BEFORE THE FEDERAL RAILROAD ADMINISTRATION
Docket No. FRA-2021-0032

TRAIN CREW SIZE SAFETY REQUIREMENTS

COMMENTS OF THE ASSOCIATION OF AMERICAN RAILROADS

EXHIBIT 9

Mark Burton, *Rail-Truck Competition in an Era of Automation Technology* (December 2022)

Rail-Truck Competition in an Era of Automation Technology

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December 2022

On July 26, 2022, The Federal Railroad Administration (FRA) announced a Notice of Proposed Rule Making (NRPM) which would require two-person crews aboard nearly all Class I Railroad freight trains. [1] *Discussions surrounding the NRPM are rightfully focused on rail safety, Positive Train Control (PTC), and other technological and operational issues. However, this proposed rulemaking also has profound implications regarding the level and nature of freight competition between railroads ad North America's truckers, particularly in an era of increased vehicle automation. It is this latter matter that motivates the current analysis.*

INTRODUCTION

Hidden from the view of most, North American commerce has grown ripe for important new competition between freight railroads and motor carriers – competition that is likely to be broad in its dimensions and transformational in its effects.

At the core of this unfolding contest is a set of labor-saving automation technologies that promise marked improvements in worker productivity and corresponding reductions in freight transportation costs across nearly every mode. However, the course of the competition, the extent and distribution of its benefits, and its ultimate value to affected economies are, as yet, unknown. Instead, these outcomes will be determined by the pace of technological development, the capacity and inclination for private sector investment, and the formidable effects of public sector policies.

Within this context, the Federal Railroad Administration's (FRA's) proposed requirement for two-person freight train crews would stand as an impediment to robust freight competition and the attendant economic rewards that competition would yield. For well over a century, labor-saving technologies have been a key source of productivity gains within transportation. These advances have been achieved without any sacrifice in operational safety or the wellbeing of labor. To think that this progression in productivity through innovation is ended simply reflects

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[1] See, Federal Railroad Administration, Docket No. FRA-2021-0032, Notice No. 1.

a poverty of imagination. As the following text demonstrates, the proposed FRA rulemaking appears contrary to the public interest.

The remainder of the current report is organized as follows. Part One describes the relevant economics faced by motor carriers and freight railroads, the competition that exists between these modes, and the ongoing course toward further automation. Based on this foundation Part Two provides some very preliminary empirical estimates of the FRA's potential effects as a result of the proposed two-person train crew mandate. Final thoughts are provided in Part Three.

Part One – The Economic Setting

WHEN TRUCKS AND TRAINS COMPETE

Railroads and motor carriers serve a wide array of markets that have differing requirements determining the relative weighting of service and price in the decisions on modal choice by shippers. However, customer decisions on the relative importance of these factors will usually be decided in terms of the lowest total supply cost to the firm which does not have an adverse impact on its sales or revenue production capability.

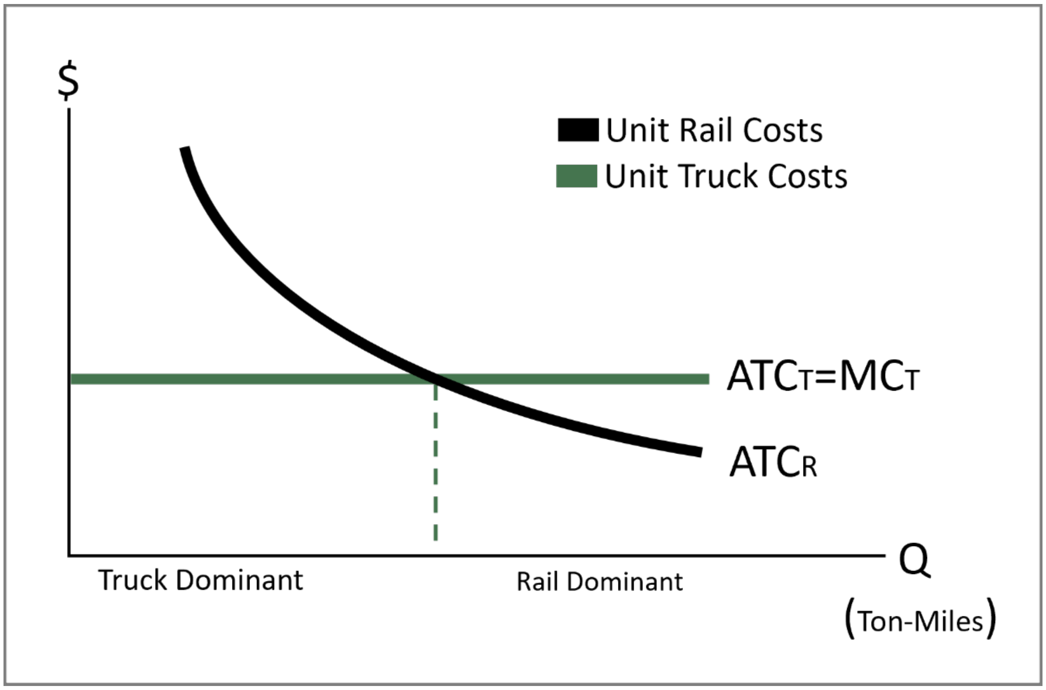
In choosing carriers and modes, or even origins and destinations, shippers match the supply-chain value of available transportation services with overall service costs. Because the cost of substituting one transportation alternative for another is relatively high, transportation practices, once established, are often insensitive to moderate, transient changes in freight rates.

