Crew Staffing: Notice of Proposed Rulemaking, Regulatory Impact Analysis, op. cit., p. 32.
Exhibit II-9: Active European Rail Operators, 2014

In addition, the European rail network handles higher numbers and types of trains on a daily basis:

- Europe has twice the daily train activity of North America (51.6 versus 22.3 trains per day), primarily due to much higher passenger train activity across the network.

- Shorter train mean shorter blocks and more signals per track-kilometer (Exhibit II-10), which increases the number of control communications required for each minute of operation.

- Because passenger trains account for 81 percent of train-kilometers on the network, average train speeds are faster than in the United States.

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26 World Bank; European Railway Agency; European Commission (Eurostat); Independent Regulators’ Group, Fourth Annual Market Monitoring Report; Association of American Railroads, Analysis of Class I Railroads; Federal Railroad Administration, Operational Data Tables; Oliver Wyman analysis.
A significant percentage of rail traffic also moves internationally (cross-border) (Exhibit II-11). Indeed, for fully half of the EEA-28 networks, international traffic makes up 50 percent or more of tonne-kilometers.

Faster train speeds, shorter blocks, and more train activity mean that European freight train crews experience more challenges to safe operation every day than do US freight train crews. In addition, because trains are scheduled by slot on a mixed passenger-freight system, railway operators pay penalties for delays, putting additional pressure on crews to maintain schedules. Thus precision operations and higher speeds suggest that margins for error in Europe are far less than in the United States.

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28 Eurostat, all railroads reporting this data. International includes cross-border and transit.
D. Country Profiles

Oliver Wyman developed more detailed profiles of seven European countries to further demonstrate how these systems compare to the US in terms of variety and complexity of operations. Five are among the largest rail markets in Europe: Germany, France, Italy, UK, and Poland. In addition, two similarly sized Eastern European railroads, one with one-person crews (Lithuania) and one with two-person crews (Latvia), are profiled.

Far from being “industrial railroads,” freight rail operators in these countries haul a wide variety of commodities, serve a range of origins and destinations – including domestic, ports, and cross-border; and offer carload, unit train, and intermodal services. Furthermore, they face daily the increased complexity of operating freight on dense networks with high volumes of passenger trains and multiple above-rail operators.

1. Germany

Germany is the largest country in Europe on a GDP basis. Germany has one of the largest and densest rail networks in Western Europe. It is also the largest freight and passenger market in Europe in terms of tonnes/passenger-kilometers. With the exception of two dedicated high-speed passenger lines, the entire network runs mixed freight and passenger traffic. On some of the more heavily traveled double-track lines, train volume can exceed 400 trains per day. On a daily basis, the German rail network carries 1 million tonnes of freight and 7.38 million passengers.29

29 Eurostat.
Single-person crews were introduced in Germany with the abolishment of steam traction in the 1950s and 1960s. There are no limitations in Germany on freight train size, train weight, or carriage of hazardous materials when trains are operated by single-person crews.

**Exhibit II-12: Germany: Key Rail Statistics, 2014**

<table>
<thead>
<tr>
<th>Overall market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP, US$ billions</td>
<td>$3,757</td>
</tr>
<tr>
<td>Standard locomotive crew size</td>
<td>1 person</td>
</tr>
<tr>
<td>Active rail operators</td>
<td>365</td>
</tr>
<tr>
<td>Network size (line-km)</td>
<td>33,483</td>
</tr>
<tr>
<td>Network intensity (train-km/line-km per day)</td>
<td>85.4</td>
</tr>
<tr>
<td>Share of total European rail activity (train-km)</td>
<td>24.1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Freight rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight rail operators</td>
<td>230</td>
</tr>
<tr>
<td>Hump yards equipped with retarders</td>
<td>9</td>
</tr>
<tr>
<td>Freight density: tonne-km per line-km</td>
<td>3.36M</td>
</tr>
<tr>
<td>Freight intensity: train-km per line-km per day</td>
<td>20.8</td>
</tr>
<tr>
<td>Avg. freight load per train (tonnes)</td>
<td>442</td>
</tr>
<tr>
<td>Freight share of network usage (train-km)</td>
<td>24%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Passenger rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger rail operators</td>
<td>135</td>
</tr>
<tr>
<td>Pass. density: pass-km per line-km</td>
<td>2.67M</td>
</tr>
<tr>
<td>Pass. intensity: train-km per line-km per day</td>
<td>64.1</td>
</tr>
<tr>
<td>Pass. share of network usage (train-km)</td>
<td>76%</td>
</tr>
</tbody>
</table>

On the freight side, some 230 rail operators actively competed for freight and share access to the rail network. German freight rail hauls 42, 946 million tonnes-km per year of intermodal, and

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27, 129 million tonnes-km per year of carload traffic. Freight accounts for 24 percent of total train-kilometers.

The top ten rail freight hauled commodities for Germany are shown in Exhibit II-13. German rail operators haul a wide range of goods, including chemicals, plastics, metal ores and products, and energy products.

**Exhibit II-13: Top Ten Rail-Hauled Commodities in Germany, 2014**

![Pie chart showing top ten rail-hauled commodities in Germany, 2014](chart.png)

### 2. France

France has the second longest rail network in Europe. It is the second largest freight market and third largest passenger market in terms of tonnes/passenger-kilometers. France uses predominantly one-person crews.

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31 Eurostat, Oliver Wyman analysis.
Exhibit II-14: France: Key Rail Statistics, 2014\textsuperscript{32}

<table>
<thead>
<tr>
<th>Overall market</th>
<th></th>
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<tbody>
<tr>
<td>GDP, US$ billions</td>
<td>$2,604</td>
</tr>
<tr>
<td>Standard locomotive crew size</td>
<td>1 person</td>
</tr>
<tr>
<td>Active rail operators</td>
<td>30</td>
</tr>
<tr>
<td>Network size (line-km)</td>
<td>36,831</td>
</tr>
<tr>
<td>Network intensity (train-km/line-km per day)</td>
<td>36.4</td>
</tr>
<tr>
<td>Share of total European rail activity (train-km)</td>
<td>11.3%</td>
</tr>
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<table>
<thead>
<tr>
<th>Freight rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight rail operators</td>
<td>18</td>
</tr>
<tr>
<td>Hump yards equipped with retarders</td>
<td>5</td>
</tr>
<tr>
<td>Freight density: tonne-km per line-km</td>
<td>0.87M</td>
</tr>
<tr>
<td>Freight intensity: train-km per line-km per day</td>
<td>5.9</td>
</tr>
<tr>
<td>Avg. freight load per train (tonnes)</td>
<td>408</td>
</tr>
<tr>
<td>Freight share of network usage (train-km)</td>
<td>16%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Passenger rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger rail operators</td>
<td>12</td>
</tr>
<tr>
<td>Pass. density: pass-km per line-km</td>
<td>2.19M</td>
</tr>
<tr>
<td>Pass. intensity: train-km per line-km per day</td>
<td>30.6</td>
</tr>
<tr>
<td>Pass. share of network usage (train-km)</td>
<td>84%</td>
</tr>
</tbody>
</table>

On the freight side, 18 different rail operators actively competed for freight and share access to the rail network. French freight rail hauls 9,071 million tonnes-km per year of intermodal traffic. Freight accounts for 16 percent of total train-kilometers.

The top ten rail freight hauled commodities for France are shown in Exhibit II-15. French rail operators haul a wide range of goods, including miscellaneous mixed goods (typically intermodal), metals, agricultural products, chemicals and plastics, and food products.

