The Safety Impact of Technology and Crew Size

An analysis of accident data, incorporation of technology, and train crew staff levels on rail safety trends

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Executive Summary

The United States economy is one of the most dynamic in world history, powered by a vast and complex supply chain. At its heart, the freight rail network moves energy resources, raw materials, and finished goods across thousands of miles of infrastructure every day. The rail sector has also added considerably to and greatly benefited from technology, which has helped drive accident numbers to unprecedented low levels. Yet a persistent 35 percent of train accidents every year are caused by human error.

Since 2000, total reported train accidents have declined by 42 percent, while those originating from human error have similarly fallen by 41 percent. In the context of this improving safety record, the Federal Railroad Administration (FRA) is seeking to mandate a nationwide minimum crew size of two people for over-the-road mainline operations to address human error. This would disrupt the status quo in which rail carriers and labor unions set crew sizes through collective bargaining. Overwhelmingly, these crew sizes are already two people, but single-operator crews are employed.

Despite withdrawing a similar proposed rule in 2019, the FRA is advancing a crew size mandate without offering incident data that it would improve safety, nor that absence of a mandate threatens safety. On both counts, we find that a crew size regulation is unnecessary and potentially detrimental to public health and safety, while the status quo is driving ever-improving safety trends. Further technological integration – rather than personnel – is the most decisive solution to human error.

Evaluating available technology, we find three applicable classes of technology within the existing regulatory framework. Roughly half of human error accidents are addressable through technology that fulfills operational tasks or assists human operators, while roughly half require personnel. Specifically evaluating the potential benefit of a crew size mandate, we find that the proposed rule would address **approximately one percent** of train accidents nationwide – those arising from human error on mainline track by freight operations that require a human solution to correct for human error.

The rule would not reach the overwhelming majority of rail accident causes, such as track deficiencies, nor the overwhelming majority of injuries and fatalities, such as trespasser and crossing incidents. By contrast, further integration of technology would perpetuate the declining accident numbers and continue to protect workers, the public, and the environment.

After reviewing technology, we analyze the effect of crew sizes on both accident prevention and accident mitigation. Our analysis, and review of government data and reports, is unable to find that multiple-person crews are more likely to prevent accidents nor that single-person crews are more accident-prone. Similarly, there is no correlation between number of crew and accident severity, indicating that there is no mitigating effect of having multiple crew members.

While failing to improve to rail safety, the rule is disproportionate in its costs and benefits. Many costs will likely accrue regardless of safety impact, resulting in net losses for efficiency, safety, and the environmental. These mainly result from economic disruption and modal diversions of the marginal unit onto trucks. The total cost of the proposed rule cannot be known until its exemption provisions are tested, as carriers may invest in technology and risk studies only to have appeals rejected. This, along with limited scope, undermine the regulatory impact analysis as untenable.

From our analysis, we provide eight recommendations. These are discussed further in our Recommendations section.

- Withdraw the current Notice of Proposed Rule Making (NPRM) unless or until better data is available
- Institute a single-crew pilot program on Positive Train Control (PTC)-governed track to collect data and compare measurable data against two-member crews
- If this NPRM proceeds to a final rule, exemptions should be based on objective and published criteria
- FRA should consider ways to augment improving safety trends rather than freeze staffing levels in hopes of preserving accident rates
- FRA should consider setting requirements for performance regulation rather than prescriptive regulation to help encourage innovation while achieving the aimed objective
- FRA should consider alternative regulations like rules for ground-based conductors within certain limited geographic regions and hours of operation
- FRA should consider penalties for remaining issues to make accidents more costly and promote efficient investment by railroads
- FRA should work with the Federal Aviation Administration (FAA) to promote the use of drones in the rail sector

Introduction

The railroad industry has been evolving since before the debut of the first steam engine in the opening decade of 1800. Not only have best practices, infrastructure, and the scale of operations expanded by orders of magnitude, but so has rail's importance to the economy, public health and safety, and the progress of science.

Rail as we know it today began at the close of the first industrial revolution. At that time, significant manpower was needed to operate, power, manage, and load rail engines and cars. At its height, a single train may have required 10 or more workers to adequately manage it,[1] which was an operational necessity even before accounting for safety. Over time, certain positions became redundant or obsolete as technology arose, was proven, and widely adopted. The advent of vacuum and automatic air brakes replaced brakemen, oiling tasks were replaced by "the real McCoy" oil-drip cup,[2] wipers and firemen were phased out as diesel engines replaced coal power, and other physically intensive roles transitioned away with greater technological integration. Employment reductions as crews declined from nearly a dozen individuals to single digits were measured against enormous gains in efficiency, capacity, and even safety.[3]

Today, there are largely two types of personnel who remain on a moving train: an engineer and a conductor. This critical team manages and operates the train by sharing responsibilities and working toward the goal of safe and efficient transportation. Yet a key distinction exists, as one is operational and the other logistical; that is, the engineer operates the train, while the conductor oversees scheduling, personnel, and cargo.[4] As it pertains to safety, the question must be whether the number and location of personnel contextualized against varying levels of technology has a discernable impact on the rate and severity of incidents.

Proponents of crew size rules have offered two primary theories of safety benefit: accident prevention and accident mitigation.

For accident prevention, the safety function of a second crew member is purportedly to catch oversights, provide additional eyes and judgement, keep awake/rouse an engineer who falls asleep, or apply brakes if the engineer becomes incapacitated – something that myriad systems help do today. The level of technology and technological overlays and redundancies integrated in the rail sector are impressive, and while many do the work that dozens of men did in decades past, they are ultimately there to aid and augment the work of rail personnel.

For accident mitigation, one of the second crew member's roles is purportedly to help limit damage or externalities by being on the scene immediately when an accident happens, including providing information to first responders. This in some ways undermines the accident prevention theory, or at least recognizes that certain accidents are unavoidable and not preventable by humans regardless of crew size or location. It also depends on the geographic location of the incident and whether distributed teams, ground-based personnel, or emergency response are in the area or able to respond quickly.

In this paper, we seek to determine the role of human operators and technological assistance in explaining rail safety trends and incident rates. The conclusion is guided by available data, comparative analysis, and economic evaluation. This will include a review of recent developments and literature on the subject, a survey of available technology, safety and incident data, cross-industry comparative analysis, economic and forward-looking factors, and a set of policy recommendations and conclusion.

Background

Before our analysis, two aspects of background require attention. First is a review of recent developments and second is a literature review on the subject of rail safety and technology relevant to crew size laws. For recent developments, not only is it important to lay out the regulatory background and recent industry actions, but to set up the broader safety, political, and technological context of the new FRA NPRM on mandatory crew size and location.

There is little debate that the general trend in rail operations has virtually always been greater adoption of technology, reductions in personnel, *and* improvements in safety. That three-pronged correlation can be further evaluated but stands as a significant rebuttable presumption for a new regulation; that is, all else equal this correlation demonstrates the lack of need for a crew size mandate when collective bargaining has facilitated investment flexibility and maintained appropriate crew levels. It is therefore incumbent on those advocating for such a mandate to present substantial evidence and argumentation to overcome the presumption. Accordingly, the role and burden of the FRA in rulemakings is for the agency to justify the need for the regulation itself under the Administrative Procedure Act (APA).[5]

Approaching this subject as an independent third party, we seek to conduct a full data analysis. We also review APA requirements and recognize the limitation FRA has placed on itself, and in order to objectively evaluate, also present logical and policy-generated constraints.[6] For example,

> FRA withdraws the March 15, 2016 NPRM concerning train crew staffing. In withdrawing the NPRM, FRA is providing notice of its affirmative decision that no regulation of train crew staffing is **necessary or appropriate** for railroad operations to be conducted safely **at this time**.[7] (*Emphasis added*)

As we review recent developments, the qualifiers that no regulation is “necessary or appropriate” “at this time” are critical. We highlight the circumstances and data at that time and compare them to data today. If the data shows circumstances and data are worse today, it does not automatically make a regulation warranted or prudent. Such a finding merely overcomes the agency’s self-imposed hurdle from its own withdrawal. If, however, circumstances and data are more favorable today (i.e., fewer accidents), then that is prima facie evidence that it is *unnecessary* and *inappropriate* to regulate train crew staffing today. Advancing a regulation in that context would present additional legal questions.[8]

Recent Developments

Two significant North American railroad incidents occurred in 2013.[9] The Federal Railroad Administration viewed these as exemplar cases of human error/human mitigation and announced its intention to regulate crew sizes for the first time on April 9, 2014.[10] In March of 2016, the Federal Railroad Administration published a NPRM to mandate minimum crew sizes to no fewer than two people.[11] The agency extended the public comment window and by 2019, withdrew the proposed rule, stating that it was clear that there was no data to support that crew sizes correlate with safety. In fact, the FRA noted "FRA's accident/incident safety data does not establish that one-person operations are less safe than multi-person train crews" and the National Transportation Safety Board (NTSB) concurred stating "[T]here is insufficient data to demonstrate that accidents are avoided by having a second qualified person in the cab. In fact, the NTSB has investigated numerous accidents in which both qualified individuals in a two-person crew made mistakes and failed to avoid an accident."[12]

Since that time, reports have come up bolstering each side, with the pro-regulation side focusing on the positive psychological effects of teamwork and the pro-collective bargaining side focusing on technology and improved safety trends. The only new report cited by FRA that has been published since the 2016 NPRM builds on the psychological aspects of teamwork. It goes on to show that there are "undocumented, informal" gains in safety and efficiency from teamwork among dispatchers, roadway workers, locomotive engineers, and freight train conductors.[13] This same study offers guidance for the deployment of new technology to enhance and augment such teamwork gains. Rather than demonstrate that crew size mandates are needed, such works offer insight and a path forward for how best to integrate technology and where teamwork can and should be retained. Likewise, recent pilot programs, studies, and reports have highlighted innovative technology with the potential to significantly improve safety, augment human activity, and prevent accidents.

With technology in mind, a significant development is the deployment of Positive Train Control technology across the entire Congressionally-mandated rail fleet and infrastructure. While only 4,247 route-miles (or 7.38 percent) featured this critical safety technology when the agency first published its proposed rule for a crew-size mandate in March of 2016, by the second quarter of 2019 when the agency withdrew the rule, 51,003 route-miles (88.65 percent) of the required track was covered.[14] Today, not only are all 57,536 required route-miles (100 percent) protected,[15] but over 60,100 miles are covered, going beyond statutorily required route-mile protection of PTC due to individual carrier investments in anticipation of future traffic.[16]

PTC Implementation									
Year (Q1)	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Miles Governed by PTC	<3,000	<4,000	4,247	16,867	36,801	48,389	56,541	57,536	60,107+
Percentage of Total Required Mileage	<5%	<7%	7.38%	29.32%	63.96%	84.10%	98.27%	100%	104.47%
FRA Actions	FRA Considers Rule		FRA Proposes Rule			FRA Withdraws Proposed Rule			FRA Proposes Rule

This is significant because the NTSB has concluded that at least 29 fatal railroad accidents from the last two decades could have been prevented with PTC. Those 29 incidents alone resulted in 58 fatalities and 1,152 injuries. Positive Train Control is a powerful system that the nation's top independent transportation safety experts confirm can prevent accidents and save lives. The FRA initially proposed a crew size rule when less than 10 percent of mileage was governed by PTC safety technology and the same agency withdrew the proposed rule when PTC implementation reached 80 percent. With PTC now exceeding 100 percent roll out, a new safety rule in light of previous agency action seems to either disregard the level of PTC implementation or discount its effectiveness.

Implemented technology on its own does not prove that further safety steps are unneeded. The safety record must be consulted. Total train accidents across the United States reported to the FRA across all railroads, all classes, and all tracks are lower today than the time the rule was initiated. In 2014, 2015, and 2016, when the initial rule was being considered, the total number of reported train accidents numbered 2,059, 2,116, and 1,917, respectively. After the rule was withdrawn in 2019, the total annual train accidents reported had fallen to 1,830 in 2020 and 1,822 in 2021.[17] The statistical trend from 2014 through 2021 demonstrates that the industry is shedding on average over 25 train accidents per year, the same slope associated with Class I railroads only. Since 2000, the safety trend is even more significant, with train accidents falling by over 78 per year across all classes and by over 67 per year for Class I only.

All Reported Train Accident Trend									
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022***[18]
All Reported Train Accidents	2,059	2,116	1,917	1,975	2,211	2,217	1,830	1,822	≤1,880
Annual Accident Cost[19] (millions of $)	333.4	421.7	301.7	316.3	334.4	355.9	316.5	305.4	≤273.54
FRA Actions	FRA Considers Rule		FRA Proposes Rule			FRA Withdraws Proposed Rule			FRA Proposes Rule

The total reported incidents above include all railroads, all carrier classes, and all tracks. When it comes to the NPRM, the most relevant category is freight rail operating on mainline track. This data also demonstrates a decline in train accident numbers for both total cause and human errors.

Main Track Freight Rail Accident Trend									
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022*[20]**
All Reported Main & Siding Track Freight Accidents	711	669	656	671	722	745	603	576	561
Main & Siding Track Freight Human Error	145	135	124	136	123	128	121	112	112
FRA Actions	FRA Considers Rule		FRA Proposes Rule			FRA Withdraws Rule			FRA Proposes Rule

Because the crew size rule would only address a small subset of all accidents – those resulting from *human error* on *main track* for *freight carriers* – which the status quo demonstrates is improving on its own, a crew size mandate appears to be unwarranted.[21]

Technology and accident trends are not the only recent developments. One additional area of focus is on train length. Available data shows that trains are getting longer on average. While this raises alarm for some, it presents a few different points to analyze.[22] Longer trains may actually have a positive effect on safety and be partially responsible for the observed reduction in accident rates by reducing the number of trains needed to run on the track. This is true not only for rail itself, but if a train carries more cars, it limits diversions to trucks that may carry that cargo instead and add pressure on highway safety concerns, road accident rates, wear and tear, and vehicle emissions.

Strictly limited to rail, two concerns are evident: first longer trains may lead to train crew fatigue if the engineer or conductor is required to walk the length of the train for maintenance or other issues. Fatigue concerns are highly relevant to safety and should be addressed. The second is blocked crossings, which can lead to trespasser casualties or prevent emergency vehicles from responding to incidents on the other side of the tracks. The FRA is currently collecting data on blocked crossings, and a robust data set is not available at this time to be relevant.[23] Without sufficient data, it would be inappropriate to use long trains to justify a crew size rule, and the relevance of crew numbers to long trains is largely limited to train splitting, which can still be safely done by well-trained single operators or ground-based (*roving* crew) and is relatively rare.

Another recent issue is the general employment trend in the rail sector. The chairman of the Surface Transportation Board (STB) has pointed to a reduction of nearly 45,000 employees at Class I railroads across the last six years.[24] In context, this period coincided with “the decline of the reliance on coal as a natural resource, an uncertain trade environment, and a new method of operations adopted by railroads called Precision Scheduled Railroading (PSR).”[25] It also featured a global recession and diminished labor force participation rate, which impacted all industries.[26]

The reduction in employment is only a safety concern if the roles are needed, are not being replaced with sufficient technology or viable alternatives (e.g., reduced inspection rates due to autonomous inspections, drones, or other options), and if there are measurable declines in safety from the lower staffing. The general reduction in employee work force looks shocking, but in context has little bearing on a crew size regulation.[27] While the reduction of employees has included conductors, two-person crews remain the standard set through collective bargaining. Nevertheless, this is a relevant field of analysis.

An obvious concern for regulators is that should they point to 45,000 employment losses despite statistical improvements in safety, a proposed rule may give the appearance that the regulation is intended to guarantee employment, which is not a safety justification. Further, STB data indicates that rail employment is actually matching or exceeding 2021 and 2020 in the latest data available, which even comes against the backdrop of consecutive quarters of negative economic growth. Rail employment data analyzed against economic data indicates that railroads appear to match staffing levels to demand, while collective bargaining safeguards two-member crews in most instances.

Importantly, while focusing on developments it is also worth noting consistencies, such as rail maintaining a steady average crew size on trains. Even extending back decades, the average crew size for freight rail has remained a consistent two-man crew, while regional lines, passenger rail, and commuter transit lines have successfully operated with single-person crews. Rather than remain static or worsen, accident numbers across these segments have instead fallen over this period without the need for larger crews or a rule locking the crew numbers in place. Even as route miles or payloads fluctuate,[28] these single and multi-member crews alongside technology have made freight rail safer in the past decades. With the status quo preserved and mostly two-person crews retained through collective bargaining, these accident trends are projected to continue improving. In time, after appropriate investment, testing, and bargaining, Class I railroads plan not to eliminate conductors altogether but to redeploy them to ground-based roles.[29] This will require its own testing and data, but existing single-operator regional freight and passenger lines indicate it can be done safely. The status quo continues to present serious challenges for justifying a new regulation.

With the status quo preserved and mostly two-person crews retained through collective bargaining, these accident trends are projected to continue improving.

The broader background is the state of markets and geopolitics. Public policy is not made in a vacuum – the present context is a world shaken by a pandemic, labor markets strained, supply chains stressed, and climate concerns launched to the forefront. Mandated crew sizes interact with each of these in one way or another. Public health experts have called for distancing and not occupying small spaces together, the transportation sector has struggled to employ an adequate workforce, efficient transport of raw materials and commodities is needed more critically than ever, and the rail industry has lower emissions rates than alternative transport methods. Labor regulations would impact these balances in multiple ways analyzed later in this paper.

Further, after narrowly averting a strike (through Congressional and Executive order), intervention by the FRA may negatively impact future negotiations and create artificial or unrealistic expectations. Even throughout the tense and years-long negotiation, the importance of collective bargaining[30] has been stressed by labor and rail companies for decades, and that is the status quo at issue with a crew size regulation.

A final important frame for review is what has *not* happened: no new significant incidents proving the need for mandated crew sizes, no major quantitative studies concluding the need for crew size mandates, and no new data from the federal government. In fact, recent history demonstrates that the FRA has little capacity for new data, as the agency has yet to act on NTSB recommendations R-16-33 and R-16-34 from June 9, 2016, to modify accident reporting forms "to include the number of crewmembers in the controlling cab of the train at the time of an accident" and "use the data regarding number of crewmembers in the controlling cab of the train at the time of an accident to evaluate the safety adequacy of current crew size regulations."[31] As of November 2022, that form has not been updated.[32,33] The existing form does include total crewmember counts, which may be relevant to the second safety theory of mitigation, but there is a significant dearth of data on in-cab crew, thus undermining the strength of any claim regarding the safety theory of accident prevention.

It is perhaps this exact lack of data that has caused the FRA to proceed with regulation not because of safety concerns borne out of data but because of hypothetical safety concerns, for example, in reviewing its own rule withdrawal, FRA states that:

> FRA over-relied on the absence of single-person crew safety data to support its 2019 Withdrawal, because there have been too few current one-person train crew operations to create any meaningful data. The lack of safety data reflects the paucity of data; it does not support any conclusions about the safety of single-person crews.[34]

By the same logic, the lack of data does not justify proceeding with a new rule. Despite attempts to distance itself from the 2019 withdrawal, FRA does not truly grapple with its own prior analysis. The agency instead reverses course by stating that it withdrew the rule because there was no data suggesting single-person crews were unsafe and is now proposing a new rule *because* they have no data saying single-person crews are unsafe. This is a reversal of the burden of proof required by the APA. Agencies are not permitted the flexibility of regulating first and collecting and understanding the data later.

While Class I railroads have recently expressed a desire to eventually operate single-person crews, the status quo remains collective bargaining. The emphasis on safety concerns of single-person crews is actually a secondary issue. The justification required of FRA is why it should alter the status quo, not why single person crews are (un)safe. The new rule would disrupt the status quo by superimposing a contract term and taking it away from the collective bargaining process, which would disrupt economic decisions, alter the pace of technological integration, and restrain modal competition in the long run. The proposed exemptions only further underscore these disruptions rather than provide the purported flexibility to apply for single-person crews at a later date.[35]

Ultimately, the primary change throughout the FRA proposed rules and withdrawal is political leadership – giving this action the appearance of political motivation, which undermines the credibility and soundness of the proposed rule. And while no new regulatory justification has arisen, new technology *has* been implemented and accident numbers *have* fallen. Proposing a new crew size mandate in this context raises serious questions about justification, appearing to be an arbitrary action, and one taken without conclusive or substantial basis in safety, economics, history, or comparative policy. This background is not dispositive of our analysis. We turn next to the literature, then a data analysis.

Literature Review

The ample literature available weighing the impacts of railroad crew mandates comprises academic publications, federal government studies, think tank analyses, industry reports, and other sources. While most publications address whether having two-person crews on trains would make trains safer overall, data on train crew sizes in accident reports from the Federal Railroad Administration, National Transportation Safety Board, and other sources is incomplete at best. Literature concerning railroad labor emphasizes benefits that arise from teamwork and potential scenarios that could occur where an extra crew member has purported benefits. Literature concerning innovation in the railway industry usually demonstrates that another crew members in the cab do not decrease accidents, but that technology has made statistically significant improvements to safety.

The FRA has emphasized as recently as 2020 that integrating new technology into railroad operations can disrupt benefits accrued from railroad crew teamwork and lead to new causes for railroad accidents.[36] This position is echoed in similar studies that seek to adopt technologies that will make trains safer and more efficient while preserving the valuable aspects that train crews bring to the job, notably for interactions on passenger trains.[37] Chief among safety concerns is the belief that tasks ranging from handling all paperwork, communicating with other trains and dispatch, on top of driving the train is too much for a single individual to do effectively and safely.[38,39] Even when a single person can handle these tasks, it is argued the benefit of a second person to observe, confirm, or repeat information helps eliminate oversight and incidents.

