Crew-Related Safety and Characteristic Comparison of European and US Railways

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I. Executive Summary

Although US rail freight trains continue to be operated primarily with two-person in-cab locomotive crews, other large, complex, and modern rail systems have a long history of safely operating trains with one-person in-cab crews. To evaluate the relative safety of two-person versus one-person crews,[1] Oliver Wyman reviewed 2006-2019 accident reporting data for 28 railroads in Europe (the European Economic Area or EEA) and for the US Class I's. More than 95 percent of European rail traffic (in train-kilometers) is moved by one-person crews. We found no evidence that railroads operating with two-person crews are statistically safer than railroads operating with one-person crews. Furthermore, an analysis of this data broken into multiple accident categories found no significant differences in safety statistics based on crew size.

The interconnected standard gauge European network serves an economy approximately as large as the United States in terms of GDP. The European rail network is larger in terms of route-kilometers, train-kilometers, and train density. The European rail 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 share infrastructure, making for a more operationally complex network. Rail freight traffic in Europe has a level of diversity similar to that of US rail freight, including mix of commodities, mix of dangerous and non-dangerous goods, and mix of train types.

Many railroads in Western Europe have operated with one-person crews since the end of World War II. As the railroads were rebuilt and electrified, countries implemented one-person crews to alleviate manpower shortages, take advantage of electric and diesel locomotive

[1] Throughout this report, "one-person crew" and "two-person crew" refers to the number of persons in the locomotive cab exclusively.

technology (no longer requiring a fireman), and to compete more economically in a 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, current plans call for installing advanced train control technology (the European Railway Traffic Management System or ERTMS) on only 22 percent of the network. By comparison, the US has installed positive train control (PTC) on 62 percent of Class I route-miles; PTC is equivalent to the most advanced form of ERTMS currently available (see Appendix A for more detail). A key difference between ERTMS and PTC is the motivation for developing and implementing each system. ERTMS was motivated by interoperability, as a train crossing European country borders may have to be equipped with up to seven different navigational systems and could face more than 20 different types of train control systems.[2] PTC was motivated by safety concerns and was "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."[3]

European freight trains are shorter than those operated in the United States, in large part because of the high density of trains operated in Europe and the desire to keep block sizes shorter, so as 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 many more signals per route-kilometer, and Europe's higher train density 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

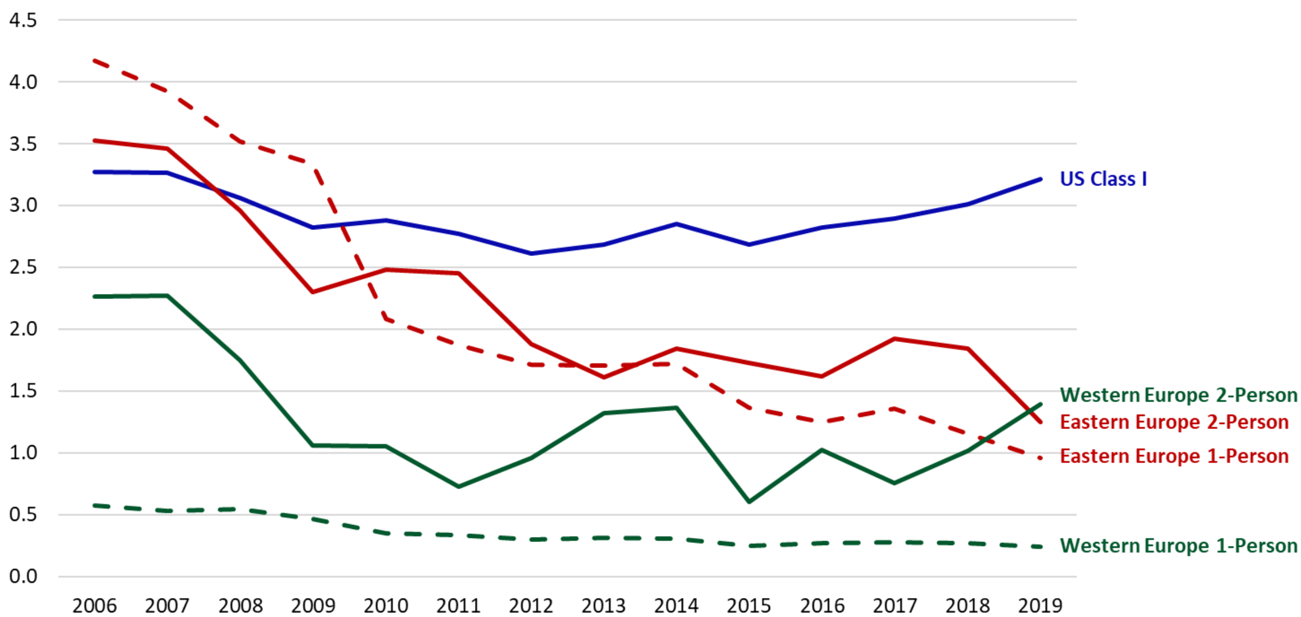
[2] The European Rail Traffic Management System, ERTMS: History (https://www.ertms.net/?page_id=49).
[3] US Code of Federal Regulations, Title 49, Section §236.

single person in an environment that often has less room for error – compared to a US environment (outside of urban hubs) of larger but slower freight trains and limited passenger traffic.

As shown in Exhibit I-1, Oliver Wyman grouped European railroads into categories based on region and crew size and compared them to one another and to US Class I railroads, to determine if there were differences in safety performance and whether those differences were related to crew size.

Exhibit I-1: All Significant Accidents, 2006-2019[4]

Per million train-km



In total, 20 European countries use one-person crews and six use two-person crews (crew size could not be determined for two countries). Oliver Wyman also compared Western and Eastern Europe, to see if accident data aligns more closely with differences in infrastructure investment and operating characteristics. (Western Europe has much higher passenger train

[4] "Common Safety Indicators data reported by National Safety Authorities" European Railway Agency (ERA); "Accident/Incident Report" US Federal Railroad Administration (FRA); Oliver Wyman analysis.

density and thus higher investment in infrastructure, while Eastern European railroads tend to run somewhat longer trains, carry relatively more freight, and have lower infrastructure investment.)

For all significant accidents, Western European one-person crews have shown the best safety record, while Eastern European railroads have seen improvement over time, regardless of crew size, and the US accident rate is fairly stable. Two-person crews do not appear to be safer than one-person crews according to this metric.

Furthermore, in looking at specific categories of accidents, Oliver Wyman did not find that crew size played a significant role in the number of collisions, derailments, accidents at grade crossings, accidents to persons, or employee fatalities. Having a second crew member also did not reduce economic damages for significant accidents. Finally, we found no evidence of higher rates of signals passed at danger for one-person crews, thus dispelling claims that one-person crews are “overloaded” with tasks.

In sum, most European rail operations use single-person crews, even though Europe has higher train density, more passenger trains sharing the network with freight trains, and more control transactions per route-kilometer. But European one-person crew operations appear to suffer no reduction in crew-related safety, despite a high level of activity and a busy environment.

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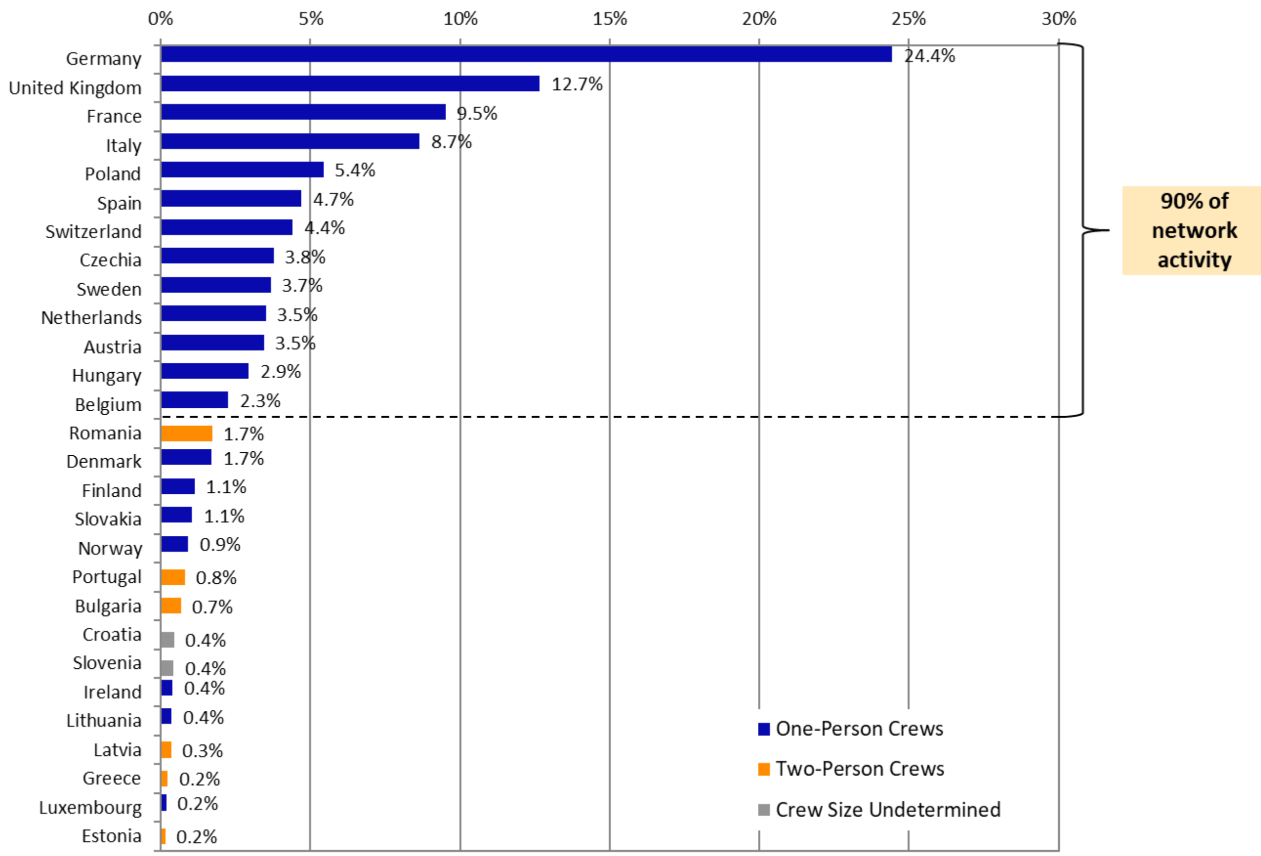
II. Comparison of US and European Railroads

The use of single-person crews is widespread internationally, for both freight and passenger trains, on large, dense, and complex rail networks. In some cases, one-person crews have been in use since the end of World War II. In others, the use of one-person crews has come about due to innovation and automation, both in-cab and on-network. In 2018, for example, 95.3 percent of all European rail traffic (train-km) was moved by one-person crews, including the 13 largest railways, which accounted for 90 percent of network activity (Exhibit II-1).[5]

Exhibit II-1: European Rail Network Activity by Crew Size[6]

Percent share of train-km



[5] 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). "Two-person crew" means that two people are present in the locomotive cab.

[6] Information on crew size is based on Oliver Wyman's direct knowledge of rail operators, interviews, and public data. Train-km from EU Transport in Figures 2020 (2018 data), Oliver Wyman analysis. Note: Estonia's legacy incumbent rail operator has since changed to one-person crews (November 2019), but this does not impact the data used in this study.

To understand how Europe compares to the United States in terms of rail operations and safety performance relative to crew size, Oliver Wyman originally conducted an in-depth review of the overall European rail network and the individual national networks of 28 European countries in 2016. In this 2021 report, we have again reviewed the latest available data on the European rail network and have updated our analysis to reflect this new information, along with incorporating US safety data available through the Federal Railroad Administration (FRA).

Because rail services in Europe freely operate across borders, a proper analysis requires consideration of rail operations within the entire European Economic Area (EEA), and on this basis, the EEA is comparable to the US rail network in terms of network size.[7] European railroads on the networks of the 28 EEA countries (Exhibit II-2) operate 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.

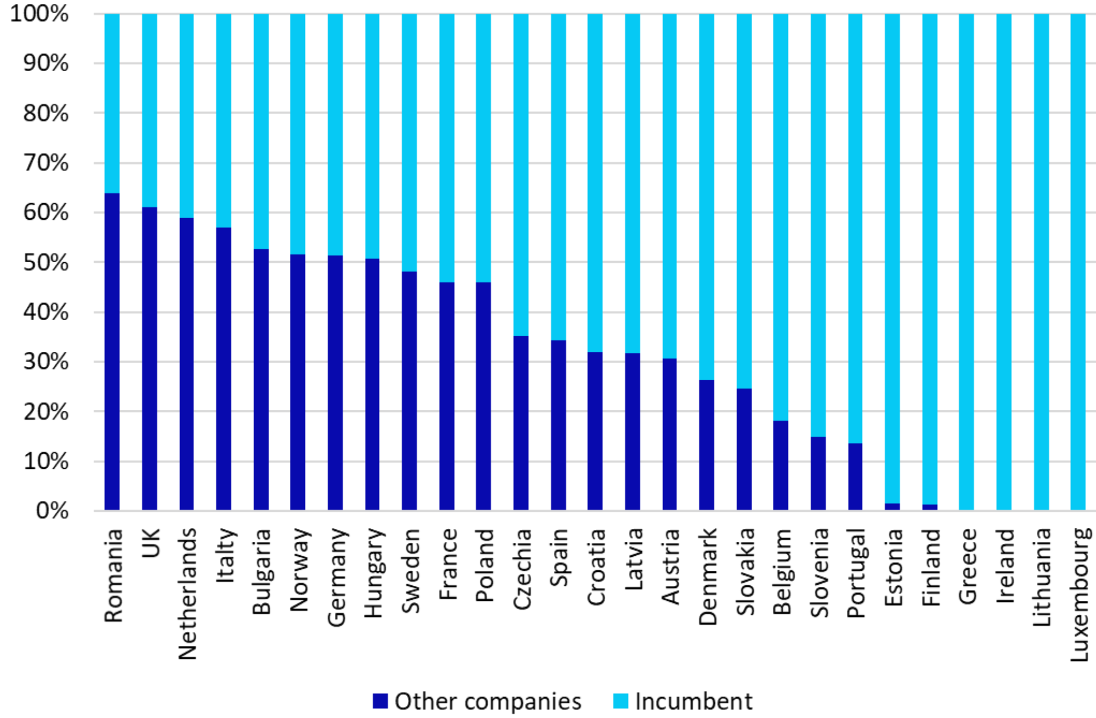
[7] The European Economic Area (EEA) includes 26 European Union Member States with railroads, plus two European Free Trade Association (EFTA) Member States, Norway and Switzerland, that have railroads. The European Railway Agency and Eurostat compile rail statistics for the EU and the EFTA states. Thus, "Europe" and "EEA" as used in this report refer to all 28 countries for which rail data has been compiled and analyzed. (Data for the United Kingdom is included, as it did not leave the EU until 2021).

Exhibit II-2: Countries with Rail Networks in the European Economic Area

Rail operations in Europe have been “liberalized” since the mid-1990’s. This means that train operations have been decoupled from infrastructure ownership and control, and any qualified “rail undertaking” may now operate freight or passenger services on the network. This has led to the creation of a European rail industry with a level of diversity similar to that of the US rail industry.

In about three-quarters of European countries, the majority of traffic is still handled by large freight rail operators that are equivalent to Class I and Class II US railroads – the legacy or incumbent carriers that were once national railroads (Exhibit II-3). Similar to US freight railroads, these operations provide intermodal, unit train, and carload manifest services for an extensive array of commodities (including hazardous materials) and serve a wide range of origins and destinations over varying distances.

Exhibit II-3: Rail Freight Market Share of Incumbents (Large Legacy Railroads) versus Other Rail Undertakings[8]



In addition, open access has led to the creation of dozens of smaller "new entrant" operators, somewhat similar to US Class III shortlines. Some provide point-to-point unit train services, while others compete in offering carload and intermodal alongside the legacy carriers. The key difference is that while US shortlines typically run on low-density, low-speed lines, small operators in Europe run on the same mainline corridors and at the same speeds as large freight rail operators and alongside high-frequency passenger train services. (Maximum running speeds for freight – no matter the size of the operator – can reach 90 to 120 kmh, equivalent to 56 to 75 mph.)[9] As a result, train operations are frequently higher density than is the case for much of the

[8] EU Transport in Figures 2020 (2018 data). As a percentage of tonne-km, in some cases as a percentage of train-km (depending on available data). A railway undertaking in the EU is a licensed public or private transport operator which provides services for the transport of goods and/or passengers by rail.

[9] "High-speed rail freight: Sub-report in efficient train systems for freight transport," Gerhard Troche, Centre for Research and Education in Railway Engineering at the Royal Institute of Technology Stockholm (Railway Group KTH), 2005, p. 11.

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.

All of these factors combine to create an agenda of operating work events and decision points for European train crews greater than those typically facing train crews in the United States. In addition, safety issues have the potential to impact more people across a wider geographic area in Europe, due to the close proximity of freight and high-density passenger services on the 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 GDP about equivalent to that of 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 much higher density (in train-km), due to large numbers of passenger trains.

Exhibit II-4: Overview of European and US Rail Networks[10]

	Total Europe (EEA-28)	Total US	US Class I
2019 GDP, US$ billions	19,590	21,433	NA
Route-km	225,616	218,991	148,513
Total train-km, millions	4,486	967.6	789.7
Total daily train density (train-km/route-km)	54.5 (10.4 freight)	12.1	14.6

In addition, total train density across most of the individual rail networks of the EEA-28 is higher on a daily basis than on the US Class I rail network (Exhibit II-5). Freight density is

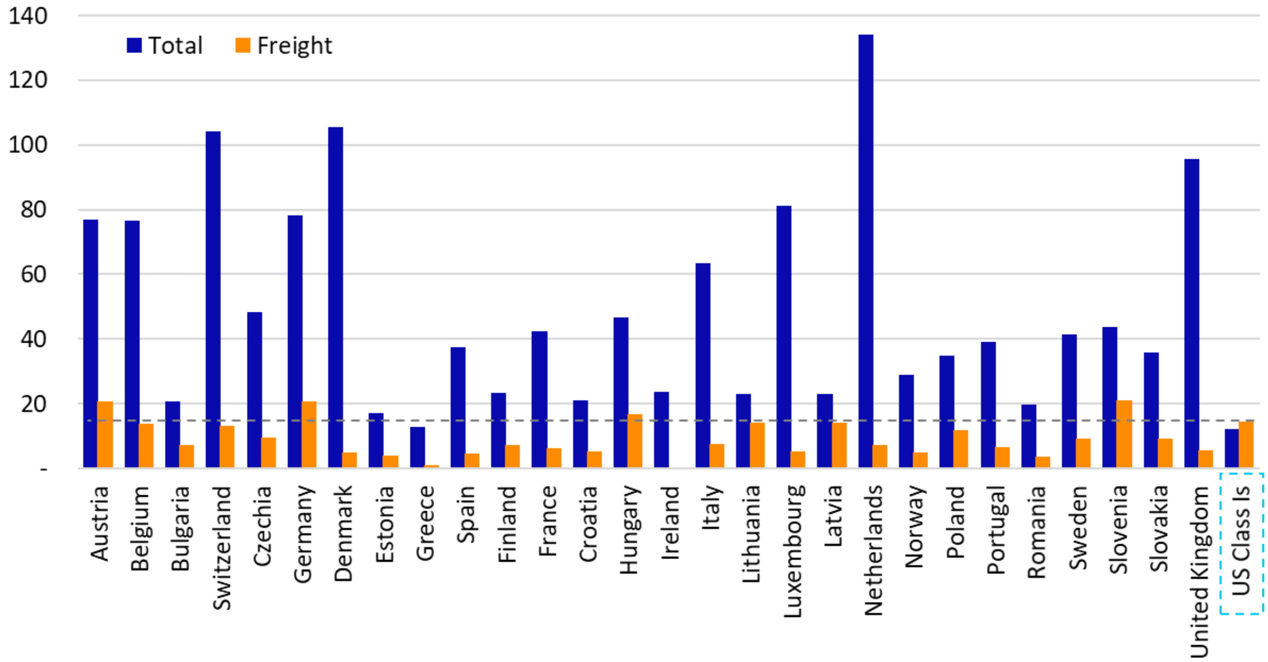
[10] Note: Latest available data (2018-2019). European data covers all passenger, commuter, and freight operations on the regulated railway networks of each constituent nation. US data covers rail freight and commuter/intercity. US Class I train-km on US Class I network only. Source: World Bank; European Commission (Eurostat); Rail Fact Book, Association of American Railroads; US Bureau of Transportation Statistics; Operational Data Tables, FRA; Oliver Wyman analysis.

comparable for some countries, but the majority of US rail freight does not run on mixed lines with high-frequency passenger services, unlike in Europe. Train density is a 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. Other trains, on-track equipment (maintenance-of-way equipment, hi-rail vehicles, etc.), highway-rail grade crossing users, weather, and other operational factors are all constantly changing the environment ahead of the train. The train crew must focus on these other actors, their movements, and the signaling equipment protecting their movements to ensure that the train safely negotiates an ever-changing operational landscape.