Exhibit II-15: Top Ten Rail-Hauled Commodities in France, 2014

Million tonne-kilometers

3. Italy

Italy is the fourth largest freight and passenger market in terms of tonnes/passenger-kilometers. Similar to other European countries, most of the network is electrified and has mixed passenger and freight operations. Starting in 2003, a new state-of-the-art train control system was introduced and installed on the entire core network, as well as parts of the secondary network.

33 Eurostat, Oliver Wyman analysis.
Freight trains are permitted to be operated with single-person crews. Passenger trains are generally operated with single-person crews and a minimum of one conductor present in the train, but not in the locomotive cab.

**Exhibit II-16: Italy: Key Rail Statistics, 2014**

<table>
<thead>
<tr>
<th>Overall market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP, US$ billions</td>
<td>$2,156</td>
</tr>
<tr>
<td>Standard locomotive crew size</td>
<td>1 person</td>
</tr>
<tr>
<td>Active rail operators</td>
<td>44</td>
</tr>
<tr>
<td>Network size (line-km)</td>
<td>15,990</td>
</tr>
<tr>
<td>Network intensity (train-km/line-km per day)</td>
<td>56.6</td>
</tr>
<tr>
<td>Share of total European rail activity (train-km)</td>
<td>7.6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Freight rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight rail operators</td>
<td>25</td>
</tr>
<tr>
<td>Hump yards equipped with retarders</td>
<td>0</td>
</tr>
<tr>
<td>Freight density: tonne-km per line-km</td>
<td>1.33M</td>
</tr>
<tr>
<td>Freight intensity: train-km per line-km per day</td>
<td>7.7</td>
</tr>
<tr>
<td>Avg. freight load per train (tonnes)</td>
<td>475</td>
</tr>
<tr>
<td>Freight share of network usage (train-km)</td>
<td>14%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Passenger rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger rail operators</td>
<td>19</td>
</tr>
<tr>
<td>Pass. density: pass-km per line-km</td>
<td>2.84M</td>
</tr>
<tr>
<td>Pass. intensity: train-km per line-km per day</td>
<td>48.8</td>
</tr>
<tr>
<td>Pass. share of network usage (train-km)</td>
<td>86%</td>
</tr>
</tbody>
</table>

---

34 Eurostat, European Railway Agency, Independent Regulators’ Group, World Bank, Oliver Wyman analysis.
On the freight side, some 25 rail operators actively compete for freight and share access to the rail network. Freight accounts for 14 percent of total train-kilometers.

The top ten rail freight hauled commodities for Italy are shown in Exhibit II-17. Data on rail-hauled goods for Italy is limited, but traffic includes metals, food products, agricultural products, and chemicals and plastics.

Exhibit II-17: Top Ten Rail-Hauled Commodities in Italy, 2014

Million tonne-kilometers

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35 Eurostat, Oliver Wyman analysis.
4. **Poland**

Poland is the third largest freight market and eighth largest passenger market in terms of tonnes/passenger-kilometers. Rail operations predominantly use one-person crews.

**Exhibit II-18: Poland: Key Rail Statistics, 2014**

<table>
<thead>
<tr>
<th>Overall market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP, US$ billions</td>
<td>$960</td>
</tr>
<tr>
<td>Standard locomotive crew size</td>
<td>1 person</td>
</tr>
<tr>
<td>Active rail operators</td>
<td>82</td>
</tr>
<tr>
<td>Network size (line-km)</td>
<td>19,265</td>
</tr>
<tr>
<td>Network intensity (train-km/line-km per day)</td>
<td>30.4</td>
</tr>
<tr>
<td>Share of total European rail activity (train-km)</td>
<td>4.9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Freight rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight rail operators</td>
<td>69</td>
</tr>
<tr>
<td>Hump yards (retarder and non-retarder)</td>
<td>24</td>
</tr>
<tr>
<td>Freight density: tonne-km per line-km</td>
<td>2.47M</td>
</tr>
<tr>
<td>Freight intensity: train-km per line-km per day</td>
<td>10.6</td>
</tr>
<tr>
<td>Avg. freight load per train (tonnes)</td>
<td>640</td>
</tr>
<tr>
<td>Freight share of network usage (train-km)</td>
<td>35%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Passenger rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger rail operators</td>
<td>13</td>
</tr>
<tr>
<td>Pass. density: pass-km per line-km</td>
<td>0.83M</td>
</tr>
<tr>
<td>Pass. Intensity: train-km per line-km per day</td>
<td>19.1</td>
</tr>
<tr>
<td>Pass. share of network usage (train-km)</td>
<td>65%</td>
</tr>
</tbody>
</table>

---

On the freight side, some 69 rail operators actively compete for freight and share access to the rail network. Polish freight rail hauls 3,334 million tonnes-km per year of intermodal and 6,794 million tonnes-km of carload traffic. Freight accounts for 35 percent of total train-kilometers.

The top ten rail freight hauled commodities for Poland are shown in Exhibit II-119. Polish rail operators haul a wide range of goods, including energy products, metal ores, chemicals/plastics, and agricultural products.

**Exhibit II-19: Top Ten Rail-Hauled Commodities in Poland, 2014**

Million tonne-kilometers

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37 Eurostat, Oliver Wyman analysis.
5. United Kingdom

The UK is the sixth largest freight market and second largest passenger market in Europe in terms of tonnes/passenger-kilometers. The Channel Tunnel provides seamless passenger and freight service to/from continental Europe. The UK uses predominantly one-person crews.

Exhibit II-20: UK: Key Rail Statistics, 2014

<table>
<thead>
<tr>
<th>Overall market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP, US$ billions</td>
<td>$2,597</td>
</tr>
<tr>
<td>Standard locomotive crew size</td>
<td>1 person</td>
</tr>
<tr>
<td>Active rail operators</td>
<td>35</td>
</tr>
<tr>
<td>Network size (line-km)</td>
<td>16,086</td>
</tr>
<tr>
<td>Network intensity (train-km/line-km per day)</td>
<td>93.0</td>
</tr>
<tr>
<td>Share of total European rail activity (train-km)</td>
<td>12.6%</td>
</tr>
</tbody>
</table>

**Freight rail market**

| Freight rail operators                | 10    |
| Hump yards equipped with retarders    | 0     |
| Freight density: tonne-km per line-km | 1.37M |
| Freight intensity: train-km per line-km per day | 6.5   |
| Avg. freight load per train (tonnes)  | 575   |
| Freight share of network usage (train-km) | 7%    |

**Passenger rail market**

| Passenger rail operators              | 25    |
| Pass. density: pass-km per line-km    | 4.02M |
| Pass. intensity: train-km per line-km per day | 86.5  |
| Pass. share of network usage (train-km) | 93%   |
On the freight side, ten rail operators actively compete for freight and share access to the rail network. Freight accounts for 7 percent of total train-kilometers.

The top rail freight hauled commodities for the UK are shown in Exhibit II-21. UK rail operators haul a significant share of energy products, as well as minerals, metals, food products, and miscellaneous mixed goods.

**Exhibit II-21: Top Ten Rail-Hauled Commodities in the UK, 2014**

Million tonne-kilometers

![Pie chart showing top ten rail-hauled commodities in the UK, 2014.]

6. Latvia

Latvia and Lithuania (below) represent smaller European markets with a high share of freight traffic. They are included in these country profiles largely because they are similar in size and function. Both are Baltic port countries and their railway networks serve as extensions of the Russian Railway network to the Baltic Sea ports. However, Latvia uses two-person crews and

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39 Eurostat, Oliver Wyman analysis.
Lithuania uses one-person train crews. Both networks have a similar distribution of commodities handled and more than 60 percent of their rail traffic is freight (among the highest percentages in Europe). Both handle heavier trains than is the case in most European countries.