Articles outside peer-reviewed journals and government studies tend to focus on how multiple crew members help mitigate additional damages once an accident has already occurred, with many citing the 2013 Casselton, North Dakota rail accident as evidence.[40] In the aftermath of the accident, crew members already on scene were able to move oil cars away from a fire, preventing further damage. Arguments from organized labor in favor of the mandate include an additional crew member making longer trains operation safer, and the on-the-job learning that occurs between conductors and engineers saving the industry money that it would have spent on classes and training.[41,42]

Studies demonstrating status quo benefits of collective bargaining or arguing against a crew size rule emphasize continually improving safety trends, the need for technology to address persistent human error, and the projected harm to innovation and technology investment from compliance with new crew size regulations. Several studies compared U.S. railroad crews with similarly developed countries[43] that have single-person or autonomous trains and found little to no correlation between the number of crew members and increased safety or a lower accident rate.[44,45,46] Other studies have pointed out that the adoption of one-person crews have led to increases in productivity in rail transit systems in several U.S. metropolitan areas.[47] The regional Indiana Rail Road (INRD) has utilized one-person crews for its railroad operations since 1997 and has been cited as evidence of how one-person crews can encourage growth and increase safety.[48] The same railroad is cited by FRA for its thorough risk assessment practices.[49]

The safety record of passenger rail is frequently cited as evidence that single-person crews are safe for freight rail, as no passenger would willingly travel on a single-crewed train unless it was safe to do so.[50] The implementation of Positive Train Control systems by federal mandate has also been cited by railroad companies as making an additional crew member redundant, as it can override certain human error during train operation on rail lines that host the system.[51] The conflict between technology adoption reducing operating costs and historical opposition from organized labor is detailed in several papers dating back to the 1960s that examine the economic feasibility of the railroad industry, safety trends, and crew workload measurement.[52,53,54]

Articles outside peer-reviewed journals and independent studies focus on railroad accident history, technology adoption, investment, and regulatory hurdles that make railroad a less viable industry overall.[55,56,57] Emphasis is placed on the collective-bargaining process as being the main avenue that organized labor and industry have used to negotiate train crew size. The existence of efficient passenger rail with single-person crews is also used as an argument in favor of future single-person freight crews, as the passenger rail safety record can make or break their operations if passengers do not choose to ride.[58]

Other papers analyze how the downturn in employment during the COVID-19 pandemic, the decline of coal's usage as a resource, and the current uncertain trade environment have led to the industry cutting jobs to maintain viability.[59] The introduction of new technology has made workers uneasy about further reductions of railroad jobs, and several studies have pointed to technology enhancing worker performance, rather than cutting out the worker entirely.[60,61] Furthermore, studies show that technologies have been proven to identify potential health risks for railroad workers, leading them to seek treatment and better inform workers of safety procedures as they develop.[62,63]

Combinations of the latest technology and a professional workforce could be the ideal scenario, in which human error is checked by alerter technologies, while humans receive information that augments their performance. The FRA has numerous projects being funded through the Research, Development, and Technology Office that are testing among other things, smart sensors that can analyze the condition of a bridge, technologies that can detect changes in tracks, and drone-based grade crossing inspections.[64,65] Similar technologies have been developed for deployment on railroads since the late 2000s.[66,67] Technology proliferated among the railroad industry as the Staggers Railroad Act of 1980 reversed decades of decline by placing reliance on competition between railroad companies and reducing regulations, leading to increases in productivity, volume, revenue, and cost reduction.[68,69,70] Many now point to crew size rules as reverting to a highly regulated industry, which would reprise a pre-1980s lag in innovation and economic growth of the industry.

The post-Staggers proliferation of technology has translated into a large reduction in accidents, with a majority of them recorded due to track, rail, and human factors.[71] Greater implementation of technology has particularly facilitated shifts in inspections, with greater emphasis on data collection and processing that enables more precise inspections and optimized maintenance and safety outcomes.[72,73] Furthermore, the railroad industry has reiterated to the FRA that incorporating more inspection technologies will continue to shrink the number of accidents caused by rail or track defects.[74] These technologies often catch deficiencies more minute than the human eye can detect and can be performed by sensors on working trains during the course of business. The implementation of PTC at a cost of $14 billion is an example of technology making railroads safer, as PTC systems will prevent several types of accidents.[75] Because the railroad industry owns and maintains its own infrastructure as well as being obligated to abide by several regulatory provisions unique to the rail industry alone, investments for technological improvements may be impacted significantly more than other transportation industries.[76]

An overall survey of literature demonstrates that a majority of studies on rail crew sizes, technology, and regulatory reform conclude a lack of need for crew size rules, while a minority indicate that such a rule is needed for safe rail operation. This speaks not only to the history of rail improving in safety despite lowering the level of employment, but also the lack of conclusive data to support a crew size rule. The available data sheds light on rail safety and what gaps demand attention by both the railroads and by regulators.

Technological Assets

To effectively evaluate the safety record of rail and the relevance of train crew size and technology, we must understand root causes and survey available solutions. This will help set the stage for a data analysis by prodding the nature of accidents, identifying the main cause behind them, and looking at whether technology could address such accidents within the existing regulatory framework. This also helps understand the ability of technology to effectively replace human operators in the future by evaluating whether certain technologies have the ability to complete operational tasks or only to supplement human operators. We conduct this analysis by identifying the accident types and causes and by isolating human error causes for all reported train accidents across the entire rail sector.[77] We then determine from the set of FRA human errors codes those which have a technological solution, others with a technological assist solution, and those that require a human solution.

Because there are two primary safety theories for crew sizes, we also frame each analysis with respect to the ability to (1) prevent accidents and (2) mitigate accidents. We will start with a review of major causes and also review the accident type.

Major Cause

Across all accident types, the major cause *human error* leads to around 35 percent of all train incidents annually and around 25 percent of damage costs. Across all accident types, the major cause *track* [deficiency] leads to around 21 percent of all incidents annually and around 38 percent of damage costs. Together, human error and track deficiency lead to over 50 percent of all accidents and over 60 percent of costs and should therefore receive the most focus by railroad companies and safety regulators. Yet it is clear that track deficiency leads to greater damage and larger costs, even while being responsible for fewer incidents. When it comes to solving these problems, "a careful analysis of the historical causes of safety improvements in rail transportation indicates that track and equipment expenditures are much more important to safety than crew size."[78]

A mandated two-person crew in the locomotive will not prevent accidents caused by track deficiencies, and little to prevent other causes, so such a regulation would have no discernible safety impact for the majority of accidents or costs. To prevent track-caused issues, a technological solution is most viable.

Although a thorough investigation of a two-person crew's impact on human error must still be undertaken, these accidents are preventable by several known technologies. With human error leading to the highest proportion of accidents, adding more humans into the equation may simply perpetuate the oversights, misjudgments, and errors rather than provide an effective backstop, while technology is specifically designed and calibrated to address known and recurrent human errors.[79] To home in on the most relevant technology, we pair the root cause with accident type.

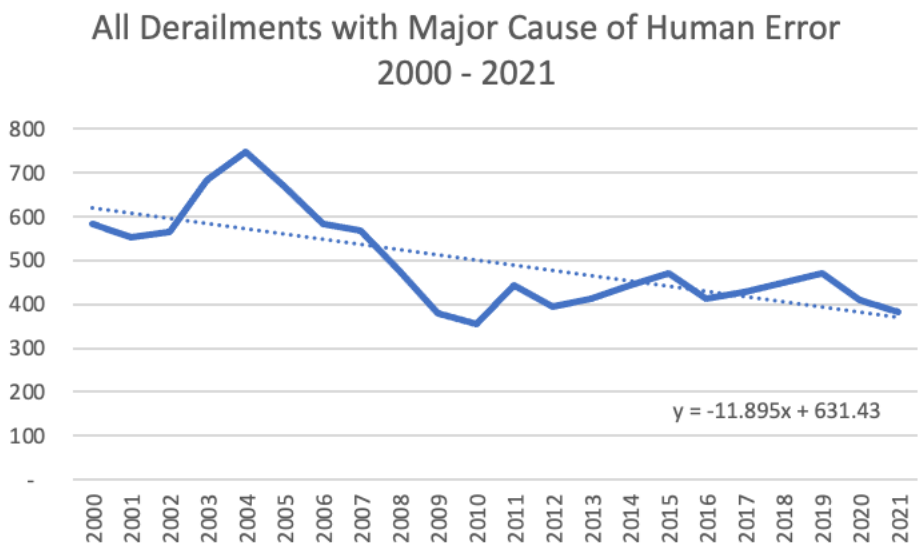
Accident Type and Prevention

The primary accident type leading to the majority of incidents and highest costs is derailment. Fully 65.3 percent of all reported[80] train accidents to the FRA from 2000 to 2021 were derailments, primarily caused by issues and defects in tracks (43.1 percent) followed by human error (30.32 percent). If safety is the top priority, then limiting derailments must be the top goal of the FRA. The FRA must exercise its commitment to safety and the prevention of economic and environmental harm by limiting derailments. In doing so, the response should be in proportion, first with emphasis on track issues and second on human error.

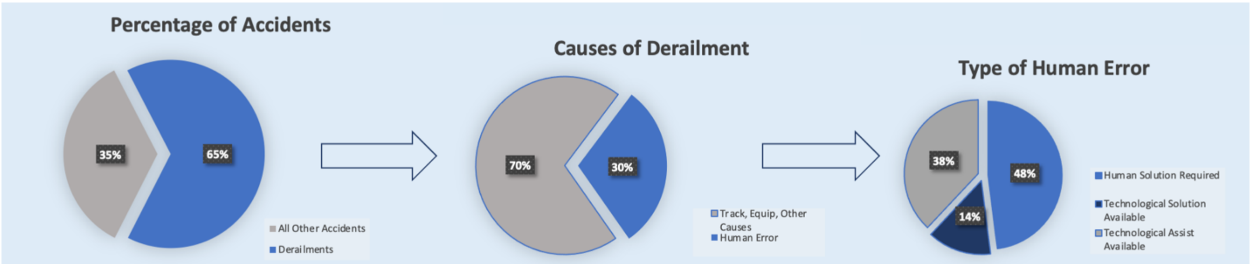
Fortunately, derailments have already been trending downward for decades, dropping 48.11 percent since 2000. On main track and siding, the decline is 61.58 percent. This is consistent with an observable improvement in rail safety already taking place and represents another hurdle the FRA must overcome to justify establishing a new safety regulation. Derailments today are lower than in 2014, when the FRA announced its intention to mandate two-person in-locomotive crews, lower than in 2016 when the initial rulemaking was proposed, and lower than 2019 when the FRA withdrew stating that data did not support a safety justification.

In fact, looking solely at derailments caused by human error, we see this too has experienced measurable improvement. Since 2000, human error is leading to far fewer derailments over time. Paired with the implementation of PTC in recent years, it is difficult to justify a crew size mandate to address human error derailments, especially as the status quo presently maintains two-person crews through collective bargaining.

A two-person crew in the locomotive will not prevent accidents caused by track deficiencies, and little to prevent other causes, so such a regulation would have no discernable safety impact for the majority of accidents or costs.



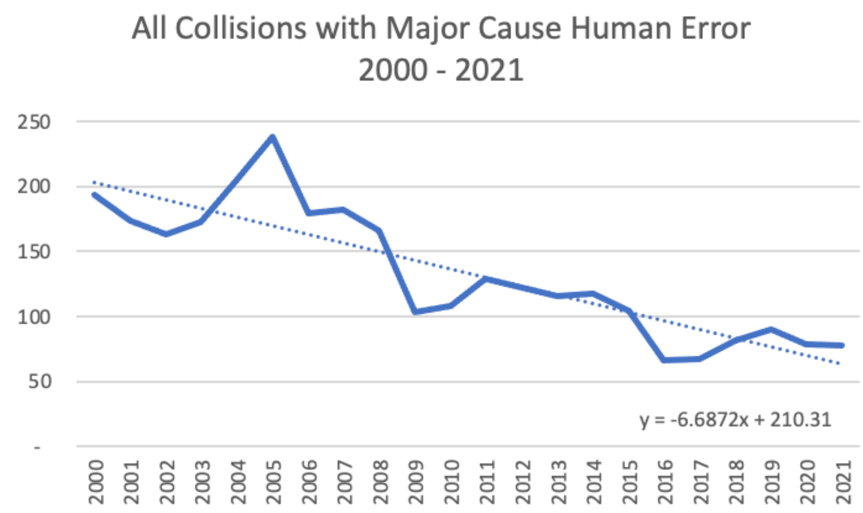
Because approximately 30 percent of all derailments are caused by human error, we must explore which can be solved by technology and which have human-only solutions. From over 100 human error cause codes and descriptions, these were categorized into those that technology can adequately address (e.g., PTC applying brakes to prevent over speeding or incursion into a work zone), those that technology provides an assistant role (e.g., alerter device or computer making the engineer aware of an issue), and those that are human-only solutions (e.g., applying or removing a derail or having a certified/qualified operator, which technology cannot detect).



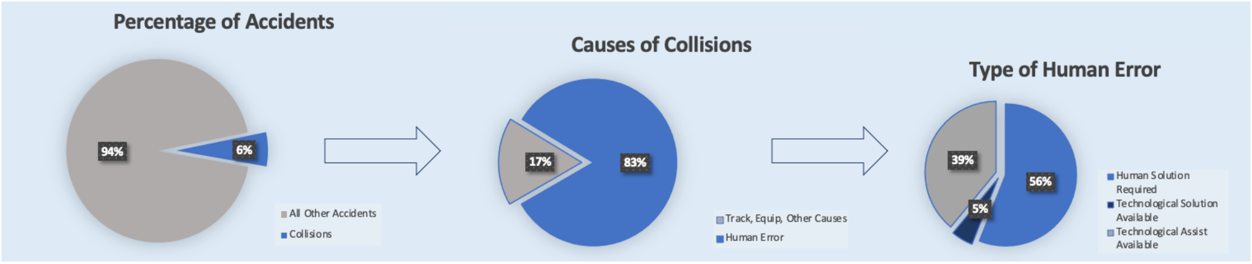
This analysis spans all years from 2000 to 2021, during which time certain cause codes have become obsolete or technology has improved. It is also retrospective, viewing which human errors committed as far back as 2000 could have been addressed by technology, and during a period with multi-person crews being the standard. Looking forward, it is likely these proportions will shift significantly. The purpose of this analysis is to determine if mandating a multi-member crews could meaningfully address human error. Accordingly, it does not look at the potential for technology to conduct fully autonomous operation, because the analysis only evaluates human error codes, some of which are constrained by existing regulation.[81,82] This analysis will ultimately support or undermine the FRA theory of a second crew member in the locomotive being necessary to counteract human error.

Already a majority (52 percent) of human error derailments have a known technological solution available. The remaining 48 percent that do require a human solution include roles in locomotive, inspector tasks, track roles, and other yard or ground-based operation. Human-only solutions would be applicable to fewer than 170 incidents annually, which is below 10 percent of all train accidents. The efficacy of an in-cab crew size rule to resolve even these human errors is very limited, due to many human issues occurring or being resolved outside of the locomotive. In fact, ground-based conductors and crew may address the same issues that an in-cab crew mandate would for many of the human error issues that require a human-only solution, such as being on-scene to safeguard blue signal tasks, handling or addressing derails, proper radio communication, and more.

All types of collisions (head-on, rear, side, raking, broken train) together account for only 6.42 percent of total accident numbers. These are the next most dangerous, damaging, and threatening to railroad employees, the public, and the environment. These are 83.17 percent attributed to human error. Again, the data indicates that these are on a significant decline, falling well before the PTC implementation in recent years. And as with derailments, the human error cause of collisions is falling. These data call into question the need for crew size regulations to correct for human error, when trends predict that *all else equal*, human error will continue to decrease as a root cause of rail incidents. This is especially true as more technology is implemented and as data becomes available on the complete roll out of PTC.



Despite representing only six percent of all accidents, the high proportion of collisions that are caused by human error requires attention. A train crew staffing rule aimed at addressing this 83 percent issue may seem natural, but technology remains a significant asset that negates the need for additional personnel.



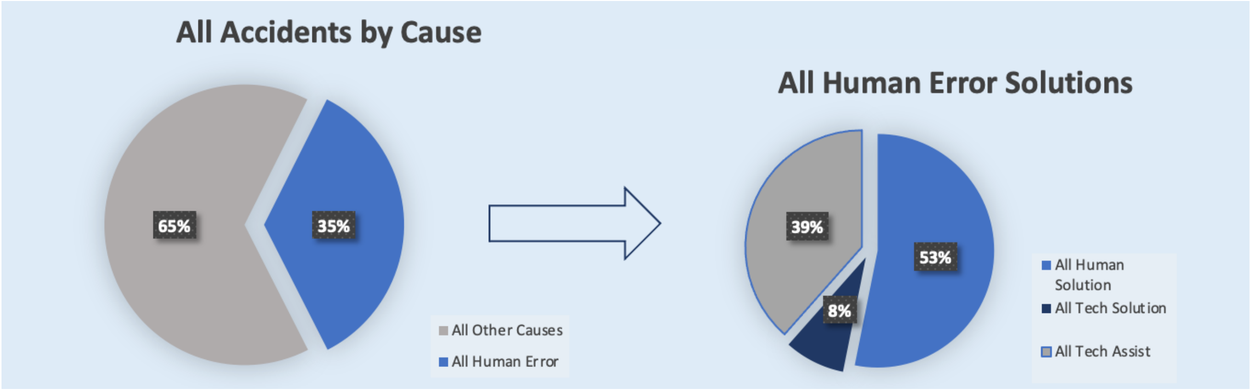
Within the subset of human error collisions, around 44 percent are addressable through technology and 56 percent require a human solution. This amounts to approximately 50 incidents each year requiring a human-only solution for collisions, below three percent of all train accidents. As with derailments, the share of human-only solutions are not all locomotive roles and again span the entire rail network. Altogether, personnel solutions to human error collisions are less than three percent of accidents across the entire country and rail networks annually.

Another 16.14 percent of accident types are reported as "not specified," "other impact," or "other." Human error is the major cause for the majority of these accidents, but without knowing the exact accident type, it is difficult to know what solution – human or technological – is most applicable. And this cannot serve as the basis for a crew size regulation because little or no supporting data can justify whether one fewer person would result in more or less safety for accident prevention and mitigation for these accidents.

Among remaining accident types are Highway-rail Crossings, RR Grade Crossings, and Obstructions, which together account for 10.79 percent,[83] and with a miscellaneous major cause being predominant. These often involve trespassing and third-party vehicles/drivers, which cannot be addressed through crews, but possibly through equipment and technology such as sensors and gates.

The last and smallest percentage is Fire/Violent Rupture and Explosion-Detonation. Since 2000, this type of accident has represented only 1.36 percent of all train accidents reported to the FRA. Moreover, the major cause is overwhelmingly equipment, while human error is not even a listed cause in most years. To use these exceptional cases to justify a crew size mandate is incongruent with their proportion and root causes.

Looking at derailments, collisions, and rare accidents that lead to significant damage, the question must be how best to prevent these accidents.[84] The answer has historically always been technology.[85] This does not displace the need for personnel; but the number of workers, their assignments, and the role they fulfill will always naturally change and evolve as technology is implemented. To keep this analysis in proportion, out of all accidents from 2000 to 2021, around 35 percent are caused by human error.

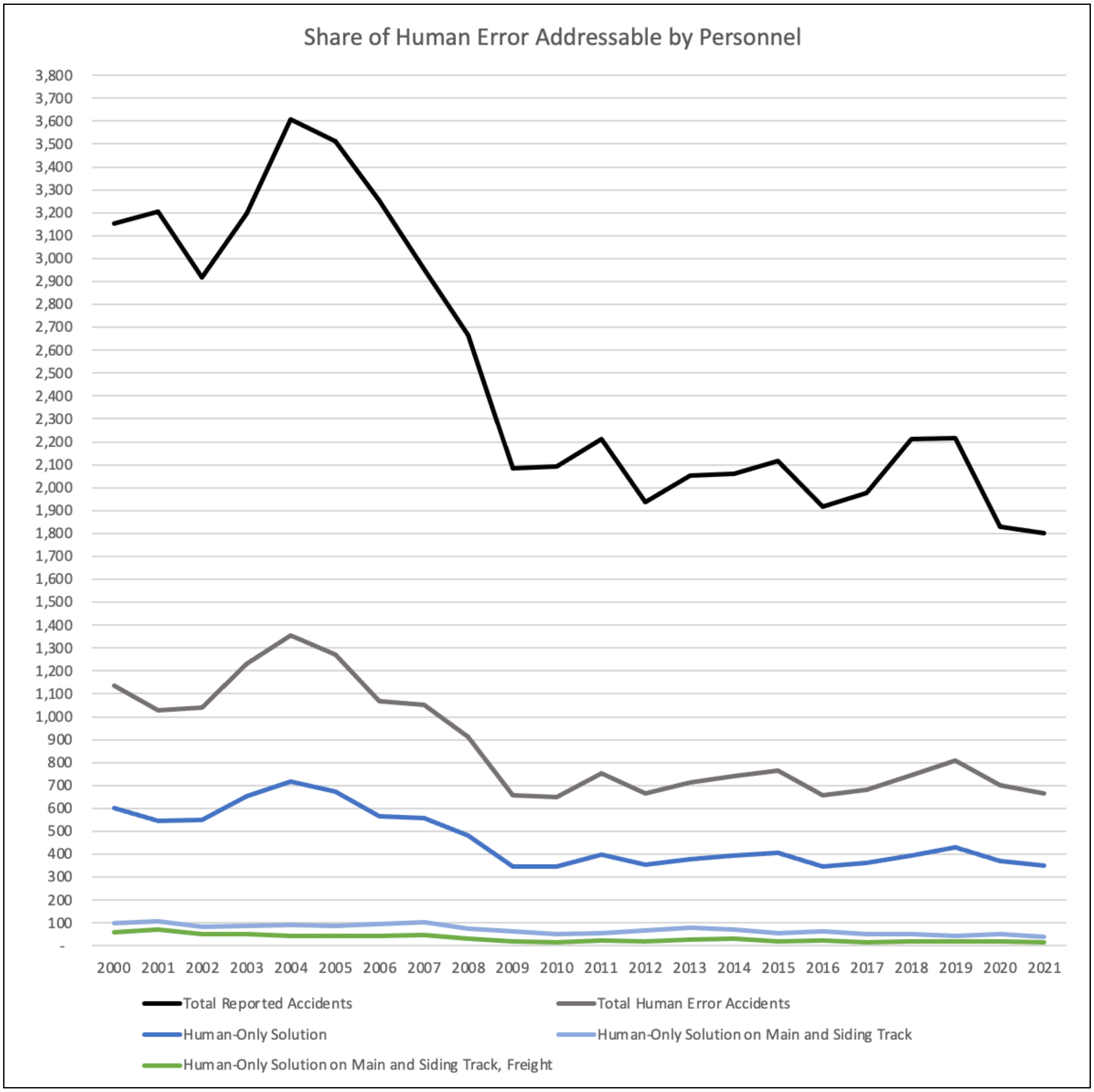


Across all reported train accidents by human error, 47 percent are addressable through technology, while 53 percent require a human solution. The human-only solution category includes approximately 10,270 total accidents since 2000. On an annual basis, that averages to 467 total human error accidents that require a human solution outside of technology – and once more the human required to prevent these is often not found in the cab, but elsewhere in the rail network. Moreover, because the number of human error accidents is declining, in 2021, there were fewer than 350 accidents requiring a human-only solution, a number expected to continue to decline on its trend line if the status quo is maintained. The trends are not guaranteed if the number of personnel decreases without new proven technology, nor is the trend guaranteed to be preserved by a crew size regulation, because that would disrupt the status quo and impose new costs.