What matters behind the train crew, from a safety standpoint, is the operational integrity of the train. In the US environment, the train crew generally cannot directly observe more that the first 40 cars, which is about the average length of European freight trains. Beyond that distance, the train crew relies on wayside equipment detectors, telemetry from end-of-train devices and distributed power locomotives, in-cab brake pipe pressure gauges, and train handling characteristics (such as sudden changes in train speed, higher throttle settings needed to maintain speed, changes in ride quality, etc.) to monitor train integrity.

Exhibit II-5: Train Density per Day[11]

Train-km per line-km; US Class I train-km on Class I rail network only



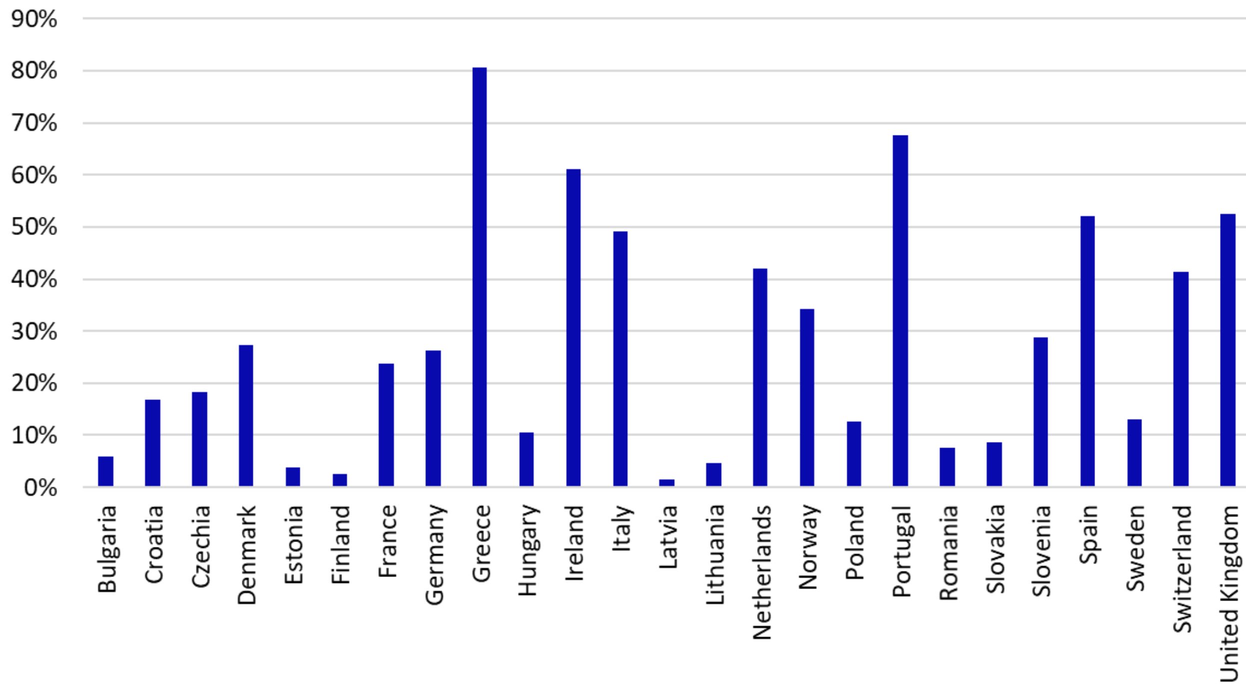
B. Freight Characteristics

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, similar to US railroads, many large rail networks carry a substantial share of intermodal traffic, as shown in Exhibit II-6.

[11]Ibid.

Exhibit II-6: Intermodal Share of Total Freight Traffic[12]

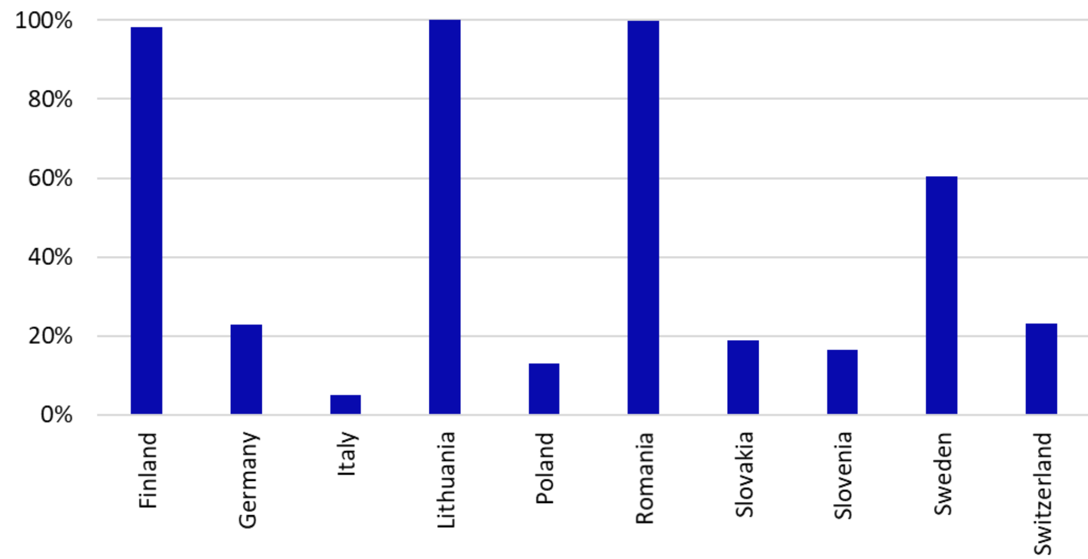
Intermodal tonne-km/total tonne-km



Evidence of the carload network in Europe is provided by a large number of retarder-equipped hump yards on the European network. These facilities are not needed for handling unit train operations. Reported carload data (tonne-km) 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).

[12] Eurostat, 2019 data. Four EEA-28 countries do not report this data. Includes containers and swap bodies.

Exhibit II-7: Carload Share of Total Freight Traffic[13]
Carload tonne-km/total tonne-km



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 15 percent of total freight tonne-km in Europe.[14] In Europe (as in the US), rail is considered the safer mode of transport, and shipment of dangerous goods by rail is often preferred over truck shipment of these goods. One reason is that rail has fewer accidents than trucking. In the US, for example, rail accounted for 1.9 percent and highway for 90.4 percent of reportable hazardous materials incidents in 2019.[15] And on most European networks, these dangerous goods are handled by one-person train crews.

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[13] Eurostat, 2019 data, all countries reporting this data.
[14] "Just the Facts – Railroads Safely Move Hazardous Materials, Including Crude Oil," Association of American Railroads; Eurostat, 2019 data.
[15] "Hazardous Materials Transportation Incidents and Property Damage," Freight Facts and Figures, Bureau of Transportation Statistics (https://www.bts.dot.gov/browse-statistical-products-and-data/freight-facts-and-figures/hazardous-materials-transportation).

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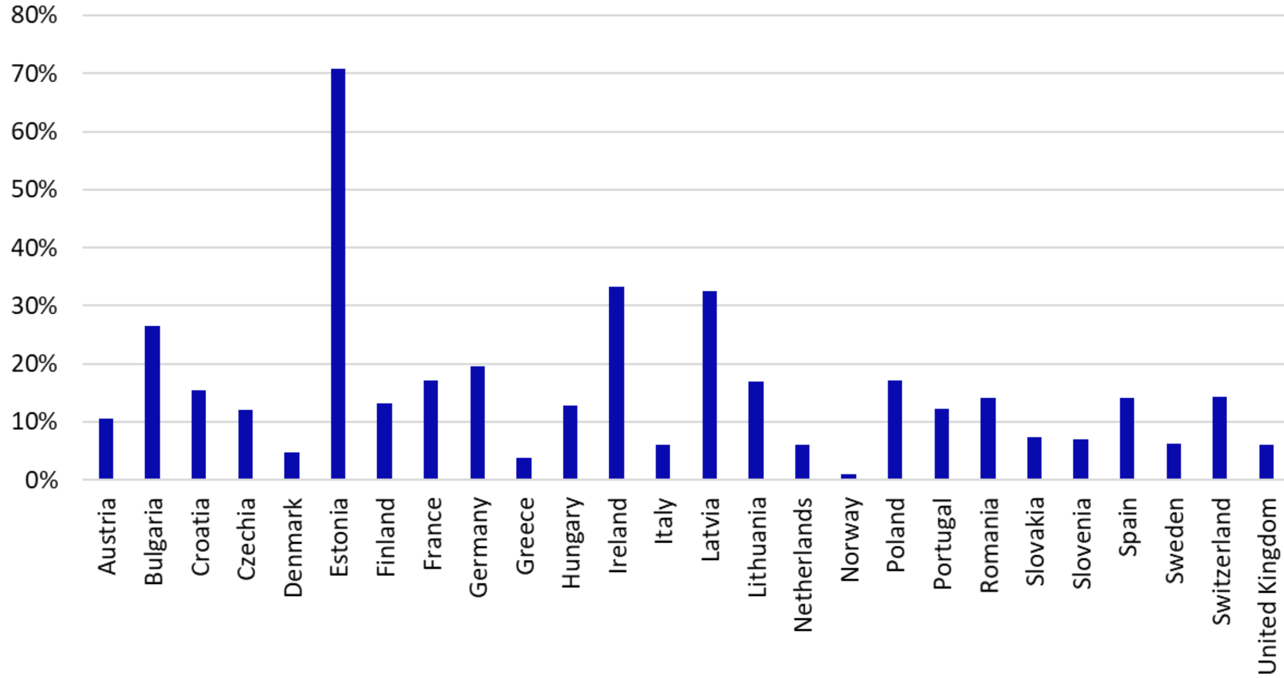
In addition, the amount of dangerous goods carried is particularly high in some European countries (Exhibit II-8). Thus, in some areas of the European railway network, the potential for an incident involving dangerous goods can be high.

Exhibit II-8: Dangerous Goods Share of Total Freight Traffic[16]

Dangerous goods tonne-km/total tonne-km



C. Operating Complexity

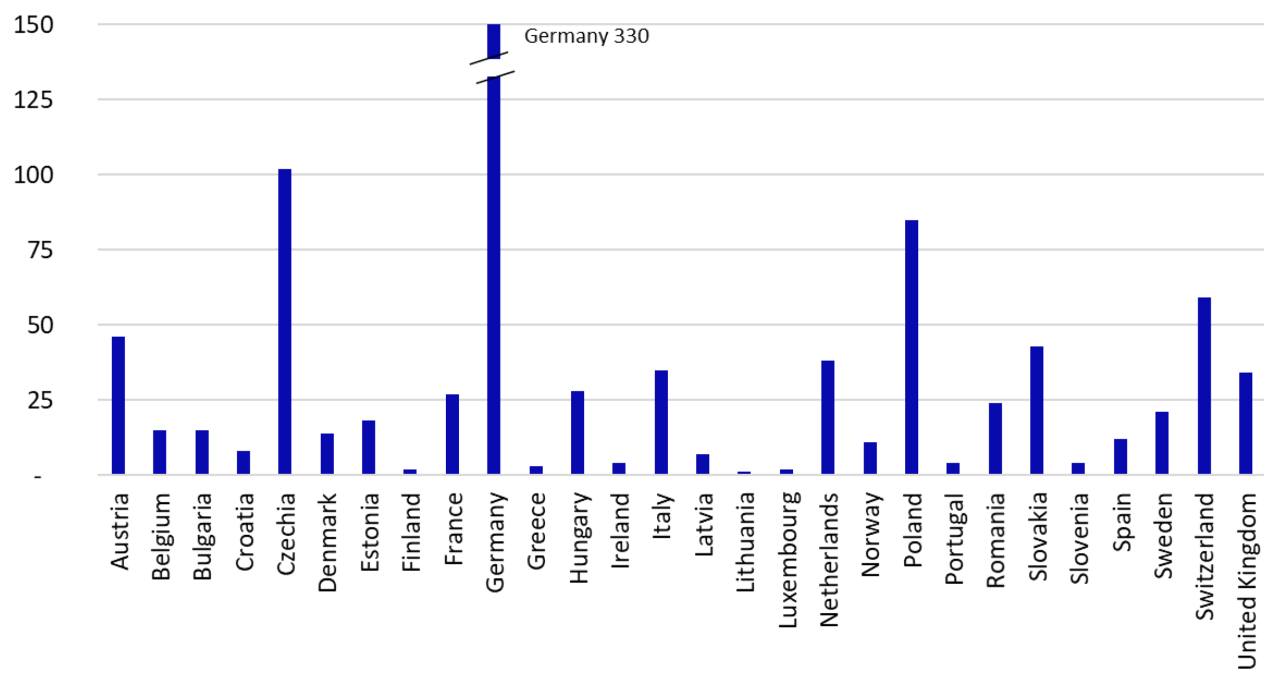
European freight trains do tend to be shorter than those operated in the United States, in large part because of high train density and the desire to keep block sizes shorter – so as to better accommodate close spacing of freight and passenger trains and to provide greater network fluidity for passenger trains. But the shorter average length of European freight trains actually creates significantly more operating complexity. Shorter block sizes and more interlockings, due to more double track and the density of trackage, create far more signals per route-kilometer.

[16] Eurostat, 2019 data, Oliver Wyman analysis.

And higher train density than in the United States means that European rail operations require far more traffic control transactions (signal indications and dispatcher communications).

The European rail operating environment also is more challenging in that a much larger number of operators run on most networks, compared to the US operating environment. In the US, most railroads are shortlines serving small, independent territories and feeding a few large Class I's that run on their own private tracks (with only limited access rights for other operators). In Europe, freight rail operators can operate virtually anywhere on the network by obtaining certification as a "railway undertaking" and then applying to the relevant infrastructure manager for each country network to obtain train slots. Total active freight and passenger rail operators for countries reporting data are shown in Exhibit II-9.

Exhibit II-9: Active European Rail Operators[17]

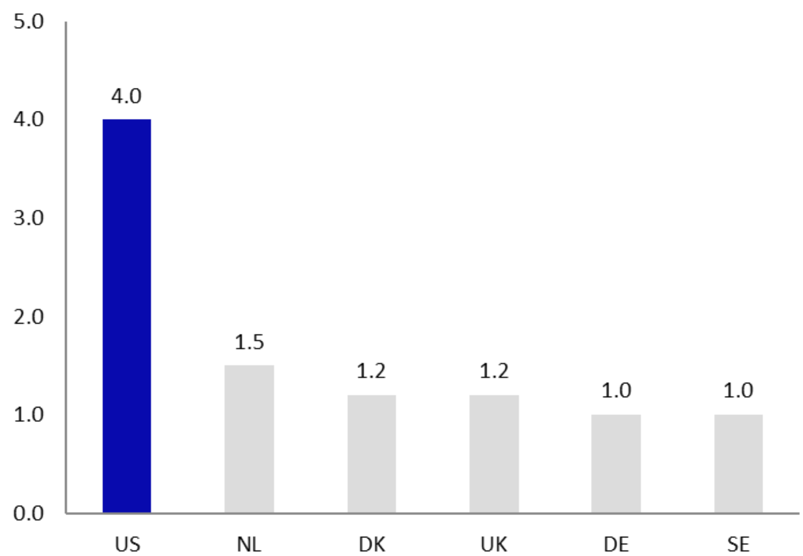


In addition, the European rail network handles higher numbers and types of trains on a daily basis:

[17] Eighth Annual Market Monitoring Report, Independent Regulators' Group – Rail.

- Europe has several times the daily train activity of North America,[18] primarily due to much higher passenger train activity across the network.
- Shorter trains allow for shorter blocks, which then require more signals per track-km (Exhibit II-10), which increases the number of control communications required for each minute of operation.
- Because passenger trains account for the largest share of network activity, average train speeds are faster than in the United States – and freight trains operate at higher average speeds as well.

Exhibit II-10: Average Signal Spacing[19]
In kilometers

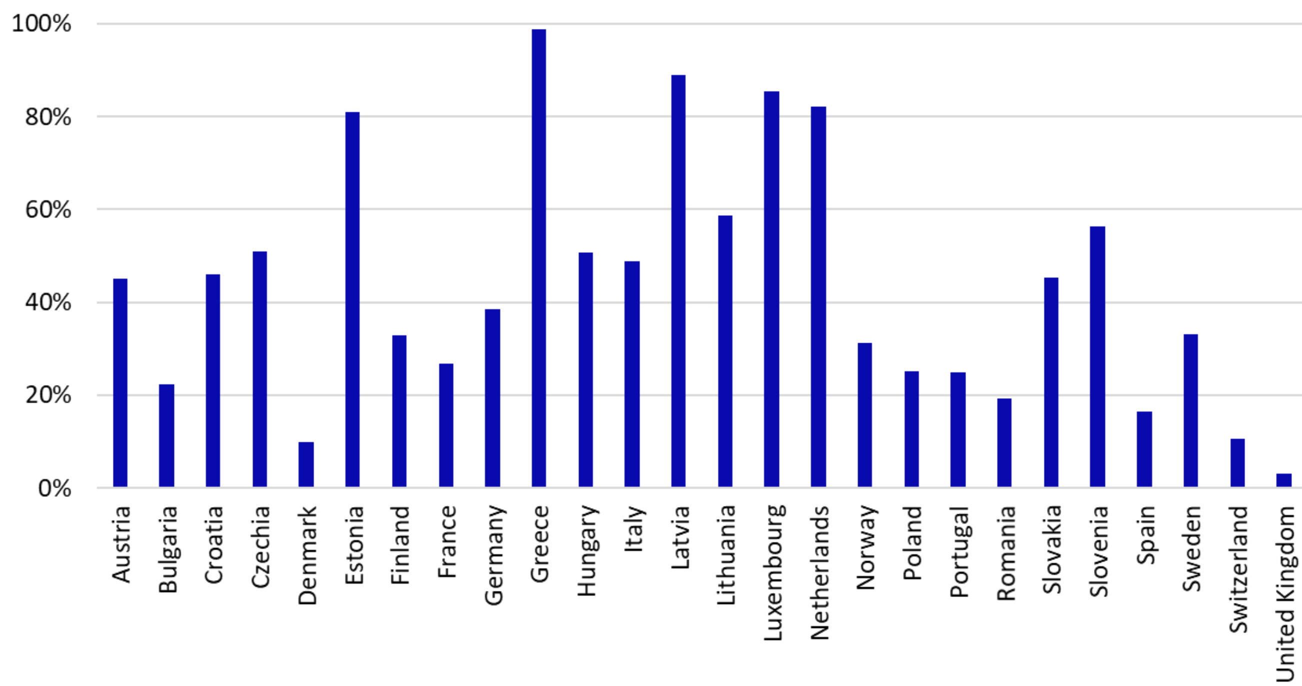


[18] World Bank; European Railway Agency; European Commission (Eurostat); Eighth Annual Market Monitoring Report, Independent Regulators' Group; Analysis of Class I Railroads, Association of American Railroads; Operational Data Tables, FRA; Oliver Wyman analysis.

[19] US data: Ede, Bill Moore and Alan Polivka, Moving Block in Communication-Based Train Control: Boon or Boondoggle, p. 7 and Bryan, Frank W. and Robert S. McGonigal, Railroad Signals: What They Do, What They Mean, Trains Magazine, (http://trn.trains.com/railroads/abcs-of-railroading/2006/05/railroad-signals). European data: Boysen, Hans E., Oresund and Fehmarnbelt, "High-capacity rail corridor standards updated," Journal of Rail Transport Planning & Management; Rail Safety and Standards Board (UK); Lineside Signal Spacing and Speed Signage; Van den Top, Jaap, Tom Heijer, and Arco Sierts, A Systemic Analysis of the Dutch Railway Signalling System.

A significant percentage of rail traffic in Europe also moves “internationally,” i.e., cross-border between countries, which can require negotiating multiple signaling and traffic control systems, complying with different national operating rules programs, as well as changes to running gear to accommodate different track gauges (Exhibit II-11). Indeed, international traffic makes up 40 percent or more of tonne-km for about half of the countries in the EEA-28 rail network.

Exhibit II-11: International Share of Total Freight Traffic[20]
International tonne-km/total tonne-km



Faster train speeds, shorter blocks, and more train activity mean that European freight train crews experience more challenges to safe operation, in terms of events per train-km, compared to 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

[20] Eurostat, 2019 data. International includes cross-border and transit.

maintain schedules. Greater operating complexity thus requires a European train driver to process more activity than would be the case in the US (e.g., signals to be interpreted, junctions/crossings, dispatcher interactions).

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, United Kingdom, 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.

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 and has one of the largest and densest rail networks in Western Europe. It is also the largest freight and passenger market in the EEA-28 in terms of tonne-km/passenger-km (Exhibit II-12). 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 nearly one million tonnes of freight and over eight million passengers.[21]

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. Germany has the busiest rail network in Europe, with more than 300 active above-rail operators.