**Exhibit II-22: Latvia: Key Rail Statistics, 2014**

<table>
<thead>
<tr>
<th>Overall market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP, US$ billions</td>
<td>$47</td>
</tr>
<tr>
<td>Standard locomotive crew size</td>
<td>2 people</td>
</tr>
<tr>
<td>Active rail operators</td>
<td>5</td>
</tr>
<tr>
<td>Network size (line-km)</td>
<td>1,860</td>
</tr>
<tr>
<td>Network intensity (train-km/line-km per day)</td>
<td>28.12</td>
</tr>
<tr>
<td>Share of total European rail activity (train-km)</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Freight rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight rail operators</td>
<td>3</td>
</tr>
<tr>
<td>Hump yards (retarder and non-retarder)</td>
<td>9</td>
</tr>
<tr>
<td>Freight density: tonne-km per line-km</td>
<td>10.45M</td>
</tr>
<tr>
<td>Freight intensity: train-km per line-km per day</td>
<td>17.0</td>
</tr>
<tr>
<td>Avg. freight load per train (tonnes)</td>
<td>1,686</td>
</tr>
<tr>
<td>Freight share of network usage (train-km)</td>
<td>60%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Passenger rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger rail operators</td>
<td>2</td>
</tr>
<tr>
<td>Pass. density: pass-km per line-km</td>
<td>0.35M</td>
</tr>
<tr>
<td>Pass. intensity: train-km per line-km per day</td>
<td>9.0</td>
</tr>
<tr>
<td>Pass. share of network usage (train-km)</td>
<td>40%</td>
</tr>
</tbody>
</table>

---

40 Eurostat, European Railway Agency, Independent Regulators’ Group, World Bank, Oliver Wyman analysis.
On the freight side, three rail operators compete for freight and share access to the rail network. Freight accounts for 60 percent of total train-kilometers. Latvia freight railroads move 305 million tonne-kilometers per year of intermodal traffic.

The top rail freight hauled commodities for Latvia are shown in Exhibit II-23. Latvia freight rail primarily hauls energy products, but also chemicals/plastics, agricultural and food products, and metals, among other goods.

Exhibit II-23: Top Ten Rail-Hauled Commodities in Latvia, 2014

Million tonne-kilometers

7. Lithuania

As noted above, Lithuania also represents a smaller European market with a high share of freight traffic. The most notable difference between Latvia and Lithuania is the number of operators on the network and the use of one-person versus two-person train crews.

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41 Eurostat, Oliver Wyman analysis.
Exhibit II-24: Lithuania: Key Rail Statistics, 2014

<table>
<thead>
<tr>
<th>Overall market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP, US$ billions</td>
<td>$81</td>
</tr>
<tr>
<td>Standard locomotive crew size</td>
<td>1 person</td>
</tr>
<tr>
<td>Active rail operators</td>
<td>35</td>
</tr>
<tr>
<td>Network size (line-km)</td>
<td>1,767</td>
</tr>
<tr>
<td>Network intensity (train-km/line-km per day)</td>
<td>22.17</td>
</tr>
<tr>
<td>Share of total European rail activity (train-km)</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Freight rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight rail operators</td>
<td>35</td>
</tr>
<tr>
<td>Hump yards equipped with retarders</td>
<td>0</td>
</tr>
<tr>
<td>Freight density: tonne-km per line-km</td>
<td>8.10M</td>
</tr>
<tr>
<td>Freight intensity: train-km per line-km per day</td>
<td>13.7</td>
</tr>
<tr>
<td>Avg. freight load per train (tonnes)</td>
<td>1,623</td>
</tr>
<tr>
<td>Freight share of network usage (train-km)</td>
<td>62%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Passenger rail market</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger rail operators</td>
<td>4</td>
</tr>
<tr>
<td>Pass. density: pass-km per line-km</td>
<td>0.21M</td>
</tr>
<tr>
<td>Pass. intensity: train-km per line-km per day</td>
<td>8.2</td>
</tr>
<tr>
<td>Pass. share of network usage (train-km)</td>
<td>38%</td>
</tr>
</tbody>
</table>

On the freight side, some 35 rail operators actively compete for freight and share access to the rail network. Freight accounts for 62 percent of train-kilometers on the network.

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The top rail freight hauled commodities for Lithuania are shown in Exhibit II-25. Lithuanian railroads haul a wide variety of commodities, including chemicals/plastics, coke/refined petroleum, metal and metal ores, and agricultural and food products.

**Exhibit II-25: Top Ten Rail-Hauled Commodities in Lithuania, 2014**

Million tonne-kilometers

![Exhibit II-25: Top Ten Rail-Hauled Commodities in Lithuania, 2014](image)

**E. Summary**

As the overall data on the EEA-28 and the individual country profiles above show, Europe’s rail system is highly diversified. Mixed freight and passenger systems are made more complex by the large number of operators and diversity of traffic, including carload, unit train, and intermodal on the freight side. Far from being single origin-destination industrial railroads, Europe’s freight railroads haul a large mix of commodities, just as do US railroads, serving both domestic (in-country) and international (cross-border) origins-destinations.

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43 Eurostat, Oliver Wyman analysis.
“The European operating environment is more complex than it is in the United States, with far more train movements; many of them passenger trains traveling at fast speeds. Train sizes and therefore block lengths are shorter, and there are many more interlockings in the network, meaning there are many more signals per track-mile than in the United States. The safety systems do not anticipate a red signal; ATP [Automatic Train Protection44] does not apply the brakes until you pass the red signal, so it does not offer as much protection as many believe it does. A far greater level of attentiveness is required in Europe, and the margin of error is much smaller than in the United States.” – Dave Brown, COO, Genesee & Wyoming

The above quote comes from someone with in-depth experience in both international and US rail operations. As COO of Genesee and Wyoming, Mr. Brown oversees an organization comprising not only the largest US shortline railroad operator but extensive operations in Europe (the UK, the Netherlands, and Poland) and Australia. Mr. Brown has extensive experience with US Class I railroading as well, having been the Chief Transportation Officer and then Chief Operating Officer of CSX, and working in the Operating Department at Norfolk Southern before going to CSX.

High complexity and train density mean that train crews in Europe face as many – if not more – decisions and work events every day than do US train crews and do not experience task overload; in addition, the technology deployed is not significantly different than that used in the United States.

“One-person crews have been used safely in Europe for decades in freight and passenger operations. Keolis having experience in both the US and European passenger environments, we have found that the task workload faced by a driver in the European environment is as great, or greater than, that experienced in North America,

44 ATP provides either a continuous or regular update of speed monitoring for each train (using trackside equipment) and causes the brakes to apply if the driver fails to bring the speed within the required profile.
as signal system block lengths are shorter and more oriented to passenger trains, and the amount of interlockings and double track are greater, leading to a greater number of signal aspects per kilometer than in the United States. Also, the number of train movements on the network is greater and therefore the number of communications activities with dispatchers and towers is greater than in the United States. “The entire network must be operated with a far greater level of precision and attentiveness to keep train activities fluid. Yet, this activity level has been safely accommodated using one-person crews since the 1980s in France, for example. Safety is a major concern in Europe as there are far more passenger trains on the network than in the United States, and to that end the European network is constantly being upgraded with new technology to automate operations to reduce driver task loads and to reduce the chance of human error.” – Bruno Auger, Rail Director, Keolis

The above quote also comes from someone with in-depth experience in both international and US rail operations. Keolis operates passenger trains on both the Virginia Railway Express (VRE) and the Massachusetts Bay Transportation Authority (MBTA) in the United States, and in Europe has operations in London, UK (Thameslink, London Midlands, Southeastern); Dusseldorf, Germany (Eurobahn); and Deventer, Netherlands (Syntus network). Keolis is a subsidiary of SNCF, France’s incumbent railroad, which operates both freight and passenger trains in Europe.
III. European Rail Safety Analysis

The FRA states that “In the absence of the proposed rulemaking, more higher-risk one-person operations could be implemented and impose larger risk on other trains, railroad employees, or society as a whole.” The evidence Oliver Wyman has obtained, based on publicly available European safety data, refutes this assertion. Indeed, as discussed later in this section, Eastern European countries, with similar economic histories and operating environments, include rail systems with both one- and two-person crew operations, and so can be directly compared with regard to resulting safety data.