Our analysis identifies that less than 18 percent of total train accidents and less than 10 percent of total costs are attributable to human errors requiring human solutions for the entire rail sector. Without data proving that a crew size regulation would effectively prevent those accidents, it is disproportionate in its costs and benefits and appears to favor labor over technology without establishing a safety rationale. While this analysis identifies approximately 18 percent of total accidents are addressable by personnel, this is limited to the existing framework. If regulation were updated to allow software and technology components to fulfill the role of "person" where applicable,[86] the share of technologically addressable human error causes would increase without any change in the level of technology currently available. In other words, the 18 percent may be artificially high and limited to existing definitional and regulatory frameworks – the true number of human-only roles may be lower, and the proportion of those needed humans in the locomotive to conduct safe operation is a fraction of that total.

The above analysis has focused on the maximal case for a crew size rule. We have included all classes, all tracks, and all types of carriers, including freight and passenger. Even with this maximal analysis most favorable to the FRA's case, the proposed rule only targets a small portion of accidents, and technology is increasingly able to reduce the same and more errors than the rule can address. When we add a final filter to the data, the costs and benefits of the rule are crystalized as disproportionate and disruptive to the status quo and trend of safety improvements.

By further refining the analysis to freight rail operation on main and siding track and looking at human errors, narrowed to those requiring a human-only solution, the result is incredibly narrow. Alongside costs imposed by regulatory compliance, modal diversions, and the possibility of rejected appeals, an impartial analysis demonstrates the rule is untenable as more costly than beneficial.



Since 2000, the human-only solutions to human error train accidents that occurred on main and siding track total only around 1,581 individual incidents. That is around 72 incidents each year on average, or 41 in 2021. This falls to 715 total incidents since 2000 when evaluating only freight trains on main and siding track with human-only solutions to human error, which is 33 incidents on average, or 16 in 2021. Because this is the primary focus of the NPRM, the rule is only capable of addressing around a dozen or more incidents each year.

We estimate that a mandated locomotive crew size regulation would address (though not resolve) **approximately one percent of incidents** annually across the entire rail sector. Such a regulation is simply not capable of addressing more incidents, because its purpose is to lock in crew size for freight rail on mainline track with the purpose of addressing human error, which is already addressed through certain technologies. It is likely not to resolve these because two-person crews are already the norm and even these accidents still occurred with multi-person crews; a mandate would simply overlay a rule to maintain this staffing level, thus not improving safety but holding the current norm constant. By contrast, incentivizing more technology alongside existing crews and updating regulatory language to allow technology to fulfill more roles would not only address the majority of human error causes, but a significant portion of track, equipment, and miscellaneous issues.

A crew size rule would not add personnel to most freight operations currently happening on main track, so the rule is unlikely to improve safety. The status quo should be maintained, with collective bargaining resulting in a two-person crew, as a change from this status quo alters conditions leading to the existing trend in safety improvements. A mandate would add costs in regulatory compliance and overhead that would disrupt the status quo, diminish investment in technology, and counterintuitively could lead to more incidents.

Technology Survey

With an understanding of the major accident causes across all accidents and a firm picture of the root causes behind the most critical accident types, we can now survey the most appropriate technologies to reduce track deficiencies and human errors.

With track issues leading to over 43 percent of derailments and over 38 percent of all reported accident costs, solutions oriented toward track should be the top priority. In 2016, data showed that "broken rails and track geometry defects are the two leading freight-train derailment causes on four major U.S. freight railroads."[87] While this is outside the reach of a crew size solution, it is still worth answering, and something railroad companies must take action to address.

Objectively, resolving track issues would lead to greater safety gains than two-person crews nationwide, given available data. A small sampling of technological solutions for track maintenance includes autonomous track inspection (ATI), automated inspection of concrete ties, track integrity sensors, ballast integrity sensors, autonomous track geometry measurements systems, gage restraint measurement systems, ultrasonic and induction rail testing, and more.[88,89,90,91] Further research and investment in monitoring and data collection systems to assess under pad ties and under ballast mats[92] is also encouraging.

Railroads should consider increasing capital investment and data collection for these and related technologies to fully capture incident reduction potential. Further, by liberalizing pilot program waivers, allowing permanent exemptions for certain technology testing, and promoting the use of innovative technology to detect track defects, the FRA can immediately achieve safety outcomes.[93] Such an approach would require a change of perspective to the lengthy and time-consuming waiver processes. Both technological and human inspections are vital, but train-mounted autonomous sensors offer the most benefit by allowing continuous data collection in real-world conditions without disruptions or delays associated with track inspections.

To address human error, both as an overall major cause and as the key root cause behind particular accident types, positive train control technologies are the most prominent technological solution.[94] During the open comment window during the 2016 rulemaking process, the NTSB stated that it would not recommend or oppose a crew size mandate due to insufficient data but directed the FRA to its ongoing investigation into a Philadelphia Amtrak accident. Months later, the final report identified lack of PTC as a contributing factor and stated that "the NTSB found that the accident could have been avoided if positive train control or another control system had been in place to enforce the permanent speed restriction."[95] By pointing to that ongoing investigation, NTSB effectively answered the question that PTC rather than crew size mandates are a core resolution to human error.

At issue on that Amtrak train was an engineer who intentionally accelerated into a curve due to misjudgment. When evaluating the type of solution to such a problem, both technology and additional humans are posited, but while another human may help avoid it, they could very likely misjudge as well, rely on the engineer's judgments, be distracted, or be a source of distraction. By contrast, PTC and other technology would address this over-speeding issue virtually every time. Other issues demand other technology, such as alerter devices, inward facing cameras, radios, and a range of train control technology. These tools are important regardless of the level of human staffing, but they may also have the future effect of making additional personnel redundant.

It is worth noting once more that the standard in the rail industry is a two-person crew, which is not expected to diminish in the short term. It was actually a string of two-member crew accidents culminating in an incident in Chatsworth, CA that finally led to the mandate for PTC to be implemented across the sector.[96] Moreover, there are now evolutions to PTC, on which industry groups are performing "proof-of-concept testing, capacity analysis, hazard analysis, and requirements development."[97] Three such modes of train control include, Enhanced Overlay PTC (EO-PTC), Quasi-Moving Block (QMB), and Full Moving Block (FMB). Further research into advanced PTC systems is continuing, with incredibly valuable potential for improved safety and efficiency.[98] Software and other technological interplays offer further safety enhancements for reducing human error and promoting safe operation, such as adaptive braking enforcement algorithms. Finally, and without regard to staffing, incidents in Canada have led advocates to demand wider adoption of automatic train control technology,[99] once more demonstrating the need and value for additional technology.

Perhaps counterintuitively, another solution to certain human errors that lead to collisions and derailments is a derail. That is, a simple device installed on the track to intentionally stop, divert or derail a train in a controlled way rather than allow it to enter a restricted portion of track or roll down an incline and collide or derail in a more disastrous fashion.[100] This technology and technique could have helped prevent such tragedies as Lac-Megantic.[101] Rather than additional crew, simple technology and devices can be the most effective.

Mitigation

The above analysis has focused on accident prevention. Technology is well-suited to that task, and in most cases is the primary tool to reduce the number and severity of accidents. They reduce the severity in some cases in the course of the accident (e.g., brakes applied reduce the speed of the train so that if an accident does occur, the train is moving slower than it would if the brakes were never applied, theoretically reducing the severity of the inevitable accident). What technology is not well-suited for at present is mitigating the effects of an accident after it has occurred. This is one safety theory proposed by the FRA to justify a crew size mandate, so that a second person in the locomotive is immediately on site to address the accident.[102]

A few technologies that may still be useful to mitigate damage include radios to call for help and drones to survey damage and identify remaining hazards or personnel in distress. Up to this point, there is little data to support that crew on site are effective in mitigating the scope and scale of an accident, so these and other technologies are proposed as alternative or supplements.

In exploring the question of the suitability of a crew size regulation to the issues at hand, the primary answer is that a train crew size rule would not have an impact, because the problems are predominantly track-related – where technology and personnel conducting inspections would help – or human error that technology is well suited for. The remaining percentage of human error that does demand personnel are tasks and issues distributed across the rail network, and few are issues that require two individuals in the cab of a locomotive. Technology should be the primary tool for helping prevent and mitigate accidents.

The actions best suited to these data seem to be investment incentives and waivers, not new regulation. If the FRA promotes and incentivizes railroads to implement new technology, granting waivers from burdensome regulations, and working with rail carriers to hone best practices and identify best ways to implement technology, there will be far fewer accidents, especially those caused by track defects and human error. Studies conducted to understand the psychological effects of teamwork and technology are useful guides but should not be used solely to defend crew staffing mandates on the grounds of teamwork, but for helping guide the most efficient and effective deployment of technology.

Technology should be the primary tool for helping prevent and mitigate accidents.

In summary, train accidents have been declining for decades, and the most dangerous and costly accident types (derailments and collisions) are also trending downward. In fact, derailments and collisions caused by human error are falling on strong trendlines. No regulation of train crew size seems to be warranted in this data. But if FRA intends to maximize the already favorable downward accident trend, then incorporating new technology – rather than codifying crew sizes – is the best course of action. That single action – reforms elevating technology[103,104] – can span all accident types and major causes because technology can minimize the root causes leading to track defects, speeding, and more, whereas crew members are only a solution to in-cab human error, a small and shrinking subcomponent of root causes.

While some may call rail old fashioned, the reality is that innovations within the industry have been largely cutting edge. The pure extent to which technology has already been deployed, coupled within continuing data analysis and use of ever-emerging new technologies all point toward a progressive safety-minded industry that has continually improved its record of safety. We turn next to accident data to validate this conclusion.

Data Analysis

This section looks at the existence and type of relevant data on train crew sizes and accident rates in the United States. It evaluates first the number and rate of accidents (the prevention safety theory of having multi-person crews) and second, evaluates the scale and costs of the accidents that have occurred (the mitigation theory of the multi-person crews).

The data analysis here is intended to be objective, but as noted before, we also review the self-imposed hurdle from FRA's own rule withdrawal. Accordingly, the data does not need to demonstrate declines in accidents, damage costs, or other metrics to show that a new rule is "unnecessary and inappropriate" at this time. Even data showing an uptick in accidents is merely necessary but not sufficient for a new rule. For the FRA now to argue it is needed, they have a burden[105] to show higher accident rates, greater harms, and dispositive data showing a causal connection between in-cab crew size and safety. It is difficult for FRA to meet this burden due to the lack of data collection, specifically the inaction to collect in-cab crew data on accident reporting forms. Absent data, the FRA should be concerned that the NPRM risks being seen as little more than an arbitrary line in the sand, especially with the continued admission that the agency does not have data on single-person crews being *unsafe*.[106]

National Transportation Safety Board

To evaluate the safety impact of crew sizes and technology, we look first to the National Transportation Safety Board for investigations into railroad incidents. The NTSB investigated over 170 train incidents from 2000 to 2021, representing the most notable incidents across the country. While a total of 54,962 reportable train accidents occurred across all classes, all carriers, and all types during this 22-year span, most were minor, resulted in no casualties, or occurred within a train yard.

With data from this window covering more than two decades, it is clear that human error is a leading cause of incidents – approximately 35 percent of all accidents every year. Interestingly, evaluation of 174 investigations conducted by the NTSB since 2000 reveals that 126 involved human error as the probable cause (72.41 percent of investigations), yet 69.64 percent of these cases involved crews of two or more people. Less than one-third (27.98 percent) had single person crews. On its face, this is not dispositive of anything, but is a raises questions for arguments that multi-person crews are safer or needed to maintain safety across all types of accidents. It also helps explain why NTSB stated, "[T]here is insufficient data to demonstrate that accidents are avoided by having a second qualified person in the cab. In fact, the NTSB has investigated numerous accidents in which both qualified individuals in a two-person crew made mistakes and failed to avoid an accident."[107]

Of those 174 accidents[108] with a known crew size, the crew counts in the at-fault train were: three accidents involving no crew, 47 accidents involving single-person crews, 73 accidents involving two-person crews, and 44 accidents involving crews of three or more. While many of the multi-person crews involved secondary engineers or conductors, these counts also include trainees, passenger-facing crew, and others. In many of these instances, the second or additional crew members may not have been in the cab where they could aid the engineer at all. The NTSB recommendation to capture in-cab crew on accident forms remains unaddressed, undercutting the key quantitative basis for any crew size mandate.

To determine whether multiple crew members helped mitigate damage, the data is also inadequate. For NTSB investigations, single-person crews led to a total of 734 casualties (or 15.62 per accident), but this sampling is skewed because passenger rail is allowed to operate with only a single engineer in the controlling locomotive, and the higher casualty number reflects the large passenger counts. Similarly, crews of three or more, which produced 1,561 casualties (or 35.47 per accident) oversample from passenger incidents in which a derailment may have injured several hundred individuals at once. Two-person crews led to 1,447 casualties (or 19.82 per accident).

Data collected and reported by the NTSB is invaluable for preventing future accidents and understanding root causes. That is why recommendations from the agency are so highly regarded. Unfortunately, available data from the last two decades does not answer whether crew sizes are able to prevent or mitigate accidents. However, we can look at recommendations to shed light on whether this independent, expert agency believes they are necessary.

The NTSB has been advocating for train control technology for 50 years. Now that PTC is fully integrated where mandated, and with advancements beyond PTC emerging, the primary rail issue NTSB has raised is well on its way to resolution without new regulation. Other recommendations have centered on inward-facing cameras, alerter devices, and fatigue solutions.[109] While the agency has made recommendations on crew alertness and attention, and even pointed to "the inadequacy of passive wayside signals to reliably capture traincrews' attention when competing sources of attention are present" and recognized that "human vigilance has limits"[110] the NTSB has never recommended an in-cab crew staffing rule or elevated multi-person crews as essential.[111]

> "The FRA and FTA need to require railroads to implement technology to provide safety redundancy."
>
> -NTSB

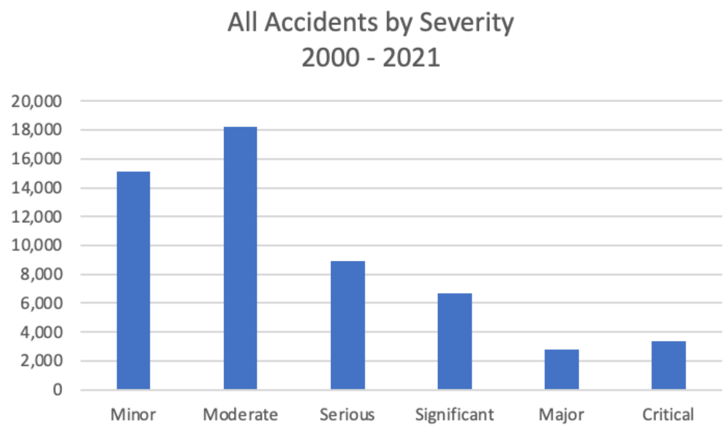
While this may strike some as an improper argument from silence, this is far from a fallacy because the NTSB is an independent agency, untethered to any political or policy agenda and unconstrained by cost benefit analysis.[112] If crew size was a safety issue, NTSB is exactly the source we would expect to hear from. Yet they have not made this recommendation. In fact, as noted above, when the crew size rule was proposed in 2016, NTSB's only comment was to point to a pending investigation, which ultimately concluded with a finding that PTC would have prevented the accident, emphasizing the importance of technology as a solution. To the extent the NTSB addresses crew staffing, it has to do with quality of operation, training, and fatigue rather than quantity or location of crewmembers. In fact, even in its Most Wanted List for railroad worker safety, NTSB identifies human error as a key issue, but asserts that, "The FRA and FTA need to **require railroads to implement technology** to provide safety redundancy."[113] *(Emphasis added)*

Federal Railroad Administration

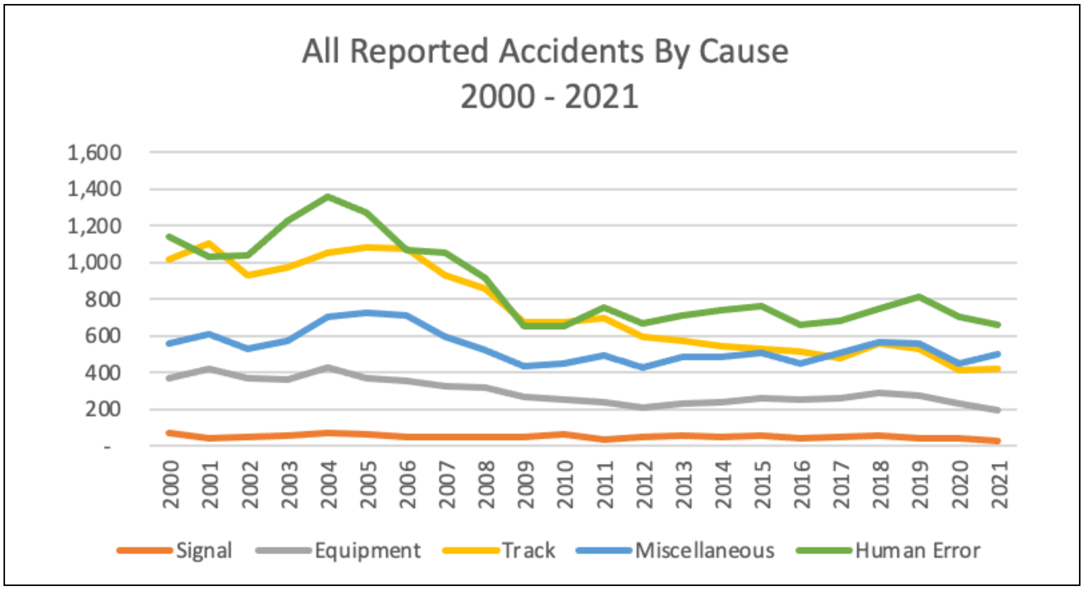
After beginning with NTSB and demonstrating that the data is insufficient to justify a crew size mandate, we turn to FRA data. Our evaluation begins with the dataset of all reported train accidents through FORM FRA F 6180.54 ("Form 54") reports. We utilize this dataset to explore both safety justifications: prevention and mitigation.

The available dataset included 68,598 accident reports from 2000 through 2021. Of these, 13,636 represent additional reports of the same incident, mainly by another involved party. There were therefore 54,962 individual incidents from this 22-year period.[114]

From this set, 15,125 report damage only up to $20,000, which we will consider minor.[115] Another 18,245 reported accidents produced damages between $20,001 and $50,000, which we consider moderate. There were 8,897 accidents reporting damage between $50,001 and $100,000, which we consider serious. A total of 6,667 accidents reported total costs between $100,001 and $250,000, which we consider significant. The 2,776 accidents between $250,001 and $500,000 are considered major. The remaining 3,360 are those reporting above $500,001 and are considered critical. Interestingly, only 1,693 of those critical cases (or 3.07 percent of all accidents) report more than one million dollars in costs.



The severity grouping is to demonstrate context, but will also be important for evaluating the two theories of crew size regulations: prevention and mitigation. As we explore each, another important piece of context is the overall trend in rail safety and accidents. Rail is getting safer every year as new technology is implemented.



This trend is why FRA in its latest NPRM references the "industry maintain[ing] its strong safety record…" It is in spite of this "***strong safety record***" and trend toward fewer accidents that FRA now seeks to impose a new rule. Yet that intervention is not to incorporate new technology that would helped drive the safety record, but to lock in place existing employment. This would not have the effect of improving safety, but at best would retain existing incident numbers.