Exhibit II-12: Germany: Key Rail Statistics[22]

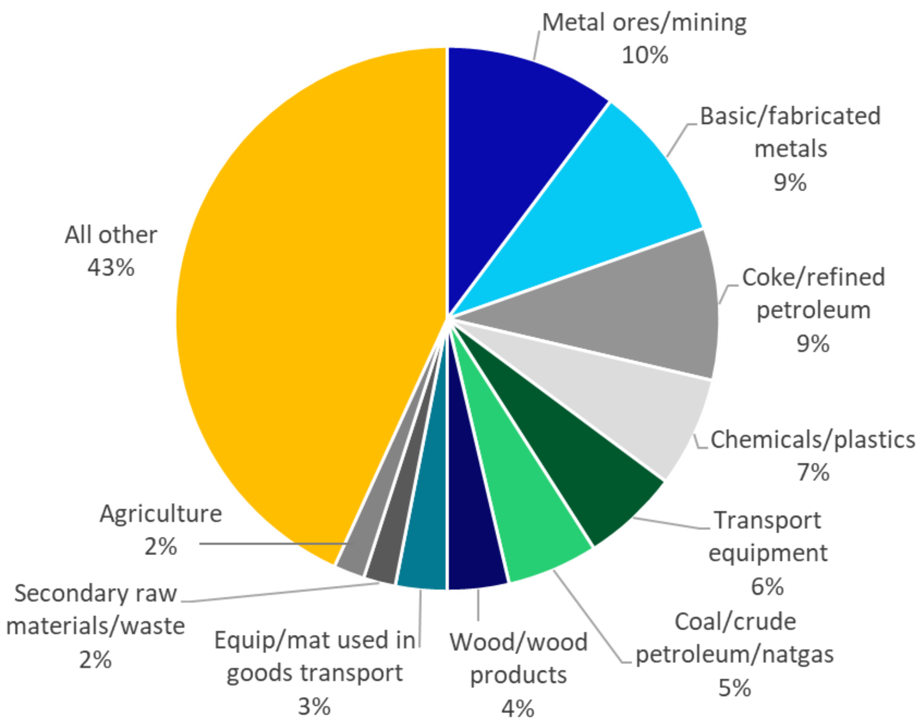
Overall market	
GDP, PPP international $	$4,660
Standard locomotive crew size	1 person
Active rail operators	330
Network size (line-km)	38,416
Network intensity (train-km/line-km per day)	78.2
Share of total European rail activity (train-km)	24.5%
Freight rail market	
Non-incumbent (multi-operator) market share	51%
Freight density: tonne-km per line-km	3.11M
Freight intensity: train-km per line-km per day	20.6
Avg. freight load per train (tonnes)	414
Freight share of network usage (train-km)	26%
Passenger rail market	
Non-incumbent (multi-operator) market share	16%
Pass. density: pass-km per line-km	2.61M
Pass. intensity: train-km per line-km per day	57.6
Pass. share of network usage (train-km)	74%

[21] Eurostat.
[22] Eurostat, European Railway Agency, Independent Regulators' Group, World Bank, Oliver Wyman analysis, 2018-2019 data (latest available). Crew size predates 2006.

On the freight side, 176 non-incumbent rail operators account for about half of market share.[23] Similar to the US, the German freight market is diverse in types of traffic hauled. On a tonne-km basis, approximately 26 percent is intermodal and 23 percent is carload. Hazardous materials make up 19 percent and cross-border (international traffic) 38 percent.

The top rail-hauled freight commodities for Germany are shown in Exhibit II-13. As in the United States, German railroads haul chemicals, plastics, metal ores and products, energy products, and a wide range of other goods.

Exhibit II-13: Top Rail-Hauled Commodities in Germany[24]
Million tonne-km



Single-person crews were introduced in Germany with the abolishment of steam traction in the 1950s and 1960s, and the second in-cab crew position was completely eliminated by 1996 (see Exhibit II-14).

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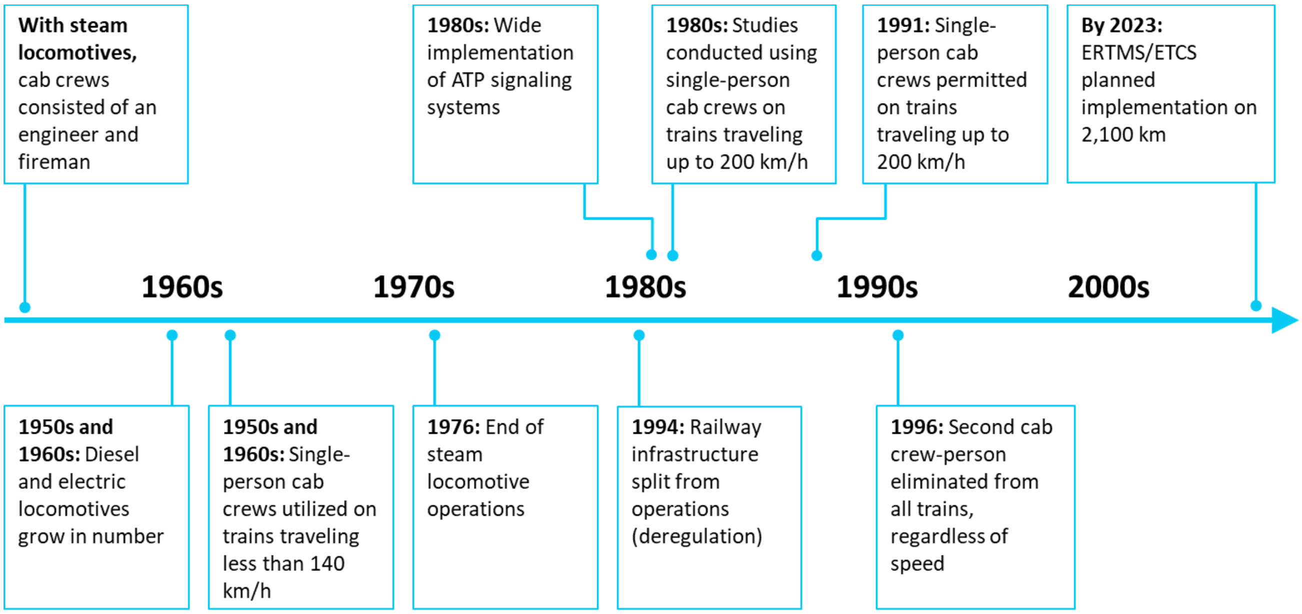
[23] Railway Market Analysis, Germany 2019, Bundesnetzagentur.
[24] Eurostat 2019 data, Oliver Wyman analysis.

Exhibit II-14: Timeline for Single-Person Crew Implementation in Germany[25]



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.[26] In 1996, all trains were allowed to operate with one-person locomotive cab crews. Germany currently has plans to install ERTMS on only 5.47 percent of its network through 2023.[27]

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[25] Oliver Wyman research.

[26] 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.

[27] EEIG ERTMS Users Group, Deutsche Bahn AG/DB Netz AG description (https://ertms.be/members/dbag).

2. France

France has the second longest rail network in Europe and has the second largest freight and passenger market in terms of tonne-km/passenger-km in the EEA-28. France uses predominantly one-person crews. (Two-person crews may be used in a small number of instances, such as failure of a deadman switch.)

Exhibit II-15: France: Key Rail Statistics[28]

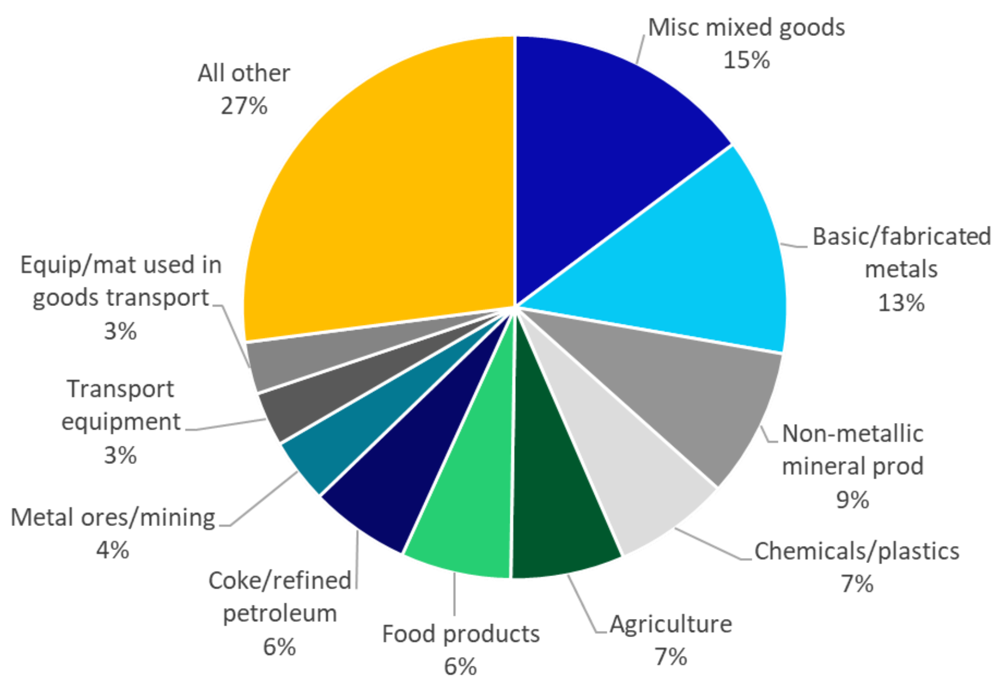
Overall market	
GDP, PPP international $	$3,315
Standard locomotive crew size	1 person
Active rail operators	27
Network size (line-km)	27,594
Network intensity (train-km/line-km per day)	42.4
Share of total European rail activity (train-km)	9.5%
Freight rail market	
Non-incumbent (multi-operator) market share	46%
Freight density: tonne-km per line-km	1.15M
Freight intensity: train-km per line-km per day	6.3
Avg. freight load per train (tonnes)	503
Freight share of network usage (train-km)	15%
Passenger rail market	
Non-incumbent (multi-operator) market share	5%
Pass. density: pass-km per line-km	3.56M
Pass. intensity: train-km per line-km per day	36.1
Pass. share of network usage (train-km)	85%

[28] Eurostat, ERA, Independent Regulators' Group, World Bank, Oliver Wyman analysis, 2018-2019 data (latest available). Crew size predates 2006.

On the freight side, non-incumbent rail operators who actively compete for freight and share access to the rail network now account for 46 percent of the market. About 24 percent of freight is intermodal, 17 percent hazmat, and 27 percent cross-border (on a tonne-km basis).

The top rail-hauled freight commodities for France are shown in Exhibit II-16. French rail operators haul significant miscellaneous mixed goods (typically intermodal), chemicals/plastics, food and agricultural products, and metals.

Exhibit II-16: Top Rail-Hauled Commodities in France[29]
Million tonne-km



3. Italy

Italy is the fifth largest freight and fourth largest passenger market in terms of tonne-km/passenger-km. 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

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[29] Eurostat 2019 data, Oliver Wyman analysis.

network. 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-17: Italy: Key Rail Statistics[30]

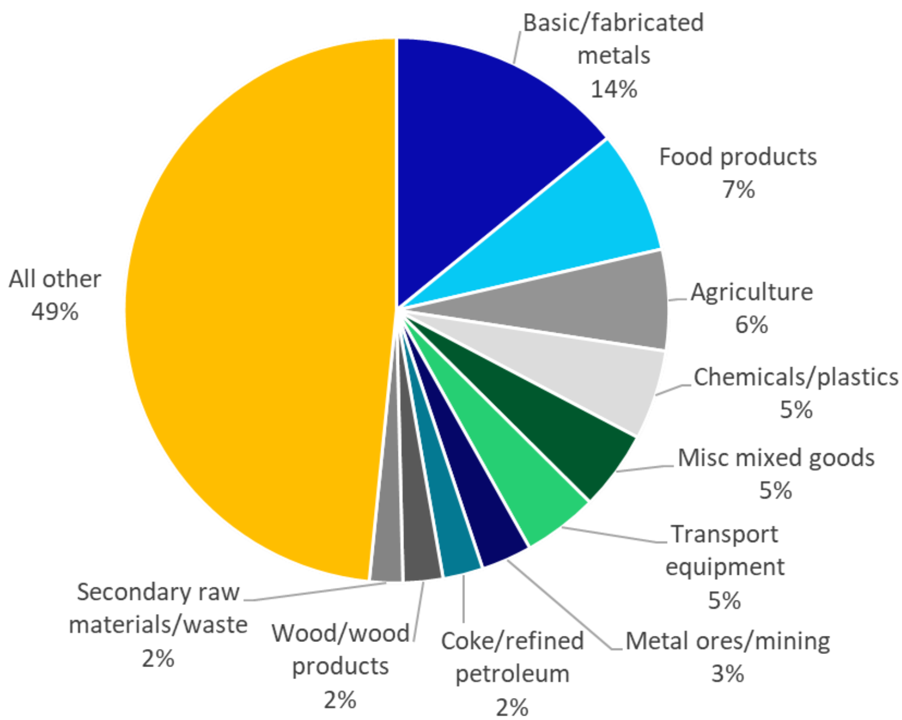
Overall market	
GDP, PPP international $	$2,665
Standard locomotive crew size	1 person
Active rail operators	35
Network size (line-km)	16,781
Network intensity (train-km/line-km per day)	63.4
Share of total European rail activity (train-km)	8.6%
Freight rail market	
Non-incumbent (multi-operator) market share	57%
Freight density: tonne-km per line-km	1.27M
Freight intensity: train-km per line-km per day	7.4
Avg. freight load per train (tonnes)	467
Freight share of network usage (train-km)	12%
Passenger rail market	
Non-incumbent (multi-operator) market share	27%
Pass. density: pass-km per line-km	3.37M
Pass. intensity: train-km per line-km per day	55.9
Pass. share of network usage (train-km)	88%

On the freight side, non-incumbents control 57 percent of market share. These companies actively compete with one another for freight and share access to the rail network. Nearly half of Italian rail traffic is intermodal About half of traffic is international. The top rail-hauled freight

[30] Eurostat, ERA, Independent Regulators' Group, World Bank, Oliver Wyman analysis, 2018-2019 data (latest available).

commodities for Italy are shown in Exhibit II-18. Italian rail traffic includes metals, agriculture and food products, chemicals/plastics, and a wide range of other goods.

Exhibit II-18: Top Rail-Hauled Commodities in Italy[31]
Million tonne-km



4. Poland

Poland is the third largest freight market and seventh largest passenger market in terms of tonne-km/passenger-km. Rail operations predominantly use one-person crews.

On the freight side, dozens of rail operators that actively compete for freight and share access to the rail network control about 46 percent of the market. On a tonne-km basis, intermodal and carload together account for 26 percent of Polish rail freight, 17 percent of traffic is hazmat, and a quarter is international (cross-border). Poland's railroads run slightly heavier trains than is the norm for Western Europe, and freight accounts for about a third of network activity (train-km).

[31] Eurostat 2019 data, Oliver Wyman analysis.

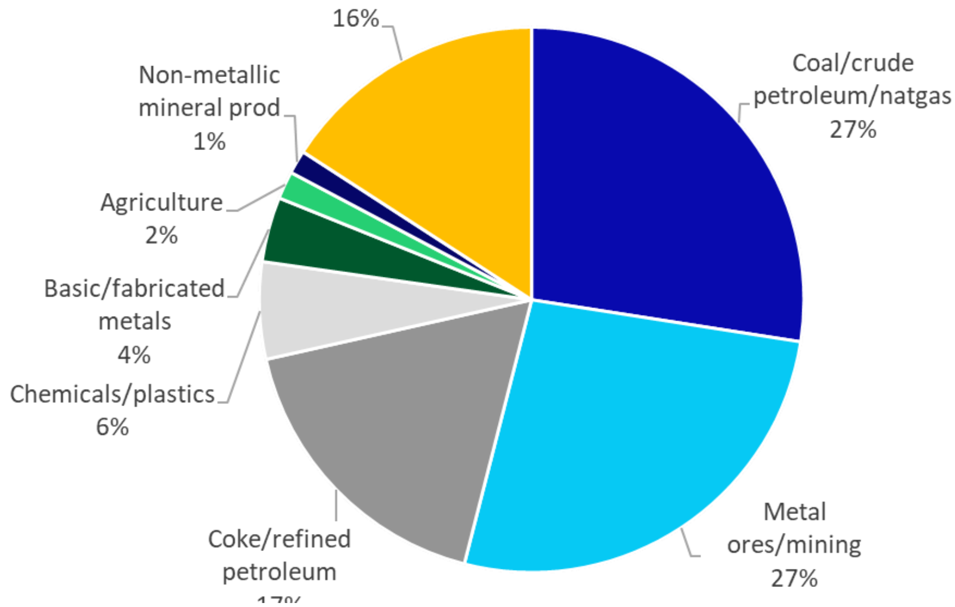
Exhibit II-19: Poland: Key Rail Statistics[32]

Overall market	
GDP, PPP international $	$1,299
Standard locomotive crew size	1 person
Active rail operators	85
Network size (line-km)	19,235
Network intensity (train-km/line-km per day)	34.7
Share of total European rail activity (train-km)	5.4%
Freight rail market	
Non-incumbent (multi-operator) market share	46%
Freight density: tonne-km per line-km	2.84M
Freight intensity: train-km per line-km per day	11.8
Avg. freight load per train (tonnes)	661
Freight share of network usage (train-km)	34%
Passenger rail market	
Non-incumbent (multi-operator) market share	42%
Pass. density: pass-km per line-km	1.05M
Pass. Intensity: train-km per line-km per day	23
Pass. share of network usage (train-km)	66%

The top rail-hauled freight commodities for Poland are shown in Exhibit II-20. Polish rail operators haul significant bulk traffic, including energy products, ores, and chemicals.

[32] Eurostat, ERA, Independent Regulators' Group, World Bank, Oliver Wyman analysis, 2018-2019 data (latest available). Crew size predates 2006.

Exhibit II-20: Top Rail-Hauled Commodities in Poland[33]
Million tonne-km



5. United Kingdom

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

The UK rail network is heavily utilized by passenger rail. On the freight side, about nine rail operators actively compete for freight and share access to the rail network, with non-incumbents accounting for 61 percent of market share. About half of freight tonne-km are intermodal.

[33] Eurostat 2019 data, Oliver Wyman analysis.

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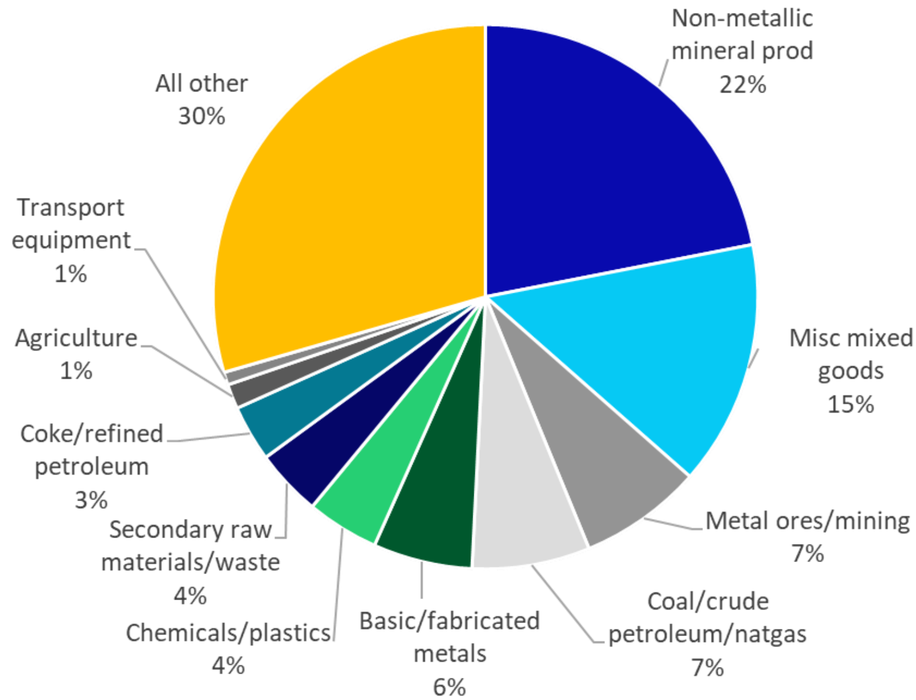
Exhibit II-21 United Kingdom: Key Rail Statistics[34]

Overall market	
GDP, PPP international $	$3,255
Standard locomotive crew size	1 person
Active rail operators	34
Network size (line-km)	16,289
Network intensity (train-km/line-km per day)	95.5
Share of total European rail activity (train-km)	12.7%
Freight rail market	
Non-incumbent (multi-operator) market share	61%
Freight density: tonne-km per line-km	1.04M
Freight intensity: train-km per line-km per day	5.6
Avg. freight load per train (tonnes)	504
Freight share of network usage (train-km)	6%
Passenger rail market	
Non-incumbent (multi-operator) market share	87%
Pass. density: pass-km per line-km	4.41M
Pass. intensity: train-km per line-km per day	89.9
Pass. share of network usage (train-km)	94%

The top rail-hauled commodities for the UK are shown in Exhibit II-22. Similar to the US, UK rail operators have seen a significant decline in coal haulage, and instead now haul a wide variety of goods, including minerals, mixed goods (usually intermodal), metal ores, and chemicals/plastics.