Vehicle automation will significantly disrupt the fundamental cost relationships that underlie current railroad and motor carrier prices. The effects will be neither temporary nor modest. Instead, they will likely be significant and lasting changes that fundamentally restructure the market roles for each mode. Moreover, once new shipper choices, patterns, and practices are settled on, reversing these new equilibria will be difficult if not impossible.

The Basic Picture

Figure 1 depicts typical unit costs for motor carriers and freight railroads that serve the same freight market. This figure illustrates a fundamental difference in cost structures between modes. Railroads are financially responsible for both freight vehicles and the networks over which these vehicles operate, whereas motor carriers do not own highways and only contribute to offsetting highway costs in limited ways, such as when they purchase fuel for use on publicly owned roads. As a result, unit rail costs decline as outputs (typically measured in ton-miles) increase, while trucking costs are relatively constant in output volumes. The implications are straightforward. When shipment sizes or origin-destination distances are relatively small, motor carriage provides the least-cost alternative. However, when either shipment size or distances make overall quantity greater, rail becomes the preferred alternative within the subject market.

Figure 1 – Market Size and Mode



LABOR-SAVING GAINS ARE KEY TO FREIGHT PRODUCTIVITY

For both motor carriage and freight railroads, the costs of labor and fuel are the primary determinants of unit operating costs depicted in Figure 1.[2] Thus, many of the productivity gains realized in both sectors have been tied to the number of ton-miles of freight achievable per labor hour or per gallon of fuel consumed. In the case of trucking, cost reductions have largely been accomplished through larger vehicles and publicly funded improvements to the highway network. Freight railroads fully fund and, therefore, completely control *both* the networks over which they operate, as well as the vehicles operating over these networks. Thus, technological

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[2] According to survey data obtained by the American Transportation Research Institute (ATRI), driver wages and benefits account for roughly one-third of operating costs. The Association of American Railroads confirms a similar figure for Class I railroad operations.

improvements in freight railroading reflect self-funded improvements to both vehicles and infrastructure.

Railroad Technologies

Arguably, many of the rail-oriented technological improvements implemented in the latter 19th century and pre-World War II, 20th century (e.g., air brakes, automatic couplers, and more powerful locomotives) improved rail labor productivity. However, enhanced labor productivity has been at the very *center* of technological enhancements achieved in the decades since.

Immediately following World War II, the railroad industry undertook the full transition from steam locomotives to diesel. This conversion dramatically reduced labor use both in terms of locomotive maintenance and train operations. Diesel locomotives require far less routine maintenance and do not require an onboard fireman. The latter meant that, practically, the locomotive crew could be reduced from three to two.[3]

During the same era signaling along mainline routes was measurably improved, with many segments upgraded to Centralized Traffic Control (CTC). CTC provides train dispatchers with direct control over railroad switches and signals. This enhances network capacity through more seamless coordination and reduces the labor activities of onboard train crew members. Even where CTC was not placed, Automatic Block Signal (ABS) systems were routinely installed.

In the 1980's improved communications technologies allowed the elimination of cabooses from most freight trains and with this came a further reduction in total train crew size (from four crew members to three).[4] Moreover, the reduced need for online switching has now led to operations with two person crews in most cases.[5]

The closing decades of the 20th century also witnessed the introduction of Distributed Power (DP) within freight train consists. This technology involves placing one or more locomotives at varying locations within the train to provide additional motive power. The distributed locomotives are uncrewed, controlled instead via radio communications from the lead locomotive. This analogue of truck platooning offers at least four advantages. DP reduces

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[3] Dieselization made the fireman's position unnecessary. However, a combination of labor and legal impediments slowed the actual elimination of firemen from freight locomotives by nearly two decades.

[4] Communications improvements included the development of End-of-Train monitoring devices and enhancements to wayside defect detection equipment.

[5] Other productivity enhancing / labor saving technological advances include the use of system wide gangs for track maintenance and the use of distributed (locomotive) power in freight train consists.

drawbar forces and, thereby, facilitates longer trains. It also improves train handling, reduces fuel consumption, and improves braking response.[6]

Finally, within the current context, one of the most important technological improvements has been the development and privately funded implementation of Positive Train Control (PTC). PTC is an overlay on existing CTC systems that automatically maintains train separation. Ultimately, PTC will reduce the distances that separate trains and in doing so significantly increase the capacity of existing rail routes and increase average train speeds. As envisioned, these improvements can further reduce the need for onboard crew members, further lessen railroad operating costs, and allow rail carriers to compete vigorously for highway traffic.

Emerging Truck Technologies

Truck automation takes many forms that range from zero enhanced sensing or automated assistance to fully autonomous vehicles that require no driver responsibility whatsoever – driverless trucks (Figure 2). The technological spread between these extremes is divided into six increments with varying combinations of sensing and independent vehicle responses. Again, in the motor carrier arena, the next step in applying cost-altering automation technologies is the implementation of *truck platooning*. The American Trucking Association (ATA) defines platooning as –

> Truck platooning is similar to a truck convoy except that the platoon of trucks (2+) is connected electronically through direct short-range communications that brings the vehicles to within close following distance (approximately 30 feet). The platooning process requires the driver of truck two to steer the truck and uses sensors to collect data that controls a truck's braking system and speed. The technology makes use of a forward collision avoidance system and vehicle-to-vehicle communication to allow two trucks to travel close together.[7]

While nascent, the technology necessary to implement truck platooning is largely in place and on-road pilot platooning projects are underway. In its early form, platooning requires no modifications or additions to existing infrastructure, but it does generally require changes to state laws.[8]

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[6] See, Lustig, David (September 2010). "Freight Train, Unbounded: Distributed power: It's a bigger deal than you think". *Trains*. Kalmbach Publishing. p.70.