Prevention

In the technology section of this report, we explored which accident types and causes are most suitable to be resolved by technology and which by personnel. Across both accident types and major causes, technology has the greatest potential to reduce incident numbers, costs, and impacts. As we go deeper into the data, we again ask what accidents we most want to prevent and analyze impacts on "railroad employees, the public, and the environment," which the NPRM identifies as its primary beneficiaries. The answer should be guided by data.

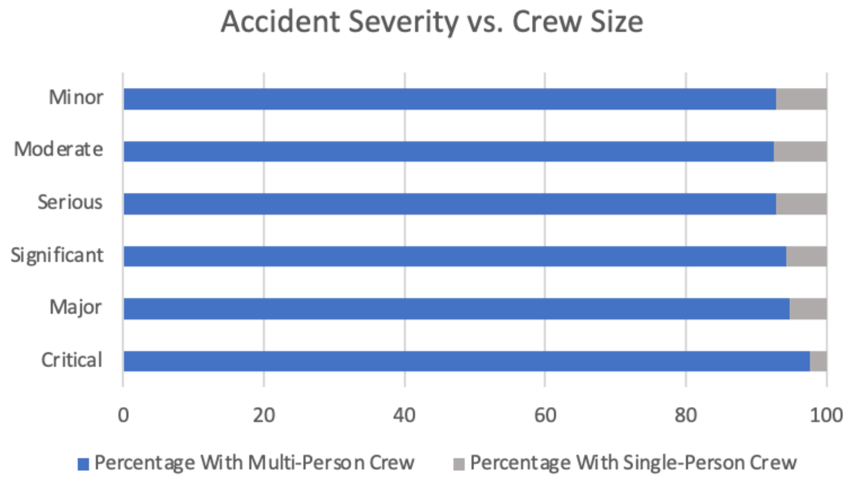
Derailments account for over 65.3 percent of all accident types along with over 76 percent of damage costs and 25 percent of reported casualties. Collisions account for over 6.42 percent of all accident types, 8.5 percent of damage costs, and 14 percent of casualties. These are the two accident types that data tell us are most important to resolve, as they account for over 70 percent of accidents, 85 percent of costs, and nearly 40 percent of casualties.

Fire, explosions, detonations, and ruptures are another 1.36 percent of accidents, 1.65 percent of costs, and 0.76 percent of casualties. Another 16.14 percent are unknown or unidentified accident types, which together account for 6.29 percent of damage costs and 7.58 percent of casualties. These are too minimal in impact or unknown cause for a blanket solution like regulation, and certainly not something crew sizes can address with such opaque data.

Finally, crossings and obstructions incidents account for just over 10 percent of accidents, seven percent of damage costs, and 52.72 percent of reported casualties. The enormous casualty impact occurring at crossings is an immediate red flag to address, and something that should be top of mind in a prevention analysis. Together, incidents at crossings and those involving trespassers explain 94 percent of all rail-related fatalities.[116] The problem is that this is outside the scope of a crew size or staffing regulation. Too many crossing incidents are the result of highway user inattentiveness/misjudgment, interference, vandalism, trespassers, and more. Further, trespassers along the rest of the rail network are acting on their own agency, very often correlating with intoxication.[117,118] These are within the ability of rail companies and the FRA to address to some extent, but a second crew member in the locomotive cannot address the majority of these issues.

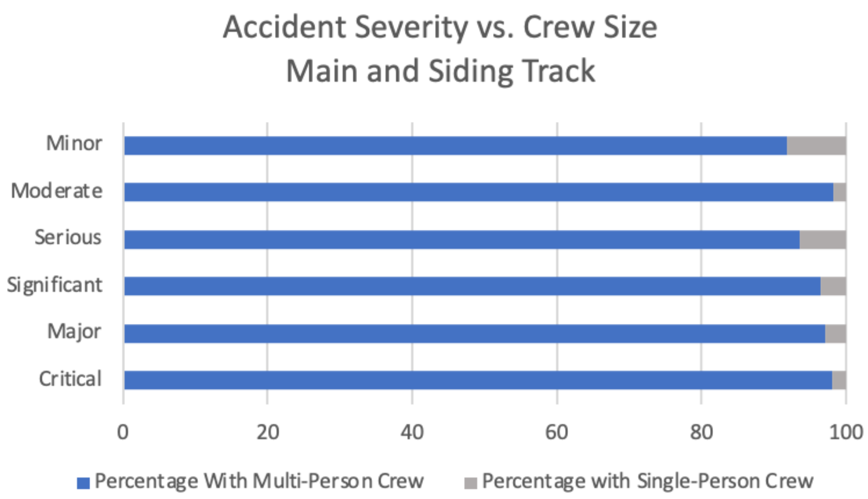
We are left with derailments and collisions as the most important accident types to prevent. We also know that these are primarily caused by track deficiencies and human error, respectively. What we find is that the largest problem and most costly is track issues, while the type of issue most suited to crew regulation is a fleetingly small grouping of human error issues, which are already adequately addressed through PTC. From the technology section, we identified 18 percent of all accidents that have a human-only solution to human error across all rail and around one percent on mainline freight rail, but to evaluate whether personnel must be in a locomotive or simply present in the rail network at some stage, we begin reviewing accidents by severity.

When listing an engineer on duty, the overwhelming majority of incidents had a two or more-person crew. Moreover, for all accidents, the severity of accidents does not correlate worse accidents occurring with fewer crewmembers.



Across all incident severity classes, there were two or more people on duty in 92.59 percent to 97.61 percent of cases. These extra eyes did not prevent the accidents, and there is no correlation between having multiple crew members on duty and less severe accidents. When it comes to prevention, there may be a coincidence between single-person crews and lower damage classes from minor oversights, for instance, the highest number of accidents occur in the moderate damage class (33 percent of accidents) and moderate also has the highest rate of single-person crews (7.41 percent), but this is too weak to identify as a meaningful correlation.

These results are even more clear for main and siding track, where a crew size rule would have its primary effect. There, multi-person crews are present between 91.88 and 98.23 percent of the time, with single-person crews being less likely in the higher damage severity. This again presents no support that single-person crews are less safe or lead to greater damage, and if anything supports a weak case that a slightly higher proportion of minor accidents occur with single-person crews.



Lac-Megantic

Before moving on to mitigation, there is a primary case cited for accident prevention. The events in Lac-Megantic led to a catastrophic incident that started with a single-person crew. However, the Transportation Safety Board (TSB) of Canada found no direct causal connection between the crew size and the accident. FRA made a similar admission in the 2016 NPRM, stating "FRA does not have information that suggests that there have been any previous accidents involving one-person crew operations that could have been avoided by adding a second crewmember."[119] And no new evidence is put forward in the new NPRM. Moreover, TSB of Canada even went as far as to say the same incident could have occurred with a multi-person crew given the poor safety culture of the company. Additionally, the Railroad Safety Advisory Committee (RSAC) convened to investigate and offer recommendations could not achieve consensus on crew size implication for Lac-Megantic. It is important to note however that rail safety regulations differ between Canada and the United States.

While FRA brought forward the 2016 NPRM in reaction to this and other incidents in 2013, it thoroughly concluded such a rule was inappropriate in 2019, no new incidents have occurred, and no new data is presented. Continued reliance on this example and putting forth no new statistical data undermines the rule and projects legal questions about the justification.

Mitigation

With mitigation in mind, we accept that the accident occurred without identifying causes and instead filter by whether conductors were on duty to determine if the added personnel led to lower costs.[120] This is done by comparing the percentage of total accidents occurring by each crew size to their respective costs and impacts.[121]

Those accidents which reported no conductor on duty represent 18.44 percent of all accidents from 2000 through 2021. The total damage costs for this period are reported as $878,783,977.[122]

Proportionately, this cost is 10.79 percent of total damage costs for the 22-year timeframe. This would be approximately $89,864 per accident. The total fatalities coinciding with no conductor on duty amount to 160 (of which two were railroad employees) and injuries totaling 1,789 (of which 180 were railroad employees). Proportionately, fatalities with no conductor on duty are 13.93 percent of all fatalities, while injuries are 16.67 percent of the total.

For having one conductor, we cannot know from this data if the individual was in the locomotive cab or elsewhere in the train, as FRA does not capture this information. Nevertheless, that question is only relevant to accident prevention. For mitigation, that conductor being anywhere on the train would theoretically help reduce damage. Approximately 78.64 percent of accidents did have a conductor on duty, and those resulted in an estimated $6,976,121,990 in reported damage costs. Proportionately, this cost figure is 85.64 percent of total damage costs across all 22 years. This would work out to approximately $167,249 per accident. The total fatalities coinciding with one conductor on duty amount to 824 (of which 46 were railroad employees) and injuries totaling 7,034 (of which 1,951 were railroad employees). Proportionately, fatalities with one conductor on duty are 71.71 percent of all fatalities, while injuries are 65.54 percent of the total.

Approximately 2.92 percent of accidents during this time had two or more conductors on duty, and the associated accident costs total was $291,037,799 or around 3.57 percent of total accident costs. This works out to around $187,766 per accident. Staffing of two or more conductors on duty coincide with 165 total fatalities (of which two are railroad employees) and 1,911 total injuries (of which 200 were railroad employees). Proportionately, fatalities with multiple conductors on duty are 14.36 percent of all fatalities, while injuries are 17.80 percent of the total.

From this analysis, we can see that having a conductor on duty did not mitigate damage costs. As a proportion of total damage, having no conductor led to a smaller proportion of damage costs than the percentage of total accidents would predict, and the average damage cost per accident was the lowest of any crew size. Having one conductor did not mitigate damage, as the proportion of costs was larger than the percentage of accidents occurring with one conductor on duty would predict. Per accident, the average total damage was higher than with no conductor on duty. Finally, two or more conductors on duty led to a slightly higher, but statistically expected cost relative to the percentage of total accidents in which two or more conductors were on duty but the highest average cost per accident.

The casualty counts show that no conductor on duty results in a lower proportion of both fatalities and injuries than the percentage of accidents with no conductor would predict. The proportion of casualties for one conductor on duty is also lower than would be predicted. It is only when multiple conductors are on duty that the proportion of casualties is higher than the percentage of accidents would predict – which is indicative that these incidents involve passenger rail derailments or collisions with many concurrent casualties among passengers.

All Track					Relative to Percentage of Total Accidents		
Secondary Crew on Duty	**Percentage of Total Accidents**	**Percentage of Total Cost**	**Percentage of Total Fatalities**	**Percentage of Total Injuries**	**Actual Cost Share Relative to Predicted**	**Actual Fatality Share Relative to Predicted**	**Actual Injury Share Relative to Predicted**
No Conductor	18.44	10.79	13.93	16.67	Lower	Lower	Lower
One Conductor	78.64	85.64	71.71	65.54	Higher	Lower	Lower
Multiple Conductors	2.92	3.57	14.36	17.80	Expected	Higher	Higher

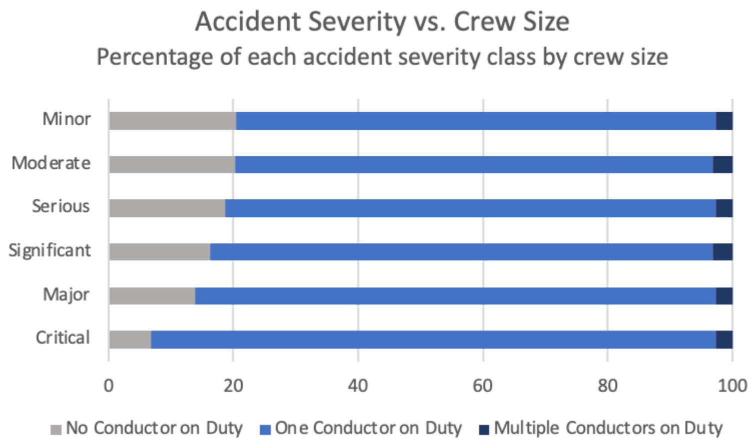
Analyzing the same information on mainline track results in similar findings. The predicted cost of damage is lower than the share of accidents would predict for no conductor on duty and higher than predicted with one conductor on duty. The predicted cost for multiple conductors is statistically equal to what it we would predict, while the share of casualties is again out of proportion. The only difference that emerges by isolating mainline track is the share of casualties, which are each higher than predicted by the share of total accidents.

The percentage of accidents caused by human error holds consistent at 35 percent, even for no-conductor, mainline track accidents. In fact, the share of fatalities *caused by human error* with no conductor is less than one percent, while the share of injuries is only three percent, below what the share of total accidents would predict even for the subset of all human error incidents on main track without a conductor. This analysis shows that at best, there is no correlation between conductors on duty and mitigation of accidents. The results further undermine the case presented by the FRA and emphasize the need for further data collection and statistical analysis.

Main and Siding Track					Relative to Percentage of Total Accidents		
Secondary Crew on Duty	**Percentage of Total Accidents**	**Percentage of Total Cost**	**Percentage of Total Fatalities**	**Percentage of Total Injuries**	**Actual Cost Share Relative to Predicted**	**Actual Fatality Share Relative to Predicted**	**Actual Injury Share Relative to Predicted**
No Conductor	10.78	6.60	14.67	18.13	Lower	Higher	Higher
One Conductor	85.82	90.29	76.64	67.87	Higher	Lower	Lower
Multiple Conductors	3.39	3.30	8.49	13.97	Expected	Higher	Higher

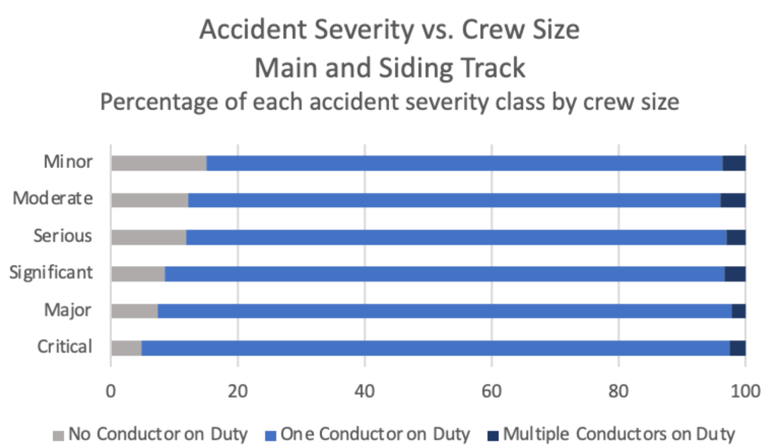
These analyses do not take into account additional engineers and other personnel like firemen or brakemen on duty. The presence of these employees only serves to underscore that additional rail employees on scene did not reduce or mitigate damages as viewed by costs or casualties. Moreover, this data relies upon reporting in accident forms. Knowing accident forms already lack the precision to note the location of crew members (e.g., in the cab or elsewhere on the train) it is difficult to make definitive causal claims with this data, especially claims upon which regulations are made.

Running a similar analysis but grouped by accident severity, we can assess whether the presence of additional crew correlates with lower severity. For the mitigation theory to hold, we would expect to find that the proportion of crew is inversely related to accident severity. If more personnel mitigate damage, then the most critical accident types should demonstrate a higher share of no conductor (or fewer people on site to mitigate, thus explaining the greater severity).



Visualizing this data shows no positive correlation between crew size and mitigation. In fact, we see the opposite – that the worst damage class, *critical*, has the lowest proportion of no conductor on duty. Rather than operations without a conductor on duty leading to accidents being more severe because fewer on-duty crew are there to mitigate, the higher accident severity classes show lower proportions of no conductor on duty. We would have expected to see a gradual and consistent growth in **no conductor** percentage as we move upward in accident severity, smallest in minor and largest in critical because a large share of "no conductor" would mean fewer people on-site to mitigate damage. **One-conductor** on duty would marginally shrink as severity increases. Then in theory, the **multiple conductor** percentage would be largest for the least severe and smallest for the most severe because many crew members on site would reduce the accident severity.

These results are replicated on main and siding track, where the NPRM is aimed. Once again, minor accidents feature a higher proportion of no conductor on duty, while the costliest accidents have a lower proportion of no conductor on duty. More personnel do not appear from this data to support the theory of accident mitigation.



Before assessing the most cited case of mitigation, it is worth noting four points: first, mitigation is a theory postulated without data, second, the available data does not seem to bolster it, third, the argument relies on a counterfactual, and fourth, the theory contradicts safety training.

For the first point, the FRA repeatedly refers to the mitigation theory as "potential" to reduce damage.[123] It is virtually never argued as an affirmative case. Second, when we assess the data that does exist, there is no clear correlation where we would expect to see it. Third, by its counterfactual nature, the mitigation theory assumes how things might have played out based on a host of assumptions that cannot be proven. For example, if a train were to derail carrying dangerous cargo in a populated area and with a large crew size, the mitigation theory says that the several rail personnel would immediately manage equipment, call for emergency response, help facilitate evacuation, or take other mitigating measures. In reality, this may happen, but in a hypothetical, it is equally likely that all crew members die or are incapacitated, that the crew members are impacted by the bystander effect and do little or no mitigating activity, or that the main mitigation that went on was by non-rail personnel in the populated area. Regulation cannot be built purely on potentiality and counterfactuals, especially when available data analysis undermines the theory.

As a final point, crew members at Class I railroads are trained to move away from danger and hazardous releases and to simply provide information to first responders. The rationale proposed for the mitigation theory is in contradiction to the safety training railroads are actually instructing their employees, at least in regard to hazardous materials.[124,125]

Casselton

In 2013, railroad employees acted with genuine heroism by responding to the derailment of their train in Casselton, North Dakota. The problem with citing it as a mitigation exemplar is that it is a single anecdote, not representative of data, and that it is not a conclusive example in itself. The new FRA rule makes reference that crewmember conduct "potentially prevented" damages and "potentially shorten[ed]" community evacuation period. These are unsupported assumptions, made more uncertain by FRA's admission of the fact that "an exact timeline was not established" in NTSB investigative reports and that emergency responders were present as well.

FRA also stated in 2019 that "FRA believes the same type of positive post-accident mitigation actions were achievable" with single-person crews or well-planned protocols, and that the underlying issues in Casselton as well as Lac-Megantic had already been adequately addressed through safety programs and other actions. By concluding that the "indirect connections between crew staffing and railroad safety" are "tangential at best and do not provide a sufficient basis for FRA regulation of train crew staffing requirements," FRA conclusively prevents itself from now citing Casselton or Lac-Megantic in support of its current NPRM and reinforces the APA burden of proof requirement. References to these incidents in the current proposed rule, alongside lack of new data, suggest an arbitrary advancement of regulation based on a policy preference rather than identifiable data.

Because Casselton fails to provide a conclusive example with respect to mitigation, it may be more preferable that one or more ground-based conductors or crew arrive on site quickly than that additional personnel are in the locomotive at the time of the accident. This is because the in-cab crew is likely to be in distress or shock, potentially injured or concussed, and may have impaired decision making. By contrast, a roving conductor may arrive with a neutral third-party view of the entire accident and have clarity of thought to address issues they identify upon arrival. This relies upon immediate notification of an incident (through instant data collection and sharing on the train) and conductors being able to mobilize and arrive on scene quickly. Rail companies seeking to transition to a ground-based conductor model should accordingly ensure communication technology is available and geographic areas are limited, that scheduling is predictable and regular to mitigate fatigue, and that an adequate number of ground-based crew are available at all times.

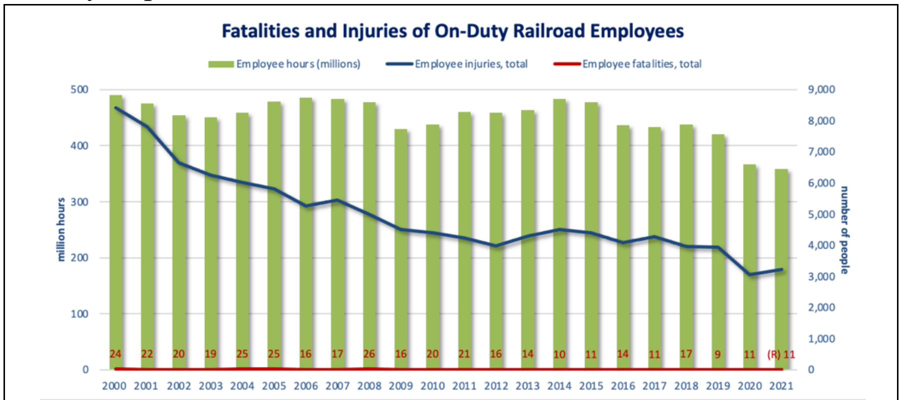
Intended Beneficiaries

Up to this point, we have explored accident prevention through the technological solutions and by assessing whether single or multi-person crews lead to fewer or less severe accidents. The limited available data does not demonstrate that crew sizes contribute to fewer accidents or that multi-person crews necessarily prevent or mitigate accidents. Next, we look at the three particular classes identified by the FRA as the beneficiaries of a crew size rule: railroad employees, the public, and the environment.