[34] Eurostat, ERA, Independent Regulators' Group, World Bank, Oliver Wyman analysis, 2018-2019 data (latest available). Crew size predates 2006.

Exhibit II-22: Top Rail-Hauled Commodities in the UK[35]
Million tonne-km



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, but Latvia uses two-person crews (at all times) and Lithuania uses one-person crews. Both are Baltic port countries and their railway networks serve as extensions of the Russian Railway network to the Baltic Sea ports. 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 much heavier trains and are more bulk commodity focused than is the case in Western European countries.

[35] Eurostat 2019 data, Oliver Wyman analysis.

Exhibit II-23: Latvia: Key Rail Statistics[36]

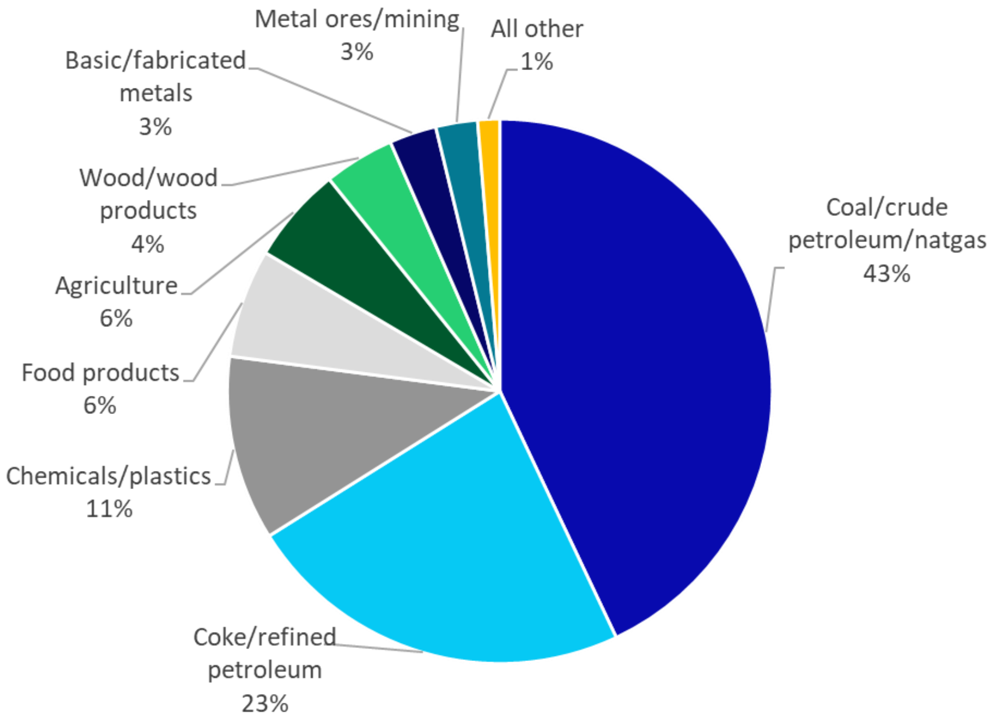
Overall market	
GDP, PPP international $	$62
Standard locomotive crew size	2 persons
Active rail operators	7
Network size (line-km)	1,860
Network intensity (train-km/line-km per day)	23.1
Share of total European rail activity (train-km)	0.4%
Freight rail market	
Non-incumbent (multi-operator) market share	32%
Freight density: tonne-km per line-km	8.07M
Freight intensity: train-km per line-km per day	14.1
Avg. freight load per train (tonnes)	1,566
Freight share of network usage (train-km)	61%
Passenger rail market	
Non-incumbent (multi-operator) market share	7%
Pass. density: pass-km per line-km	0.35M
Pass. intensity: train-km per line-km per day	8.9
Pass. share of network usage (train-km)	39%

On the freight side, several rail operators compete for freight and share access to the rail network, with non-incumbents accounting for 32 percent of market share. Freight accounts for 61 percent of total train-km. Latvian freight railroads move 230 million tonne-km per year of intermodal traffic.

The top rail-hauled commodities for Latvia are shown in Exhibit II-24. Latvian freight rail primarily hauls energy products, but also chemicals/plastics, agricultural and food products, and other goods.

[36] Eurostat, ERA, Independent Regulators' Group, World Bank, Oliver Wyman analysis, 2018-2019 data (latest available).

Exhibit II-24: Top Rail-Hauled Commodities in Latvia[37]
Million tonne-km



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.

Lithuania has one primary active freight operator. Freight accounts for 61 percent of train-km on the network. About 17 percent of freight is hazmat and 59 percent international (on a tonne-km basis).

[37] Eurostat 2019 data, Oliver Wyman analysis.

Exhibit II-25: Lithuania: Key Rail Statistics[38]

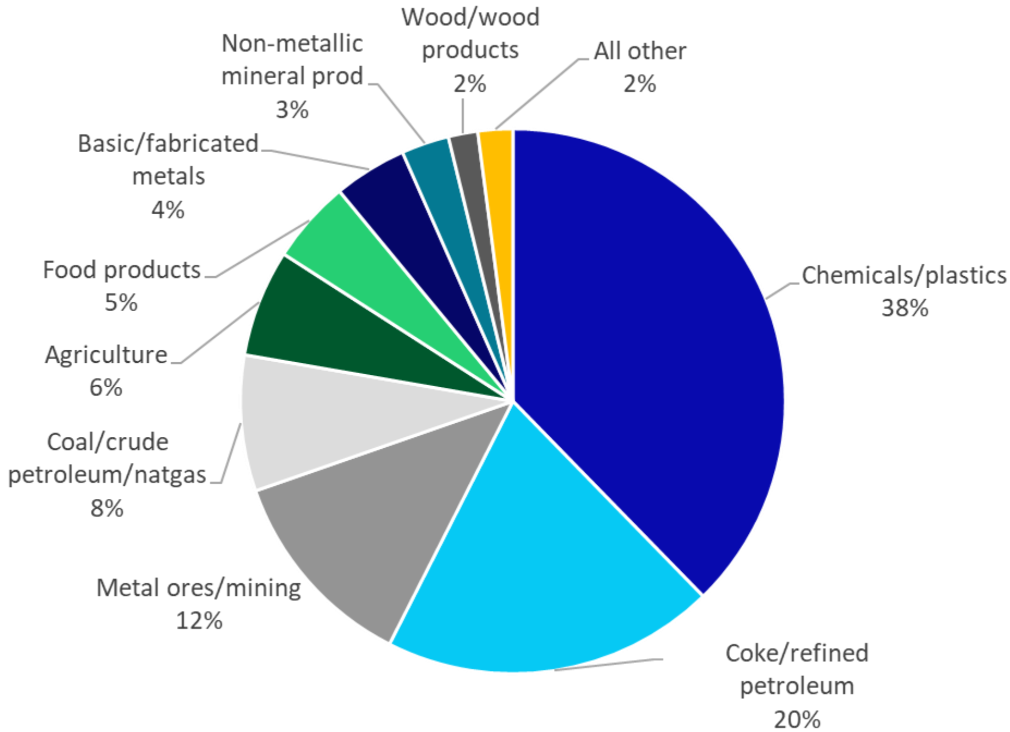
Overall market	
GDP, PPP international $	$106
Standard locomotive crew size	1 person
Active rail operators	1
Network size (line-km)	1,911
Network intensity (train-km/line-km per day)	23.1
Share of total European rail activity (train-km)	0.4%
Freight rail market	
Non-incumbent (multi-operator) market share	0%
Freight density: tonne-km per line-km	8.47M
Freight intensity: train-km per line-km per day	14.1
Avg. freight load per train (tonnes)	1,649
Freight share of network usage (train-km)	61%
Passenger rail market	
Non-incumbent (multi-operator) market share	0%
Pass. density: pass-km per line-km	0.19M
Pass. intensity: train-km per line-km per day	9.1
Pass. share of network usage (train-km)	39%

The top rail freight hauled commodities for Lithuania are shown in Exhibit II-26. Lithuania's railroad hauls a variety of commodities, including chemicals/plastics, energy products, ores, and agricultural and food products.

[38] Eurostat, ERA, Independent Regulators' Group, World Bank, Oliver Wyman analysis, 2018-2019 data (latest available). Crew size predates 2006.

Exhibit II-26: Top Rail-Hauled Commodities in Lithuania[39]

Million tonne-km



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, and significant hazardous materials haulage. 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 and destinations. And yet, the majority of these systems operate with one-person crews.

Both Genesee & Wyoming, a freight train operator, and Keolis, a passenger train operator, provide rail transportation in both North American and Europe. Their senior management are

[39] Eurostat 2019 data, Oliver Wyman analysis.

therefore in a unique position to compare the safety of single-person versus two-person crew operations. The COO of Genesee & Wyoming and the Rail Director of Keolis have previously provided statements about the safety of single-person crews:

> *"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 Protection] 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*

As COO of Genesee & Wyoming (2012-2020), Mr. Brown had in-depth experience in both international and US rail operations, and oversaw 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 had 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, yet they 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, 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

Mr. Auger, Director of the Railway Division at Keolis since 2006, has in-depth experience in both international and US rail operations. Keolis has operated passenger trains on both the Virginia Railway Express (VRE) and the Massachusetts Bay Transportation Authority (MBTA) in the United States. In Europe, Keolis has operated services in London, UK (Thameslink, London Midlands, Southeastern); Dusseldorf, Germany (Eurobahn); and Deventer, Netherlands (Syntus network). Keolis is a subsidiary of SNCF, France's legacy national railroad, which operates both freight and passenger trains in Europe.

III. US and European Rail Safety Analysis

In the prior section, Oliver Wyman demonstrated that European rail operations are an appropriate basis for comparison to US rail operations along many dimensions. Yet operations with one-person train crews account for over 95 percent of all train-km in Europe and have overall safety metrics as good as, or better than, operations with two-person crews. According to the European Union Agency for Railways (ERA), "*The railway safety level of the Union railway system remains high; it is one of the highest worldwide.*"[40]

In 2016, Oliver Wyman analyzed accident data for the EEA-28 countries and compared it to US Federal Railroad Administration (FRA) accident/incident data, based on nine years of available data. In this report, we have now updated our analysis to include 14 years of data. The European data was divided into Eastern and Western Europe and into countries operating one-person crews and those operating two-person crews. The analysis found no detectable differences in railway safety based on crew size.

A. Single-Person Crew Operations in Europe

In the European Union, single-person crew operation has two preconditions, both of which are met in the United States: [41]

- A working deadman control system must be present 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.

[40] "Report on Railway Safety and Interoperability in the EU," European Union Agency for Railways, 2020, p. 14.
[41] Regulation promulgated at the national level, but consistent across the EU.

- The locomotive must be equipped with working Automatic Train Control/Automatic Train Protection (ATC/ATP),[42] where such systems are installed on main track. That is, ATC/ATP enables dispatchers to remotely operate signals and switches to ensure trains do not make conflicting movements.

Implementation of single-person crews in Europe occurred decades ago on many railroads, prior to the regulatory overhaul of the mid-1990's that separated rail operations from infrastructure ownership and control, and that mandated open access for any qualified rail operator. Freight and passenger train operations were originally largely provided by state-owned railroads. 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 truck-competitive marketplace characterized by shorter lengths of haul. 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 78 percent of its network.[43] By comparison, the US has installed positive train control on 62 percent of its network.[44]

The FRA has compiled the following list of tasks for conductors:[45]

1. Managing the train consist

[42] 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.
[43] European Commission Mobility and Transport website, Eurostat. Projected deployment by 2030 of ERTMS on 50,000 kilometers of 225,600 line-kilometers.
[44] "FRA: PTC operating on over 99 percent of required route miles," Progressive Railroading, November 18, 2020; Analysis of Class I Railroads, 2019, AAR; Bureau of Transportation Statistics. PTC is installed on 57,536 of 92,282 Class I route-miles.
[45] Train Crew Staffing: Notice of Proposed Rulemaking, Regulatory Impact Analysis, US Federal Railroad Administration, February 18, 2016, p. 31.

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 or has been fully automated into wireless devices, while tasks 2 and 3 are handled by the engineer. Further, the FRA has stated 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."[46] 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 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 ERTMS on key high-density corridors (see Appendix A), which at more advanced levels is similar to North American positive train control (PTC).

Temporary slow orders and other exceptional circumstances along the train run are typically communicated to train crews in written or electronic form before departure. While the train is

[46] Train Crew Staffing: Notice of Proposed Rulemaking, op. cit., pp. 31-32.

moving, transmission via radio or directly to a wireless device on the train is possible under current operating practices.

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.

B. Safety Data Used in the Analysis

Data on rail accidents and incidents for 2006 through 2019 from the European Railway Agency (ERA) and the FRA were obtained and used by Oliver Wyman for this analysis. A combination of interviews and Oliver Wyman expertise was used to determine the policy of each European 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.[47] This is an important fact that allowed the assumption that the default crew size applied to all accidents within a country, as individual accident data is not available from the ERA.

For purposes of the analysis, Europe was divided into "Western" and "Eastern" based on geography.[48] Exhibit III-1 illustrates the geographic divide as well as the countries still operating two-person crews. The statistical analysis contained in this report subdivided Europe into four

[47] 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 (deadman 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.
[48] There is no precise definition of "Eastern" vs. Western" Europe. The UN uses statistical regions of eastern, southern, western and northern Europe. The CIA World Factbook includes a Central Europe. Oliver Wyman primarily followed the UN east/west divide, though Czechia was included in Western Europe, with which its spending on rail infrastructure is most closely aligned.

categories: Western one-person crews (16 countries); Western two-person crews (one country); Eastern one-person crews (four countries); and, Eastern two-person crews (five countries). Crew size could not be determined for two countries (Croatia and Slovenia). The comparative analysis of safety statistics uses averages based on the four categories, giving equal weight to each country so that countries with higher rail volumes (such as Germany) do not dominate the results. To test that equal weighting did not improperly bias the results, the analysis was repeated for All Significant Accidents where countries were weighted by train-kilometers, and the conclusions were unchanged (see Appendix D).

Exhibit III-1: Eastern and Western Europe with Rail Crew Size

Eastern Europe: light blue; Western Europe: dark blue; 2-person crews: yellow highlight

Oliver Wyman analyzed total "significant accident" data as well as five subcategories (see Appendix B for definitions): collisions, derailments, level crossings, accidents to persons, and other accidents. In addition, we analyzed employee fatalities, economic impact of accidents, and signals passed at danger (SPADs – which are often a precursor to accidents) from the ERA data, but this information is not provided by the FRA, or in the case of employee fatalities, the FRA and ERA data could not be aligned. Suicides and attempted suicides were not analyzed. The ERA data was used “as is,” without any attempts to clean or modify it or impute missing values.

The FRA’s accident/incident data is more comprehensive than the ERA data, and therefore had to be filtered to provide an equal, “apples-to-apples” comparison. Exhibits III-2 and III-3 show the initial number of FRA data records, the categories of filters, the number of records eliminated from consideration by each filter, and the final number of filtered records for equipment incidents and injuries, respectively. For equipment incidents (Exhibit III-2), 8,980 FRA records were filtered out because the ERA data reporting threshold is €150,000 ($178,700) of damage versus a $10,700 threshold for 2019 in the FRA data. The other large category of equipment incident records filtered out from FRA data involved incidents occurring in a yard or at industrial sites, as this information does not exist in the ERA data. Overall, 13.9 percent of the FRA reported equipment incident data was retained for the analysis.

Categories of injuries filtered out of the FRA data to match the ERA data (Exhibit III-3) included injuries not occurring on mainlines or sidings, injuries involving stationary equipment and injuries not involving train movements. Line-haul movements of trains, the focus of this analysis, were retained. Overall, 9.5 percent of the injury data was retained from the FRA data after the filters were applied.

Exhibit III-2: Filtering FRA Data to Match ERA Data: Equipment Incidents, 2006-2019[49]

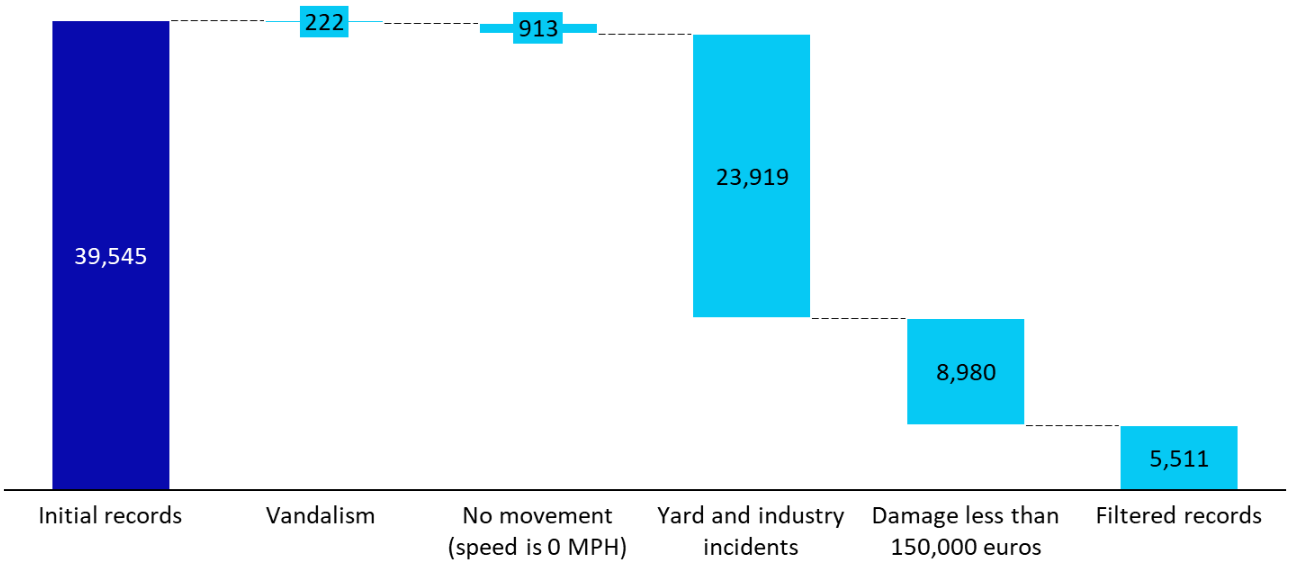
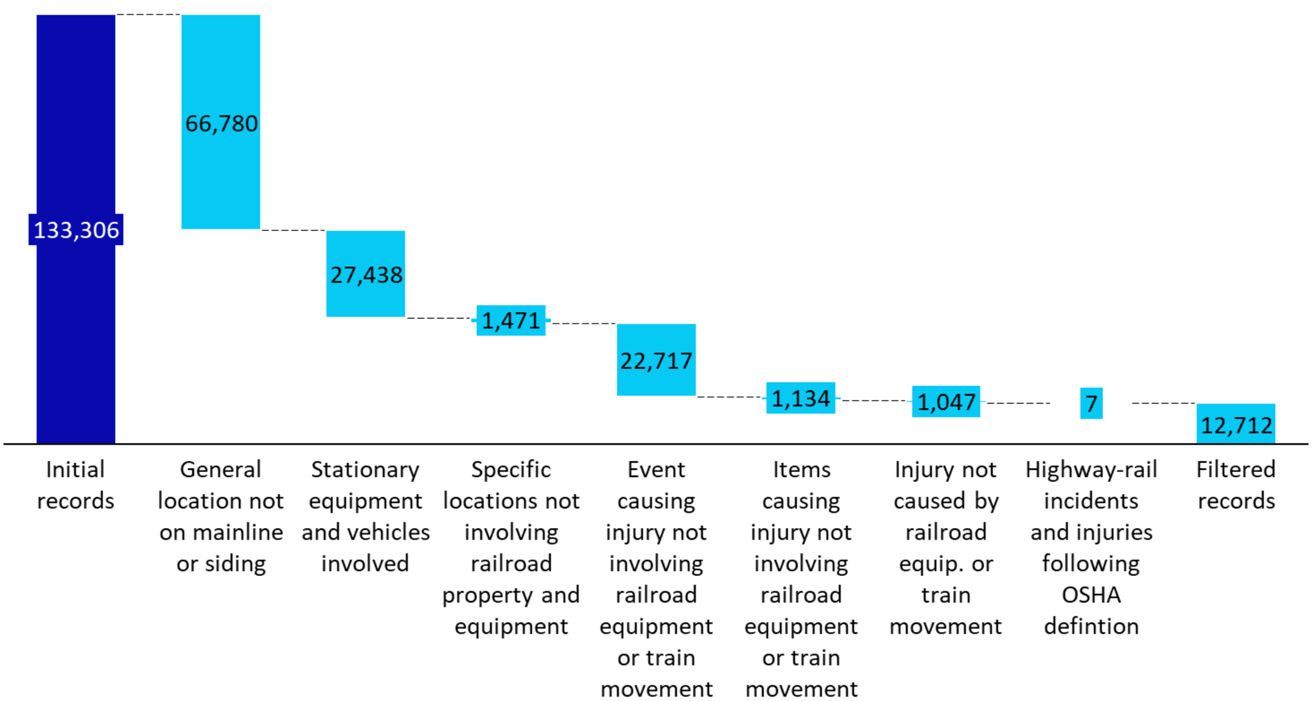


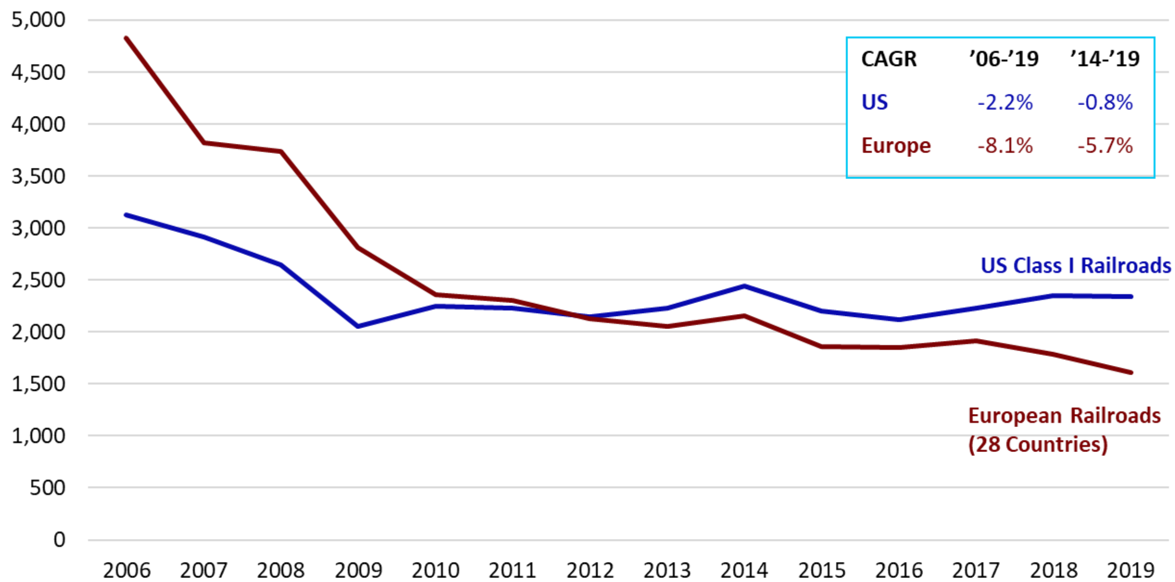
Exhibit III-3: Filtering FRA Data to Match ERA Data: Injuries, 2006-2019[50]



[49] Accident/Incident Data, 2006-2019, FRA; Oliver Wyman analysis.
[50] Ibid.