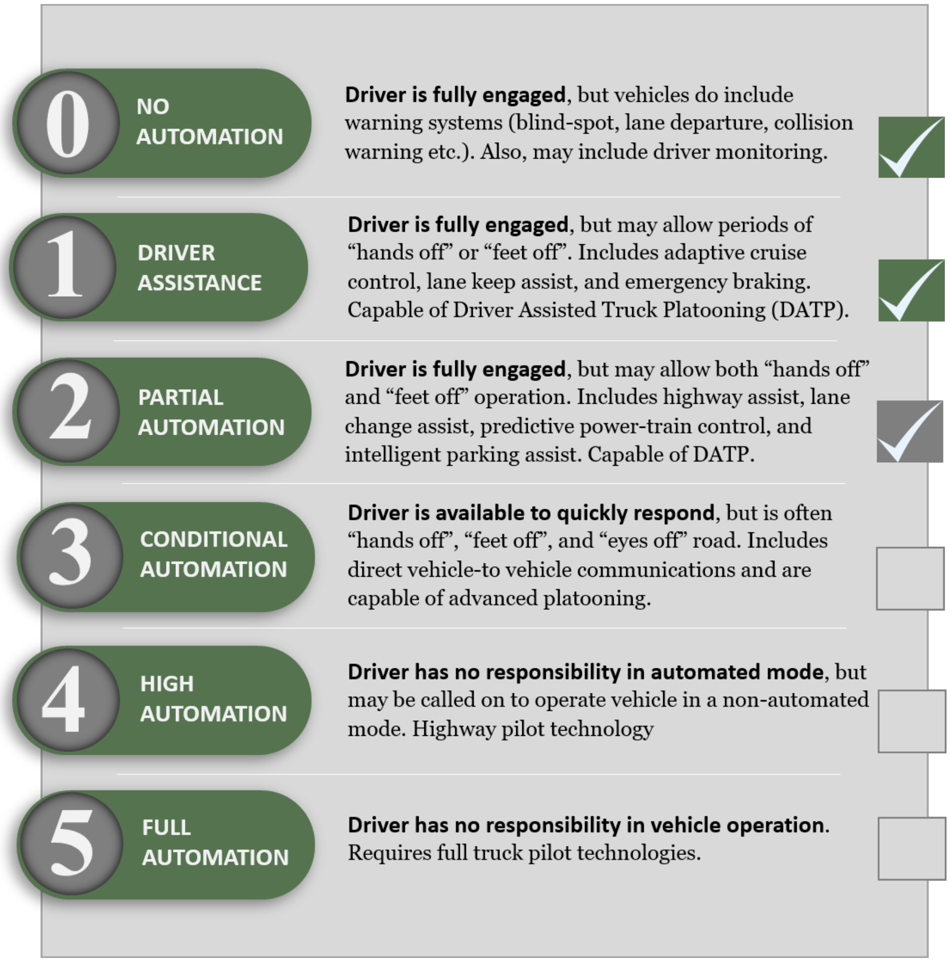
[7] See: http://www.trucking.org/article.aspx?uid=88d4ea4c-8c43-4073-bd2b-2242c79cc081

[8] While not necessary, truck platooning is often discussed in conjunction with truck-only highway lanes. For example, see: "Separation of Vehicles – CMV-Only Lanes," National Academy of Sciences, Transportation Research Board, NCHRP Report 649, NCFRP Report, March 2016.

As envisioned, truck platooning does not eliminate the need for a driver in each unit, nor does it currently affect applications of federal hours-of-service regulations for drivers. Consequently, initially, platooning will not affect motor carrier labor costs.

Platooning does, however, measurably reduce fuel consumption and related costs. While data are limited, equipment manufacturers suggest that fuel use for trailing units is reduced between 10 and 14 percent and fuel consumption for the lead truck is diminished by roughly four percent. Given that fuel represents as much as 40 percent of motor carrier per-mile costs, the application of platooning could reduce carrier costs by as much as six percent.[9] Advocates of platooning also suggest that the improved safety performance they predict will lower motor carrier insurance rates.