In the prior section, Oliver Wyman demonstrated that European rail operations are relevant along many dimensions to US rail operations. Yet operations with one-person train crews account for 94.1 percent of all train-kilometers in Europe and have overall safety metrics as good as, or better than, operations with two-person crews. And according to the European Railway Agency (ERA), there has been a positive long-term trend of declining rail accident risk within the EU, despite significant reductions in overall railroad staff and the expansion of single-person operations over the same period.46

Oliver Wyman analyzed accident data for the 28 countries of the European Economic Area to determine the relative safety of European one-person and two-person crews. In the European Union, single-person crew operation has two preconditions:47

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47 Regulation promulgated at the national level, but consistent across the EU.
The presence of a working dead-man control system on the locomotive. This system involves a pedal or button that must be periodically pressed, thereby signaling that the train engineer is active and alert. If the device is not pressed when required, the train will come to a stop.

The locomotive is equipped with working Automatic Train Control/Automatic Train Protection (ATC/ATP) where such systems are installed on the main track. That is, ATC/ATP enables dispatchers to remotely operate signals and switches to ensure trains do not make conflicting movements.

One-person crews have been broadly implemented in many European countries as motive power and signal technology have changed. The example of Germany is shown in Exhibit III-1.

Exhibit III-1: Timeline for Single-person Crew Implementation in Germany

- 1960s: With steam locomotives, engine crews consisted of an engineer and fireman
- 1970s: Diesel and electric locomotives grow in number
- 1980s: Wide implementation of ATP signaling systems
- 1980s: Studies conducted using single-person engine crews on trains travelling up to 200 km/h
- 1991: Single-person engine crews permitted on trains travelling up to 200 km/h
- 1996: Second locomotive crew-person eliminated from all trains regardless of speed
- 2000s: ERTMS/ETCS implementation:
  - 2022: 2,500 km, 7.8% of network
  - 2030: 5,000 km, 14.9% of network
  - 2050: 21,000 km, 62.7% of network

ATP provides either a continuous or regular update of speed monitoring for each train (using trackside equipment) and causes the brakes to apply if the driver fails to bring the speed within the required profile. ATC is an integrated signaling system that guarantees the secure movement of trains. It integrates various subsystems positioned on-board and wayside, including ATP.

Oliver Wyman research.
Germany’s mainlines were electrified starting in 1949 and continuing through the 1980’s. Diesel locomotives replaced steam in non-electrified corridors during the 1950’s and 1960’s. As one-person crews in Germany were implemented, they were first restricted to trains which traveled at a maximum speed of 140 kmh. When automatic train protection (ATP) signaling systems (the US equivalent of automatic train stop or ATS) were widely implemented in the 1980’s, the maximum speed for one-person crewed trains was raised to 200 kmh as of 1991. In 1996, all trains were allowed to operate with one-person crews in the locomotive cab. While Germany is installing ERTMS on its network, it expects to achieve deployment of 60 percent (comparable to the level of PTC deployment in the US) only by 2050.

Implementation of single-person crews in Europe was done prior to the adoption of open access rules in 1994. Freight and passenger train operations were largely provided by state-owned railroads prior to liberalization. Employees were unionized, but as the government was also the railway owner, national policy superseded the perpetuation of unproductive work rules. In particular, implementation of one-person crews helped stem operating losses from intense modal competition in a more truck competitive market place characterized by shorter lengths of haul. Implementation of advanced train control technology has not been a prerequisite for the adoption of one-person crews. Indeed, despite the predominance of one-person crews, the EU has no plans to install advanced train control technology (ERTMS) on 75 percent of its network. (By comparison, the US will install positive train control on at least 60 percent of its network.)

The FRA lists the following tasks for conductors:

50 ATP provides either a continuous or regular update of speed monitoring for each train (using trackside equipment) and causes the brakes to apply if the driver fails to bring the speed within the required profile. ATS is a system that works in conjunction with onboard and wayside equipment to apply brakes at designated restrictions or on a dispatcher's signal, should the operator not respond properly.
1. Managing the train consist
2. Coordinating with the locomotive engineer for safe and efficient en route operation
3. Interacting with dispatchers, roadway workers, and others outside the cab
4. Managing paperwork
5. Dealing with exceptional situations (e.g., diagnosing and responding to mechanical problems or conditions in the operating environment)

In Europe tasks 1, 4, and 5 are handled by lineside personnel and Tasks 2 and 3 are handled by the engineer.\textsuperscript{51} Further, the FRA states that “Conductors are the link between engineers and the dispatchers” and “responsible for providing reminders to the locomotive engineer of speed restrictions and limits of authority and ensuring compliance.”\textsuperscript{52} In Europe, these responsibilities are typically handled exclusively by the train driver, and there is no chance for misunderstanding, miscommunication, or distraction due to a second supervisory person in the locomotive cab.

In addition, European rail lines are traditionally equipped with lineside signaling and interlocking facilities, some of which have recently been centralized into larger control centers, similar to North American CTC, while others remain locally controlled. In most countries, ATC/ATP systems have been installed for decades on portions of the main track that see regular train activity. The EU is in the process of further upgrading ATC/ATP to next-generation ETCS/ERTMS (see Appendix A), which is similar to North American positive train control (PTC) on about 25 percent of the network.

\textsuperscript{52} Ibid., pp. 31-32.
Temporary slow orders and other exceptional circumstances along the train run are typically communicated to train crews in written or electronic form before departure; their transmission via radio is possible, but confined to exceptional situations such as lineside signal failures.

Dark territory and operating regimes in which safety depends on (radio) communication and/or the equivalent of track warrants exchanged between the train crew and a dispatcher are typically low-density lines with limited traffic. Such lines (like the rest of the network) are typically operated with single-person crews; however, there are instances where the single-person crew receives support from ground personnel, when needed.

A. Safety Data Analyzed

Oliver Wyman analyzed data on accidents for 2006 through 2014 from the European Railway Agency for the 28 EEA countries. We also used a combination of interviews and Oliver Wyman expertise to determine the policy of each country regarding crew size, along with any exceptions to that policy. Trains operated in a country use the default crew size except in cases of extraordinary circumstances, such as failure of the “deadman” system or cab signaling system.\(^{53}\) This is an important fact that allowed us to assume that the default crew size applied to all accidents within a country, as individual accident data is not available.

