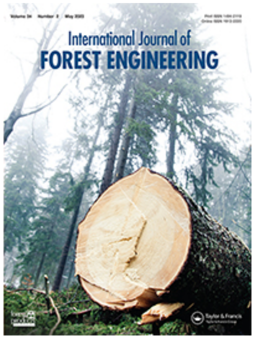

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An assessment of the safety and efficiency of log trucks with increased weight limits on interstate highways in Wisconsin and Minnesota, USA

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ABSTRACT

Design standards for the Federal Interstate Highway System in the US are generally higher than those on other roads within most states, making it the safest road system in the US. Federal law prevents states from enforcing vehicle weight limits on interstate highways that deviate from established Federal weight limits or state-specific grandfathered weight limits or exceptions. As a result, trucks hauling logs at state-legal limits must travel on other roads, passing through towns/cities and school zones where they may encounter on-coming traffic and intersections. All these encounters increase the risk of an accident. This study compared fatality rates of log trucks to other heavy trucks in the lower 48 states, road damage cost estimates for interstate and non-interstate roads and assessed the impact of relaxing interstate weight limits on various factors for hauling logs along three travel corridors in Wisconsin and Minnesota, USA. On a per-load basis, log trucks have a lower fatality rate than other heavy trucks in 83% of the lower 48 states. Due to the higher design standards, pavement damage costs are lowest on interstate highways as compared to other road types. Allowing state-legal, loaded log trucks access to federal interstate highways would improve the overall safety and efficiency of timber transportation and reduce pavement damage costs and CO_2 emissions within the study areas. Overall, the study findings suggest that allowing state-legal, loaded log trucks to operate on interstate highways would improve the safety and efficiency of timber transportation in Wisconsin and Minnesota.

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KEYWORDS
Fatalities; pavement damage; traffic control structures; gross vehicle weight (GVW)

Introduction

Background

Safe and efficient transportation of raw forest products (logs, pulpwood, chips and biomass) is a requirement for suppliers to maintain a healthy and viable wood supply chain. Across all vehicle-types, transportation incidents accounted for 37% of all work-related fatalities in the United States during 2020 (US Department of Labor, Bureau of Labor Statistics 2020).

Cole et al. (2019) reported that log tractor-trailer crashes occurred at a rate of 0.7 fatalities per 100 million cubic feet of wood delivered between 2011 and 2015. Furthermore, , Cole et al. (2019) reported that national log tractor trailer crashes and fatalities increased by 33% and 41%, respectively, during the 5-year period. The study concluded that nationally, among other factors, aging log trucks and tractor-trailer equipment was a leading cause of crashes.

Conrad (2019) compared log trucking to other heavy trucking using various crash factors in Georgia and confirmed the conclusion of Cole et al. (2019) that aging log trucks cause crashes. Heavy trucks are typically defined as any commercial medium- or heavy-duty on-highway vehicle or work truck as defined in 49 U.S.C. 32901(a)(7) and (19), and include heavy-duty pickup trucks and vans, trailers, and truck tractors that exceed 11,793 kg (26,000 pounds) Gross Vehicle Weight (GVW).

US interstate highway system

Conrad (2020) provided an overview of the history of the US Interstate Highway System which includes 75,440 km (46,876 mi) of highways. Design standards of those interstate highways are higher than for most roads in the US and include full control of access, at least two travel lanes in each direction, 3.66 m (12-foot) lane widths and paved shoulders. As a result, the Interstate System is the safest road system in the US (US Department of Transportation, Federal Highway Administration 2021a). Since 1974, vehicle weight for commercial vehicles on interstate highways has been limited to 9,072 kg (20,000) pounds on a single axle 15,422 kg (34,000 pounds) on a tandem axle group, and 36,287 kg (80,000 pounds) GVW (US Department of Transportation, Federal Highway Administration 2017, (23 CFR Part 658.17)).