Figure 2 – Stages of Truck Automation



0	NO AUTOMATION	**Driver is fully engaged**, but vehicles do include warning systems (blind-spot, lane departure, collision warning etc.). Also, may include driver monitoring.	✓
1	DRIVER ASSISTANCE	**Driver is fully engaged**, but may allow periods of "hands off" or "feet off". Includes adaptive cruise control, lane keep assist, and emergency braking. Capable of Driver Assisted Truck Platooning (DATP).	✓
2	PARTIAL AUTOMATION	**Driver is fully engaged**, but may allow both "hands off" and "feet off" operation. Includes highway assist, lane change assist, predictive power-train control, and intelligent parking assist. Capable of DATP.	✓
3	CONDITIONAL AUTOMATION	**Driver is available to quickly respond**, but is often "hands off", "feet off", and "eyes off" road. Includes direct vehicle-to vehicle communications and are capable of advanced platooning.	☐
4	HIGH AUTOMATION	**Driver has no responsibility in automated mode**, but may be called on to operate vehicle in a non-automated mode. Highway pilot technology	☐
5	FULL AUTOMATION	**Driver has no responsibility in vehicle operation.** Requires full truck pilot technologies.	☐

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[9] Cost calculations are based loosely on information published by the American Transportation Research Institute (ATRI) see: "An Analysis of the Operational Cost of Trucking: 2016 Update," September 2016, http://atri-online.org/wp-content/uploads/2016/10/ATRI-Operational-Costs-of-Trucking-2016-09-2016.pdf

Automation Trucking Beyond Platooning

Motor carrier vehicle automation is comprised of elements that can be applied in various ways. Truck platooning is highlighted because its use is likely in the immediate future. However, higher degrees of automation are foreseeable, and the more advanced applications may make it possible to further reduce driver use and costs. Under such scenarios, the incentives for carriers to invest in automation technology become sufficient to offset the much higher capital costs.[10]

While there is no robust prediction of the timing, there are numerous estimates of the savings to be had through truck automation. Early estimates suggested that full automation over all but the "first" and "last" mile of truck service could reduce motor carrier costs by approximately 15 percent. However, two more recent studies – one authored by Swedish researchers and a second produced by engineering faculty at Georgia Tech – suggest an average cost reduction of 29 percent and a possible maximum savings of as much as 40 percent.[11] The remainder of the current analysis will focus on the mid-range figure of 29 percent.

EXTERNALITIES, INCREASED AUTOMATION AND TEMPORAL COMPLICATIIONS

Transportation practitioners are well familiar with the relationship between freight transportation and the imposition of external costs – costs which are incurred by individuals who are not participants in the transportation transaction. While freight transport affects the broader community in a variety of ways, the two most noted freight externalities are tied to the sector's effects on public safety and air quality. Thus, to the extent that the proposed FRA rulemaking affects the distribution of traffic between freight modes it has the potential to affect the magnitude of the external costs that are imposed on the communities where freight moves. Specifically, a diversion of traffic from rail to all-highway routings will increase the magnitude of external costs. These outcomes are, to a degree, considered in Part Two of this report.

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[10] For example, U.S. Xpress has recently conducted demonstrations using fully driverless trucks in the Atlanta-Dallas traffic lane, as well as more localized Texas markets. See, U.S. Xpress, "Mapping a route to the future of autonomous trucks," https://www.usxpress.com/2022/05/11/mapping-a-route-to-the-future-of-autonomous-trucks/ or Wilner, Frank, "Reason Together or Face the Sword," *Railway Age*, September 2022, p. 10.

[11] See, Albin Engholm, Anna Pernestal, and Ida Kristoffersson, "Cost Analysis of Driverless Truck Operations," *Transportation Research Record* 2020, Vol. 2674(9) 511–524 ! National Academy of Sciences: Transportation Research Board. Also see, Ryder System, Inc. and the Socially Aware Mobility Lab (Georgia Tech), "The Impact of Autonomous Trucking A Case-Study of Ryder's Dedicated Transportation Network." 2021.

What is not treated here or (or elsewhere) are the likely time paths and extents of additional automation in either rail or motor carriage. Ultimately, in the case of trucking, the goal is driverless trucks over long, line-haul segments, with traditional drivers providing service over movements first and last miles. Presumably, labor would also be involved in monitoring driverless segments and responding in the event of mechanical (or other) issues. A similar result is equally possible in the case of rail. No one, however, has ventured to predict the time paths over which automation will advance to the point where such outcomes a reality. Thus, assessing the present value of future advances in either industry is difficult.

Part Two – Preliminary Empirics

POTENTIAL RAILROAD TRAFFIC DIVERSIONS[12]

Based on the above discussion, the current analysis is extended to provide what can only be regarded as very preliminary estimates of automation-induced railroad traffic diversions to all-highway routings that may result from the proposed FRA rulemaking. These estimates are based on the following assumptions.

- A reduction in motor carrier costs of 29 percent for non-coal freight resulting from full motor carrier automation;
- A mandatory onboard train crew of two individuals (status quo) as proposed by the FRA;
- No diversion of remaining railroad coal traffic; and
- No additional reduction in non-crew railroad operating costs.

In combination, the first two assumptions are presumed to lead to the outcome depicted in Figure 3. Within this figure, progress in truck automation is captured by a downward shift in the curve labelled ATC_T. When scenario truck rates fall below the line-haul rates currently offered by railroads, the subject freight traffic diverts to truck. Alternatively, if the scenario truck rate still exceeds the currently observed rail rate, the traffic is retained by the railroads. While this modest deterministic modeling approach is simple, it is not materially different than the approach employed by more complex deterministic models including the Intermodal