Oliver Wyman analyzed total “significant accident” data as well as six subcategories (see Appendix B for definitions): collisions, derailments, level crossings, accidents to persons, fires on rolling stock, and other accidents. Suicides and attempted suicides were not analyzed. In addition, we analyzed employee fatalities on the railroads, economic impact of accidents, and

\(^{53}\) The only exception to standard crew size is Croatia, which uses both one-person and two-person crews depending on the locomotive type and the safety system with which the locomotive is equipped (dead-man control and/or cab-signaling for example). Each locomotive contains instructions on crew size. For this reason, Croatia was treated as “crew size undetermined” since we could not infer the crew size for an accident. See Appendix C for additional information on data sources for crew size.
signals passed at danger (SPADs – which are often a precursor to accidents). The data was used “as is,” without any attempts to clean or modify it or impute missing values. Also, unless otherwise stated, when a result is said to be “statistically significant” or “not statistically significant,” this is based on a two-tailed T-test using a 95 percent level of confidence.\textsuperscript{54}

**B. Overall Significant Accident Rates**

Overall, the majority of European countries have less than one significant accident per million train-kilometers in Western Europe, and between one and two significant accidents per million train-kilometers in Eastern Europe (Exhibit III-2). In general, countries operating two-person crews are located along the eastern edge of Europe, where accident rates are higher as well (Exhibit III-3).

Passenger traffic accounts for more than 50 percent of train-kilometers in all countries other than Lithuania and Latvia. With the exception of Greece, the top ten countries with the highest levels of passenger traffic (which generally indicates higher complexity and density), all have one-person crews and the lower levels of significant accidents.

\textsuperscript{54} The t-tests were run in Microsoft Excel using either “t-Test: Paired Two Sample for Means” or “t-Test: Two-Sample Assuming Unequal Variances.” When there were a sufficient number of observations (>30) then the “z-Test: Two Sample for Means” was used. In all cases the hypothesized mean difference = 0, alpha = 0.05, and the two-tailed test was used since it was unknown if one-person crews or two-person crews would have the lower value.
Exhibit III-2: EEA-28: Crew Size and Significant Accidents
Per million train-km, 2014

Predominant crew size
- One-person crews: White border
- Two-person crews: Red border
- Crew size undetermined: Yellow border

2 or more
1 to 2
Less than 1

European Railway Agency, “Common Safety Indicators data reported by National Safety Authorities,” Table 0, Field N10; Oliver Wyman analysis and interviews.

55
Statistical analysis of data from the past nine years found that countries with one-person crews have maintained a lower overall rate of significant accidents (Exhibit III-4). This is not to say that one-person crews are the cause of lower accident rates—Western European countries have lower accident rates due to a variety of reasons, including investments in infrastructure and safety, operating practices, technology, etc. But clearly one-person crews are as safe, if not safer, than two-person crews in Europe, and overall one-person crews in Europe have an impressive safety record. And contrary to the FRA’s speculation, there is no evidence to show that a second person in the crew has any positive effect on safety.

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56 European Railway Agency, “Common Safety Indicators data reported by National Safety Authorities,” Table 0, Field N10; Oliver Wyman interviews and analysis.
C. Investment and Accident Rates

One factor impacting overall accident rates that is worth examining in detail is that Western European countries with typically lower accident rates spend more per track-kilometer than Eastern European countries on rail infrastructure (Exhibit III-5).

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57 European Railway Agency, “Common Safety Indicators data reported by National Safety Authorities”; Oliver Wyman analysis.
The exhibit above shows that there is a fairly strong correlation (.55) between the amount of infrastructure investment and the accident rate, and this relationship appears to account for much of the difference in safety rates between Eastern and Western Europe. It should be noted however that these infrastructure investments include not only safety-related investments (e.g., track maintenance, removal of level crossings, signal system upgrades), but also large infrastructure expansion projects, such as Switzerland’s recently opened Gotthard Base Tunnel and new high-speed passenger lines in Spain (which is why investment figures for those two countries were the highest in Europe during our study period).

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Where infrastructure spending is comparable, crew size appears to have no impact on accident rates (Exhibit III-6). This would indicate that investments in rail infrastructure integrity and in technology are the keys to a safer rail network, rather than how many crew members are present on a train. Similar to the mature economies of Western Europe, freight railroads in the United States have spent tens of billions of dollars in recent years on improving track quality and on improving safety, such as the installation of positive train control (PTC) systems.

Exhibit III-6: Significant Accidents Compared to Investment and Crew Size

Average 2006-2014, per million train-km

From 2006-2014, the average annual spending on rail infrastructure in Western Europe was €175,000/track km, while in Eastern Europe it was €33,500/track km

OECD (2016), Infrastructure investment (indicator). doi: 10.1787/b06ce3ad-en (Accessed on 04 May 2016). European Railway Agency, “Common Safety Indicators data reported by National Safety Authorities,” Table 7, Field R03 and Table 0, Field N10. Oliver Wyman interviews and analysis. Croatia was considered Eastern Europe and Slovenia Western Europe in the averages for infrastructure spending.
D. Recent Crew Transition and Accident Rates

Italy provides an example of a country that made a recent transition from two-person to one-person crews, while maintaining the same level of safety. Italy began implementing one-person crew operations when new railway undertakings entered the market, in 2001. As shown in Exhibit III-7, accidents relative to train-kilometers in Italy have remained on-par with other major Western European railway systems operating one-person crews.

E. Eastern European Accident Rates

As Eastern Europe accounts for the majority of countries in Europe that still use two-person crews, Oliver Wyman carried out a further analysis of accident rates for one-person versus two-person crews just in Eastern European countries.

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1. Significant Accidents

As shown in Exhibit III-8, Eastern European countries with one-person crews are similar to Eastern European countries with two-person crews with regard to accident rates, network size and percentage of freight trains.

<table>
<thead>
<tr>
<th>Country</th>
<th>Crew size policy</th>
<th>Significant accidents/ train-km (2014)</th>
<th>Freight share of total train- km</th>
<th>Route- km</th>
<th>Exceptions to default crew size policy (if known)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hungary</td>
<td>One</td>
<td>1.879</td>
<td>18%</td>
<td>7,706 km</td>
<td>Use two-person only if safety or vision problem. Est. 1-2% of trains</td>
<td>Ministry of Transportation established crew size policy</td>
</tr>
<tr>
<td>Lithuania</td>
<td>One</td>
<td>1.119</td>
<td>62%</td>
<td>1,767 km</td>
<td>No exceptions</td>
<td>Established in 2005 by the Safety Dept. of Lithuanian Railways with the Ministry of Transportation</td>
</tr>
<tr>
<td>Poland</td>
<td>One</td>
<td>1.467</td>
<td>35%</td>
<td>19,265 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slovakia</td>
<td>One</td>
<td>2.404</td>
<td>30%</td>
<td>3,627 km</td>
<td>No exceptions</td>
<td>Ministry of Transportation established policy of one-person crews provided locomotive has deadman horn and brake (“vigilance control”).</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Two</td>
<td>2.014</td>
<td>24%</td>
<td>3,897 km</td>
<td>Use one-person for double traction and shunting. Est. 10% of all trains.</td>
<td>August 8, 2006 Ministry of Transport regulation requires two-person crews</td>
</tr>
<tr>
<td>Estonia</td>
<td>Two</td>
<td>2.003</td>
<td>34%</td>
<td>918 km</td>
<td>No exceptions</td>
<td>All freight trains use two-person crews. Passenger uses one-person.</td>
</tr>
<tr>
<td>Greece</td>
<td>Two</td>
<td>2.001</td>
<td>8%</td>
<td>2,238 km</td>
<td>One-person only used in sorting yards.</td>
<td>OSE (Hellenic Railways Organization, the infrastructure authority) established policy of two-person crews</td>
</tr>
<tr>
<td>Latvia</td>
<td>Two</td>
<td>1.156</td>
<td>61%</td>
<td>1,860 km</td>
<td>No exceptions</td>
<td>Latvian Railways (infrastructure provider) established crew size policy</td>
</tr>
<tr>
<td>Romania</td>
<td>Two</td>
<td>2.045</td>
<td>26%</td>
<td>17,028 km</td>
<td>No exceptions</td>
<td>Minister of Transportation established the crew size.</td>
</tr>
</tbody>
</table>

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61 European Railway Agency, “Common Safety Indicators data reported by National Safety Authorities,” Oliver Wyman research and interviews.
Both one-person and two-person crew Eastern European countries saw a significant decline in accident rates from 2006 to 2010. Since then accident rates have continued to improve, but at a slower rate, as shown in Exhibit III-9. In neither case are accident rates as low as for one-person crews in Western European countries.