In 2019, the number of significant accidents for the combined 28 countries in the ERA data was 1,614, compared to 2,341 in the filtered FRA data for US Class I railroads. The number of significant accidents for EEA-28 countries (including rail systems with both one-person and two-person crews) has been declining at a rate of 8.1 percent per year since 2006, slowing slightly to 5.7 percent over the past five years. The US Class I railroads also have seen a reduction in total accidents over time, but at a slower rate of decline than in Europe (Exhibit III-4).

Exhibit III-4: Total Number of Significant Rail Accidents[51]
US Class I vs. combined total for EEA-28; 2006 through 2019

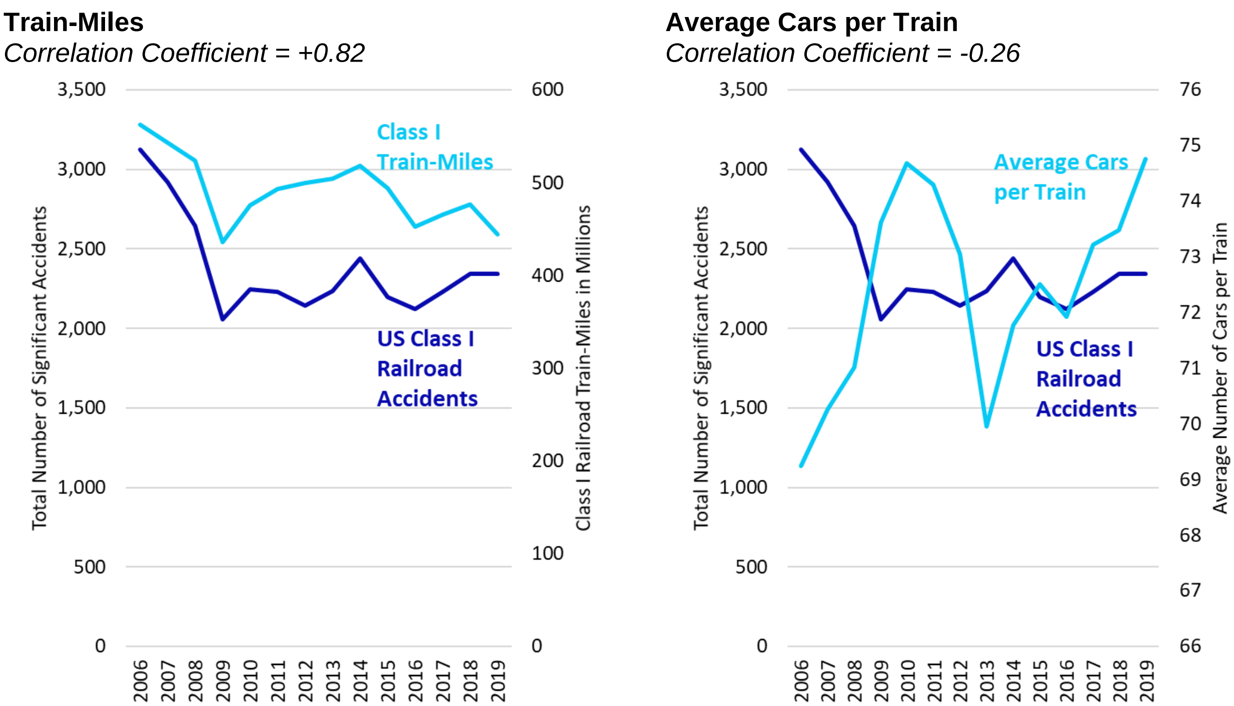


Comparing the total number of accidents does not provide the best indication of trends, however, since traffic volumes and operations change over time. As would be expected, there is a strong correlation between the number of train accidents and number of train-miles (Exhibit III-5, left exhibit). The US Class I railroads also have been running longer trains the past few years by increasing the number of cars per train, which would lead to fewer train-miles to move

[51] Accident/Incident Data, 2006-2019, FRA; "Common Safety Indicators data reported by National Safety Authorities," ERA, 2006-2019; Oliver Wyman analysis.

the same volume. The number of significant accidents reported in the FRA data, however, shows no difference in accidents based on the number of cars in the train (Exhibit III-5, right exhibit).

Exhibit III-5: US Class I Accidents vs. Train-Miles and Average Cars per Train



The statistical analysis in the following sections normalizes both European and US safety data by using accidents/incidents per million train-kilometers, to allow for a more equal comparison of safety records.

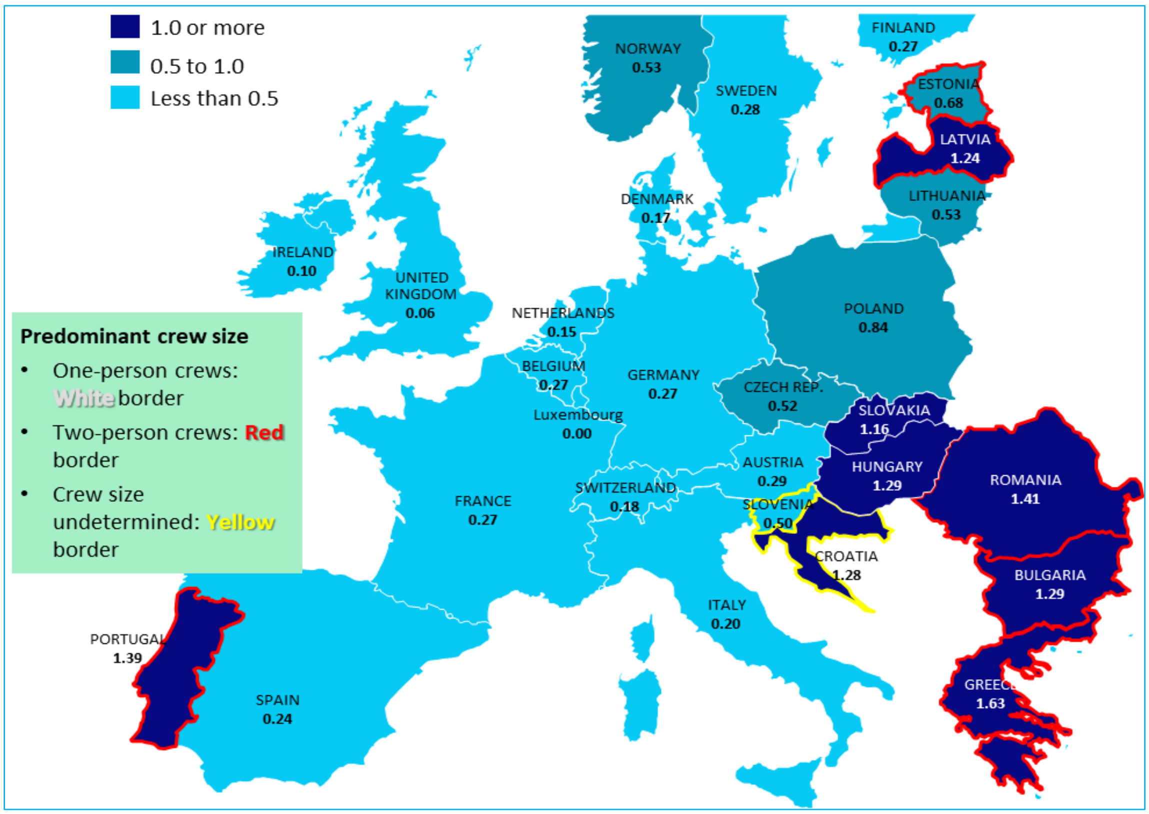
C. Overall Rates of Significant Accidents

Significant accidents are defined as any accident involving at least one rail vehicle in motion, resulting in at least one killed or seriously injured person, or involving significant damage to rolling stock, track, other installations or environment, or extensive disruptions to traffic. Accidents in workshops, warehouses, and depots are not relevant to our study of the impact of crew size on safety. Significant damage exceeds a threshold of €150,000 in the ERA safety data, and has been filtered to the same level in the FRA safety data.

Overall, the majority of European countries have less than 0.5 significant accidents per million train-km in Western Europe, and between 0.5 and 1.5 significant accidents per million train-km in Eastern Europe (Exhibit III-6). In general, countries operating two-person crews are located along the eastern edge of Europe, where accident rates are higher as well.

Passenger traffic accounts for more than 50 percent of train-km 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 lower levels of significant accidents.

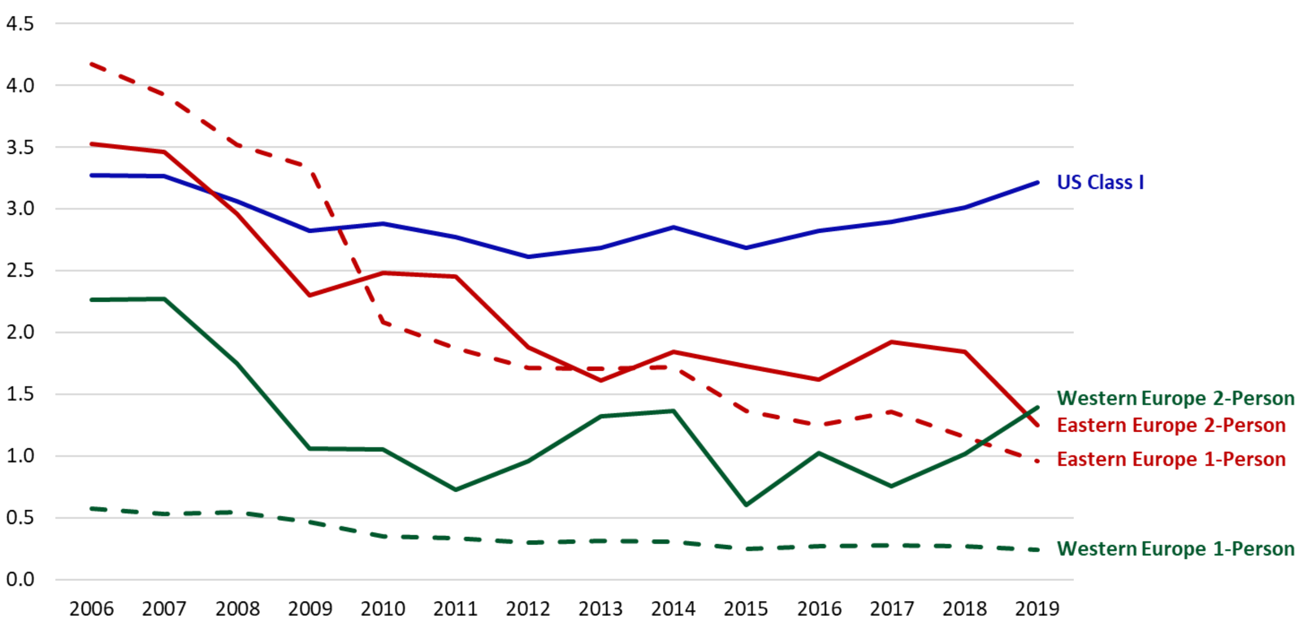
Exhibit III-6: EEA-28: Crew Size and Significant Accidents[52]
Per million train-km; 2019



[52] "Common Safety Indicators," ERA, Table 0, Field N10, 2019; Oliver Wyman analysis and interviews.

Statistical analysis of data from the ERA and FRA for the past 14 years found that countries with one-person crews have maintained a lower overall rate of significant accidents (Exhibit III-7). This is not to suggest 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, available accident data provides no basis for concluding that two-person crews are safer than one-person crews. And overall, one-person crews in Europe have an impressive safety record. The available accident data, compared among and between European and US rail carriers, establishes no safety-based justification for staffing a second crew member in the locomotive cab.

Exhibit III-7: All Significant Accidents, 2006-2019[53]
Per million train-km



Although Exhibit III-7 appears to indicate one-person crews are equally safe, if not safer, than two-person crews, a series of statistical tests were performed to validate this appearance. A

[53] "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Oliver Wyman analysis.

"t-test" determines whether the difference in two data sets is "statistically significant" or whether there is no statistically significant difference in the data at a specified level of confidence.[54] The result of this analysis is shown in Exhibit III-8.

Exhibit III-8: T-Test Results for All Significant Accidents, 2006-2019[55]

Read across row	US Class I	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	NA	Worse	Worse	Worse	Worse
Western Europe 1-Person	Better	NA	Better	Better	Better
Western Europe 2-Person	Better	Worse	NA	Better	Better
Eastern Europe 1-Person	Better	Worse	Worse	NA	No Sig Dif
Eastern Europe 2-Person	Better	Worse	Worse	No Sig Dif	NA

Each row in Exhibit III-8 shows how the railroad category represented by that row compares to the other railroad categories (i.e., columns). For example, the row labeled "US Class I" shows that the US Class I railroads have a statistically significant worse safety record than the four categories of European railroads for all significant accidents – both one-person and two-person – indicating that crew size is *not* the reason for this difference.[56]

Equally, the large group of Western European one-person operations showed fewer significant accidents than all other one-person and two-person crews, indicating that the reasons are not related to crew size. The Eastern European one-person and two-person crews showed no statistically significant difference – these had about the same accident rates regardless of crew size.[57] The results in Exhibit III-8 appear to be consistent with the line chart in Exhibit III-7, the

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[54] The t-tests were run in Microsoft Excel using the "T.TEST" function, which assumes a difference in the hypothesized mean = 0 and a level of confidence (alpha) = 0.05. The parameters were set for a two-tailed test, since it was unknown if one-person crews or two-person crews would have the lower value and for unequal variances in the data. For a cell to show "Better," the t-test must indicate a greater than 95 percent confidence that there is a difference in the means of the two groups, and the group represented by the row must have a lower mean (better safety record) than the group represented by the column.

[55] "Common Safety Indicators data," ERA ; "Accident/Incident Report," FRA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis. Numerical results of the t-test are contained in Appendix D.

[56] Class I railroads include BNSF, Canadian National, Canadian Pacific, CSX, Kansas City Southern, Norfolk Southern, and Union Pacific. Class I subsidiaries were including with the Class I (e.g., Gateway Eastern and Texas Mexican with KCS).

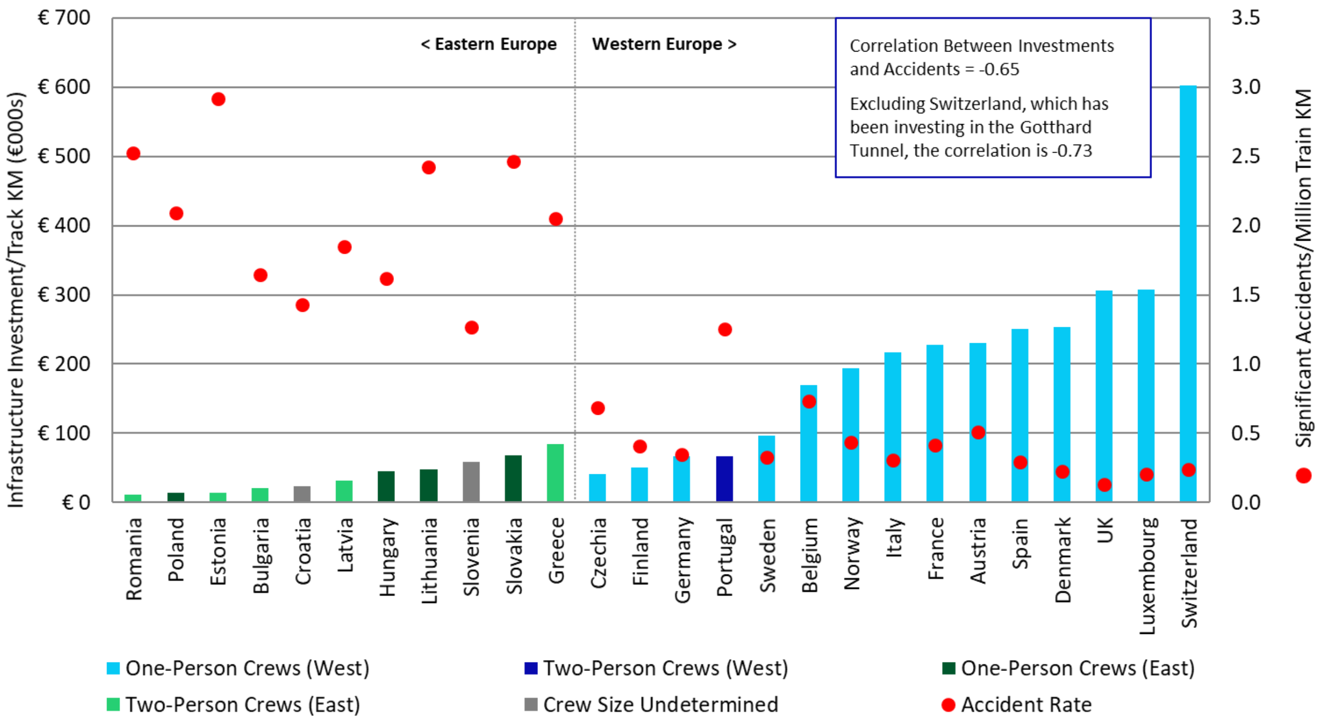
[57] "No significant difference" indicates the t-test returned less than a 95 percent confidence level that these data were different.

key takeaway being that the rate of all significant accidents, while it may vary by geography, is unrelated to crew size.

D. Investment and Accident Rates

One factor impacting overall accident rates that is worth examining further is that Western European countries with typically lower accident rates spend more on rail infrastructure (per track-km) than Eastern European countries (Exhibit III-9).