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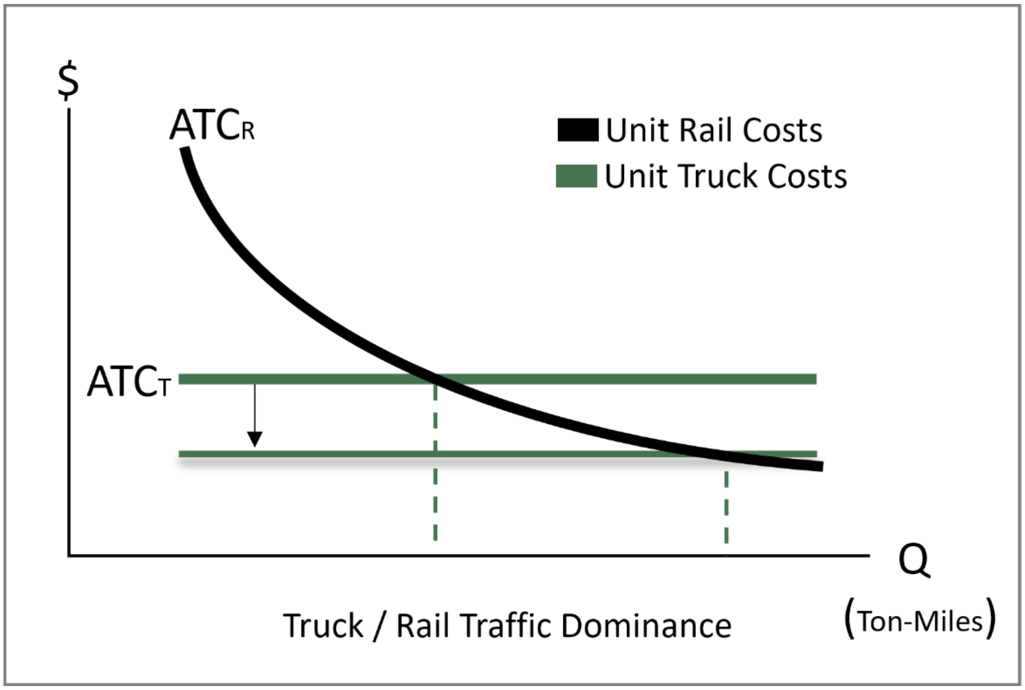
[12] The analysis presented here is limited to rail-to-truck diversions and does not include the increased use by existing truck customers in response to lowered trucking rates.

Transportation and Inventory Cost (ITIC) model routinely used by U.S. DOT in its deliberations.[13]

Figure 3 – Truck Automation Only



The current division of freight traffic between rail and motor carriage reflects existing economic conditions and pricing practices within each mode with respect to each commodity and customer served by that mode. Under the proposed NPRM, railroad costs (and rates) will be constrained within these current conditions. At the same time, emerging truck automation has the potential to eventually reduce motor carrier costs significantly. If this cost-based diversion occurs and, as has been the case in the past, these cost savings are passed along to the customer by motor carriers, traffic may be driven from rail to truck by the changing economic relationships and the ability of the two modes to modify their prices to reflect these changes.

Trucking Costs/Rates

As noted above, each year ATRI surveys both common carrier and private trucking operations to ascertain operating costs. It is these costs as for 2019 that are used as the basis for the analysis

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[13] The ITIC was originally developed by the Association of American Railroads during the 1990s. Later, it was adopted and adapted by the FRA, which periodically updates this model. FRA has continued to rely on the ITIC to produce analytical results. For example, see, Federal Highway Administration, Modal Shift Comparative Analysis Technical Report, *Comprehensive Truck Size and Weights Study*, June 2015.

here.[14] The ATRI values are summarized in Table 1.[15] The final column in this table converts the per mile costs to the cost per ton-mile based a simple conservative assumption.[16]

The average per ton-mile cost for 2019 is estimated to be 11.3 cents. Again, based on the *Transportation Research Record* study and the study produced by Georgia Tech, we estimate that driverless trucks would reduce trucking costs with a mid-range value of 29 percent. The corresponding rate related to this cost reductions is 8.0 cents per ton-mile.[17]

Table 1 – 2019 Average Marginal Motor Carrier Costs

Cost Item	Per Mile Cost	Per Hour Costs	Percent	Per Net TM
Fuel	0.3840	15.14	22.6%	0.0256
Equipment	0.2560	10.09	15.1%	0.0171
Maintenance	0.1490	5.87	8.8%	0.0099
Insurance	0.0710	2.80	4.2%	0.0047
Permits	0.0200	0.79	1.2%	0.0013
Tires	0.0390	1.54	2.3%	0.0026
Tolls	0.0350	1.38	2.1%	0.0023
Driver	0.5540	21.84	32.6%	0.0369
Benefits	0.1900	7.49	11.2%	0.0127
TOTAL	**1.6980**	**66.94**	**100.0%**	**0.1132**

Source: American Transportation Research Institute

Railroad Traffic, Rates, and Traffic Diversions

The source of rail data is the Surface Transportation Board's Carload Waybill Sample (CWS) as summarized by the Board.[18] The CWS is a stratified sample of roughly 600,000 records that can be used to replicate the whole of rail commerce. Here, the revenue per ton-mile was calculated for each record and grouped by commodity and compared to the automation truck rate thresholds discussed above, the results of this analysis are provided in Table 2.[19]

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[14] 2021 data are not yet available and 2020 data were distorted by the COVID pandemic. Accordingly, the whole of the current analysis is anchored in 2019.

[15] See, American Transportation Research Institute, "An Analysis of the Operational Costs of Trucking: 2021 Update," November 2021.