Federal law prevents states from enforcing vehicle weight limits on interstate highways that deviate from established Federal weight limits or state-specific grandfathered limits or exceptions (US Department of Transportation, Federal Highway Administration 2019b). According to these provisions, "the United States Secretary of Transportation shall withhold 50 percent of appropriated funds from a state that sets weight limits for interstate travel that are higher or lower than the standard Federal limits for interstate highways, with some exceptions" (23 U.S.C. §127[a]).

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Heavy trucks can cause damage to roads and bridges if too much weight is concentrated on any axle. The Federal Bridge Formula, enacted by Congress in 1975, established the maximum weight any set of axles may legally haul on interstate highways to avoid overstressing of bridges (US Department of Transportation, Federal Highway Administration 2019a, p. 3 U.S.C. § 127 and 23 C.F.R. § 658). This is accomplished either by spreading the overall weight over additional axles or by increasing the distance between axles. The formula effectively lowers the legal weight limit for shorter trucks where the load is concentrated on fewer axles.

These weight rules apply nationwide, but the federal government allows exceptions. States with higher weight limits than federal limits at the time the interstate highway system was established in 1956 were allowed to retain those higher weight limits through "grandfather" clauses for various commodities (US Department of Transportation, Federal Highway Administration 2019b), In addition to those "grandfather" rights, federal law (23 U.S.C. 127) includes one other exception to the Federal Bridge Formula, so that trucks with two consecutive sets of tandem axles may carry 15,422 kg (34,000 pounds) each if the overall distance between the first and last tandem axle is at least 11 meters (36 feet) (US Department of Transportation, Federal Highway Administration 2019a). Twelve states have been grandfathered to allow state-legally loaded log trucks to use the interstate system (Idaho, Louisiana, Maine, Michigan, Nevada, New Hampshire, Oregon, South Dakota, Utah, Vermont, Washington and Wyoming) (US Department of Transportation, Federal Highway Administration 2019b).

State weight limits for log trucks exceed federal interstate highway weight limits in all major timber-producing states (Conrad 2020). This disparity discourages log trucks from traveling loaded on interstate highways. Shifting trucks hauling forest products away from interstate highways to secondary state, county, and local roadways forces them to drive slowly through intersections, downtowns, and school zones in communities where they also encounter two-way traffic, stop signs and stoplights, sharp turns, roundabouts, pedestrians, elderly and school children (Conrad 2020). This high traffic volume through sensitive areas increases risks of a collision or other accidents (Wang et al. 2013; Retallack and Ostendorf 2019, 2020). It also forces them to avoid bridges on local roads which may not have been designed to support loaded log trucks. Slower routing of log trucks increases the delivery duration, resulting in fewer daily loads. The increased risk of accidents increases insurance rates and premiums while the frequent stops reduce fuel efficiency and mechanical longevity while increasing driver fatigue.

Previous assessments of heavy trucks on US interstate highways

A pilot study was conducted in 2010 to assess the impacts of raising commercial hauling weight limits for heavy trucks on interstates in Maine and Vermont (US Department of Transportation, Federal Highway Administration 2012). A six-month report determined that the change had not caused any major impacts to road conditions and no unexpected damage occurred within the pilot test area. While pavement life was expected to be reduced on the interstate highways within the two states, reduced heavy truck hauling on secondary highways was likely to offset any increased long-term cost of maintenance.

After North Carolina (2012) and Virginia (2015) increased their gross vehicle weight limits for log trucks Conrad (2021) reported that there were no significant changes in the estimated cost of pavement damage caused by log trucks, or the percentage of log trucks disabled in those two states.

Using a proprietary delivery tracking system and ArcGIS, Conrad (2020) estimated travel distance and travel time on 907 optimal unique interstate routes from 257 harvest sites located within eight wood baskets in the US South, comparing those routes to current routes that avoided interstate highways. On average, 39% of the routes studied would have benefitted from interstate highway access. The interstate routes would likely have been safer as they encountered 41% fewer intersections, 33% fewer stop signals and approximately one fewer school zone per route.