Exhibit III-9: Comparison of Annual Infrastructure Investments and Significant Accident Rates[58]



The exhibit above shows that there is a fairly strong correlation 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

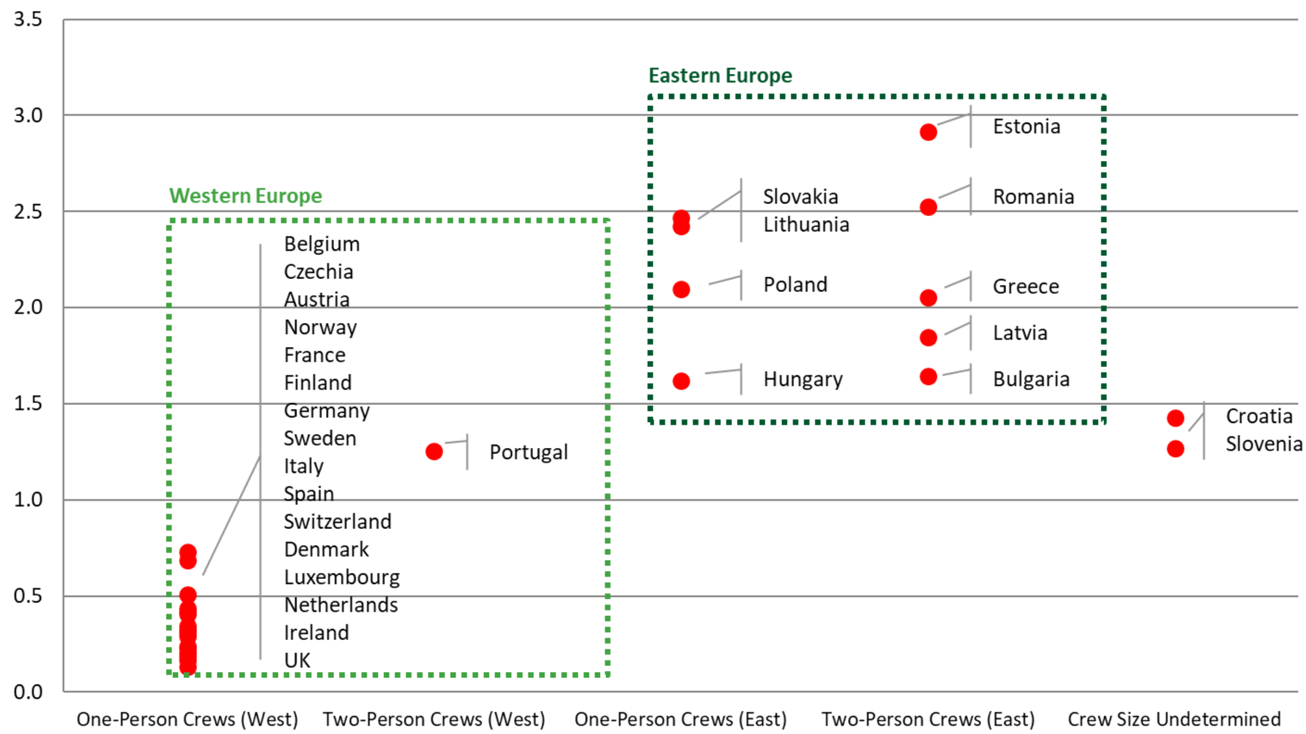
58 Note: Annual infrastructure investment/track-km (average 2006-2018), significant accidents/train-km (average 2006-2019). Source: OECD (2021) Infrastructure investment (indicator). doi: 10.1787/b06ce3ad-en (accessed on February 5, 2021). "Common Safety Indicators," ERA, Table 0, Field N10.

© Oliver Wyman

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 Gotthard Base Tunnel and new high-speed passenger lines. The countries with the highest spending on infrastructure tend to be those with the highest-density passenger rail services.

Where infrastructure spending is comparable, crew size appears to have no impact on accident rates (Exhibit III-10). This indicates that investments in rail infrastructure integrity and in technology are the keys to a safer rail network, rather than the number of crew members.

Exhibit III-10: Significant Accidents Compared to Investment and Crew Size[59]
Average 2006-2019, per million train-km

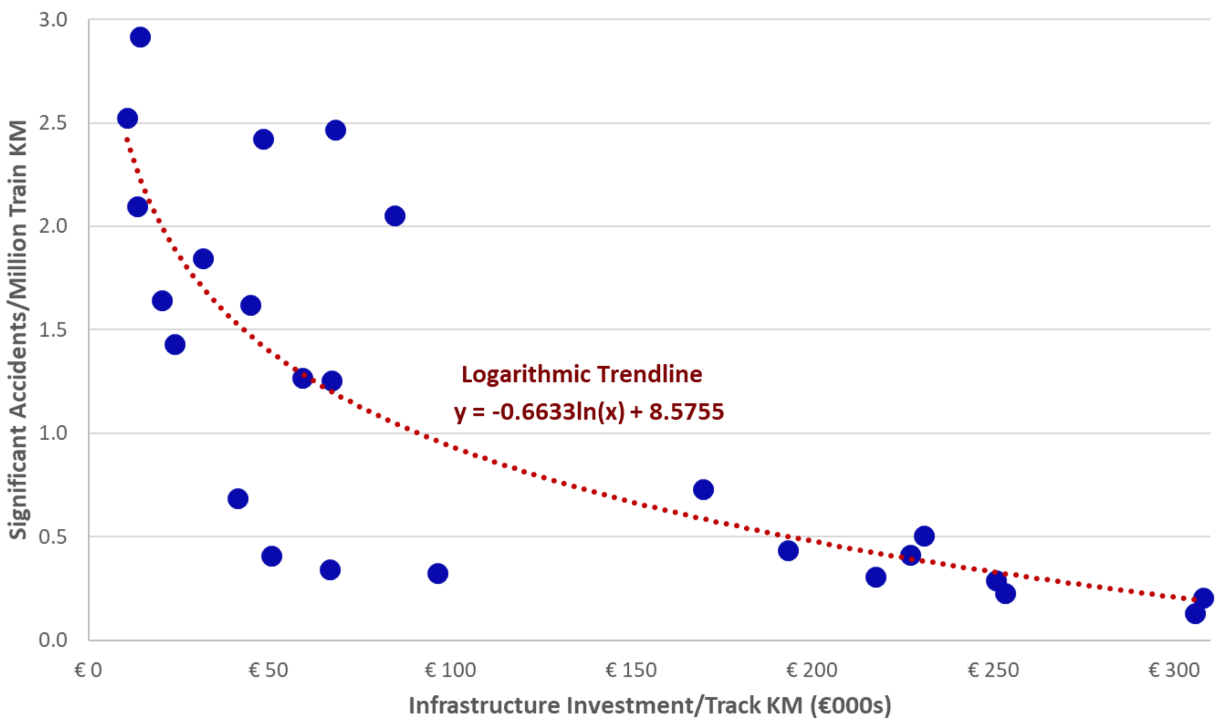


[59] OECD (2021), Infrastructure investment (indicator). doi: 10.1787/b06ce3ad-en (Accessed on February 5, 2021); "Common Safety Indicators," ERA, Table 0, Field N10. Oliver Wyman analysis.

To better quantify the impact of investments on accident rates, Exhibit III-11 provides a plot of infrastructure investment per track-km versus significant accidents per million train-km. The data follows a logarithmic trendline (in red), which logically demonstrates that increasing investments at lower investment levels results in a greater impact on safety than similar increases at higher investment levels. For example, a doubling of investment from 10,000 to 20,000 euros per track-km reduces significant accidents per million train-km from 2.47 to 2.01 (a reduction of 0.46), while an increase of 10,000 euros from 200,000 to 210,000 per track-km reduces significant accidents per million train-km from 0.48 to 0.45 (a reduction of only 0.03).

Exhibit III-11: Relationship Between Annual Infrastructure Investments and Significant Accident Rates[60]

Note: Switzerland excluded due to the high expense of the Gotthard Tunnel construction



[60] Note: Annual infrastructure investment/track-km (average 2006-2018), significant accidents/train-km, (average 2006-2019). Source: OECD (2021) Infrastructure investment (indicator). doi: 10.1787/b06ce3ad-en (accessed on February 5, 2021); "Common Safety Indicators," ERA, Table 0, Field N10; Oliver Wyman analysis.

While the values above are indicative of the relationship between infrastructure spending and accident rates, there are several additional factors which would need to be considered to fully quantify the relationship, including adjustments for large investments in new construction and maintenance spending levels for rolling stock.

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 safety, such as the installation of PTC systems on the primary mainlines. Across the entire 118,500 miles of trackage operating by the US Class I railroads, the average capex spend equates to €31,831 per track-km, which is between the Eastern Europe and Western Europe averages.[61] The US Class I railroad average capex spend is even higher on the 57,500 miles where PTC is installed. This is partially due to the billions invested in PTC, but also because these routes represent the highest-density rail corridors in the US, including freight-passenger shared use corridors and routes used to transport hazardous materials.

E. Analysis of Accident Rates By Category

The following sections provide further breakdowns of ERA and FRA safety data by examining collisions, derailments, grade/level crossings, accidents to persons, and other accidents. Employee fatalities, signals passed at danger (SPADs) and the economic impact of accidents also are assessed, but only for Europe, since the FRA does not report this information, or in the case of fatalities, the FRA and ERA data could not be aligned.

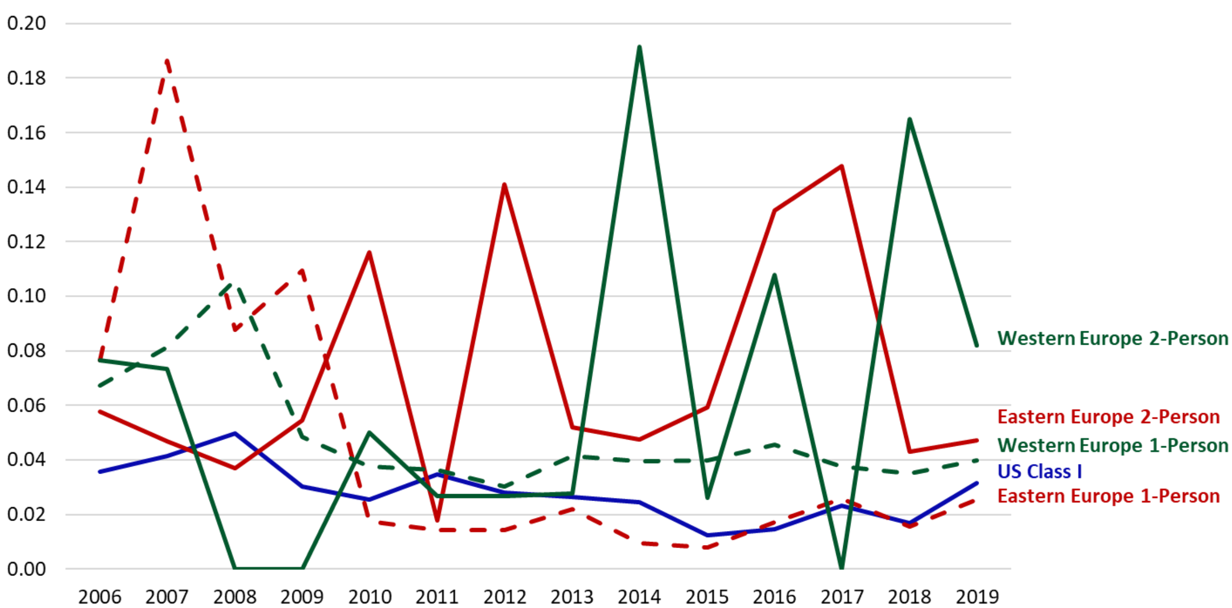
[61] R-1 Annual Reports for 2019, Schedule 700, Total track miles minus Class 5 (trackage rights) track miles, US Surface Transportation Board; Analysis of Class I Railroads, line 378, AAR; US$ to Euros conversion, YCharts.com.

1. Collisions and Derailments

Collisions cover both collisions of trains and collisions with obstacles within the track clearance. This safety category 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. The exception is at grade/level crossings involving a crossing vehicle/user, which are recorded under grade/level crossing accidents.

Exhibit III-12 shows that on an annual basis, collisions rates for European one-person crews and US Class I's have followed a roughly similar pattern over the past decade, and that the rate of collisions across these railroads is small, between 0.02 and 0.04 per million train-km in 2019.

Exhibit III-12: Collisions by Geography and Crew Size, 2006-2019[62]
Per million train-km



As shown by the results of the statistical test in Exhibit III-13, the US Class I railroads have a statistically significant better record with regard to collisions than some European one-person and two-person crews but not others, indicating that any differences in collision rates are not

[62] "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Oliver Wyman analysis.

related to crew size. In the case of European one-person versus two-person crews, there was no significant difference in collisions, regardless of crew size.

Exhibit III-13: T-Test Results for Collisions, 2006-2019[63]

Read across row	US Class I	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	NA	Better	No Sig Dif	No Sig Dif	Better
Western Europe 1-Person	Worse	NA	No Sig Dif	No Sig Dif	No Sig Dif
Western Europe 2-Person	No Sig Dif	No Sig Dif	NA	No Sig Dif	No Sig Dif
Eastern Europe 1-Person	No Sig Dif	No Sig Dif	No Sig Dif	NA	No Sig Dif
Eastern Europe 2-Person	Worse	No Sig Dif	No Sig Dif	No Sig Dif	NA

Derailments involve any case in which at least one wheel of a train leaves the rails. Exhibit III-14 shows that over the past decade, US Class I's have had a consistently higher level of derailments than most European rail operators, regardless of their crew size. This is confirmed by the results of the statistical test in Exhibit III-15, which shows that US Class I railroads have a statistically significant worse record than both European one-person and two-person crews, indicating that any differences in derailment rates are not related to crew size. Within Europe, there are differences by geography, but no relationship between overall crew size and derailment rates.

63 "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis. Numerical results of the t-test are contained in Appendix D.

Exhibit III-14: Derailments by Geography and Crew Size, 2006-2019[64]
Per million train-km

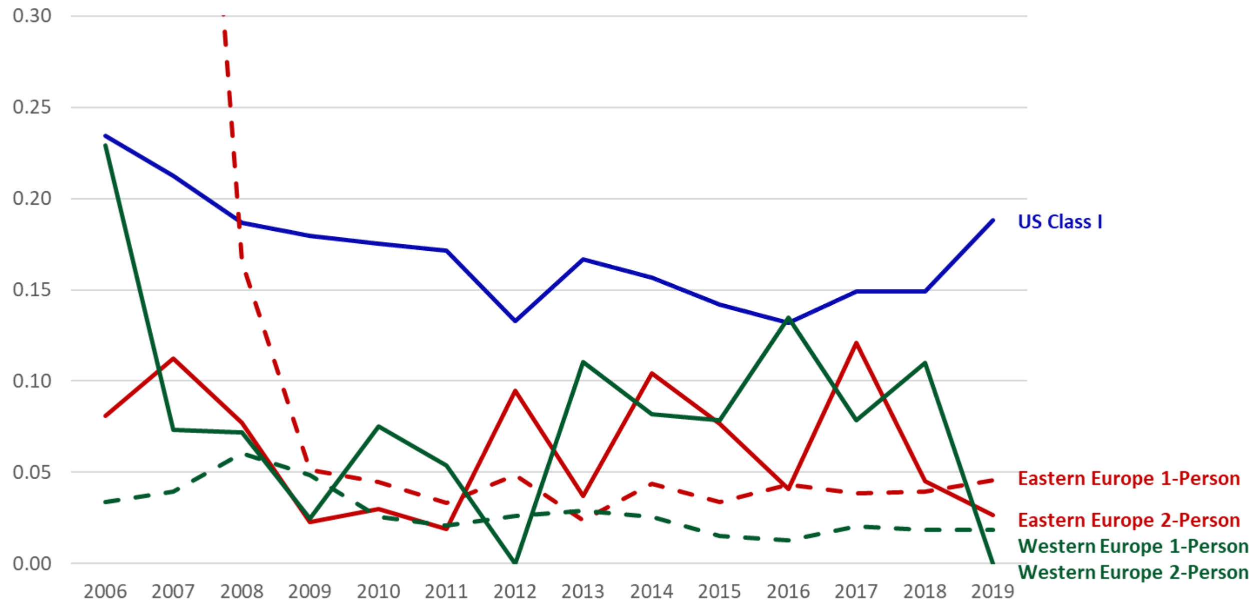


Exhibit III-15: T-Test Results for Derailments, 2006-2019[65]

Read across row	US Class I	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	NA	Worse	Worse	No Sig Dif	Worse
Western Europe 1-Person	Better	NA	Better	No Sig Dif	Better
Western Europe 2-Person	Better	Worse	NA	No Sig Dif	No Sig Dif
Eastern Europe 1-Person	No Sig Dif	No Sig Dif	No Sig Dif	NA	No Sig Dif
Eastern Europe 2-Person	Better	Worse	No Sig Dif	No Sig Dif	NA

2. Grade/Level Crossings

Accidents at grade crossings (US terminology) or **level crossings** (European terminology) involve 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.

64 "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Oliver Wyman analysis.
65 "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis. Numerical results of the t-test are contained in Appendix D.

It is clear from Exhibit III-16 that the US Class Is have consistently higher accident rates at grade/level crossings than European rail operators with either one-person or two-person crews. This is confirmed by the statistical test in Exhibit III-17, indicating that the rate of grade/level crossing accidents is unrelated to crew size. Within Europe, grade/level crossing accident rates vary by geography but are unrelated to overall crew size.

Exhibit III-16: Grade/Level Crossing Accidents by Geography/Crew Size, 2006-2019[66]
Per million train-km

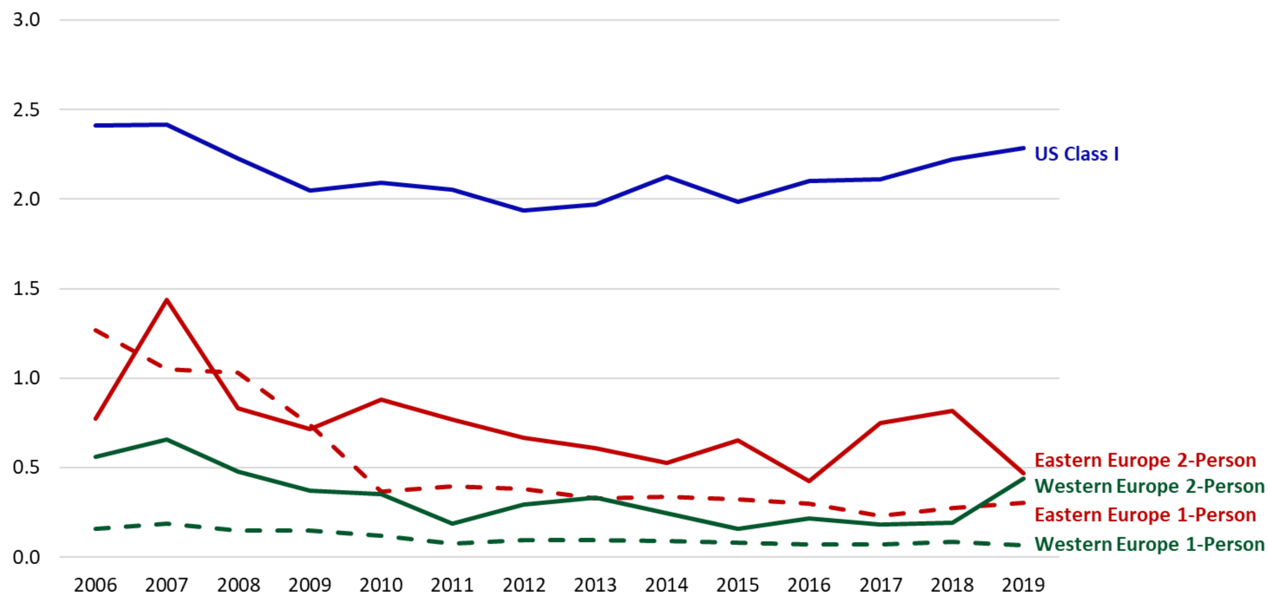


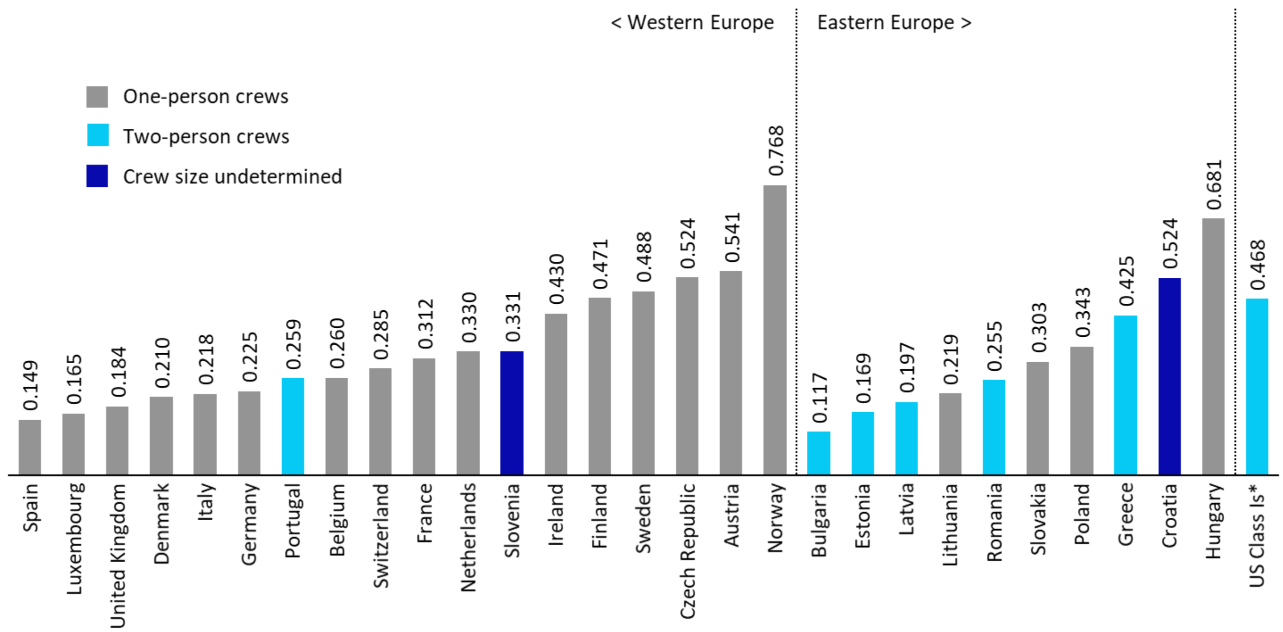
Exhibit III-17: T-Test Results for Grade/Level Crossing Accidents, 2006-2019[67]

Read across row	US Class I	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	NA	Worse	Worse	Worse	Worse
Western Europe 1-Person	Better	NA	Better	Better	Better
Western Europe 2-Person	Better	Worse	NA	No Sig Dif	Better
Eastern Europe 1-Person	Better	Worse	No Sig Dif	NA	No Sig Dif
Eastern Europe 2-Person	Better	Worse	Worse	No Sig Dif	NA

[66] "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Oliver Wyman analysis.
[67] "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis. Numerical results of the t-test are contained in Appendix D.