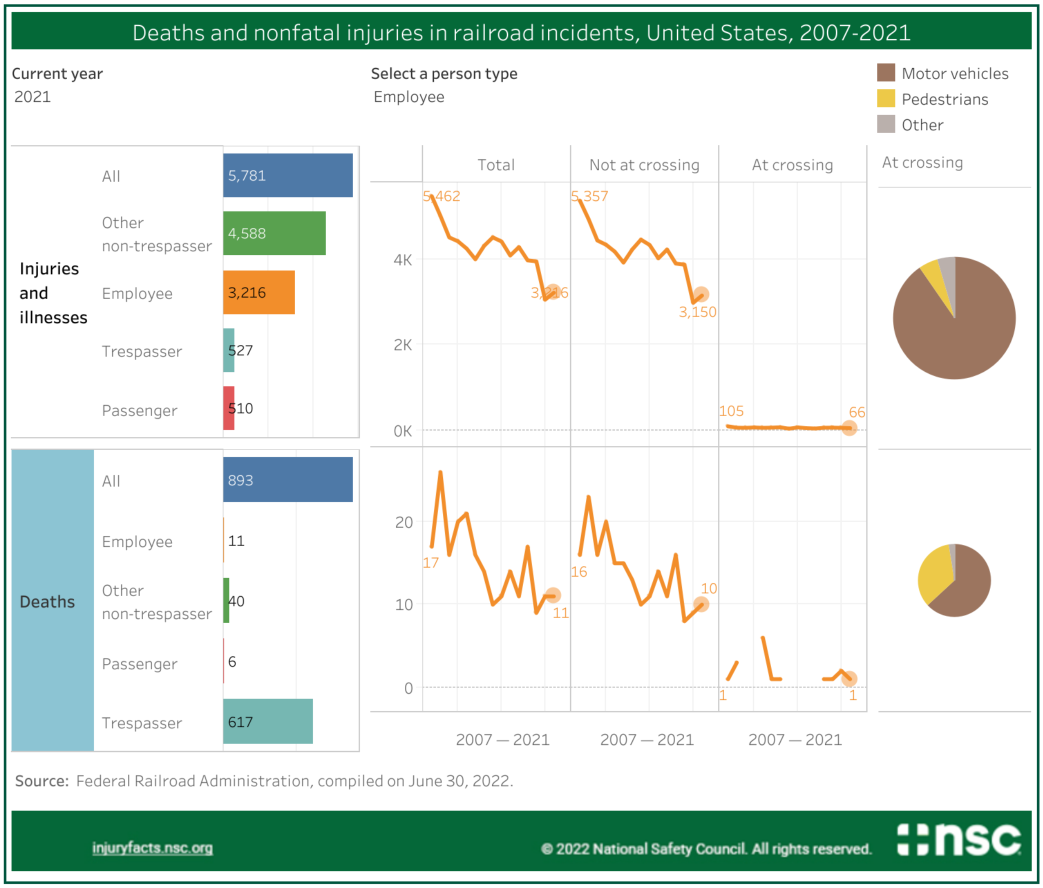
The FRA does not present an affirmative case for any of the three classes being better protected by a crew size rule. Instead, FRA asserts that a crew size rule would result in safer outcomes. By failing to make a data-driven case, the agency leaves the door open to two blunt criticisms: first, there is insufficient data to make the case that crew size rules lead to safer outcomes, and second, from the data that does exist, the opposite conclusion is reached. Rail is safe now and experiencing significant safety gains in spite of having no crew size regulation in place.

Railroad Employees

The safety of rail personnel is critically important. It is both good and noteworthy then to see the safety trend employees are experiencing. Across injuries, illness, and death, railroad employees have been on a safety improvement trend since at least 2000.



On-duty railroad employee fatalities remain at a low level, while employee injuries show a declining trend, along with a slight deline in employee hours working in the past two decade. *Source: Bureau of Transportation Statistics.*



Using FRA FORM F6180.55A, we can confirm that railroad worker safety is improving.[126] Further, the fact that some 97 percent of Form 55As report not filing a Form 54, reinforce that the overwhelming number of injuries and illnesses are not occurring on moving trains, resulting from derailments or collisions, or highly pertinent to crew sizes. Indeed, most slips, trips, falls, and sprains occur throughout the rail network, while others occur in office jobs or machinist/smithing/welder type jobs. Injury and illness in any of these roles is important, but not relevant to locomotive crew sizes. Where the relevance does lie, it centers around needed technology to protect and aid operators of moving trains and any ground-based support teams.

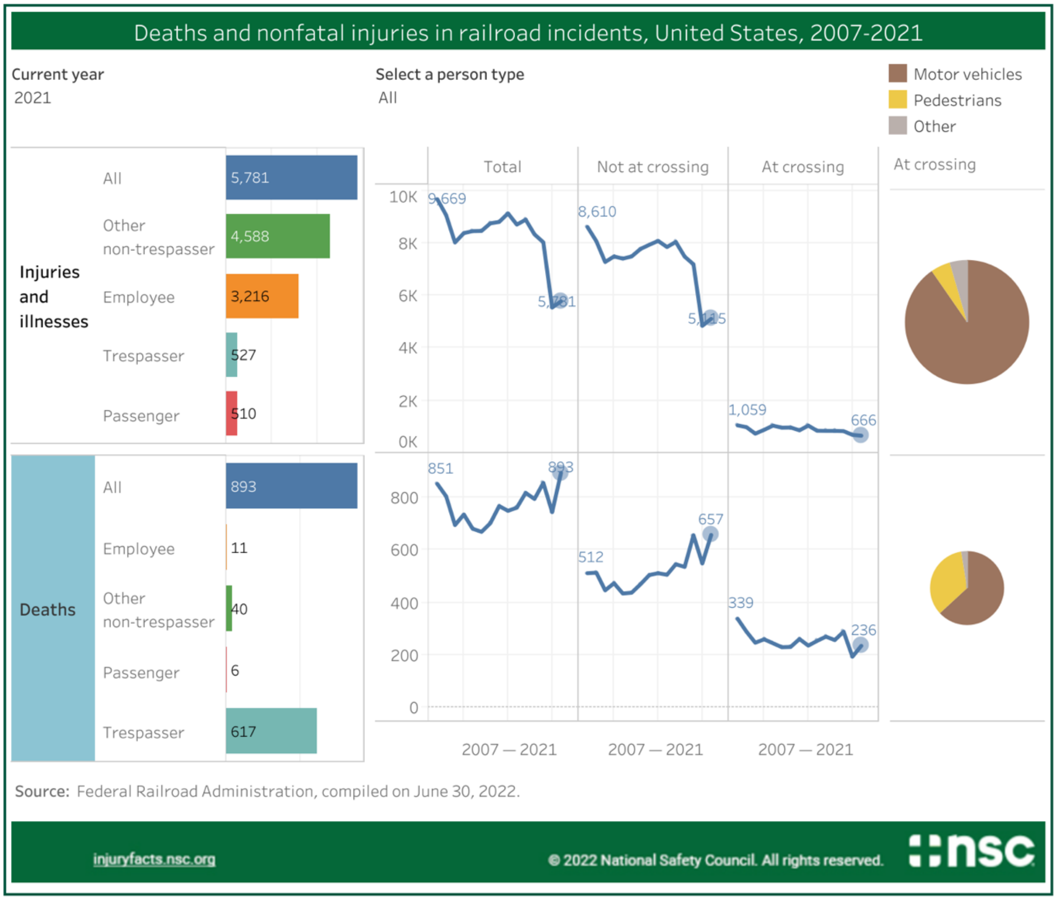
From Form 54, the three types of accidents causing 84 percent of railroad employee deaths and 86 percent of injuries are derailments, collisions, and crossing incidents. Having already analyzed these issues, we know that the most effective way to reduce incidents is through technology. To the extent that personnel are the best solution, they are again best suited to be in distributed teams. This is especially true where the human error cause has to do with fatigue, if roving conductors responsible for a geographic area and with set daily schedules can assist. Because over half of railroad worker fatalities are the result of collisions or derailments, mandating additional employees in the locomotive may ensure more worker fatalities in inevitable incidents, while ground-based crew would reduce those at risk in the locomotive. Reviewing human error and crew size helps illustrate this point.

Out of every incident since 2000 that reported railroad worker fatalities, 57.89 percent were primarily caused by human error, yet 97.37 percent consisted of multi-person crews. Similarly for railroad workers injured, 36.19 percent were caused by human error, and 87.80 percent consisted of multi-person crews. Clearly, the presence of additional crewmembers did not prevent these accidents or resulting casualties.

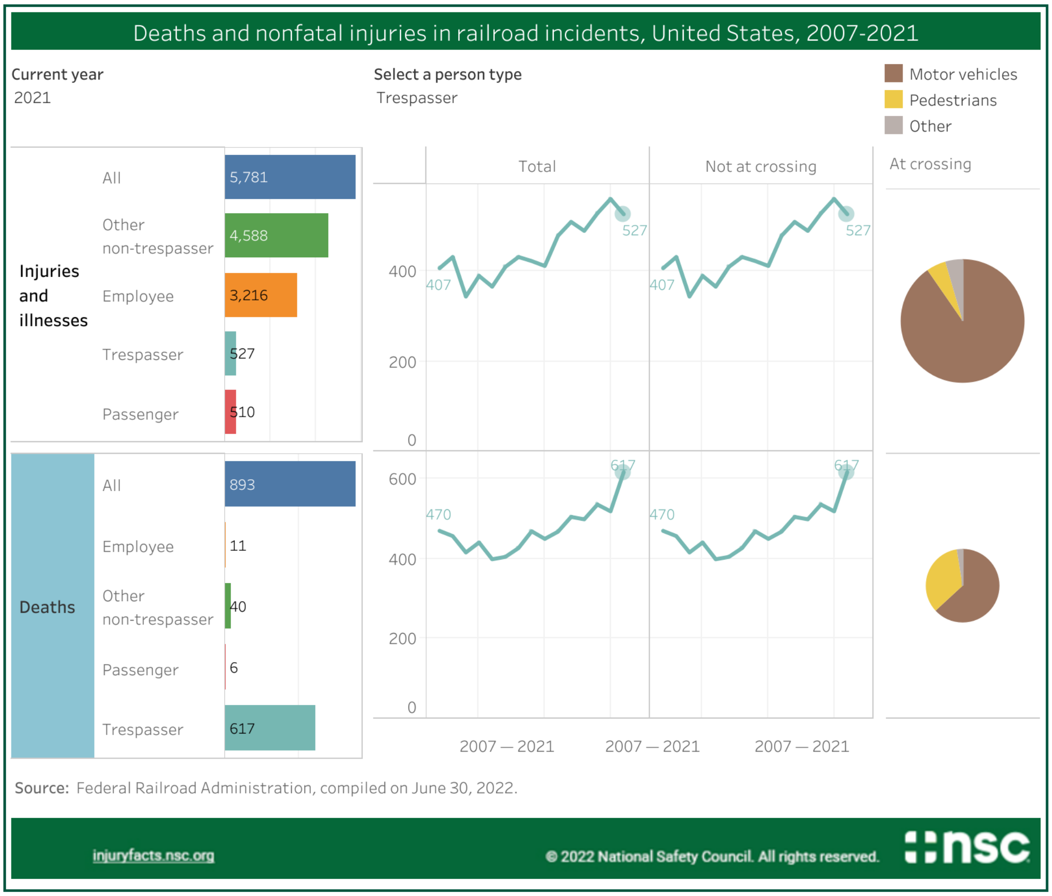
The conclusion from this data is that multi-member crews are not needed to protect workers, and in fact, of the accidents that resulted in fatalities and injuries to workers, there were overwhelmingly already multiple crew members. A rule purporting to protect workers by codifying crew sizes would have no impact based on available data.

The Public

The casualty trends for the public follow a similar favorable trend, as total rail incidents have declined in recent decades and therefore spared incident and injury to the public. There are two lenses to view the public, first as a total population and second by removing trespassers. As a total population, it appears deaths are persistent, even as injuries are experiencing steep decline:



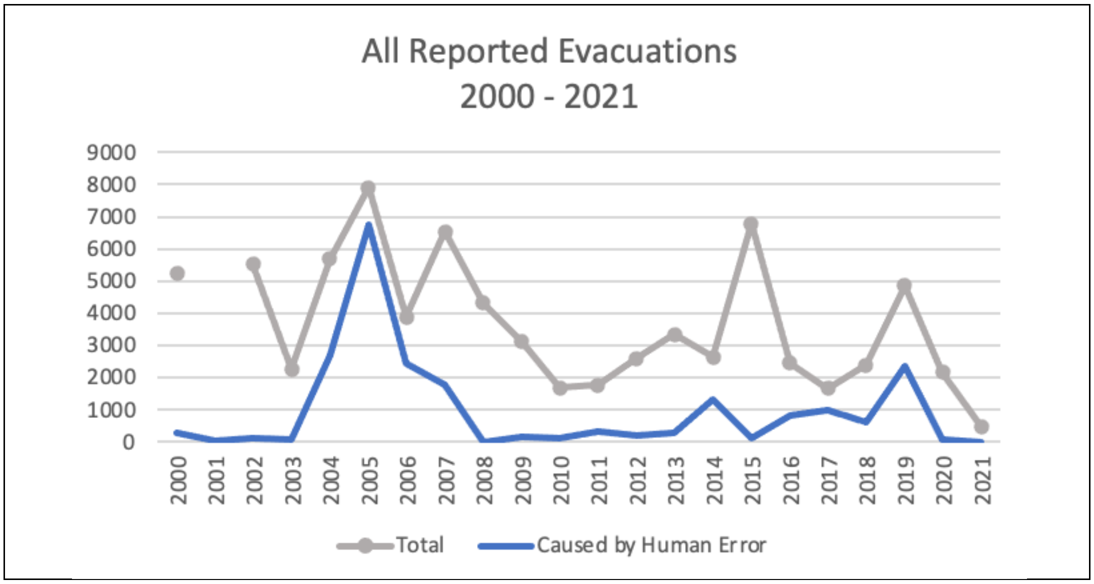
Yet when recognizing that the upticks are the result of trespassers, the overall death and casualties are on strong downward trends. In fact, even with trespassers experiencing higher rates of injury (below), the overall public injury trend (above) is still sharply downward.



Derailments and collisions are the source of only 10 percent of total fatalities and 42 percent of injuries, with largely track-based issues and technological solutions suited to address the majority of human errors. At crossings, over 86 percent of public fatalities and half of injuries occur. This is largely the result of trespassers or third-party agents like automobile drivers.[127] A proper analysis should remove third parties and trespassers, because they are outside the scope of a locomotive crew size rule. At best, the in-cab crew can sound a horn to alert or deter trespassers, but no available data suggests that single-person crews do not sound their horn, that multi-person crews always sound the horn, or that any correlation exists between crew sizes and trespasser casualties.

For all incidents reporting deaths since 2000, less than six percent were caused by human error. Already, it is clear that a crew size rule is not equipped to address public casualties. Of all reported injuries, less than 25 percent were primarily human error. In fact, public fatalities coincided with a multi-member crew 81 percent of the time, while total injuries had multi-member crews 81.22 percent of the time.

Another way to view the interaction of rail with public safety is to track reported evacuations. The relevant assessment regards the share of evacuations due to human error accidents, as other causes are beyond the reach of a crew size rule.



The share of evacuations necessitated by human error incidents is low relative to evacuations from other accident causes.[128] This once more illustrates the lack of data behind the FRA intention to "enhance safety" "to protect…the public" by using a tool (regulation of crew sizes) that is ill-suited to the task. Such a rule would only potentially avert a fraction of a fraction of evacuations, if having any meaningful impact at all.

Certain incidents will occur no matter the in-locomotive crew number because they are not within the control of the engineer/conductor. Mandating employment in the locomotive will not meaningfully reduce deaths or injuries to the public, because very often multi-member crews still fail to prevent such incidents, while technology could, or a solution elsewhere in the rail network could. To the extent that personnel are required, there is little or no data to suggest that they must be fixed locomotive roles. Qualified engineers, those certified as engineers and conductors, and those working with an abundance of technology are well equipped to avoid accidents and to be supported by a strong network of inspectors, conductors, and others outside of the locomotive.

The Environment

Assessing impact to the environment from rail can be difficult. The two primary metrics are release of hazardous materials from incidents and emissions from operation. On both counts, rail is already doing impeccable work, with broadly safe and low-impact operation. Contextualized against alternative modes, rail is as safe or cleaner than many, coming in only below pipelines in its safety record and emission rate.[129] When evaluating the movement of hazardous materials, we can look at volumes moved and accident rates. For example, from 2004 to 2014, as shipments of crude oil increased 50-fold, rail safety improved by 49 percent.[130] This occurred before the first PTC protections were in place within the system. Because an incident must happen for hazardous materials to be a concern, and incident rates are falling, hazardous material cars do not present added danger any more than additional cargo of another kind adds danger.[131]

Yet rail carries far more cargo than simply oil and gas that can move through a pipeline. Its payload includes many of the raw materials, energy products, and finished goods that keep the economy running. In fact, over the last 22 years, less than one percent (0.87 percent) of reported incidents identified a release of hazardous materials.

Since 2000, only 22.87 percent of incidents with any hazardous material releases were primarily caused by human error. Of those, over 86 percent had multi-person crews on duty. Additional technology and supporting personnel roles are also the most viable solution to prevent these. A crew size rule oriented to resolve hazardous material releases would ultimately be targeting less than a tenth of a percent of all accidents.

Perhaps counterintuitively, a crew size rule may actually increase net emissions due to freight diversion owing to compliance costs and rigidity over time. This would ultimately mean that whatever safety benefit accrues (although none is supported by available data) the net impact of a crew size rule would be net harm to the environment. This will be explored in greater detail in the subsequent economic evaluation.

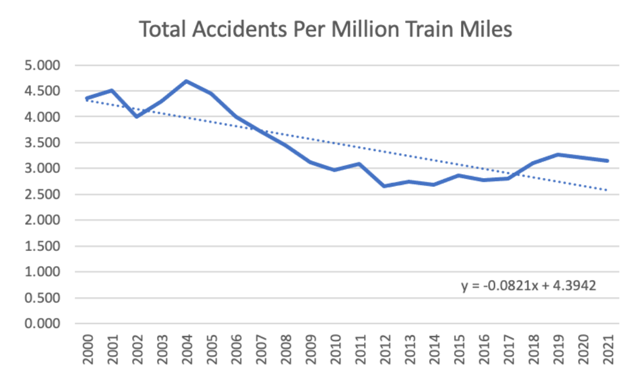
A rule purporting to protect workers by codifying crew sizes would have no impact based on available data.

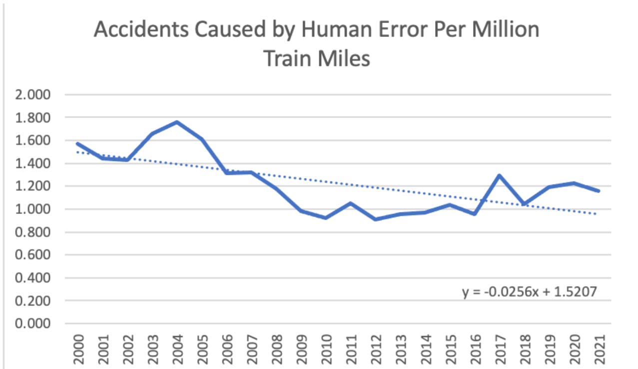
Contextualized Safety Data

Because we have been looking at incident data, we only see the instances of failure. This can give the impression that there is insufficient safety or that certain human errors demand additional personnel to correct. To the contrary, the rail industry is operating more safely today than virtually any prior point in history. Accident data can also demonstrate this by revealing lower numbers of incidents over time, but another set of data is also important. That is the mileage occurring without incident and the economic value transported. In this context, the net positive impact of rail highlights how it has succeeded within its current regulatory and private sector context, with crew sizes determined by collective bargaining – a process clearly resulting in positive safety trends.

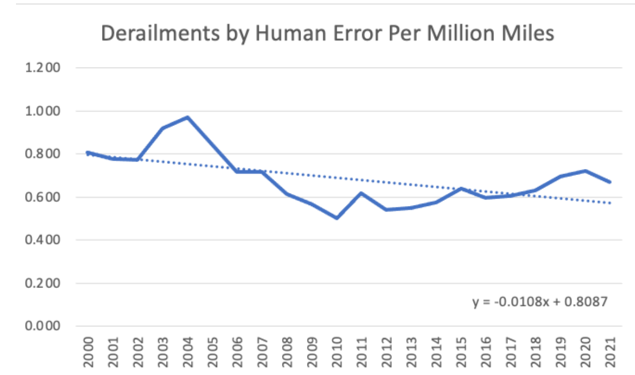
Since 2000, the total number of train accidents has declined by 42.91 percent, while accidents due to a major cause of human error have declined by approximately 41.73 percent, falling proportionately with all accidents. Since the 2019 rule withdrawal, total train accidents have fallen by 18.81 percent and human error accidents have reduced by 18.17 percent. According to accident reporting forms, worker casualties reported have fallen by 50.3 percent since 2000, while total reported casualties have fallen by 41.39 percent, and hazardous material car releases fell by 64.38 percent. Since 2019, reported railroad employee casualties have fallen by 4.05 percent and total casualties have fallen by 13.35 percent. The hazardous material car releases since 2019 have increased marginally, by 23.81 percent, although the reported car difference is a change from 21 to 26 cars.

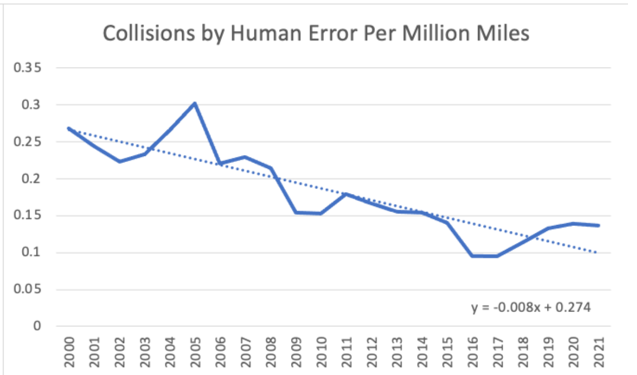
The data reviewed so far has included over 50,000 train accidents since 2000. But in that time, trains have exceeded 15.8 billion train miles. Not only have trains crossed the country millions of times, but the rate of accidents has declined over time. This is true for both total train accidents and those caused by human error.