[16] The analysis assumes an average shipment lading of 15 tons.

[17] In the case of motor carriage, the rates are assumed to equal marginal costs.

[18] See, Surface Transportation Board, *Annual Rail Rate Index* Study (supporting materials), https://www.stb.gov/wp-content/uploads/Annual_Rail_Rate_Index_Study_2020.pdf. Because the current work excludes the potential diversion of railroad coal movements, the STB data on this commodity group are not included here.

[19] Revenue per ton-mile is used in place of the marginal movement costs based on the proven need for railroads to recover common and sunk network costs through the application of at least some rates that exceed marginal cost. This practice is routinely referred to as demand-based pricing.

Table 2– Retained Non-Coal Rail Traffic, 29 Percent Truck Cost Reduction

Commodity Group	Distance Group[20]	2019 Nominal RPTM (Cents)	2019 Ton-Miles (Millions)	Retained Ton-Miles (Millions)
Intermodal	1	11.513	9,359.0	0.0
Intermodal	2	7.221	39,505.0	39,505.0
Intermodal	3	6.777	34,371.0	34,371.0
Intermodal	4	4.734	226,396.0	226,396.0
Farm Products (not Grain)[21]	0	4.250	4,831.0	4,831.0
Grain (Single Car)	1	8.606	714.0	452.0
Grain (Multi-Car)	1	6.544	2,403.0	2,403.0
Grain (Unit)	1	6.002	3,439.0	3,439.0
Grain (Single Car)	2	5.553	2,790.0	2,790.0
Grain (Multi-Car)	2	4.732	7,714.0	7,714.0
Grain (Unit)	2	3.873	27,912.0	27,912.0
Grain (Single Car)	3	3.755	7,976.0	7,976.0
Grain (Multi-Car)	3	3.822	9,504.0	9,504.0
Grain (Unit)	3	3.024	85,590.0	85,590.0
Metallic Ores	1	8.622	2,127.0	0.0
Metallic Ores	2	7.075	2,356.0	2,356.0
Metallic Ores	3	3.736	4,584.0	4,584.0
Crude Oil	1	5.699	1,247.0	1,247.0
Crude Oil	4	2.722	10,720.0	10,720.0
Crude Oil (Multi-Car)	0	2.747	61,191.0	61,191.0
Non-Metallic Minerals	1	11.221	2,101.0	0.0
Non-Metallic Minerals	2	5.991	8,687.0	8,687.0
Non-Metallic Minerals	3	3.995	71,179.0	71,179.0
Food and Kindred	1	7.196	7,622.0	7,622.0
Food and Kindred	2	4.895	27,834.0	27,834.0
Food and Kindred	3	3.584	95,752.0	95,752.0
Lumber and Wood Products	1	8.171	2,752.0	0.0
Lumber and Wood Products	2	5.994	6,661.0	6,661.0
Lumber and Wood Products	3	4.216	42,406.0	42,406.0
Pulp, Paper and Allied	1	10.970	2,723.0	0.0
Pulp, Paper and Allied	2	6.946	7,819.0	7,819.0
Pulp, Paper and Allied	3	4.832	27,109.0	27,109.0
Chemical	1	9.872	22,078.0	0.0
Chemical	2	5.663	62,084.0	62,084.0
Chemical	3	3.817	143,205.0	143,205.0
Petroleum	1	10.166	7,657.0	0.0
Petroleum	2	5.973	16,576.0	16,576.0
Petroleum	3	4.637	45,279.0	45,279.0
Stone, Clay and Glass	1	7.712	6,895.0	6,895.0
Stone, Clay and Glass	2	5.427	12,090.0	12,090.0
Stone, Clay and Glass	3	4.526	15,519.0	15,519.0
Primary Metal Products	1	8.909	5,945.0	0.0
Primary Metal Products	2	7.035	10,435.0	10,435.0
Primary Metal Products	3	4.836	28,143.0	28,143.0
Transportation Equipment	1	29.771	4,800.0	0.0
Transportation Equipment	2	16.284	11,073.0	0.0
Transportation Equipment	3	11.310	27,806.0	0.0
Waste and Scrap	1	8.691	4,932.0	0.0
Waste and Scrap	2	4.716	9,829.0	9,829.0
Waste and Scrap	3	3.880	6,879.0	6,879.0
All Other	1	29.317	254.0	0.0
All Other	2	15.880	774.0	0.0

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[20] Distance Groups are as follows: 0 Undefined, 1 < 500 Miles; 2 >500, but < 1,000 miles; 3 > 1,000, but <1,500 miles; and 4 > 1,500miles

[21] Single Car refers to six cars or less; Multi-Car refers to between seven and 49 carloads; and Unit Train includes shipments of 50 or more carloads.

All Other	3	10.484	3,255.0	0.0
TOTAL			1,292,882.0	1,184,984.0 91.7%

Cautions and Caveats

The results presented here represent an extreme case. The data are highly aggregated and, therefore, mask circumstances where rail traffic would not divert to highway routings. For example, some rail movements require shipper investments in equipment and facilities with long asset lives. If diversion to all-truck routings would require the abandonment of these assets, the diversion may not take place over a relevant time horizon, even if truck rates are lower than competing railroad prices.[22] There are also examples where shipment characteristics favor rail transportation to the exclusion of truck. This is particularly true of many liquid chemical and petroleum products, including plastics. Finally, the analysis assumes that the rail industry will not engage in further non-crew-related cost saving activities. In summary, the empirical results provided in Tables 2 likely represent a long-run upper bound on foreseeable diversions. Nonetheless, this upper limit should not be dismissed.