One could speculate that a higher rate of grade/level crossing accidents in the US might be due to more grade/level crossings per route-km, but Exhibit III-18 indicates that there are seven European countries with higher levels of crossings. Differences in deployment of safety technology at crossings could be another reason, but that is beyond the scope of this analysis. The key takeaway is that while the difference between US and European safety records for grade/level crossings cannot be determined from this data, it is not due to crew size.

Exhibit III-18: Number of Grade/Level Crossing Per Track-Kilometer by Country, 2019[68]



3. Accidents to Persons and Other Accidents

Accidents to persons caused by rolling stock in motion is defined as when one or more persons 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 traveling onboard vehicles.

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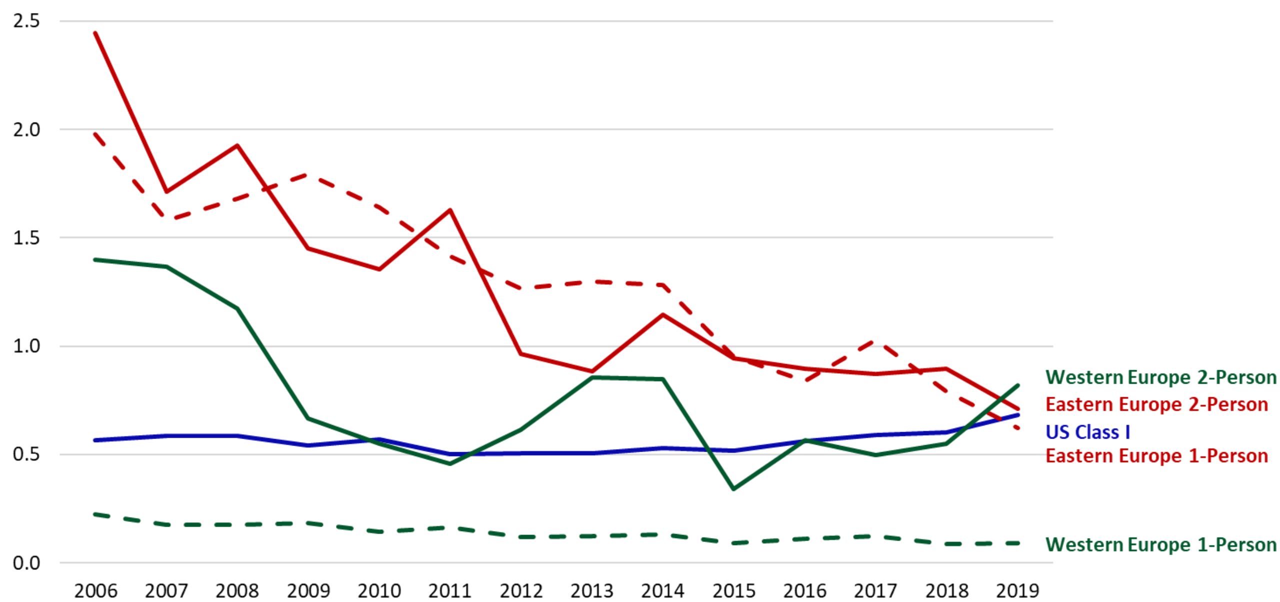
68 *Total open, at-grade public and private highway grade crossings as of 7 February 2021 divided by 2019 track-kilometers. "Common Safety Indicators," TO4, Total number of active and passive level crossings relative to track-km, ERA; 2019 R-1 Annual Reports, Schedule 700, STB; Crossing Inventory by State and ID, FRA; Oliver Wyman analysis.

Rates of accidents to persons have been consistent for US Class I's and Western European operations with one-person crews over time, while accident rates for Eastern Europe regardless of crew size have improved over time (Exhibit III-19).

Exhibit III-19: Accidents to Persons by Geography and Crew Size, 2006-2019[69]
Per million train-km



The statistical test in Exhibit III-20 shows that US Class I's had lower rates of accidents to persons than some European one-person and two-person rail operations, while within Europe rates varied by geography only. In either, case, rates of accidents to persons is unrelated to crew size.

[69] "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Oliver Wyman analysis.

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Exhibit III-20: T-Test Results for Accidents to Persons, 2006-2019[70]

Read across row	US Class I	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	NA	Worse	Better	Better	Better
Western Europe 1-Person	Better	NA	Better	Better	Better
Western Europe 2-Person	Worse	Worse	NA	Better	Better
Eastern Europe 1-Person	Worse	Worse	Worse	NA	No Sig Dif
Eastern Europe 2-Person	Worse	Worse	Worse	No Sig Dif	NA

Other accidents are defined as all accidents except for train collisions, train derailments, accidents at level crossings, to persons caused by rolling stock in motion, and fires in rolling stock. Examples of other accidents include:

- Collisions/derailments due to applying safety procedures in an emergency
- Dangerous goods release during transport
- Objects projected by trains, like ballast, ice, etc.
- Electrocution related to rolling stock in motion

The US has a consistently low rate of other accidents and the lowest average rate (0.012 per million train-km) among the geographic regions analyzed. Most European operations have had a relatively low rate of occurrence over the past decade as well, which can lead to what appear to be large fluctuations, as demonstrated by Western Europe two-person, which had zero occurrences from 2013 through 2018, followed by the second highest rate in 2019 (Exhibit III-21).

As confirmed by the statistical test in Exhibit III-22, the rate of other accidents is unrelated to crew size, since the US Class I's had a better rate than both other one-person and two-person operations, and European rates varied by geography but not crew size.

[70] "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis. Numerical results of the t-test are contained in Appendix D.

Exhibit III-21: Other Accidents in Rolling Stock by Geography/Crew Size, 2006-2019[71]
Per million train-km

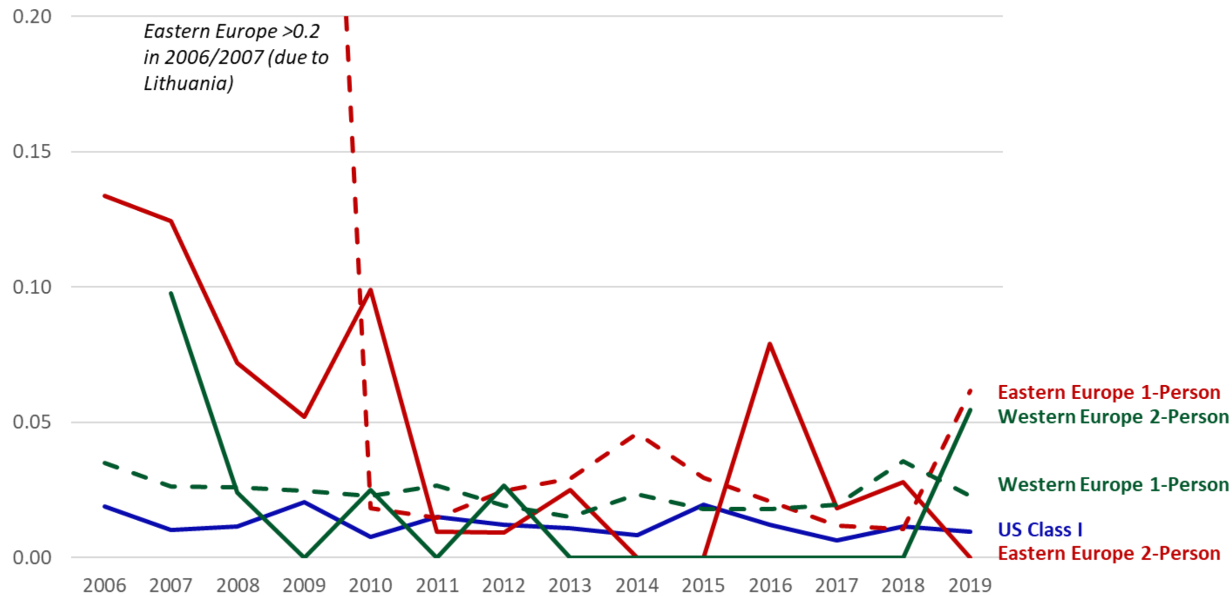

Exhibit III-22: T-Test Results for Other Accidents, 2006-2019[72]

Read across row	US Class I	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	NA	Better	No Sig Dif	Better	Better
Western Europe 1-Person	Worse	NA	No Sig Dif	Better	No Sig Dif
Western Europe 2-Person	No Sig Dif	No Sig Dif	NA	Better	No Sig Dif
Eastern Europe 1-Person	Worse	Worse	Worse	NA	No Sig Dif
Eastern Europe 2-Person	Worse	No Sig Dif	No Sig Dif	No Sig Dif	NA

4. Employee Fatalities

Employee fatalities include 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. FRA data could not be aligned with ERA data; thus the comparison excludes US Class I railroads.

[71] "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Oliver Wyman analysis.
[72] "Common Safety Indicators," ERA; "Accident/Incident Report," FRA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis. Numerical results of the t-test are contained in Appendix D.

Western Europe one-person operations have had the lowest consistent rate of employee fatalities, while Eastern Europe regardless of crew size has shown higher rates and greater variability (Exhibit III-23). Western Europe two-person (Portugal) had zero fatalities between 2011 and 2017 but a higher rate in other years.

The FRA has opined that "In rare instances, having a second crew member aboard may result in an additional injury or fatality if a serious accident occurs."[73] Based on Oliver Wyman's analysis, it may be true in Europe that a second crew member on board leads to a higher fatality rate, based on the performance of one-person operations in Western Europe. However, there is no statistically significant difference in employee fatality rates in Eastern Europe based on crew size. The spikes seen in Exhibit III-23 are more prominent for European two-person crew operations and could be the result of an additional crew fatality in an accident, or it could be the result of additional accidents. The ERA data, unfortunately, does not have the necessary level of detail to examine individual accidents.

The statistical test in Exhibit III-24 shows that Western Europe one-person operations have a better record for employee fatalities than Eastern Europe, and that within Eastern Europe fatality rates are unrelated to crew size.

[73] Train Crew Staffing: Notice of Proposed Rulemaking, Regulatory Impact Analysis, FRA, February 18, 2016, p. 5.

Exhibit III-23: Railroad Employee Fatalities by Geography and Crew Size, 2006-2019[74]

Per million train-km

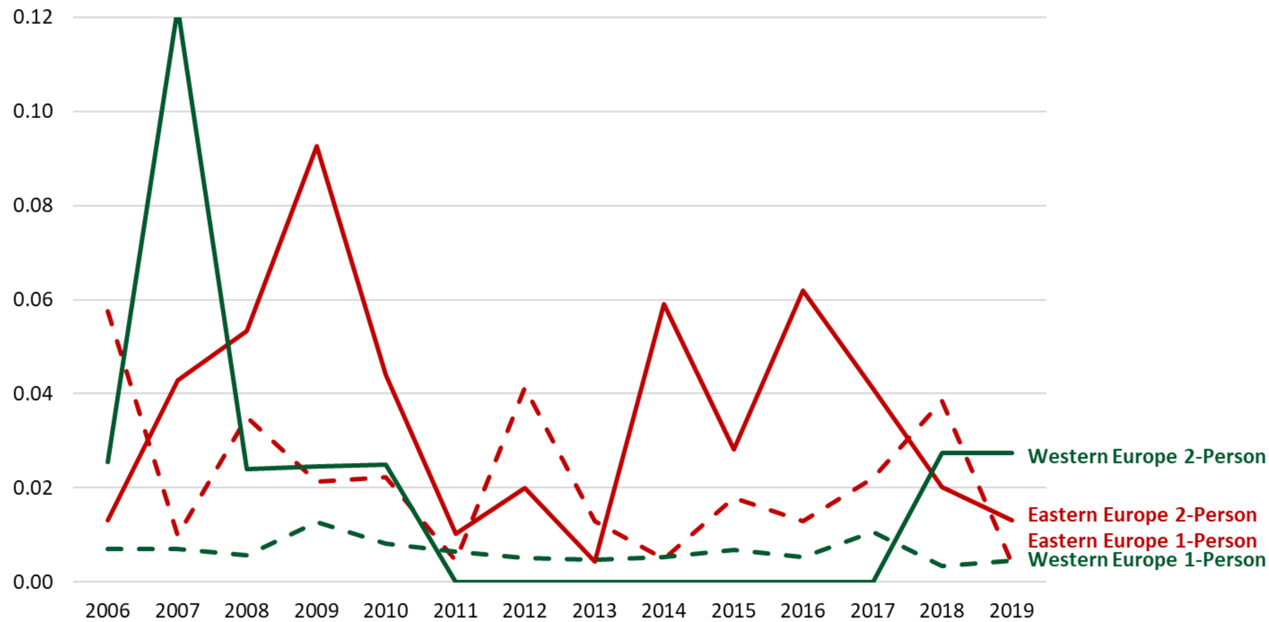

Exhibit III-24: T-Test Results for Railroad Employee Fatalities, 2006-2019[75]

	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
Western Europe 1-Person	NA	No Sig Dif	Better	Better
Western Europe 2-Person	No Sig Dif	NA	No Sig Dif	No Sig Dif
Eastern Europe 1-Person	Worse	No Sig Dif	NA	No Sig Dif
Eastern Europe 2-Person	Worse	No Sig Dif	No Sig Dif	NA

5. Economic Impact and Signals Passed at Danger

The **economic impact of accidents** is determined in Europe by the sum of the value of preventing a casualty;[76] the cost of environmental, rolling stock, and infrastructure damage; and the value of time (economic costs incurred by users of railway services). This information is not provided in available FRA data, so this section will focus solely on the ERA data.

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[74] "Common Safety Indicators," ERA; Oliver Wyman analysis.

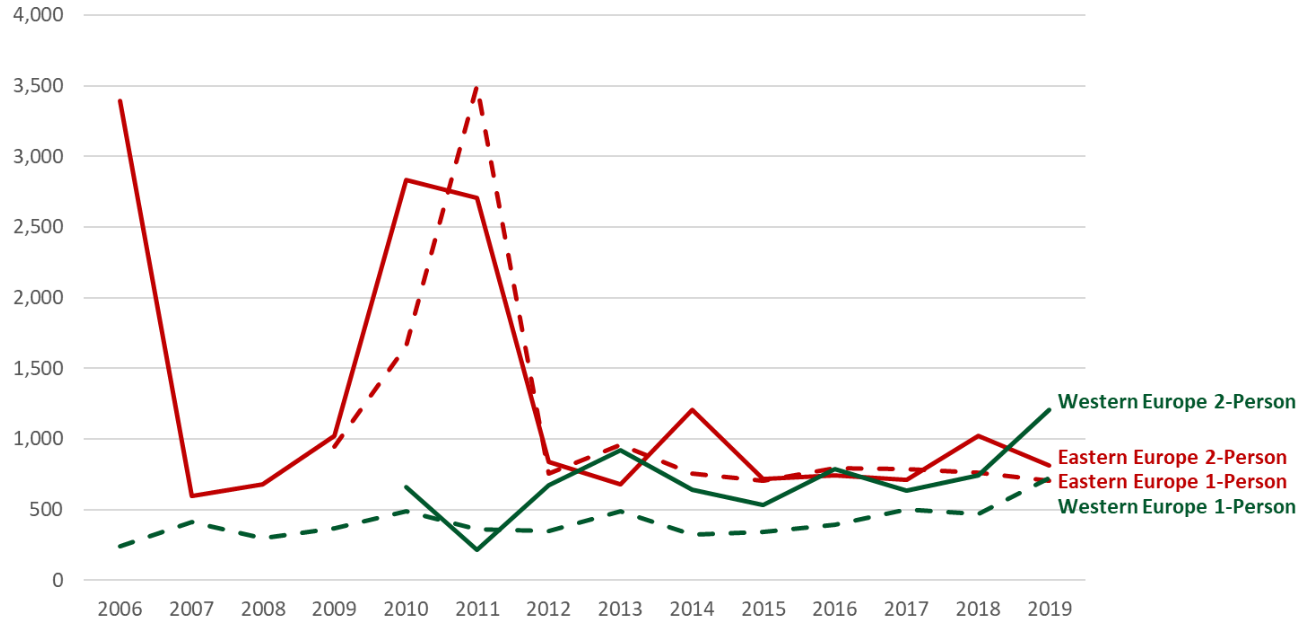
[75] "Common Safety Indicators," ERA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis. Numerical results of the t-test are contained in Appendix D.

[76] 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.

As shown in Exhibit III-25, more variable rates of economic impact for Eastern Europe have declined over time and economic impacts for both European one-person and two-person operations now fall within roughly the same range.

Exhibit III-25: Economic Impact per Significant Accident, by Geography/Crew Size[77]

Thousands of euros, 2006-2019, US data not available



The statistical test in Exhibit III-26 indicates that there is no statistically significant difference in the total economic impact of an accident between one-person and two-person crew operations. While Western Europe one-person operations do show a lower economic impact per accident than the other categories, which suggests that these accidents may be less severe, this appears to be unrelated to crew size and is likely related to higher capital expenditure per track-km, as previously discussed.

[77] "Common Safety Indicators," ERA.

Exhibit III-26: T-Test Results for Economic Impact per Significant Accident, 2006-2019[78]

Read across row	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
Western Europe 1-Person	NA	Better	Better	Better
Western Europe 2-Person	Worse	NA	No Sig Dif	Better
Eastern Europe 1-Person	Worse	No Sig Dif	NA	No Sig Dif
Eastern Europe 2-Person	Worse	Worse	No Sig Dif	NA

Signals passed at danger (SPADs) occur any time a train, or part of a train, proceeds beyond its authority. Also known as red-block violations in the US, SPADs are widely considered to be a precursor to accidents. As such, SPADs would appear to be an indicator of task overload and loss of situational awareness. Many of the automatic train protection (ATP) systems in use in Europe and ATS (Automatic Train Stop) used in the US do not stop the train until after the red signal is passed. More advanced ERTMS systems and PTC can actually prevent SPADs.

Exhibit III-27 illustrates SPAD rates for Europe since 2006. Across the entire 14 years of data, Western Europe has shown a lower average incident rate of SPADS compared to Eastern Europe, regardless of crew size.

Oliver Wyman's analysis however indicates there is no statistically significant difference in the rates of SPADs in European countries, whether or not they use one-person or two-person crews (Exhibit III-28). Thus, there is no evidence that one-person crews are "overloaded," resulting in a higher rate of SPADs and therefore a higher rate of accidents.

[78] "Common Safety Indicators," ERA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis. Numerical results of the t-test are contained in Appendix D.

Exhibit III-27: Signals Passed at Danger, Average for 2006-2019[79]

Per million train-km, US data not available

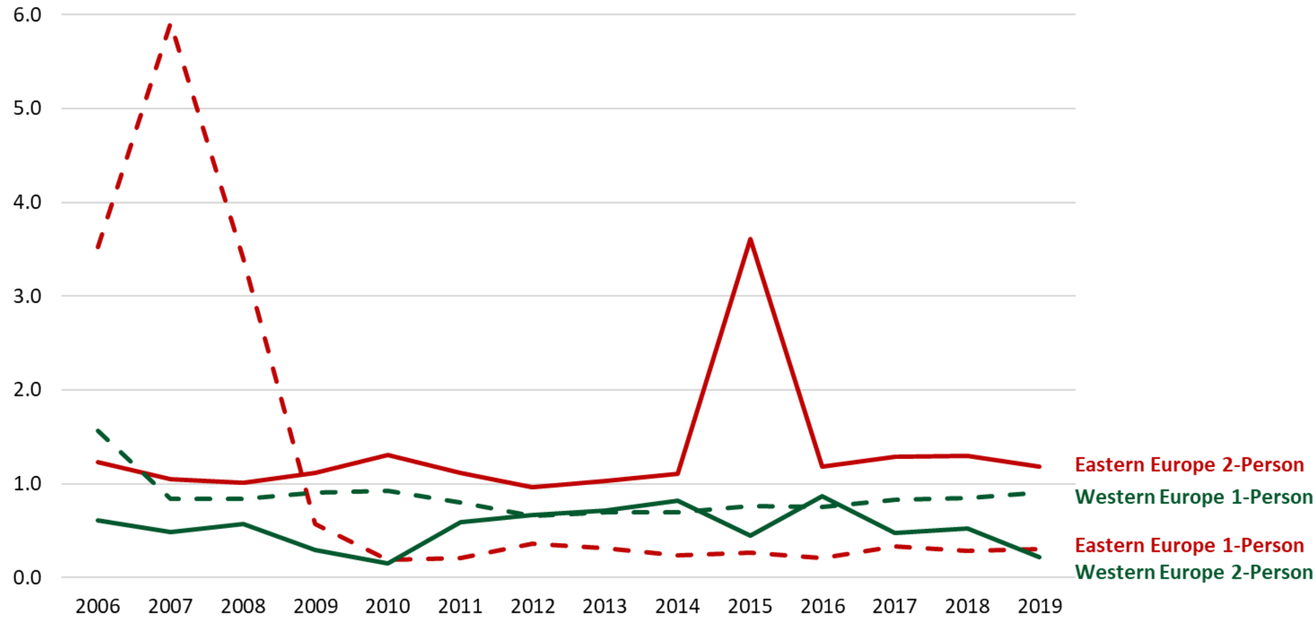


Exhibit III-28: T-Test Results for Signals Passed at Danger, 2006-2019[80]

Read across row	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
Western Europe 1-Person	NA	Worse	No Sig Dif	Better
Western Europe 2-Person	Better	NA	No Sig Dif	Better
Eastern Europe 1-Person	No Sig Dif	No Sig Dif	NA	No Sig Dif
Eastern Europe 2-Person	Worse	Worse	No Sig Dif	NA

F. Summary

In Western Europe, where the use of one-person crews is nearly universal (excepting Portugal), accident rates are significantly lower than in Eastern Europe, where countries vary more 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

[79] "Common Safety Indicators," ERA.