Consistent with the prior analysis that derailments and collisions represent the greatest risk and harm to railroad employees, the public, and the environment, it is fitting to also identify trends in these accident types. Overall, both derailments and collisions per million train miles are declining, each having fallen by 40 percent or more since 2000 and around five percent since 2019. Relevant to a crew size rule, we look at derailment and collision accidents per million train miles caused by human error. In both cases, we see safety improvement trends since 2000. Recent years have seen a new uptick in human error causes of derailments per million train miles. The strong improvement (reduction) in human error collisions since 2000 is currently showing a fluctuation. These recent upward fluctuations both demand attention, explanation, and further review by rail companies. These are consistent with slight upticks in total train accidents per million train miles above, meaning human error is not causing more accidents, but remains responsible for around 35 percent of all accidents regardless of increase or decrease in incidents.





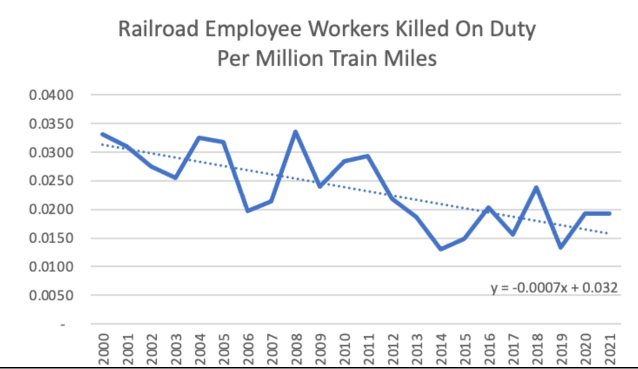
According to this data, a train in the United States on average can travel 1.43 million train miles before having a derailment caused by human error. Similarly, an average train can travel over 7.35 million train miles before having a collision caused by human error. These statistical realities are also changing for the better on a trend line that has spanned over two decades of the same average crew size. With higher incorporation of PTC and related technology, we can expect these trends to continue. When we isolate the human error causes of these accident types that require only a human solution outside of technology, the rate of accidents per million train miles drops by nearly half. Once more, available data demonstrates both a strong safety record for rail that is in a continual process of improvement and that for the remaining and shrinking safety concerns, in-locomotive crew size rules are ill-suited to address them.

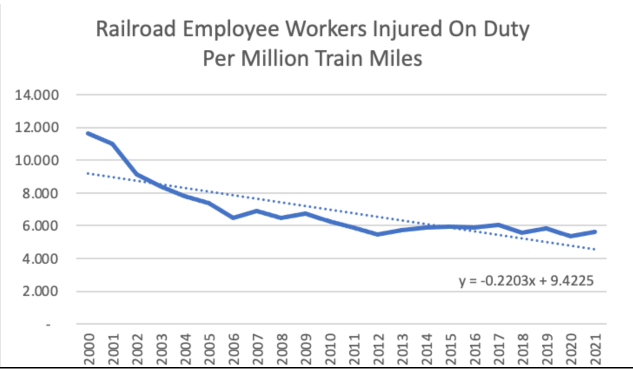
Even with this data demonstrating improving safety in context, other concerns exist, namely fatalities. If crew sizes are capable of addressing employee and public casualties, it should be explored.

There has been an increase of deaths per million train-miles since 2017 which presents a serious issue to further analyze.[132] As the above sections have already made clear, the cause and accident types most likely to lead to fatalities are track deficiencies and derailments, which are not within the reach of a crew size regulation to address. Those simply are not avoidable by in-cab crew. They may be addressable through technology and inspections. A second piece of context is the issue of trespassers, highway vehicles, and tragic but intentional events like suicides.[133]

Removing crossing collisions and suicides, the trespasser fatality rate has been increasing. With the high correlation between trespassing and intoxication as well as suicide attempts, there is no way to address these tragedies through a crew size rule, and they should be removed from the total fatalities per million train miles for the purposes of this evaluation. To the extent that horn sounding, flashing or colored lights, or cattle guards are able to mitigate the very real trespasser concern, they should be explored further.

Looking specifically at railroad employees, we also see a declining casualty trend for both deaths and injuries. This trend is true in absolute numbers, per million train miles, per full-time employee ratio, and per employee on-duty ratio. As expressed through train miles, which best contextualizes the work done by railroads and their economic benefit, the railroad employee casualties have trended toward greater safety.

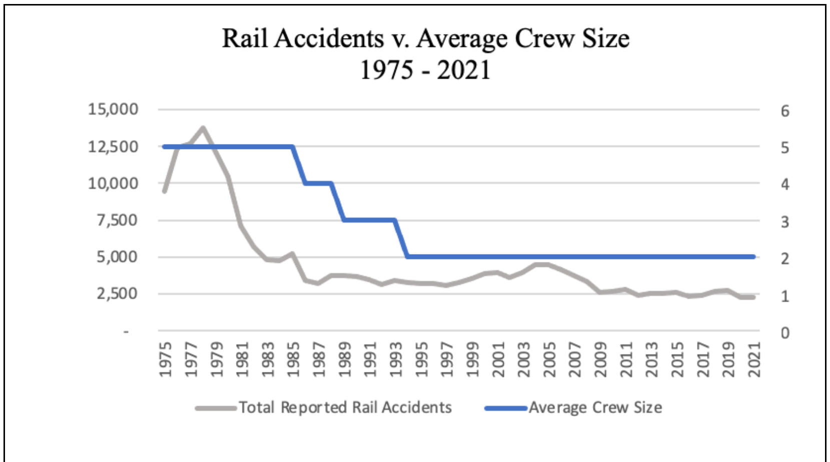




The data is not available to analyze employee casualties from rail accidents caused by human error, but the above graphs represent total annual casualties. The proportions from human error will be roughly 35 percent, assuming the average annual accident rate also correlates exactly with casualties. Even then, technology can address roughly half of those accident root causes, leaving personnel-only solutions to address employee casualties to around 18 percent of the total. In absolute terms, around 24 railroad employees on duty were killed annually in 2000, while 2020 and 2021 each saw 11 railroad employees on duty lose their lives. Similarly, in 2000, injuries were above 8,000 to on-duty rail employees, while only around 3,000 have experienced injury in each of the last two years. Applying the roughly 18 percent human-only solution to general root causes, this would mean that personnel solutions would address roughly two fatalities and 540 injuries on an annual basis. For mainline freight rail, statistically no fatalities are addressed, while 30 injuries may be addressed. The roles those personnel may be required for, however, span the rail network.

With appropriate rules and regulations – primarily alongside technology – existing safety trends can continue. They stand in stark contrast, however, to the implied view of the FRA that a new rule is needed to enhance safety to protect railroad employees, the public, and the environment, especially without data linking such a proposal to safety outcomes. For the most part, the crew size rule would lock in place crew sizes that already exist, thus having no impact on safety (because the standard is already two people). As the next section will explore, while no benefit is evident, there may be additional costs from the regulation.

Available data and trends extending back at least 50 years show improvements in rail safety. In fact, crew sizes saw significant decline during this time frame, dropping from around five employees to an average of two, with many examples of single-person crews now operating safely. During all of these changes and across all of these years, debates centered on economic competitiveness, costs, and employment – virtually never around safety. That is because the safety data showed continual improvement. Throughout all these years, and despite oftentimes tense debate and bargaining, the FRA "had not regulated or even publicly considered regulatory issues relating to crew size prior to 2016."[134] Now, at nearly the lowest rate of accidents, least human error causes, and best rate of safe train miles from available data, and when technology is most sophisticated and accessible, the FRA is seeking to regulate crew sizes.



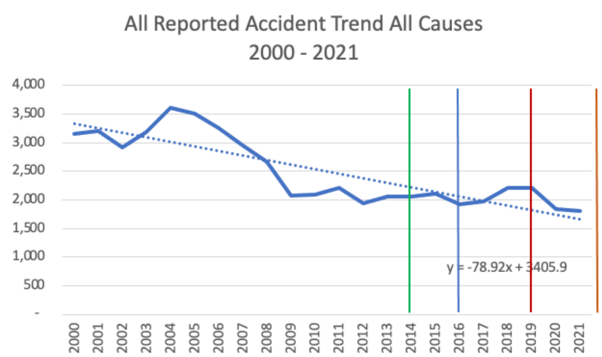
Source: FRA, Form FRA F 6180.54, Rail Equipment Accident/Incident Data

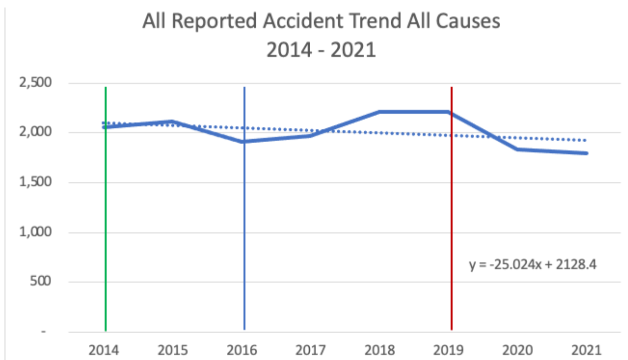
Before moving on, it is instructive to view the data once more with respect to the trends in human error and the solution proposed by the FRA to mandate human solutions. As posited at the beginning of this report, due to the agency withdrawing its own proposed rule and needing to satisfy a burden under the APA, rail incidents would need to show worsening trends to justify the proposed rule today.

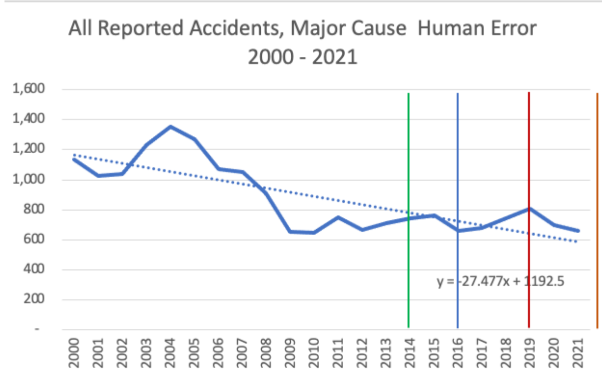
Accident Trends by Human Error Against FRA Crew Size Proposals

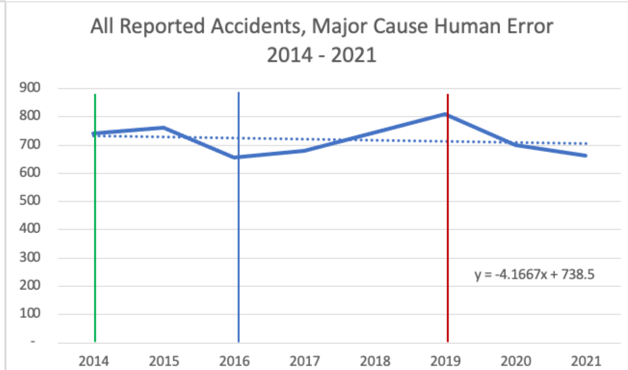
Announced Intention | First NPRM | NPRM Withdrawn | New NPRM

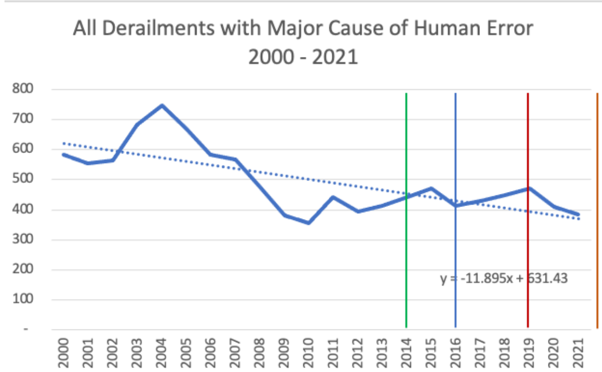
Viewing the trend graphs on the left, it is clear that rail is still improving. Even with a window of time from the first FRA proposed crew size in 2014 through 2021, the trends still show improvement in the type of accidents FRA seeks to address through crew staffing regulations.

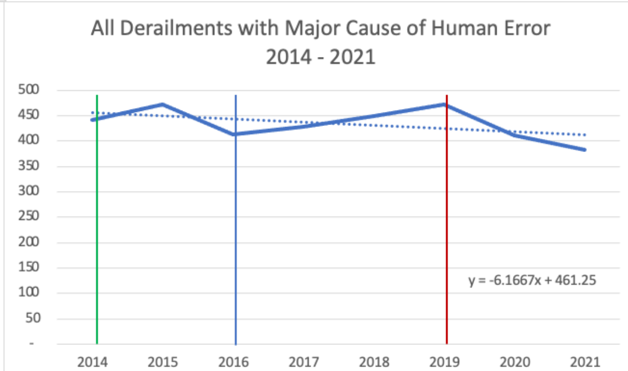


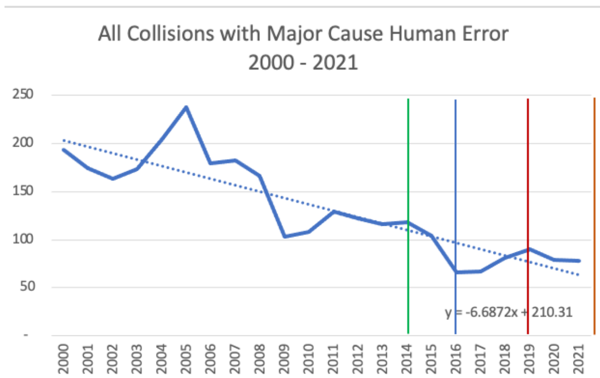


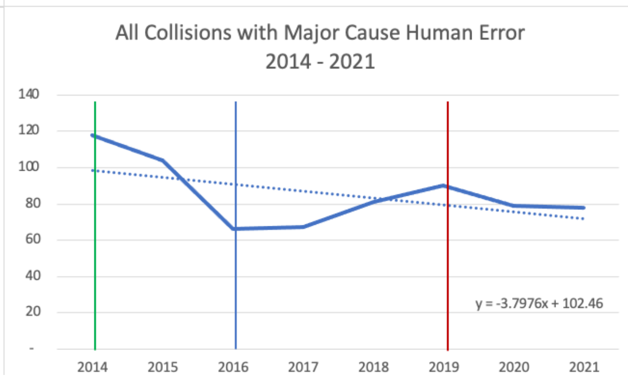












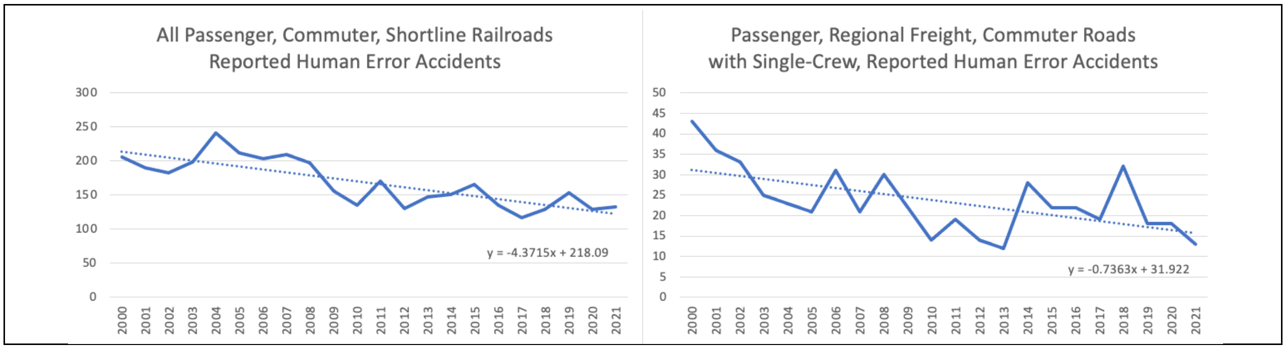
Comparative Analysis

Available accident data through railroad reporting and other information collected by the NTSB and FRA do not provide evidence that multi-person crews prevent or mitigate accidents differently than single-person crews. The implicit bias against single-person crews and the belief that they lack safety is an assertion, not a conclusion. The FRA even indicates its current proposed rule is not because data shows a safety concern, but because it does not know the data, thus flipping the burden of proof on its head. To explore the question further, we survey examples of single-person and crewless operations and look at the record of other countries and comparable industries.

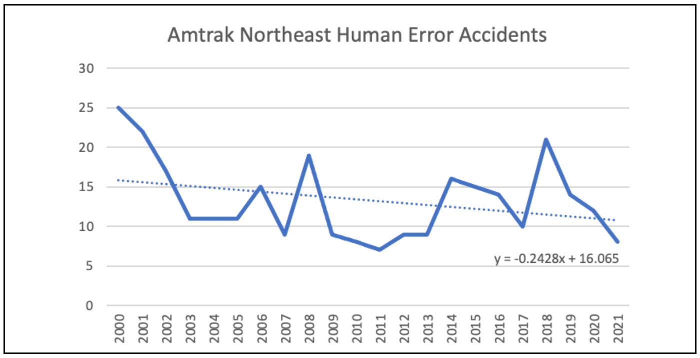
One-Member Crew in the U.S.

In 1981, when accident rates across the rail sector were over three times higher than today, Congress enacted the Northeast Rail Service Act of 1981, which ended a legal requirement that two crewmembers be present in the operating cab of commuter rail in the Northeast Corridor. Since that time, Amtrak trains have carried hundreds of millions of passengers with only a single operator in the cab.

Both in absolute terms and as a trend over time, accidents from passenger rail and similar operations where single-person crews are common demonstrate little human error concern in need of correction. When grouping the type of the railroads that may operate with single-crews (e.g., passenger, regional freight carriers) and narrowing to a subset that do (though not necessarily exclusively) operate with single-crews (e.g., Amtrak, Indiana Rail Road, etc), each demonstrates declining accident numbers over the last two decades, and specifically continued declines in human error accidents. If single-crew operation was unsafe, these groupings would give an indication of that because the higher rate of single-person crews would result in different performance and human error rates.



Even where the single-member crew movement began over 40 years ago, and single operators are extensively used, the accidents from human error remain on a downward trend, even amidst fluctuations.



Passenger rail is central to the question of safety because the value on board is infinitely higher than mere cargo. If we entrust single operators to move passengers and those passengers trust the operation by purchasing fares, then it is a demonstration of both safety and public confidence. Moreover, passenger rail moves far faster than freight rail. Speed is a major root cause of derailments, collisions, and crossing incidents because the train's momentum can exert continued force into a curve in the track or applying brakes can take a long distance to slow or stop the train. Safe passenger operation with these factors raises questions for why a rule would be needed, even if it offers exemptions to legacy operations who apply and prove their safety.

The United States also features single-crew freight rail, some of which are sampled in the above graphs. While the latest FRA NPRM highlights one example extensively, it seems like the agency may be holding that railroad's process up as a standard for achieving a rule exemption. If that is the case, it would likely mean that railroads may not be able to simply present safety data and risk analyses but may be expected to work extensively with the FRA itself and revise practices to conform with FRA preferences even with objectively sufficient safety data. Until the rule is finalized and the exemption process is tested, the NPRM itself stands out as evidence that single-person crews are safe. Relying on the exhaustive process the Indiana Rail Road company undertook to maintain that safety does not prove that such extensive action is required for safe operation, as data from other single-operator railroads and passenger lines demonstrate.

One-Member Crew Outside of the U.S.

Examples of single-person crews in the controlling locomotive cab can be found outside of the United States as well, including Australia, Canada, Denmark, France, Germany, Ireland, Italy, Japan, New Zealand, Spain, Sweden, and the United Kingdom. The earliest of these began running single-operator crews for passenger transit and commuter lines in 1964, and many employed a single person throughout the 1970s and 1980s. These nations comprise examples of both freight and passenger lines, demonstrating that the public, as determined by actual customers and representative government bodies, trust the safe operation of these rail operators.

Once again, the speed of passenger trains far exceeds that of freight in other countries that operate single-member crews. It is also true that U.S. freight moves more weight and longer distances than most comparable countries. Data nevertheless indicates that single-person crews can and do conduct a significant portion of rail movement outside of the United States, with little or no data to support a difference in safety relative to multi-person crews.[135] In fact, other countries in Europe even feature greater operational complexity[136] than the U.S. and have allowed single operators without high implementation of train control technology, while in the U.S. over 60 percent of Class I railroads are now governed by PTC.[137]

Statistical studies and analysis should be consulted further – by rail companies and the FRA. Existing literature reviewed for this analysis supports the conclusion that single-member crews outside the United States are as safe as multi-person crews. That is consistent with available data within the United States and the previous conclusions of the FRA and NTSB that no data supports single-person crews being less safe than multi-person crews.

Autonomous Rail Outside of U.S.

Consistent with our analysis in the Technology section of this paper, there are certain technologies that resolve human error, some that assist humans to reduce human error, and some tasks that still require personnel. Outside of the United States, the proportion of these is sometimes different. For instance, in Australia, a fully autonomous freight train operates over a 186-mile track carrying hundreds of cars of heavy mineral ore with no personnel present. That train is equipped with stop and start technology that conducts the entire range of necessary operations to safely transport materials. It has also traveled approximately three million miles since it was put into operation in 2018.

Others have framed the level of technology into Grades of Automation (GoA).[138] At four levels, these demonstrate the amount of automation ranging from assistant-protection applying emergency brakes to more autopilot style with a human still interacting or supervising, all the way to full automation not only without a human needed in the cab, but none present at all.[139]

GoA4 is not merely a projection into the future, as Australia's freight rail demonstrates, but something found across a range of rail operations. With some variation in population density, speed, and distance traveled, some form of fully autonomous passenger transit rail can be found in over 40 cities spanning the Northern, Southern, Eastern, and Western Hemispheres.[140] Some examples can even be found dating back to the 1970s, although in limited operations.[141] In these settings, certain human error causes are either irrelevant or non-locomotive issues. For instance, on a fully autonomous track, there would be no need to install or remove a derail, and if it is needed for maintenance or other reason, it would be ground-based crew locking or unlocking it. This example also applies to the human-only solutions in the United States context, because many tasks are fulfilled outside of the locomotive.