TRAIN CREW MANDATES AND THE RESULTING TRAFFIC DIVERSIONS MAY IMPOSE UNNECESSARY AND OTHERWISE AVOIDABLE EXTERNAL COSTS

In the face of emerging technologies, mandating two-person train crews seems is unnecessary and the resulting diversion of rail traffic to all-road routings may impose avoidable economic losses. Specific categories include:

- A potential incremental increase in truck-involved crashes;
- An incremental increase in freight-related fuel consumption;
- Potential incremental increase in pollutant emissions; and
- A probable incremental increase in necessary highway expenditures (both federal and state).

Each of these is treated in the text that follows:

Truck Crashes and Public Safety

Table 3 provides truck crash fatality data for 2019 as proffered by the Federal Motor Carrier Safety Administration (FMCSA).[23] They suggest there were 0.01668 fatalities in truck-involved crashes per one million truck miles. The rail to truck diversions described above imply an additional 5.4 billion truck miles each year. This translates into scores of additional fatalities

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[22] The static nature of the discussion implies that automation's implementation and the resulting shipper response would occur instantaneously. In fact, both are likely to be quite gradual, occurring over decades.

[23] See, https://www.fmcsa.dot.gov/safety/data-and-statistics/trends-table-4-large-truck-fatal-crash-.statistics-1975-2019.

from incremental truck-involved crashes. The 2020 monetization values from the U.S. Department of Transportation suggest each statistical life is valued at $11.6 million.[24] Accordingly, the current value of attributable crash-related fatalities is estimated at more than $10 billion over a 20-year time horizon.[25] Because this figure does not include injury and property damages from non-fatality truck-involved crashes, it necessarily understates the public safety impacts of the estimated rail-to-truck traffic diversions.

Table 3 – 2019 Truck-Involved Crash Fatality Statistics

Variable	Value per Million Miles
Fatal Crashes Involving Large Trucks	4,479
Large Trucks Involved in Fatal Crashes	5,005
Large Truck Occupant Fatalities	892
Total Fatalities in Large Truck Crashes	5.005
Million Vehicle Miles in Large Trucks	300,050
PER MILLION MILES TRAVELED	
Fatal Crashes Involving Large Trucks	1.49
Large Trucks Involved in Fatal Crashes	1.67
Total Fatalities in Large Truck Crashes	1.67
Total Large Trucks Registered	13,085,643

Clearly, based on these statistics, improvements in motor carrier safety offer greater potential gains. However, *potential* gains do not necessarily equal *realized* gains. On the one hand, the technologies associated with motor vehicle automation are generally credited with improved safety performance. On the other hand, the motor carrier industry has an inconsistent record on matters of vehicle maintenance as related to safety.

Hazardous Materials

The same outcome is also evident in transportation-related hazardous materials releases and their consequences (Table 4). Overall, trucks are responsible for the largest number of hazmat movements, but marine vessels are more heavily loaded, and rail shipments travel longer distances, so that on a ton-mile basis, hazardous material shipments are divided almost equally between the three modes. Yet, trucks are responsible for 87.3 percent of hazmat incidents, 95.4 percent of all hazmat fatalities, and 71.1 percent of all hazmat property damages.[26]

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[24] Based on a real discount rate of seven percent. See, "Benefit-Cost Analysis Guidance for Discretionary Grant Programs," U.S. Department of Transportation, March 2022.

[25] Based on a real discount rate of seven percent.

[26] Hazardous material data are available through USDOT's Pipeline and Hazardous Materials Safety Administration, Office of Hazardous Material Safety. https://www.phmsa.dot.gov/hazmat-program-management-data-and-statistics/data-operations/incident-statistics

Table 4 – Transportation-Related Hazardous Materials Incidents

Freight Mode	1--Year Annual Average	Percent
INCIDENTS		
Motor Carriers	14,402.4	87.3%
Railroads	680.8	4.1%
ALL MODES	16,491.7	100.0%
FATALITIES		
Motor Carriers	10.3	95.4%
Railroads	0.2	1.9%
ALL MODES	10.8	100.0%
INJURIES		
Motor Carriers	147.5	71.1%
Railroads	46.8	22.5%
ALL MODES	207.6	100.0%
DAMAGES ($ MILLIONS)		
Motor Carriers	$59.9	72.3%
Railroads	$22.4	27.1%
ALL MODES	$82.9	100.0%

Source: U.S. DOT, Pipeline and Hazardous Materials Safety Administration

Fuel and Emissions

Table 5 duplicates emission factors per-mile for rail and heavy trucks as provided in a University of Delaware study of land-side emissions. It also contains incremental tons of pollutant emissions attributable to rail-to-truck diversions, along with annual dollar values. Finally, based on an estimated 125 ton-miles per gallon for trucks and 525 ton-miles per gallon for railroads, the calculations suggest an incremental annual increase in diesel fuel consumption of more than 29 million gallons.