[80] "Common Safety Indicators," ERA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis. Numerical results of the t-test are contained in Appendix D.

continue to make, to the tune of billions of dollars in capital spending each year. Differences in infrastructure spending between Western Europe and the United States reflect variations in infrastructure usage. In particular, higher-density, faster multi-modal operations on main lines, and much more expansive passenger services in Western Europe necessitate much higher levels of infrastructure spend.

In Eastern Europe, where countries vary more in their policy regarding crew size, it is possible to more 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. 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 and US accident rates, it is difficult to see why two-person crews should be the presumptive standard for the United States, when one-person crews have been the longstanding presumptive standard on the far busier European network. Further, when we specifically compare countries operating with one-person crews against those operating with two-person crews, we cannot conclude that two-person crews provide any greater level of safety. 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.[81]

[81] For example, Estonia began testing one-person crews in late 2019. "Operail starts single-person operations on freight train," Railway Pro, November 7, 2019 (https://www.railwaypro.com/wp/operail-starts-single-person-operations-on-freight-train/).

Appendix A. European Advanced Safety Technology[82]

The European Union is in the process of implementing the European Railway Traffic Management System (ERTMS) to increase rail safety. The ERTMS system enforces compliance with speed restrictions and signals by trains. By 2030, it is expected to cover nearly 50,000 kilometers of track. ERTMS will replace national ATP/ATC[83] systems with a European-wide system of automatic train protection and control, further enhancing interoperability. 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.

ERTMS will replace more than 20 different train command and control systems (and locomotives might be equipped with up to seven different navigational systems). This multitude of systems has impeded the EU's goal of interoperability and added 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.

[82] UNIFE, European Commission, UIC.
[83] 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.

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 specifications. The specifications continue to be subsequently reviewed to include additional functionalities and to better meet the needs of railway companies and infrastructure managers. To ensure that ERTMS is constantly adapted to 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 was implemented. Four successive Memoranda of Understanding have been signed between 2005 and 2016 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.

The European Commission is currently focusing on the implementation of ERTMS on six of nine "Core Network Corridors" (CNC), which are high-density corridors that cross multiple countries and carry both passenger and freight traffic (Exhibit A-1).

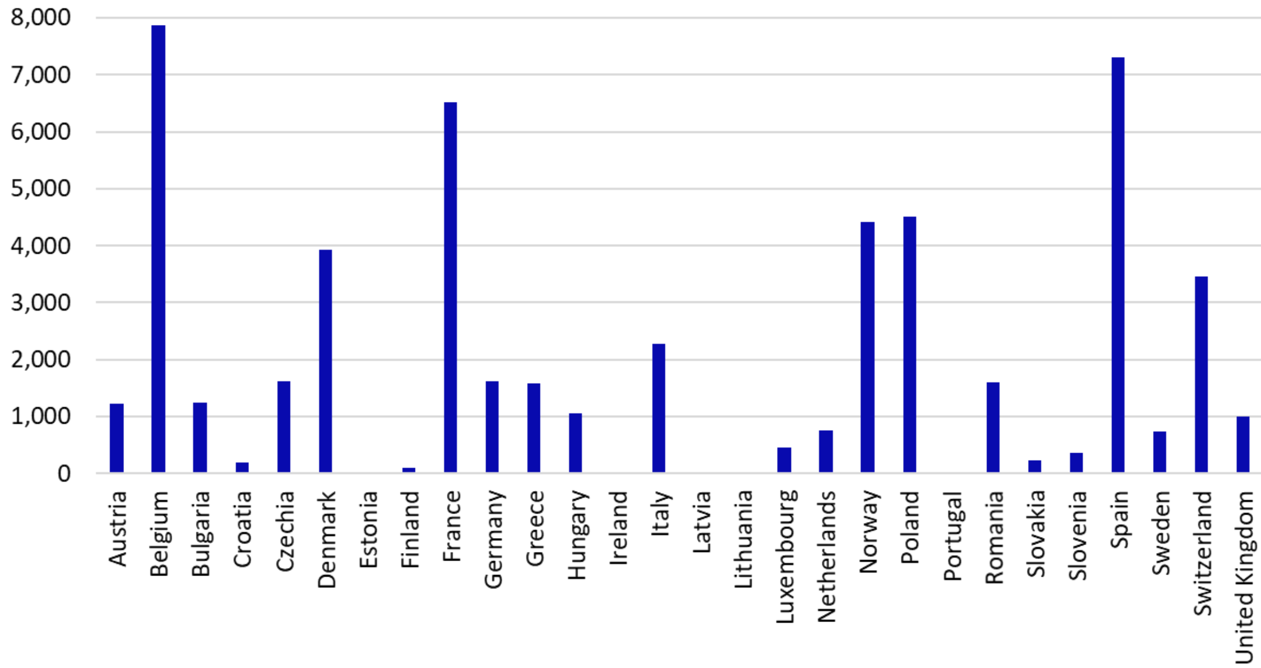
Exhibit A-1: Core Network Corridors Requiring ERTMS Deployment[84]

All EEA-28 countries are expected to implement ERTMS along the portions of these corridors that cross their countries. In addition, new infrastructure projects (or significant upgrades) are to include ERTMS. The current "European Deployment Plan" (EDP), implemented into regulation in January 2017, sets deadlines for the implementation of ERTMS on the CNCs for 2017-2023. To date, 24 countries have begun implementing ERTMS, led by Belgium, Spain, and France (Exhibit A-2).

[84] European Commission website (https://ec.europa.eu/transport/sites/transport/files/modes/rail/ertms/doc/edp/ertms_map.pdf).

Exhibit A-2: European ERTMS (Level 1 and 2) Contracted Tracks[85]

In kilometers



ERTMS has multiple "levels" of deployment. Levels 0-2 are operational. Level 3 is a planned future development:

- **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 non-PTC-equipped operations in much of North America. This system is equivalent to 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 or overlays a conventional line already equipped with lineside signals and train detectors. Communication between the tracks and the train is

[85] ERTMS.net.

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 movement authority through the Eurobalises, the ETCS onboard equipment automatically calculates the maximum speed of the train and the next braking point if needed, taking into account train braking characteristics and 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 developed and deployed by US freight railroads 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 is 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" – a 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 immediate plans to implement an equivalent to ERTMS Level 3 in the United States, although research is being done on moving block technologies.

The Rail Safety Improvement Act (2008) required 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).[86] PTC has been implemented on 57,536 miles of railroad track, equal to 62 percent of the Class I route network and over 99 percent of the designated PTC required route-miles.[87]

[86] P.L. 110-432, §104.
[87] "FRA: PTC operating on over 99 percent of required route miles," Progressive Railroading, November 18, 2020; US Federal Railway Administration.

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.”[88] 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.”[89]

[88] US Code of Federal Regulations, Title 49, Section §236.
[89] “Positive Train Control (PTC): Overview and Policy Issues,” Congressional Research Service, July 30, 2012, summary page.

Appendix B. Safety Analysis Definitions and Reporting[90]

1. Safety Analysis Definitions

The following definitions apply to the analysis of the European Union Agency for Railway 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 the object was lost by a 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 (payment 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).

[90] Implementation Guidance for CSIs, Annex 1 of Directive 2004/49/EC as Amended By Directive 2009/149/EC, European Railway Agency, Reference: ERA/GUI/09-2013, Version: 2.3.

- **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.
- **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 that were lost by a crossing vehicle/user.
- **Other accidents:** all accidents other than train collisions, train derailments, at level crossings, 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 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.[91] 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 US and EU laws and regulations, and must therefore contain information that is accurate and complete to the highest degree possible.

- Under US federal law, 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.
- In the European Union, member state railroad regulatory agencies are required to report safety-related incidents meeting certain specified thresholds to the ERA. Publicly available data is grouped into the following categories: rail equipment accidents, railroad casualties, grade-crossing accidents, and signals passed at danger (SPADs).[92] Like the FRA, the ERA

[91] FRA safety data is accessible at: http://safetydata.fra.dot.gov/OfficeofSafety/Default.aspx, while ERA safety data is available at: http://erail.era.europa.eu/safety-indicators.aspx.
[92] According to the ERA, SPADs occur when any part of a train proceeds beyond its authorized movement.

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.[93] 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."[94] CSIs are not expected to provide the same level of detail as the safety databases of individual railroads and infrastructure management companies, which are tailored to specific company needs.[95] 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.

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[93] US Code of Federal Regulations, Title 49, § 225.1.
[94] Article 5 of Directive 2004/49/EC, European Parliament.
[95] Implementation Guidance for CSIs; Annex I of Directive 2004/49/EC as Amended by Directive 2009/149/EC, version 2.3, ERA, May 24, 2013, p. 7.

Exhibit B-1: Differences in FRA and ERA Data

Category	Item	FRA	ERA
Equipment incidents	Minimum cost threshold for reporting	$7,700 (2006) to $10,700 (2019)	€150,000
Serious injuries	Hospitalization	Hospital stays not reported	Only reported if there is a 24-hour minimum hospital stay
Fatalities	Length of time after accident	Any fatality occurring within 180 days of the accident is recorded	Any fatality occurring within 30 days of the accident is recorded

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, etc.) and casualties (injuries and fatalities).

3. US Class I versus Other US Railroads

The FRA Accident/Incident data includes separate reporting for some subsidiaries of the US Class I railroads. Exhibit B-2 contains the full list of railroads included in US Class I data.

Exhibit B-2: US Class I Railroads in the FRA Accident/Incident Data

Group	System	Railroad	Name	Notes
Class I	BNSF	BNSF	BNSF Railway Company	
Class I	CN	BLE	Bessemer & Lake Erie Railroad Company	
Class I	CN	CC	Chicago, Central & Pacific Railroad Company	
Class I	CN	CEDR	Cedar River Railroad Company	
Class I	CN	CN	Canadian National	
Class I	CN	DMIR	Duluth, Missabe & Iron Range Railway Company	
Class I	CN	DWP	Duluth, Winnipeg & Pacific Railway	
Class I	CN	EJE	Elgin, Joliet & Eastern Railway Company	Include starting February 2009
Class I	CN	GTW	Grand Trunk Western Railroad Incorporated	
Class I	CN	IC	Illinois Central Railroad Company	
Class I	CN	MMR	Minnesota & Manitoba Railroad	
Class I	CN	PI	Paducah & Illinois Railroad Company	
Class I	CN	WC	Wisconsin Central Ltd. (also Railway)	
Class I	CP	CP	Canadian Pacific	

Group	System	Railroad	Name	Notes
Class I	CP	DH	Delaware & Hudson Railway Company	
Class I	CP	DME	Dakota, Minnesota & Eastern Railroad	Include starting November 2008
Class I	CP	ICE	Iowa Chicago and Eastern Railroad Corporation	Include starting November 2008
Class I	CP	SOO	SOO Line Railroad Company	
Class I	CSX	CSX	CSX Transportation	
Class I	KCS	GWWE	Gateway Eastern Railroad Company	
Class I	KCS	KCS	Kansas City Southern Railway Company	
Class I	KCS	TM	Texas Mexican Railway Company	
Class I	NS	NS	Norfolk Southern Corporation	
Class I	UP	UP	Union Pacific Railroad Company	

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. This Excel spreadsheet contained data on a variety of safety statistics for 2006 through 2019 for 28 European countries and the Channel Tunnel. Additionally, the European Railway Agency's "Report on Railway Safety and Interoperability in the EU, 2020" is also available on 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-investment.htm. Using the filters on this web page, rail infrastructure investment was selected.

The FRA Accident/Incident Database is available from the FRA Office of Safety Analysis at https://safetydata.fra.dot.gov/OfficeofSafety/default.aspx.

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

- The survey identified two-person crews in Bulgaria, Greece, Latvia, Portugal, and Romania. One-person crews were identified in Czechia, 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.[96]

[96] 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.

- In Croatia, crew size varies with the type of locomotive and installed safety equipment, such as deadman 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.

Appendix D. T-Test Numerical Results

The following series of tables contain the details of the t-test run in Microsoft Excel. A t-test is used to determine whether two samples are likely to have the same mean and to have come from the same data population. This is used in hypothesis testing, for example, in a clinical trial where a group receiving a new drug is compared to a control group receiving a placebo to test whether there is a statically significant difference in the mean of a monitored outcome. The analysis in the report, however, was based on observational data and did not have a control group like a clinical trial. Therefore, the results can identify statistical differences in the data categories but cannot prove causation.

The null hypothesis was that there is no difference in means between two different data categories. The null is rejected if the result of the t-test is less than 0.05, which is equivalent to a 95 percent chance the two means are different. A two-tailed test assuming unequal variances was used in all cases. The column labeled "Mean" contains the arithmetic mean of accident rates for each year between 2006 and 2019, inclusive.

For the table "all significant accidents," the t-test returned 0.0227 for US Class I versus Eastern Europe one-person. This value is below 0.05, indicating the hypothesis of zero difference in means should be rejected, i.e., there is a statistically significant difference between the mean of US Class Is (2.918 significant accidents per million train km) and the mean of Eastern Europe one-person (2.153). Since the mean of the US Class Is is higher than Eastern Europe one-person, the accident rate for US Class Is is considered "worse" based on this data. Conversely, the results of the t-test for Eastern Europe one-person and Eastern Europe two-person is 0.8809, which is greater than 0.05, indicating the hypothesis is accepted that there is no difference in means.

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All significant accidents	Mean	# Countries	US Class 1	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	2.918	1	NA	0.0000	0.0000	0.0227	0.0022
Western Europe 1-Person	0.358	16	0.0000	NA	0.0000	0.0000	0.0000
Western Europe 2-Person	1.255	1	0.0000	0.0000	NA	0.0125	0.0004
Eastern Europe 1-Person	2.153	4	0.0227	0.0000	0.0125	NA	0.8809
Eastern Europe 2-Person	2.205	5	0.0022	0.0000	0.0004	0.8809	NA

Collisions	Mean	# Countries	US Class 1	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	0.028	1	NA	0.0039	0.0643	0.2569	0.0024
Western Europe 1-Person	0.049	16	0.0039	NA	0.4944	0.7891	0.0975
Western Europe 2-Person	0.061	1	0.0643	0.4944	NA	0.4583	0.6025
Eastern Europe 1-Person	0.045	4	0.2569	0.7891	0.4583	NA	0.1554
Eastern Europe 2-Person	0.071	5	0.0024	0.0975	0.6025	0.1554	NA

Derailments	Mean	# Countries	US Class 1	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	0.170	1	NA	0.0000	0.0001	0.2897	0.0000
Western Europe 1-Person	0.028	16	0.0000	NA	0.0055	0.0919	0.0031
Western Europe 2-Person	0.080	1	0.0001	0.0055	NA	0.4888	0.3717
Eastern Europe 1-Person	0.116	4	0.2897	0.0919	0.4888	NA	0.3032
Eastern Europe 2-Person	0.063	5	0.0000	0.0031	0.3717	0.3032	NA

Grade/Level Crossings	Mean	# Countries	US Class 1	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	2.142	1	NA	0.0000	0.0000	0.0000	0.0000
Western Europe 1-Person	0.107	16	0.0000	NA	0.0001	0.0006	0.0000
Western Europe 2-Person	0.333	1	0.0000	0.0001	NA	0.0768	0.0000
Eastern Europe 1-Person	0.523	4	0.0000	0.0006	0.0768	NA	0.0707
Eastern Europe 2-Person	0.737	5	0.0000	0.0000	0.0000	0.0707	NA

Accidents to persons	Mean	# Countries	US Class 1	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	0.561	1	NA	0.0000	0.0416	0.0000	0.0001
Western Europe 1-Person	0.139	16	0.0000	NA	0.0000	0.0000	0.0000
Western Europe 2-Person	0.764	1	0.0416	0.0000	NA	0.0009	0.0046
Eastern Europe 1-Person	1.298	4	0.0000	0.0000	0.0009	NA	0.8896
Eastern Europe 2-Person	1.273	5	0.0001	0.0000	0.0046	0.8896	NA

Other accidents	Mean	# Countries	US Class 1	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	0.012	1	NA	0.0000	0.5484	0.0268	0.0187
Western Europe 1-Person	0.024	16	0.0000	NA	0.4684	0.0406	0.0977
Western Europe 2-Person	0.018	1	0.5484	0.4684	NA	0.0333	0.0679
Eastern Europe 1-Person	0.140	4	0.0268	0.0406	0.0333	NA	0.0960
Eastern Europe 2-Person	0.046	5	0.0187	0.0977	0.0679	0.0960	NA

The t-tests above were conducted by giving equal weight to each country, so that countries with significantly more train activity, such as Germany, did not dominate countries with less train activity. To determine whether this equal weighting introduced any unplanned biases in the results, t-tests were performed on the "All Significant Accidents" category, with the countries weighted by track-kilometers. The following results were obtained:

All significant accidents	Mean	# Countries	US Class I	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	2.918	1	NA	0.0000	0.0000	0.0051	0.0062
Western Europe 1-Person	0.337	16	0.0000	NA	0.0000	0.0000	0.0000
Western Europe 2-Person	1.255	1	0.0000	0.0000	NA	0.0192	0.0006
Eastern Europe 1-Person	2.020	4	0.0051	0.0000	0.0192	NA	0.5082
Eastern Europe 2-Person	2.244	5	0.0062	0.0000	0.0006	0.5082	NA

While there are differences in the values from weighted t-tests compared to those from unweighted t-tests, no values crossed the 0.05 threshold between tests. In other words, the conclusions stated in Exhibit III-8 (shown below) apply to both the unweighted and weighted datasets of all significant accidents, as the weighted t-tests did not change any crew/region comparisons from not statistically significant to statistically significant or vice versa.

T-Test Results for All Significant Accidents, 2006-2019[97]

Read across row	US Class I	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
US Class I	NA	Worse	Worse	Worse	Worse
Western Europe 1-Person	Better	NA	Better	Better	Better
Western Europe 2-Person	Better	Worse	NA	Better	Better
Eastern Europe 1-Person	Better	Worse	Worse	NA	No Sig Dif
Eastern Europe 2-Person	Better	Worse	Worse	No Sig Dif	NA

The European Railway Agency and the FRA use different reporting thresholds for recording employee fatalities, therefore only the ERA data was used for consistency.

Employee fatalities	Mean	# Countries	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
Western Europe 1-Person	0.007	16	NA	0.1515	0.0036	0.0007
Western Europe 2-Person	0.020	1	0.1515	NA	0.8294	0.1471
Eastern Europe 1-Person	0.022	4	0.0036	0.8294	NA	0.0876
Eastern Europe 2-Person	0.036	5	0.0007	0.1471	0.0876	NA

[97] "Common Safety Indicators data," ERA ; "Accident/Incident Report," FRA; Microsoft Excel, "T-TEST" function; Oliver Wyman analysis.

The FRA does not report signals passed at danger, therefore only the ERA data was used.

Signals passed at danger						
	Mean	# Countries	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
Western Europe 1-Person	0.857	16	NA	0.0004	0.5521	0.0259
Western Europe 2-Person	0.531	1	0.0004	NA	0.2195	0.0007
Eastern Europe 1-Person	1.150	4	0.5521	0.2195	NA	0.7439
Eastern Europe 2-Person	1.320	5	0.0259	0.0007	0.7439	NA

The FRA does not report economic damage, therefore only the ERA data was used.

Economic damage is in thousands of euros.

Economic damage						
	Mean	# Countries	W Eur 1-Person	W Eur 2-Person	E Eur 1-Person	E Eur 2-Person
Western Europe 1-Person	410,329 €	16	NA	0.0060	0.0186	0.0043
Western Europe 2-Person	700,445 €	1	0.0060	NA	0.1397	0.0438
Eastern Europe 1-Person	1,119,030 €	4	0.0186	0.1397	NA	0.6528
Eastern Europe 2-Person	1,281,625 €	5	0.0043	0.0438	0.6528	NA