These examples not only serve as demonstrations that safe rail operation can be done with no locomotive personnel – undermining the argument that *two* are essential – but they also demonstrate the safety technology waiting in the wings to be tested, refined, and deployed with adequate levels of investment.[142,143]

With human error leading all root cause groupings for rail incidents in the United States, continued investment and development of technology is the subject of considerable research.[144] This is also why research anticipates both improved **efficiency and safety** as the world evolves to adopt more automated train technology.[145,146] In conjunction with the Internet of Things, automated vehicles including trains "will efficiently address rising demand, safety concerns, increased costs, environmental concerns, human errors, and traffic congestion."[147] Specifically related to the impact that human errors can have, "autonomous trains have less chances of rail fatalities, owing to deployment of upgraded technologies," which is all part of why the market growth is projected to surpass $15 billion within four years.[148]

As this technology proliferates, it is incumbent on rail companies to test and integrate it as data and safety goals indicate. Perhaps more important is for regulator to remove rigidity that precludes such testing and deployment. Further, as the GoA scales increases, regulation must keep pace. When the new baseline in the rail industry is higher than GoA1, crew size rules will do more harm than good by discouraging investment and constraining modal competition.

Autonomous Trucks in the U.S.

Trucks are the most proximate comparison to rail, as they are direct competitors and engage in the same business sector. When comparing the two, basic difference set them apart from the outset, including that railroads operate on their own private track while trucks utilize public roadways. This is significant, because it means rail has limited exposure to third-party risks and often does not interact with the public at all, while trucks operate among the public, in highly dynamic settings often impacted by weather, season, lighting, traffic, and the errors or actions of other drivers more so than rail.

These factors and the total number of trucks on the road explain why fatalities associated with trucks are an order of magnitude higher than rail, according to the Bureau of Transportation Statistics.

Fatalities in Freight Movement

			2000	2010	2015	2018	2019
Freight	All	Total	6,079	4,290	4,665	5,578	5,653
	Highway	Total	5,282	3,686	4,095	5,006	5,005
		Large-truck occupants[1]	754	530	665	890	892
		Others killed in crashes involvin..	4,528	3,156	3,430	4,116	4,113
	Railroad	Total	717	520	500	540	597
		Highway-rail grade crossing[2]	353	187	155	178	177
		Train accidents	8	4	1	4	0
		Trespassers	328	310	300	342	399
		Other incidents	28	19	44	16	21

When normalizing the safety record of trains and trucks, rail results in far fewer accidents per million miles traveled.[149,150] In fact, rail's impact on workers, the public, and the environment all demonstrate favorability relative to trucks. It is noteworthy, then, that the U.S. Department of Transportation is allowing the pilot programming of fully autonomous trucks.[151] These are expected to take over a significant portion of long haul trucking within as little time as the next decade.[152] There have, indeed, already been thousands of miles driven on public roads in the United States testing this technology in trucks.

While the safety data on automated trucks is not robust or available, it is the principle that deserves analysis. If trucks, which are already more deadly and accident prone than rail, and which operate in open and dynamic public settings are beginning to test the removal of the sole operator, why would the same Department of Transportation mandate multiple operators for the far safer and more technologically-integrated rail network? As we analyze in the following section, the NPRM may artificially impose market disruption upon modal competition, which will likely also result in safety *losses* on the highway and railroads.

Rail and Other Industries

With rules calibrated to enhance safety to protect employees, the public, and the environment, it is important to evaluate the rail industry in comparison to other industries. No death or injury is desirable, and all industries should strive for zero casualties, but it is nevertheless true that accidents and casualties do happen, and some baseline number or rate is accepted. Rail routinely falls below the baseline for other industries. For instance, compared with mining, construction, manufacturing, trucking, grocery stores, and agriculture, railroads have the lowest employee injury per 200,000 employee-hours.[153] Strictly within the transportation sector, railroads have lower injury rates per 100 full-time employees than barges, trucking, or airlines, and lower employee fatality than water transport and trucking.[154] The type and severity of injuries roughly correlates with others in the transportation sector and broader industry.[155]

Rail also consumes far less energy than other transportation modes, per the Bureau of Transportation Statistics.[156,157] This speaks to overall efficiency, as well as environmental impact. It also applies to fuel consumption, where the rail sector consumed only seven percent of the total fuel consumed by trucks in 2019.

	Energy Consumption (trillions of Btu)				
	2009	2010	2015	2018	2019
Truck	5,329	5,416	5,261	5,582	5,490
Class I Rail	439	480	507	502	470
Water	1,086	1,185	1,083	958	864
Pipeline (natural gas only)	695	699	703	909	979

Existing rail operations are more favorable than comparable industries and modal competitors in key metrics, but also relative to itself in previous years. That is because rail is demonstrating efficiency and safety gains for its employees, the public, and the environment on clear trends. A new mandate on personnel is not warranted by data within the rail sector, nor from data outside of it.

Improper Comparison

A final comparison deals with a prevalent false analogy presented frequently in this discussion. It is often phrased as: “Even with all the safety-related technology that the government has mandated on commercial airlines, the public would never accept an airline operation with a single person in the cockpit. There is no reason that rail employees and rail passengers’ lives should be viewed any differently.”[158,159]

While it may be the case that multi-person crews are desirable for rail, it does not make rail and airlines suitable for comparison. At best, their similarities are superficial, while their differences are categorical. Both are modes of transport for goods, cargo, and people; both predominantly have two person crews in the operational cab of the vessel; and both have a logistics support infrastructure like air traffic controllers or dispatchers. But the key similarities end there.

Airplanes operate in the open sky, unbound by and untethered to anything and not limited to any route. By sharp contrast, trains are literally bound to set tracks from which they cannot deviate. Without diminishing the legitimate complexities that exist within the rail sector, the reality is that trains can only move forward or backward. At most, they can utilize sidings or rail yards, but can only arrive there by following permanent infrastructure paths. Practically, this means pilots are responsible for not only maintaining a lateral course, but a vertical course, and diagonal courses, all while maintaining control in the open atmosphere, to find a way from point A to point B through the sky. A rail engineer applies the accelerator and brakes, responds to signs and signals, and makes calculations about speed, momentum, curvatures, and distances all on a single-axis lateral track.

The safety related technology in an airplane can maintain altitude, speed, or control for periods of time while the airplane is airborne but is only intended to moderate and simplify pilots' tasks. Even while the introduction of autopilot led to a 90 percent reduction in human error accidents,[160] to date, technology does not take off and land commercial airplanes on its own,[161] and if the pilots are incapacitated, the airplane could immediately crash threatening the lives of all on board and almost certainly explode on impact. Technology on a train, and PTC in particular, can safely bring a moving train to a complete stop. An airplane does not have an option to stop. PTC can also prevent trains from entering work zone or over speeding, but no technology guards against dangerous airspace or obstacles. Moreover, a train accident does not virtually guarantee an explosion like an airplane crash likely would (unless its fuel is dumped).

The analogy also breaks down because pilot and co-pilot fulfill the same role, each operationally trained and certified for the full range of duties and capable of controlling the airplane from their seat in the cockpit, sharing and dividing tasks. By contrast, engineers and conductors have different roles, with the engineer as the operationally certified individual and conductor in a logistical support role. This is further underscored by only one set of controls at the engineer's seat, unlike two pilots seated with controls before them. The argument is also undermined by serious discussions about the future in which there may be single pilots.[162,163] This is consistent with the long-term view of rail – not that all rail can or should reduce to a single operator, but that the regulatory structure should allow for it to as technology and practices evolve.

Finally, risk to the lives of passengers has no place in the analogy, given that certain passenger rail already employs single-person crews across the country and freight rail does not carry passengers. Moreover, there are currently operating transit and commuter trains with zero operators across over 40 cities worldwide.[164] Unlike commercial airlines, which have two pilots and a flight crew and carry hundreds of souls on board, a freight train is entrusted with raw materials, commodities, and other cargo. The analogy simply does not hold. And for reasons explained above, analogies to trucks only weaken the argument for a crew size mandate in rail. Rather than argue through analogy, the debate should be centered on rail data.

As a final point of data, rail actually enjoys an advantage over airlines when it comes to worker casualties. Air has a marginal edge over rail in fatalities per 100,000 full-time employees, but rail performs more than twice as well as air transportation in injuries per 200,000 employee hours.[165] More significant safety benefits are demonstrated in worker injury and fatality relative to trucking. Because those modes of transport are closer in function, they provide another opportunity to evaluate the issue of rail safety and the proposed crew size rule through the lens of economics. None of this should be construed to say conductors are not valuable, only that the comparison to airlines is improper. In fact, multiple conductors and engineers may be more than just valuable,[166] but needed. But that's a decision up to collective bargaining and determined based on individual railroad needs, safety records, efficiency, and economics.

Economic Analysis

Economics and safety are intimately related. Not only is there a positive relationship between technology and safety, but between productivity and safety.[167] Thus, negative impacts to efficiency may also reduce safety. This is underscored by research findings that "economic deregulation of railroads is associated with large improvements in safety."[168]

Economically speaking, safety and productivity can be explained formulaically, whereby given a level of available technology, a firm effectively chooses a level of output, (expected) accidents, and other variables. Because safety and productivity are intimately related, the calculation before companies is not as binary as choosing between profit and accidents.[169] However, viewing the variables as prices can help regulators pinpoint the best variable to address and helps companies make economically efficient adjustments. Rather than impose costs on railroads to comply with safety regulation – ultimately increasing the *price* of operation – it is more efficient to make accidents more costly. That is, by causing railroads to internalize higher costs when accidents occur, railroad companies will reallocate resources to best reduce accidents, improve productivity, and achieve better safety.[170,171] This ultimately must still recognize the safety-productivity relationship and priority rail companies already place on achieving both. Regulation that causes companies to change their priority may actually reduce both productivity and safety.

The safety gains discussed in this paper have been made possible because of a confluence of factors including research and development, testing and deployment of new technology, skilled employees, institutional knowledge, and a lowered cost of information. As technology improves and creates an opportunity to collect and analyze data, the improved access to and volume of information reduces its cost, which allows for more economically efficient investments in both productivity and safety. The natural correlation between productivity and safety underscores the importance of efficient investments – if a train moves efficiently to its destination and arrives without incident, it is both productive and safe; if the same train derails or collides with another, it is not safe or productive. Railroads have an interest in both productivity and safety because their business model depends on *not* having incidents.[172] This is how railroads have maintained declining accident rates even with the introduction of Precision Scheduled Railroading.

Research focused on understanding the impact of economic and safety regulation also reveals a counterintuitive reality. The Staggers Act of 1980 substantially deregulated the rail industry from economic regulation, while safety regulation from the FRA more than quadrupled since 1975. Yet across a 35-year timeframe, it was the economic deregulation associated with the Staggers

Act that explained approximately 89 percent of the decline in accident rates.[173] This led the study authors to conclude, "it is clear that economic deregulation improved safety more effectively than actual safety regulations by restoring market incentives for firms to pursue safety measures and innovations instead of focusing on complying with regulatory mandates."[174] Robust and independent historical economic evaluation similarly concludes that stifling economic regulation rather than inadequate safety regulation caused an uptick in rail accidents in the mid twentieth century, and only through deregulation and increased investment did that trend reverse.[175]

When economic costs are imposed that disrupt efficient investments in research or development, in training, in technology deployment, and others, there is a consequence to safety. This is true not only within the rail sector, but as a ripple out from it. The net effect may be less safe rail and less safety across transportation methods, as trucks and other vehicles absorb marginal shipments.

Making Investments

Much has been said about the reason for a rail staffing regulation. From the position of labor, a primary argument is that rail companies are seeking to maximize profits by cutting costs, which means reducing crews to one and eventually operating fully autonomous trains. Labor and regulators contend this will diminish safety. From the position of rail companies, a primary argument is to preserve the status quo – that is, crew consists set through collective bargaining – which currently allows one or two-member crews, and which predominantly already features two-man crews. The rail companies further believe retaining the status quo will afford them flexibility and competitiveness into the future as modal competitors like trucks begin testing more automation.

As it pertains to crew sizes, technology, and safety, the motivation or argumentation from labor or rail are secondary. The matter of first importance is safety data. Even if rail companies were maximizing profit and compensating executives exorbitantly, it would only affect this analysis to the extent it impacts safety, incident rates, and incident severity as measured against railroad employees, the public, and the environment.

A basic rule of microeconomics is that all firms maximize profit and must do so to sustain and grow their business. Profit is any surplus revenue after paying expenses, which must exist to expand (i.e., add more expenses like research and development, capital, technology, labor, or trainings). Despite many voices adamantly labeling profit as greed or a threat to supply chains,[176] it is that very profit that enabled billions of dollars in investment to develop and deploy positive train control technology throughout tens of thousands of miles of infrastructure and technology components. To date, the available data indicates that safety has been maintained or improved even while labor has been reduced, efficiency improved, and profits increased.

That trend is predicted to continue, but with certain assumptions and conditions currently present. If those change – namely labor strikes, voluntary departures, or customer/investor dissatisfaction[177,178] – the safety trend is not guaranteed. Accordingly, this analysis highlights the safety improvements made in recent years and investments in technology, while cautioning railroad companies to "go slow"[179] in order to maintain the quality and skilled workforce and underlying components of the economic model that have achieved productivity and safety gains.

In fact, even as technology arises to the point that certain roles are redundant, there should be a transition period where technology and full crew staffing exist to work out remaining glitches and bugs in the technology. Regulators similarly should go slow, not taking steps that would disrupt investment in technology or adversely impact productivity, such as allowing pilot programs on single-person crews rather than asserting a mandate to make staffing more rigid than it is today.

The introduction of technology not only helps save lives directly, but indirectly. Technology is one of the primary ways the cost of information is reduced. While the cost of information was once very high (e.g., an engineer may have had to leave the train and diagnose a mechanical problem, then relay that information in person) today, certain tasks can be completed instantaneously saving time, money, and improving safety (e.g., a computer system flags a mechanical problem and the engineer radios a superior, or the computer informs them directly). Everything from signals to flags represented lower information costs because it helped level asymmetries of information that railroaders had encountering different situations. Today, the cost of information is far lower because the processes are simplified, computerized, or relayed through phones, radio, and internet instantaneously. All of this required profit to make investment, and they require strong productivity to maintain.

Beyond these, the data collection made possible by technology will reduce information costs and improve safety even further by creating a roadmap for understanding key major causes, contributing factors, and where investment can be most efficiently made to reduce or prevent them altogether.[180] At its core, economics is about tradeoffs. Investments made in labor are investments not made in technology, and certain plans pursued leave others unpursued. The way opportunity cost affects a crew size rule – in the absence of any data supporting its safety rationale – may be surprising, because they are virtually all negative.

Likely Consequences Regardless of Safety Impact

There may remain a natural impulse to err on the side of higher personnel requirements. It may seem rational that two is safer than one, and with data being inconclusive, one may think *there is no harm in requiring two crew members because at best it advances safety outcomes and at worst it has no effect*. In other words: *it can't hurt*.

But there are multiple reasons that this is flawed thinking. In fact, there are at least three reasons that erring on the side of higher personnel levels <u>is in fact erring</u> in a way that could actually decrease safety outcomes.

First, the requirement to maintain crew sizes has a cost. That cost is in regulatory compliance, logistics, personnel, benefits, training, and administrative overhead. Applying the opportunity cost theory of economics, these dollars are prevented from going to their next highest use, such as technology, safety investment, or research. In other words, this locks costs in place that diminish the investment and roll out of safety technology that can and do decrease incidents. Effectively, erring on the side of added personnel requires railroads to allocate more resources to a solution based on a hunch while diverting resources from solutions with a long and proven track record of reducing incidents and improving safety.

Private investment is responsible for rail receiving the highest rating of any infrastructure component in the American Society of Civil Engineers report card.[181] The high score is partially attributed to resilience and innovation, where ASCE states,

> Rail technology development continues to focus on improving system **efficiency and safety**. Industry technological advances include identifying freight car, locomotive, cargo, and track problems before accidents, damage, or delays occur. Numerous track and infrastructure improvements have been advanced including the use of defect detection vehicles, which detect internal flaws in rails; improved metallurgy and fastening systems, which have enhanced track stability; and research to extend rail life, reduce maintenance costs, and improve safety.[182] (*Emphasis added*)

Technologies like PTC and automated track inspection equipment represent significant investment by rail companies that have a demonstrable effect on improving safety. PTC is able to correct for human error in many situations, while track sensors can detect issues that are imperceptible to the human eye even after close inspection by rail personnel. Disrupting the ability of rail carriers to invest in these technologies will result in more accidents, casualties, and costs, not fewer. This is not only true in the short term, but there is no apparent sunset of this rule, and when modal competition changes, rail will be subject to artificially higher costs. Available exemptions do not resolve this point, but highlight the further added costs (e.g., conducting costly safety analyses) needed to apply for exemptions that are not at all guaranteed. If single-crew legacy operations are exempted outright, rather than being subject to the rule with exceptions they must apply for, then there will be far lower costs imposed by this rule.

Second, the added costs will be worked into shipping costs, which will shift the marginal freight load to other modes of transit, a concept known as diversion.[183] Added costs to rail mean these diversions primarily result in more trucks on the road. Already, the U.S. is seeing an increase in road fatalities, with a 13 percent annual increase in deaths resulting from accidents involving large trucks.[184] Moreover, higher traffic on the roads increases wear and tear,[185] which has secondary safety issues leading to traffic accidents.[186] The effect of higher rail costs is higher net deaths on the road from higher road traffic as vehicles interact with more large trailer trucks. Those in turn add more wear and tear on the roads, which are correlated to additional accidents and injuries.[187] It likely also means more trucks moving over passive crossings around the country, which could result in more rail incidents of this type.

Beyond the net safety loss resulting from shifting the marginal freight load from rail to truck, there are measurable environmental harms. Rail is by far more fuel efficient than trucks, capable of moving a ton of freight approximately 480 miles on a single gallon of diesel, while trucks may move this volume around 140 miles. The associated carbon dioxide emissions from burning a gallon of diesel demonstrate that environmentally, rail is the preferred mode of transport. For instance, moving 100 rail cars of grain from Topeka, Kansas to Washington, D.C. by rail would prevent 427 trucks from taking to the road and spare over 546 tons of CO_2 emissions.[188] The introduction of more battery-electric locomotives will only expand this emissions disparity.[189]

Higher traffic volumes on public roads, increased wear and tear, and more large vehicles all add to safety risks and environmental consequences.[190] Even potholes that result from wear and tear lead to safety risks,[191] vehicle repair costs, and traffic delays that result in more idling and higher vehicle emissions from all vehicles in the area. With data showing that even a one percent increase in truck volumes resulting "in a disproportionately higher increase in severe crash probability,"[192] it is clear that there are real, measurable, and negative impacts to raising costs in the rail industry that ripple across the supply chain.

Third, because available data shows that crew sizes do not make a difference in safety, it is reasonable to conclude that certain accidents would happen regardless of the number of personnel in the cab. A crew-size mandate would simply lock in place a greater number of potential victims for such unavoidable tragedies. If the worst came to pass, rather than one operator in the train as disaster occurs, a mandate would double the potential casualties.[193] An alternative like ground-based or roving conductors could help prevent accidents in the first place, limit inevitable accident casualties, and allow for better response mitigation with quick reaction. It may also help improve scheduling regularity and predictability, which may limit fatigue concerns for both conductors and engineers, and help rail retain workers.

In each of these three considerations, railroad employees, the public, and the environment are more likely to see negative impacts from a crew size regulation. Given the costs associated with regulatory compliance, staffing, and operation, these net negative effects are likely to accrue regardless of any safety benefit that may result. The FRA has stated that its rule is intended "to enhance safety" but focuses narrowly on railroads themselves. Without recognizing the negative externalities this regulatory action will create outside of the rail network, the agency is likely to fail to bring about this outcome within rail (given the lack of data demonstrating it would improve rail safety) *and* cause other harms in the short term and into the future.

A Note on Reading Comments

The FRA has received over 12,000 comments as of publication of this report.[194] The overwhelming majority of the comments state that commentors believe single-person crews are unsafe or that two-person crews are needed. While this sounds like it is relevant to the regulation, it is not. These sincere and valuable anecdotes, observations, and arguments support commentors' belief that *at the present moment* two people should be in the train, ***not*** that the federal government should mandate and preempt state rules to assert as such. This says nothing about whether collective bargaining should continue, or if a mandate should be superimposed, nor does it shed any light on the safety or risk of single-person crews with new, developing, or future technology. The status quo already affords two-person crews, and the above referenced comments are compelling arguments that unions should employ during collective bargaining for specific rail carries in specific contexts. A blanket rule that would treat a regional freight line the same as a Class I, single commodity trains the same as mixed or hazardous material loads, and shorter and longer trains all the same is economically inefficient, unsupported by safety or incident data, and legally dubious with regard to obligations under the APA. The FRA should not fall into the logical trap that reading a comment in support of two-person crews is the same as a comment in support of this NPRM; this would be confirmation bias.

The FRA should instead evaluate the comments and insights alongside the countervailing points and data presented to determine whether a federal mandate is necessary and fully justified in available data. We have not found that to be the case.