Breaking down these statistics further into specific types of accidents, there are no statistically significant differences in the accident rates for Eastern European countries operating one-person and two-person crews for collisions and derailments (Exhibit III-10), fires on rolling stock and other accidents (Exhibit III-11), and level crossing accidents and accidents to persons (Exhibit III-12). (See Appendix B for accident definitions.)

62 Ibid.
Exhibit III-10: Collisions and Derailments by Year and Crew Size, 2006-2014

Exhibit III-11: Fires on Rolling Stock and “Other” Accidents by Year and Crew Size, 2006-2014

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63 Note: Values used are median accident rate for the countries within the same crew size group for each year. Median was used to prevent any unusually high accidents rates in a single country from overly influencing the rate for the entire group. Source: European Railway Agency, “Common Safety Indicators data reported by National Safety Authorities”; Oliver Wyman analysis.

64 Ibid.
2. Employee Fatalities and Economic Impacts

Eastern Europe and Portugal had the highest rates of employee fatalities during 2006-2014. In Eastern Europe, the average employee fatalities per accident for two-person crews (0.017) is almost double the average for one-person crews (0.009), perhaps reflecting the greater exposure rate for two-person crews when an accident occurs (Exhibit III-13).

The FRA states that “In rare instances, having a second crew member aboard may result in an additional injury or fatality if a serious accident occurs.”\textsuperscript{66} Based on Oliver Wyman’s analysis of the data from Eastern Europe, where nine different countries use different train crew sizes, there are more employee fatalities per accident when two-person crews are employed. Thus it

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\textsuperscript{65} Ibid.

appears that increasing the exposure to the field operating environment actually does lead to more fatalities when there is a significant accident.

Exhibit III-13: Railroad Employee Fatalities in Eastern Europe, 2006-2014

Employee fatalities per significant accident vs. significant accidents per million train-km

The FRA also asserts that “A second crew member could be instrumental in limiting the damages and injuries after an accident takes place.” Oliver Wyman’s analysis of Eastern European data suggests there is no statistically significant difference in the total economic impact of an accident between one and two-person crew operations.

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67 European Railway Agency, “Common Safety Indicators data reported by National Safety Authorities,” Table 2, Field SK00 divided by Table 0, Field N00.
In Europe, the average economic impact of accidents relative to train-kilometers is lower for one-person crews (€616,416) than two-person crews (€1,309,487) (Exhibit III-14). This difference is statistically significant. When focusing only on Eastern Europe, countries operating one-person crews still have a lower economic impact relative to train-kilometers (€1,138,000) than countries with two-person crews (€1,417,813), however this difference is not statistically significant.

Exhibit III-14: Economic Impact per Significant Accident
€ thousands, for 28 countries averaged for 2006-2014

69 Based on the “t-Test: Two Sample for Means” in Microsoft Excel using a 95 percent level of confidence (alpha = 0.05). The null hypothesis of zero difference between the means is rejected.

70 Note: Both zeros and blanks were treated as missing values since an economic impact of zero when there were significant accidents appeared to be incorrect. To account for economic differences between countries for the value of a serious injury, the economic impact per significant accident was normalized by using the “Fall Back Value of Preventing a Serious Injury.” This fall back value was averaged from 2006-2014 for each country and for all the countries. The average for each country was divided by the overall average to obtain an index used for normalizing the data. The economic impact per significant accident was divided by the index. Source: European Railway Agency, “Common Safety Indicators data reported by National Safety Authorities,” Fields C10, N00, R17, Oliver Wyman analysis.
3. **Signals Passed at Danger**

Signals passed at danger (SPADs), known as red block violations in the US, are widely considered to be a precursor to accidents by the European Railway Agency. Many of the ATP systems in use in Europe do not stop the train until after the red signal is passed, similar to ATS (Automatic Train Stop) systems in the United States. More advanced ERTMS systems, which are similar to Amtrak’s ACSES system and positive train control (PTC) systems being widely installed in the US can actually prevent SPADs.

SPADs are generally regarded as being precursors to accidents and would appear to be a solid indicator of task overload and loss of situational awareness. The FRA argues that “Studies show that one-person train operations can increase risks by overloading the sole crew member with tasks. Task overload can lead to a loss of situational awareness, and thus… could be a contributing factor in some accidents.”

Oliver Wyman’s analysis indicates there is no statistically significant difference in the rates of SPADs in Eastern European countries, whether or not they use one-person or two-person crews (Exhibit III-15). The rate of signals passed at danger relative to train-km for one-person crews (1.0075) is essentially equal to the rate for two-person crews (1.0035). Furthermore, there is almost zero correlation between crew size and SPADs (-0.0009), indicating that crew size does not appear to influence SPADs.

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72 The null hypothesis of zero difference between the means is not rejected based on the “z-Test: Two Sample for Means” in Microsoft Excel using a 95 percent level of confidence (alpha = 0.05).
Despite the greater number of traffic control transactions that are a consequence of higher train density and a greater number of signals and interlockings on the European network, there is no evidence that one-person crews are “overloaded,” resulting in a higher rate of SPADs and therefore a higher rate of accidents.

F. Summary

In Western Europe, where the use of one-person crews is nearly universal, the accident rate is significantly lower than in Eastern Europe, where countries are varied in crew size. Rather than being a function of crew size, however, lower accident rates in Western Europe appear to be driven by the kind of investments that mature economies make in infrastructure and technology –
the same kind of investments that US railroads have made and continue to make, to the tune of billions of dollars in capital spending each year.

By isolating Eastern Europe, where countries vary in their policy regarding crew size, it is possible to directly compare concurrent experience with one-person and two-person crews across a range of accident types. In the case of significant accidents, analysis yielded no evidence that two-person crews provide any safety advantages over one-person crews. The European data also shows that the economic impact of accidents is not alleviated by having a second person in the cab, while employee fatality rates commonly go up in the case of two-person crews. Nor did Oliver Wyman’s analysis find a higher level of signals passed at danger for one-person crews, despite the increased transactional workload on the European network.

Looking at readily available and current data on European accident rates, it is difficult to support the FRA’s assertions that two-person crews should be the presumptive standard for the United States, when one-person crews have become the presumptive standard on the far busier European network. Further, when we specifically compare the five remaining Eastern European two-person crew countries with the four one-person crew countries, we cannot conclude that two-person crews provide any greater level of safety than one-person crews. And it is Oliver Wyman’s expectation that within the next decade, all remaining countries in Europe using two-person crews will convert to one-person crews.
Appendix A. European Advanced Safety Technology

The European Union is in the process of implementing the European Railway Traffic Management System (ERTMS). When completed, it will cover approximately 56,000 kilometers of track – equivalent to 25 percent of the network. ERTMS will replace national ATP/ATC systems with a European-wide system of automatic train protection and control, further enhancing interoperability. Deployment is currently planned through 2030.