Based on methods mandated by the U.S. Department of Transportation for use within benefit-cost analyses, the annual value of the 20-year value of incremental pollution is estimated at $14.8 billion.[27]

Highway Expenditures

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[27] Note that, based on allowed USDOT methods, this estimate is necessarily conservative. Specifically, the USDOT guidance allows (but does not compel) a separate and more aggressive treatment of CO2 emissions that was not applied here.

The results developed thus far suggest that if the potential labor-saving effects of truck automation are unmatched by similar efficiencies in freight railroading, total annual highway ton-miles will increase 26 and 30 percent based on railroad traffic diversions.

Table 5 – Emission Factors and Diversion-Related Incremental Pollution

Pollutant	Truck[28] Emissions per TEU (grams)	Rail Emissions per TEU (grams)	Diversion-Induced Difference (Tons)	USDOT[29] Value per Ton	Annual Dollar Value
Nitrogen Oxide (NOX)	6.8600	2.8100	48,124	$15,600	$750,735,654
Particulate Matter (PM10)	0.1200	0.0700	594	$47,600	$28,280,324
Sulfur Oxide (SOX)	0.2200	0.0300	2,258	$41,500	$93,693,426
Carbon Dioxide (CO2)	1,001.0000	144.9700	10,171,767	$52	$528,931,886
ANNUAL SUM					$1,401,641,290

Comparatively, the projected annual diversion-induced additions to truck ton-miles are roughly equivalent (500 billion ton-miles) to the growth in truck traffic evidenced in the U.S. from the middle 1980s through the present.[30] This incremental change would be in addition to natural economy-wide traffic growth and any induced traffic growth among existing all-truck users.

Given the anemic performance of the Interstate Highway Trust Fund (IHTF), it would be tempting to invoke hyperbole and assume a Chicken-Little posture, but to do so seems irresponsible. A significant diversion from rail and rail-truck to all-truck carriage *would* place large demands on roadway infrastructure. However, the requisite roadway infrastructure investments would likely be needed over the course of a generation. There are, however, three takeaways. These include:

- The public roadway elements of a highly automated roadway system – network design, network elements (ramps, lane markings, etc.), and capacity implications – have yet to be estimated;
- An increase in motor carrier productivity that is met with an artificially and unnecessarily suppressed response by the railroad industry will, absent any other pressures, waylay an already overburdened federal system of highway financing; and,

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[28] See, Corbett, James, Winebrake, James, and Hatcher, Jill, "Emissions Analysis of Freight Transport Comparing Land-Side and Water-Side Short-Sea Routes: Development and Demonstration of a Freight Routing and Emissions Analysis Tool (FREAT)," U.S. Department of Transportation, RSPA DTRS56-05-BAA-0001, 2005.

[29] See, U.S. Department of Transportation, "Benefit-Cost Analysis Guidance for Discretionary Grant Programs," Revised March 2022, Appendix A, Table A-6.

[30] For time series data reporting freight ton-miles by mode see, Bureau of Transportation Statistics, Table 1-50: U.S. Ton-Miles of Freight (BTS Special Tabulation).

- As currently configured and administered, the IHTF will be incapable of meeting the infrastructure demands that will result from unfettered motor carrier automation.

Part Three – Concluding Thoughts

PUBLIC DISCUSSIONS AND RESULTING POLICIES WILL BE FRAMED AROUND SAFETY AND THE ENVIRONMENT

Policy discussions surrounding vehicle automation and implementation will continue to touch on many issues and outcomes related to the technology's commercial value, its labor effects, and land use implications, but important as these matters may be, they will ultimately be eclipsed by two issues – public safety and the environment. Both in the case of rail and motor carrier automation, it is the possible safety and environmental benefits that have driven public policy to date and these topics' dominance will continue. For both railroads and trucking, there are two questions that emerge – (1) How large are the potential gains from improving safety and air quality; and (2) will the implementation of automation technologies help secure those available gains?

Regarding the first question, whether focusing on highway crashes, hazardous material releases, or pollutant emissions, the superior performance of rail carriage, when compared to trucking, makes the potential gains from improved railroad safety relatively large. Similarly, air quality impacts are significant. An unbalanced program of technological advancement will divert tens of millions of tons of freight from rail to truck and, in doing so add measurably to the degradation of air quality. Railroad locomotives burn less fuel per ton-mile and emit fewer pollutants. When monetized, based on USDOT guidance, the potential rail-to-truck diversions would inflict nearly $15 billion in, otherwise avoidable, air quality damages over a 20-year planning horizon.

SUMMARY OF FINDINGS AND FINAL THOUGHTS

Labor-reducing automation has the potential to improve competition between North American railroads and motor carriers. In turn, this will ease supply-chain troubles and otherwise benefit the economy. However, realizing these gains will require solid, forward-looking public policies that facilitate rather than impede technological innovation. The safety and environmental implications of further rail and truck automation must be fully understood before FRA imposes a crew-size mandate.

While extremely simplistic, the empirical sketch developed here suggests that the FRA rule will divert a significant volume of rail traffic to all-highway routings, reducing non-coal rail traffic between seven and 14 percent. Corresponding railroad revenues are also predicted to fall. The diversions seemingly would diminish public safety, increase annual fuel consumption by as much as 40 million gallons, and lead to major increases in the demand for highway capacity. However, much like the safety outcomes these additional economic projections can and should be verified or refuted through a carefully designed, disaggregated, and dynamic analysis. Both the data and techniques for doing so are (or will soon become) available.