Recommendations

- FRA should withdraw this NPRM and allow collective bargaining to continue setting crew sizes. Without supporting data – and with available data undermining certain safety theories – this rule appears arbitrary. The purported benefits are unlikely to result, and unintended consequences may leave rail, the public, and the environment in a net negative position. Collective bargaining, rather than a crew size rule with proposed exceptions based on appeal, best allow the railroads and unions to adjust to new technology. A mandate chills the ability of railroads to invest in and incorporate technology and eventually to reduce crew size compatible with safety and efficiency needs.

- FRA should consider sponsoring a crew size pilot program, setting specific parameters and collecting data to determine measurable safety metrics from railroads operating with single and two-person crews for a set period of time. This could include allowing single-person crews with redeployed ground-based conductors on PTC-governed track. Only after FRA has data on single-person crews should the agency revisit proposing a rule.

- It is unclear if or how the exemptions will work in practice. While no crew size rule is justified by the data, if it becomes a final rule, all exemptions should be a "***shall issue***" rather than a "***may issue***" exemptions. In other words, FRA should clearly set out objective and published criteria that, if met, guarantees railroads an exemption, rather than leaving up to the discretion of the agency. Complete discretion leads to concerns that the application of the rule will be arbitrary and capricious, and that uncertainty inflates costs.[195]

    - Presently, the rule's risk assessment paradigm does not make clear that there are **objective** standards for exemptions. The burden of proof is entirely on rail companies to prove that they are safe (rather than any burden on FRA to show a concern). Effectively, the FRA deems all freight rail operations without two in-cab crew as unsafe and creates a "prove otherwise" standard.[196] The process of conducting risk analyses and requesting exemption leaves broad and unaccountable discretion to FRA to grant exemptions. Under this proposal, it is possible that two rail companies could submit similar safety data and risk analyses and yet one receives an exemption while the other does not. Without objective criteria, there is significant concern that the rule provides vague requirements, and its enforcement and function will be arbitrary and capricious.
    - By mandating the crew size rule on all freight railroads, including legacy freight with single-person crews, it imposes significant costs on the entire rail industry. This will result in significant paperwork, costs to conduct safety reviews, application time and logistics, regulatory compliance, staffing, legal fees, and all with no guarantee of achieving an exemption. For legacy operators who fail to meet the standard, they will ultimately have the added cost of additional personnel without an associated safety benefit. Even the exemption process appears to be a substantial cost not contemplated in the agency's cost benefit analysis.

- Moreover, the rule sets forth a *might makes right* standard that will allow a heckler's veto by opening rail company applications for exemption to notice and comment, where a carrier may be denied because enough public voices argue against it and in spite of whether data supports the exemption or not. There is recent precedent for this concern, as certain carriers were denied a pilot extension for automatic track inspection based on a single comment in opposition.[197] Given that example and the number and ratio of pro-crew size mandate comments in submitted in 2016 (approximately 1,545 out of 1,584), unless FRA determines and publishes a metric that it will weigh safety data more than anecdotal input, this all but guarantees no freight rail currently employing two-member crews will receive an exemption to reduce the number.

o FRA should consider ways to further the trend in accident reduction, improve safety, and incorporate technology to make rail more competitive and help improve net safety across all transportation and decarbonize the transportation sector (by shifting modal preference from truck to rail). Waivers and pilot programs for automated inspection technology, more PTC and related control technology, and others should be pursued.

o FRA should consider setting requirements not for in-cab crew, but for safety-oriented objectives. Such performance regulation (in contrast to prescriptive regulation) helps encourage innovation while achieving the aimed objective – and can even feature stringent penalties for failing to achieve the performance metrics.

o FRA should consider alternative regulations like rules for ground-based conductors within certain limited geographic regions to ensure capacity and ability to respond to any engineers and rail yards in need of support and immediate response to accident scenes. This can also include scheduling or hours on call to limit fatigue and improve predictability.

o FRA should consider penalties for remaining issues (e.g., if failed inspection caused a derailment, FRA issues fine to offending railroad). This would enable rail carriers to set economically efficient solutions and incentivize them to perform better inspections. This would also set a higher price for *accidents* rather than operation.

o The Federal Aviation Administration (FAA) should consider allowing railroads to use drones for more applications, including beyond line of sight. This may allow locomotive operators to deploy drones on longer trains and minimize fatigue as well as improve inspections. FRA and FAA should work together to promote pilot programs and waivers.

Conclusion

The rail industry in the United States has seen significant improvements in safety and reduction in accidents across passenger and freight rail for decades. The continued decline in accidents also features a decline in the number of accidents caused by human error. Even for the most critical accidents that lead to the greatest impact to railroad workers, the public, and the environment, human error caused accidents remain on falling trends. With these trends clearly demonstrated in available data and the increase in deployment of technology, the future of rail is likely to see further reductions in the total number of accidents and those attributed to human error.

Analysis of available data leads to the conclusion that human error can be resolved through one or more of technology-only solutions, technology assist solutions, or human-only solutions. Across all accident types, roughly half of human errors are addressable through existing and available technology, while half require personnel to address. Within the human-only solutions, however, are tasks and roles that span the entire rail network, such as locomotive roles, ground-based roles, inspections, and support.

The Federal Railroad Administration proposed a new rule that would mandate all freight rail operations in the U.S. to have two crew members in the controlling cab of a locomotive. This is based on an assertion that single-person crews are inherently unsafe and that two people are required to effectively counteract human error. This is also in spite of human error comprising approximately 35 percent of human errors with two-member crews being the norm for decades.

As it pertains to safety, the question must be whether the number of personnel contextualized against varying levels of technology have a discernable impact on incident rates. The answer is that within the existing regulatory framework and level of technology integration on U.S. railroads, single and multi-member crews both operate safely. No clear correlation exists between higher personnel counts and lower accident numbers or less severe accidents. If any trend is present, it is that more technology – even when it displaces personnel and reduces crew sizes – leads to safer outcomes.

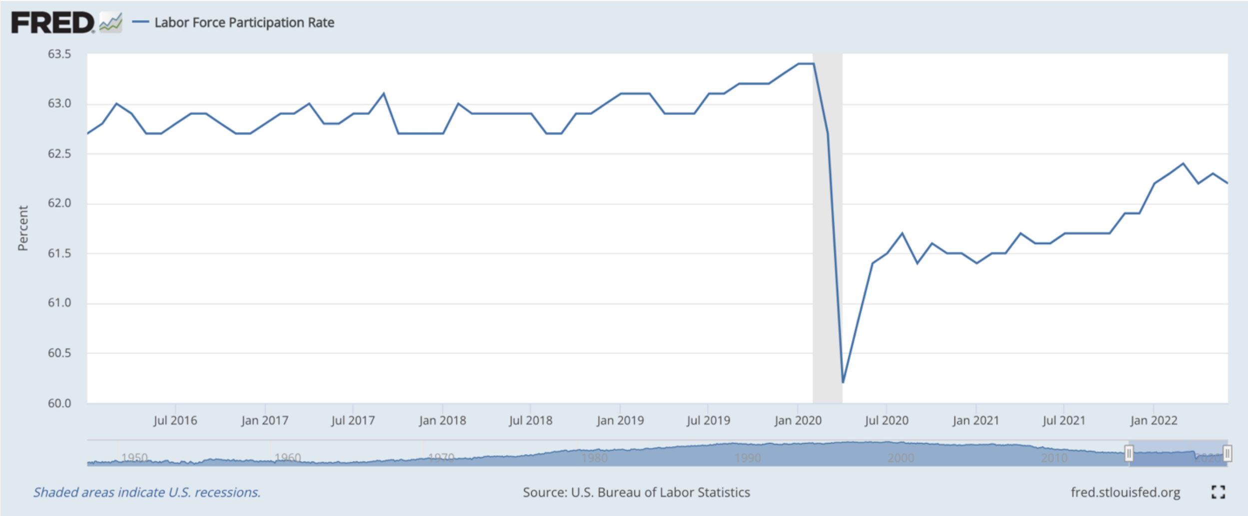
If the FRA intends to follow the data, it should take serious pause to evaluate the dearth of data underlying its theory of safety. The agency has looked at the issue for a decade and through at least three presidential administrations yet has been unable to establish a data-driven safety justification for such a proposal. We now recommend that the agency evaluate this data, **withdraw the proposed rule**, and consider a **crew-size pilot program** to settle the question in a controlled and robust data collection exercise. The agency should simultaneously seek to improve the implementation of innovative technology already known and proven to counteract human error and work with railroads to identify gaps rather than prescribe unproven safety rules.

Aii does not advocate for complete industry self-regulation – the federal government has the core responsibility to ensure the movement of products and persons across state lines is done safely and in the best interest of the public. However, good governance also requires being open to new ideas from industry experts about how to best achieve public safety and ensuring that new and existing regulations do not “unnecessarily stifle innovations that may be possible in the future.”

Our conclusion is not to recommend single-person crews. The analysis conducted above does demonstrate that single-person crews can safely operate freight trains alongside sufficient levels of technology. However, our analysis also heavily relies upon the existing status quo of two operators settled upon by collective bargaining *and* improved technology in explaining and projecting future safety trends. Ultimately, data demonstrates both that the FRA should not mandate train crew sizes and that rail companies should not quickly move to reduce crew sizes.

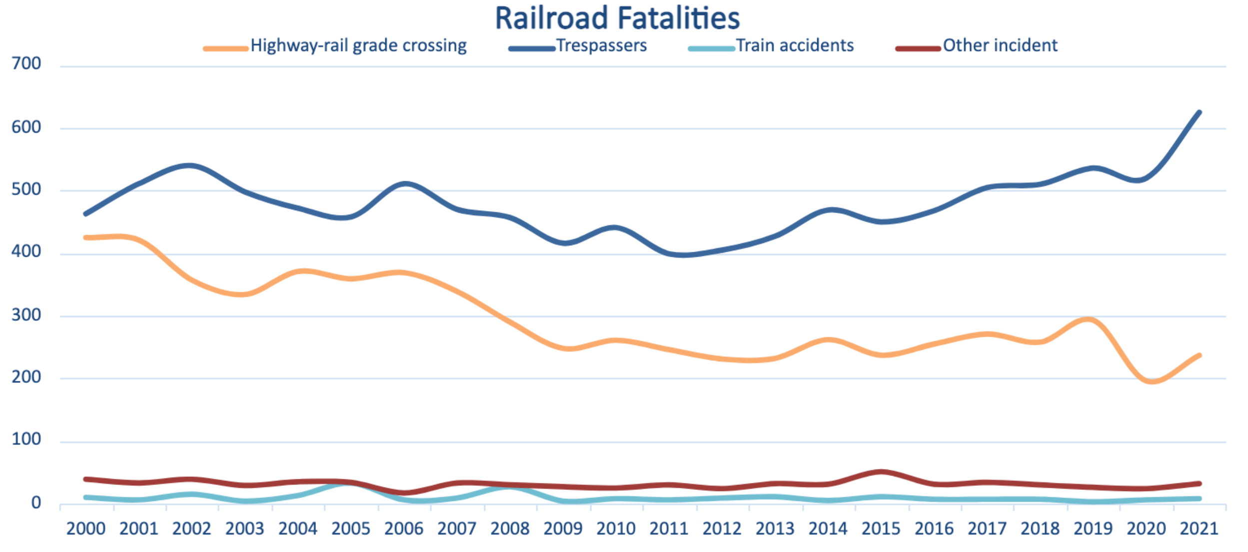
Appendices

Appendix A.



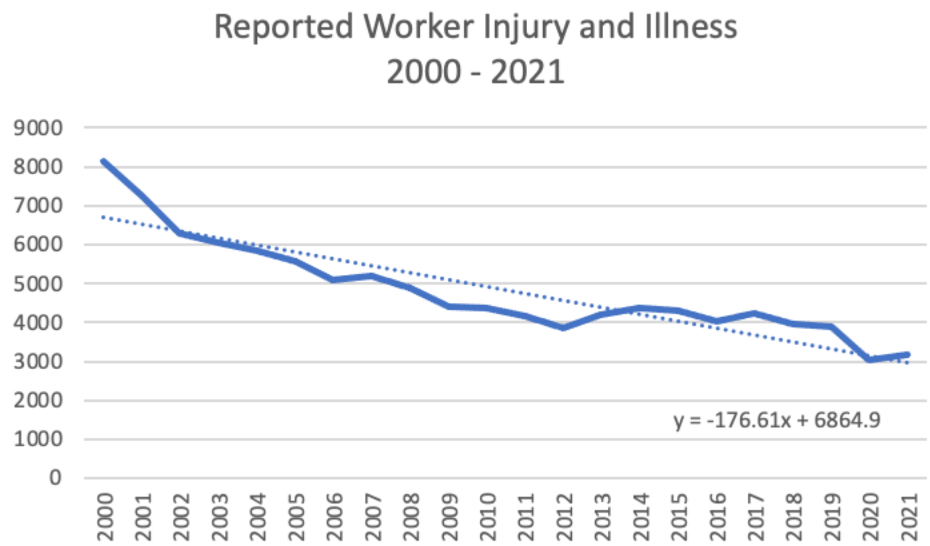
Labor Force Participation Rate[198]

Appendix B.[199]



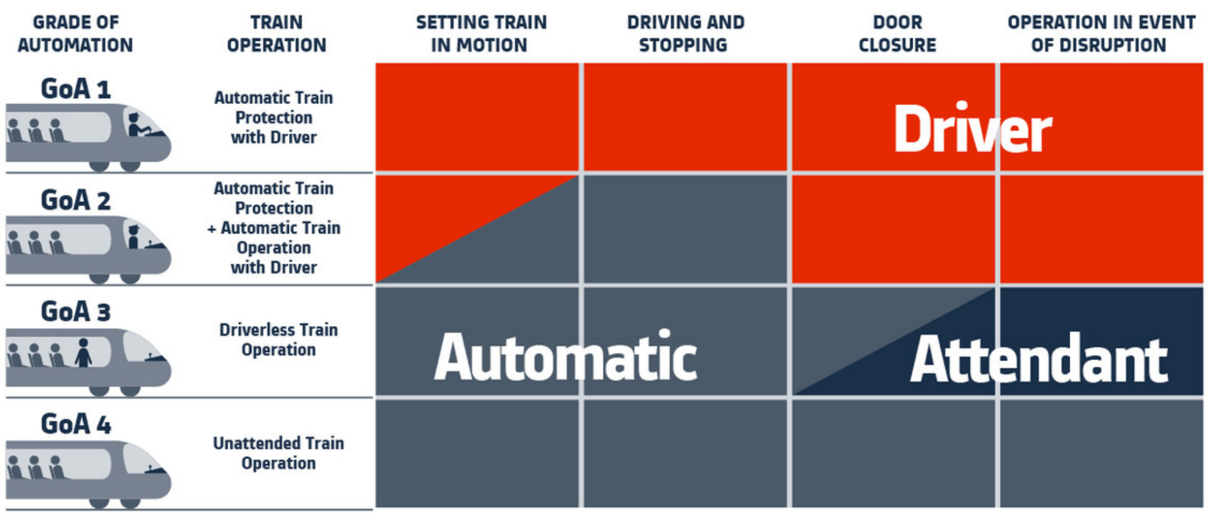
Tresspassers are consistently the leading cause of railroad fatalities, highlighting the need for safety measures and awareness.

Appendix C.



FRA Form F6180.55a, filtered for workers, volunteers, and contractors whether on or off duty, omitting trespassers and passengers

Appendix D.[200]



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[3] Data from 1828 to 2021, demonstrates accidents and casualty trends fall with the advent of technology. This correlation generally holds even with crew sizes decreasing, passengers and freight increasing, and mileage increasing, depending on the type and level of technology adopted. Notably, new technology often protects railroad employees first and foremost by removing them from risky situations or improving their control over equipment.
[4] Individuals can be certified for both roles.
[5] 5 U.S. Code § 556 (d): "Except as otherwise provided by statute, the proponent of a rule or order has the burden of proof."
[6] To the extent that this component of the analysis is perceived as biased, the only bias intended is toward maintaining a predictable, data-based, and pro-innovation regulatory framework.
[7] 84 FR 24735.
[8] *See e.g.,* 5 U.S. Code § 706 (2)
[9] Referred hereafter simply as "Lac-Megantic" and "Casselton"
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[16] Information provided by Association of American Railroads. Data as of May 2022.
[17] Part of this decline is likely attributable to policies and conditions during COVID-19 as well as PTC and related technology.
[18] *Projection based on publicly available accidents reported to FRA through November 1, 2022. The projection accounts for the remaining months of the year.
[19] All dollar values are inflation adjusted to 2021 dollar values.
[20] **Supra* note 18.
[21] In this report, "status quo" always refers to crew size set through collective bargaining, which is almost universally two members. Therefore, even though a crew size rule would freeze the existing crew level in most cases, it is a departure from the status quo which sets that number through bargaining. Regulation would also impose compliance costs and create rigidity for future staffing changes in response to new technology, as discussed later.
[22] It is also not new and in fact an issue the industry has faced before. Consulting history is valuable here. (e.g., 1890-1939)
[23] Further, the public portal for reporting blocked crossings allows for redundant submissions and is susceptible to false or inaccurate information.
[24] Booth, M. (2022, April 7). *STB issues hearing notice for urgent issues in freight rail service*. Surface Transportation Board. Retrieved from https://www.stb.gov/news-communications/latest-news/pr-22-21/.
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[26] See Appendix A.
[27] For instance, 'Between 1920 and 1995, national rail employment dropped by 89 percent, although the proportion of white-collar and skilled jobs grew.' This very drastic drop in employment coincided with improvements in safety, incorporation of technology, and increases in movement of goods. *See*, Thale, C. (n.d.). *Railroad Workers*. The

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[30] For example, the PEB recommended that parties continue to negotiate the issue at the local level, while U.S. Senate Majority Leader Chuck Schumer stated days before a potential strike that Congress would not intervene, but rail companies and labor should resolve the negotiations on their own.

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[33] The Infrastructure Investment and Jobs Act included a provision that will require this update. Specifically, the law directs the Secretary that within one year, he must update "Special Study Block 49 on Form FRA F 6180.54 (Rail Equipment Accident/Incident Report) to collect, with respect to trains involved in accidents required to be reported to the Federal Railroad Administration…(2) the number of crew members who were aboard a controlling locomotive involved in an accident at the time of such accident."

[34] 87 FR 45564.

[35] Due to the cost of compliance, poorly defined appeal process, and comment period where a hecklers veto is likely. Analyzed further below.

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[80] The reporting requirements have changed over the years. In 2000, the threshold for reporting was track and equipment damage costs at $6,600 or more, while in 2022, the reporting threshold is $11,300. This analysis does not attempt to adjust for minor incidents that may have been reportable one year and not another. It simply presents available data from all reported incidents.
[81] See, 49 CFR 242.7. “Locomotive engineer” is defined as a “person,” so the human error “Operation of locomotive by uncertified/unqualified person” is definitionally not addressable by technology. The underlying operation of a locomotive, however, is addressable by technology, as evidenced by fully automated rail discussed in other sections.
[82] An analysis demonstrating whether human operators are *needed at all* (rather than which FRA human error codes require personnel) would recategorize many human error codes and assess what technology is available for general rail operation and what human roles remain. This is not that analysis and should not be viewed to mean technology cannot address up to 100 percent of human error.
[83] From the train accident database.
[84] The theory of accident mitigation is set aside.
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[106] *Supra* note 34.
[107] *Supra* note 7.
[108] Some of which are outside of FRA jurisdiction, such as certain city transit or airport transport rails.
[109] In addition to the primary mitigation recommendation of improved crashworthiness of rail cars – which accepts that some level of accidents will always occur.
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[112] "NTSB has a very broad mandate: Investigate causes and potential remedies," said former PHMSA administrator Brigham McCown. "But unlike all the other executive branch agencies, they're not constrained by cost-benefit analysis or any of the other regulatory restrictions that are typically placed on other executive branch agencies." Eric Weiss, an NTSB spokesperson agreed with McCown's interpretation of the NTSB's mission. "Our focus is on safety, on representing the American people when it comes to safety," Weiss said. Retrieved from:
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[115] Since 2000, the FRA has changed its minimum threshold for reporting 14 times. In 2000, the reporting threshold was $6,600 (approximately $10,385.62 in 2021 dollars). Today, the threshold is $11,300. See, https://railroads.dot.gov/forms-guides-publications/guides/monetary-threshold-notice.
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[120] That is, for the following analysis, the marginal addition of crew members is assessed not for the ability to prevent an accident, but to lessen the damage of an accident once it occurs. Accordingly, correlations between low or high crew sizes in this analysis say nothing about whether those roles or numbers have any effect on accident *prevention*.
[121] Random sampling shows that the share of costs and casualties are statistically similar to the proportion of total accidents. Therefore, we use share of accidents as our baseline from which to measure the impact of crew sizes on mitigation.
[122] As noted above, all dollar values are inflation-adjusted to 2021 dollars. Accordingly, the amount "reported" refers to self-reported nominal dollars subsequently adjusted for inflation.
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[126] *See* Appendix C.
[127] See Appendix B for visualization
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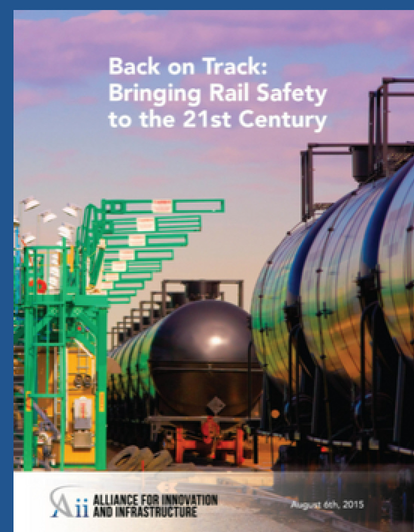

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