European railways deal with at least 20 different train command and control systems (and locomotives might be equipped with up to seven different navigational systems). This multitude of systems impedes the EU’s goal of interoperability and adds significant cost and complexity. For this reason, starting in the early 1990s, the European Commission (EC) seated working groups to define new communication and signaling standards. At the end of 1993, the EU Council issued an Interoperability Directive and a decision was taken to create a structure to define the Technical Specification for Interoperability.

At the beginning of the 4th Framework Programme, in 1995, the EC defined a global strategy for the further development of ERTMS, with the aim to prepare for its future implementation on the European rail network. This strategy included a validation phase to perform full scale tests on-site in different countries (France, Germany and Italy).

In the summer of 1998, UNISIG, comprising the European signaling companies, was formed to finalize the specifications. The specifications were subsequently reviewed to include additional functionalities and better meet the needs of the railway companies and infrastructure.

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74 UNIFE, European Commission, UIC.
75 ATP provides either a continuous or regular update of speed monitoring for each train (using trackside equipment) and causes the brakes to apply if the driver fails to bring the speed within the required profile. ATC is an integrated signaling system that guarantees the secure movement of trains. It integrates various subsystems positioned on-board and wayside, including ATP.
managers. The specifications currently in force are contained in the SRS 2.3.0d, which was adopted by the European Commission in April 2008. To ensure that ERTMS is constantly adapted to the railways’ needs, technical specifications are maintained under the lead of the European Railway Agency in cooperation with the signaling industry and railway stakeholders.

In parallel to this specification work, a joint effort from the EU and the Member States to finance ERTMS/ETCS has been implemented. Three successive Memorandums of Understanding were signed in 2005, 2008 and 2012 by the EC and the railway stakeholders to further deploy ERTMS on Europe’s rail network. “Priority” corridors were identified for ERTMS deployment, while specially crafted financial incentives were designed to support both infrastructure and onboard installation.

In July 2009, retrofitting of ERTMS was required for a number of listed lines, with deadlines ranging from 2015 to 2020, depending on line section. All new infrastructure projects (and significant upgrades) also must include ERTMS. ERTMS consists of two subs-systems:

- **ETCS (European Train Control System)**, a standardized automatic train protection system that continuously ensures that the train does not exceed the safe speed and distance.

- **GSM-R (Global System for Mobile Communications - Railways)**, a dedicated radio communication system for voice and data services supporting railway operations and communications.

The European Commission is currently focusing on the implementation of ERTMS on selected high-density corridors that cross multiple countries, with six of nine total corridors as the immediate focus through 2020 (Exhibit A-1). All EEA-28 countries are expected to implement ERTMS along the portions of these corridors that cross their countries.
To date, 21 countries have begun implementing ERTMS. Switzerland and Germany have each deployed ERTMS on more than 1,000 km of track (Exhibit A-2).

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76 European Commission, UIC.
ERTMS has multiple “levels” of deployment. Level s 0-2 are operational, Level 3 is a planned future development.\(^78\)

- ERTMS level 0 consists of ETCS-compliant locomotives or rolling stock that interact with lineside equipment that is non-ETCS compliant. Frequently equipped with ATP/ATC (Automatic Train Protection/Automatic Train Control) systems.

  European Level 0 is similar to current operations across much of North America. A handful of North American lines have Automatic Train Stop.\(^79\) This system is equivalent to

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\(^{77}\) “ERTMS Deployment Statistics,” UNIFE.  
\(^{78}\) “ERTMS Fact Sheet,” UNIFE.  
\(^{79}\) ATS is a system that works in conjunction with onboard and wayside equipment to apply brakes at designated restrictions or on a dispatcher’s signal, should the operator not respond properly.
European automatic train control/automatic train protection (ATC/ATP) systems and stops trains which run past stop signals and which do not slow for restricting signals.

- ERTMS level 1 is designed as an add-on to or overlays a conventional line already equipped with lineside signals and train detectors. Communication between the tracks and the train is ensured by dedicated transponders (known as “Eurobalises”) located on the trackside adjacent to the lineside signals at required intervals, and connected to the train control center. It is an intermittent system, as the signaling system transmits data to the train through the fixed-position transponders.

  Receiving the movement authority through Eurobalises, the ETCS onboard equipment automatically calculates the maximum speed of the train and the next braking point if needed, taking into account the train braking characteristics and the track description data. This information is displayed to the driver through a dedicated screen in the cabin. The speed of the train is continuously supervised by the ETCS onboard equipment. Thus, the train will automatically brake if exceeding the maximum speed allowed under the movement authority.

  The US equivalent of Level 1 appears to be Amtrak’s ACSES, because of its reliance on fixed transponders. ACSES provides the ability to bring a train to a full stop before passing a red signal, slow trains through speed restricted areas, prevent incursions into work zones, and prevent train movement through a main line switch in the improper position.

- ERTMS level 2 does not require lineside signals. The movement authority is communicated directly from a Radio Block Centre (RBC) to the onboard unit using GSM-R. The balises are only used to transmit “fixed messages” such as location, gradient, speed limit, etc. A continuous stream of data informs the driver of line specific data and signals status on the
route ahead, allowing the train to reach its maximum or optimal speed but still maintaining a safe braking distance factor.

PTC functionality being developed by the US freight railroads (see below) appears to be similar to ERTMS/ETCS Level 2, due to the direct and continuous transmission of authorities, position, aspects of lineside signals, switch positions, etc. between back offices, trains, and wayside equipment. In the US case, lineside signals will still be used for the most part. PTC also will be largely an overlay system, using many of the same blocks, signals, etc., used in the pre-PTC days.

- ERTMS Level 3, still in its conceptual phase, introduces a “moving block” technology. Under ERTMS level 1 and 2, movement authorities are determined using “fixed blocks” - section of tracks between two fixed points which cannot be used by two trains at the same time. With ERTMS level 3, accurate and continuous position data is supplied to the control center directly by the train, rather than by track based detection equipment. As the train continuously monitors its own position, there is no need for “fixed blocks” – rather the train itself will be considered as a moving block. There are no plans to implement an equivalent to ERTMS Level 3 in the United States.

The Rail Safety Improvement Act (2008) requires each Class I railroad carrier and each entity providing regularly scheduled intercity or commuter rail passenger transportation to implement positive train control (PTC) on all segments or routes of mainline railroad tracks that (a) carry intercity passenger or commuter rail service, or (b) carry more than five million gross tons of freight per year and also are used for transporting poison-by-inhalation hazardous
materials (PIH) (more commonly known as TIH – toxic inhalation hazard). \(^80\) This mandate is expected to apply to about 60,000 miles of railroad track – or approximately 60 percent of the network.

As per federal law, PTC it is a “system designed to prevent train-to-train collisions, over speed derailments, incursions into established work zone limits, and the movement of a train through a switch left in the wrong position.”\(^81\) The government has not imposed technical specifications for PTC systems, but all PTC systems share similar characteristics, and most importantly, from a safety perspective, “if the locomotive is violating a speed restriction or movement authority, onboard equipment will automatically slow or stop the train.”\(^82\)

\(^80\) P.L. 110-432, §104.
\(^81\) US Code of Federal Regulations, Title 49, Section §236.
Appendix B. Safety Analysis Definitions and Reporting

1. Safety Analysis Definitions

The following definitions apply to the analysis of European safety statistics in Section III:

- **Accidents to persons caused by rolling stock in motion:** one or more persons that are either hit by a railway vehicle or by an object attached to or that has become detached from the vehicle. Persons that fall from railway vehicles are included, as well as persons that fall or are hit by loose objects when travelling on-board vehicles.

- **Collisions:** covers both collisions of trains and collisions with obstacles within the clearance gauge. Includes front to front, front to end or a side collision between a part of a train and a part of another train, as well as with shunting rolling stock or fixed or temporarily present objects on or near the track (except at level crossings if lost by crossing vehicle/user)

- **Derailments:** any case in which at least one wheel of a train leaves the rails.

- **Economic impact of accidents:** The sum of the value of preventing a casualty (the willingness to pay for reductions in individual risk of injury or death plus the medical and rehabilitation cost of the individual, legal costs, investigative costs, emergency services, insurance, indirect costs of lost individual economic utility, and the like), cost of environmental damage, cost of rolling stock damage, cost of infrastructure damage, and the value of time (economic costs incurred by users of railway services).

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- **Employee fatalities**: the immediate death (or death within 30 days) of any person whose employment is in connection with a railway and is at work at the time of the accident. This includes the crew of the train, persons handling rolling stock and infrastructure installations, and contractors. Employee suicides are not included.

- **Fires on rolling stock**: fires and explosions that occur in railway vehicles (including their load) when they are running between the departure station and the destination, including when stopped at the departure station, the destination or intermediate stops, as well as during re-marshalling operations.

- **Level crossings**: accidents at level crossings involving at least one railway vehicle and one or more crossing vehicles, other crossing users such as pedestrians or other objects temporarily present on or near the track if lost by a crossing vehicle/user.

- **Other accidents**: all accidents other than train collisions, train derailments, at level crossing, to persons caused by rolling stock in motion, and fires in rolling stock.

- **Signals passed at danger**: any time that a train, or part of a train, proceeds beyond its authority.

- **Significant accident**: any accident involving at least one rail vehicle in motion, resulting in at least one killed or seriously injured person, or in significant damage to stock, track, other installations or environment, or extensive disruptions to traffic. Accidents in workshops, warehouses, and depots are excluded. Significant damage is damage that is equivalent to 150,000 euros or more.
2. Availability and Reporting Requirements

Data covering many different aspects of railroad incidents, accidents, and casualties is generated by railroads and tracked by rail regulatory authorities. Reporting categories for equipment and infrastructure incidents and accidents include collisions, derailments, fires, explosions, acts of god, and other events involving mechanical or infrastructure failure or human error that result in damage. Reporting categories for casualties include injuries resulting in medical treatment, loss of consciousness, time away from work, restricted work, job transfer, and death.

The FRA and ERA both collect incident data from the railroads and store the information in electronic databases that are available to the general public. Data collection is ongoing, and thus data is both current and supported by many years of history. Additionally, the incident, accident, and casualty reports provided by the railroads are required by federal law, and must therefore contain information that is accurate and complete to the highest degree possible.

- Under federal law, US railroads are required to report all fatalities, grade crossing collisions, grade crossing signal equipment failures, and rail traffic signal equipment failures to the FRA. In addition, railroads must report rail equipment incidents and personal injuries to the FRA subject to certain financial and medical treatment thresholds, respectively. Publicly available data is grouped into the following categories: rail equipment accidents, railroad casualties, highway-rail accidents, and signal equipment failures. The FRA also collects operational data from the various railroad companies concerning train-miles and employee hours to provide a basis of comparison for safety data.

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In the European Union, member state railroad regulatory agencies are required to report safety-related incidents meeting certain specified thresholds to the ERA. Publically available data is grouped into the following categories: rail equipment accidents, railroad casualties, grade-crossing accidents, and signals passed at danger (SPADs). Like the FRA, the ERA also collects operational data for the purpose of providing a consistent basis for comparison of safety statistics.

For the purposes of comparison of FRA and ERA data, it should be noted that each organization has its own mandates detailing which data is to be collected and at what level of detail. These differences are largely due the agencies’ different purposes in collecting data:

- The FRA uses the data it collects to develop hazard elimination and risk reduction programs for the railroad industry that focus on preventing railroad injuries and accidents. To develop effective safety programs, the FRA must collect data concerning not only the “who, what, and where” of an incident, but also the “how and why.” Thus, the safety data collected by the FRA includes all of the basic information concerning an incident, as well as information on the underlying causes and circumstances.

- The ERA collects statistics based on agency-defined common safety indicators (CSIs) “to facilitate the assessment of the achievement of [common safety targets] and to provide for the monitoring of the general development of railroad safety.” CSIs are not expected to provide the same level of detail as the safety databases of individual railroads and infrastructure.

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85 According to the ERA, SPADs occur when any part of a train proceeds beyond its authorized movement.
management companies, which are tailored to specific company needs. Consequently, the available public data provides for limited analysis of underlying incident causes and circumstances.

Exhibit B-1 contains a summary of key differences between the FRA and ERA data.

**Exhibit B-1: Differences in FRA and ERA Data**

<table>
<thead>
<tr>
<th>Category</th>
<th>Item</th>
<th>FRA</th>
<th>ERA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment incidents</td>
<td>Minimum cost threshold for reporting</td>
<td>$10,500</td>
<td>€150,000</td>
</tr>
<tr>
<td>Serious injuries</td>
<td>Hospitalization</td>
<td>Hospital stays not reported</td>
<td>Only reported if there is a 24-hour minimum hospital stay</td>
</tr>
<tr>
<td>Fatalities</td>
<td>Length of time after accident</td>
<td>Any fatality occurring within 180 days of the accident is recorded</td>
<td>Any fatality occurring within 30 days of the accident is recorded</td>
</tr>
</tbody>
</table>

It should be noted that only certain data will be relevant to evaluating the effect of road train crew size on railroad safety; specifically, this includes data on incidents where the crew has some control, and where the presence of multiple persons versus one person in the cab could arguably make a difference in the outcome of the incident. Such incidents potentially could include equipment incidents (train derailments, collisions, fires, etc.) and casualties (injuries and fatalities).

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Appendix C. Data Sources

The safety data for the analyses contained in this report was obtained from the European Railway Agency’s European Railway Accident Information Links web page at https://erail.era.europa.eu/safety-indicators.aspx, and downloaded as an Excel spreadsheet (highlighted in red below).

This Excel spreadsheet contained data on a variety of safety statistics for 2006 through 2014 for 28 European countries and the Channel Tunnel. Additionally, the European Railway Agency’s 2014 Railway Safety Performance in the European Union report is available to download on the right hand side of the web page.

The data for infrastructure investment was obtained from the Organization for Economic Co-operation and Development (OECD) web page at https://data.oecd.org/transport/infrastructure-
assessment.htm. Using the filter at the bottom of this web page, rail infrastructure investment was selected.

Finally, the information on crew size was based on Oliver Wyman knowledge, supplemented with a survey of 12 countries that were unknown:

- The survey identified two-person crews in Bulgaria, Greece, Latvia, Portugal and Romania. One-person crews were identified in the Czech Republic, Hungary, Lithuania, and Slovakia.
- Estonia uses two-person crews for freight trains and one-person crews for passenger trains, thus Estonia was classified as using two-person crews. Note that one person in the cab and other crew members aboard the train on passenger trains is consistent with US practices.89
- In Croatia the crew size varies with the type of locomotive and installed safety equipment, such as dead man controls and cab signaling, so crew size was listed as “undetermined.” We were unable to identify the crew size in Slovenia and so listed it as “undetermined” as well.

89 As noted previously, a “one-person crew” means one person in the cab of the locomotive, without regard to whether, in the case of passenger service, there is an additional rail employee in the passenger section of the train (i.e., a conductor). Note that in Germany and possibly other countries, some passenger trains are operated with no additional rail employees in the passenger consist.