Other benefits from more efficient trucking

More efficient trucking can also provide additional benefits in terms of reducing fuel consumption, carbon dioxide (CO_2) emissions, and pavement damage. Carbon dioxide is a greenhouse gas (GHG) that enters the atmosphere through the burning of fossil fuels (e.g. oil, coal) and other materials whereupon it traps heat in the atmosphere (US Environmental Protection Agency 2022a). It is the primary GHG emitted through human activities, accounting for about 79% of all GHG emissions from those activities in 2020. According to the US Environmental Protection Agency, the transportation sector is the largest contributor to anthropogenic GHG emissions in the United States (US Environmental Protection Agency 2022c). The International Energy Agency (2022) reported that CO_2 emissions from heavy-duty vehicles increased an average of 2.2% annually since 2000 with trucks accounting for more than 80% of that growth. The US Department of Energy (2020) reported that on average across the US, Class 8 trucks (trucks with a gross vehicle weight rating exceeding 14,969 kg (33,000 pounds)) get 2.25 $km^{-1}l$ (5.29 $miles^{-1}gal$) of diesel fuel. According to the US Energy Information Administration (2022), 10.19 kg (22.45 lbs) of CO_2 are emitted per 3.79 l (gallon) of diesel fuel consumed

Motor-vehicle crashes at intersection traffic control structures, particularly stop signs which are the primary form of traffic control at intersections in the United States, are a considerable source of injuries and property damage (Retting et al. 2003). Traffic lights are another common traffic control device at intersections in urban areas within North America (Navarro et al. 2022). Roundabouts, a type of circular intersection control structure, present a potential safety issue for trucks due to the possibility for a rollover.

While traffic control structures such as roundabouts, stop signs and traffic lights are designed to increase road safety, they require deceleration before reaching the control structure, stopping at stop signs and red lights on a traffic signal, and acceleration after passing through the control structure. Those changes in vehicle speed result in increased fuel consumption and greenhouse gas emissions (Tunnel 2009; Alshayeb et al. 2021).

Tunnel (2009) modeled the performance of a 6-axle vehicle operating at a maximum gross vehicle weight of 45,359 kg (100,000 pounds) on two roughly parallel routes in Maine. While the one-way approximately 117.5 km (73 mile) interstate route was 8.35 km (5.19 mi) longer in the northbound direction and 7.1 km (4.41 mi) longer in the southbound direction, travel times on the interstate route were from 26 to 33 minutes less in either direction due to avoidance of 14 traffic signals which required deceleration, stopping and acceleration and 28 changes in posted speed limits. An overall fuel savings of approximately 3.78–7.57 l (1–2 gallons) (a reduction of 14–21%) per trip were estimated along the interstate route. Carbon dioxide emissions ranged from 6% to 11% lower on the longer interstate route due to not having to stop at traffic signals.

The pavement damage caused by a heavy truck is much higher than that of lightweight passenger vehicles (US Government Accountability Office 1979; Gibby et al. 1990; Carson and Kearney 2009). The structural design of pavement layers influences the pavement damage caused by heavy trucks (Dey et al. 2014). A truck that might cause little or insignificant damage to an interstate might cause significant damage to local streets because of the differences in the structural design of the two roadway types (i.e. an interstate has a thicker pavement and a higher quality road subgrade than secondary roads).

Conrad (2020) estimated that by allowing state-legal, loaded log trucks to operate on interstate highways within eight wood baskets in the US South, annual fuel consumption would be reduced by nearly 7.95 million l (2.1 million gal.), carbon dioxide emissions by 5,591 tonnes (6,163 tons), and pavement damage by $4.9 million USD.

Transport of forest products in Wisconsin and Minnesota

The forest products industry is important in both Wisconsin (WI) and Minnesota (MN). Between the two states, nearly 95,000 individuals are employed within the industry with a total industry output of approximately $34 US billion and $10.1 US billion of value added in WI and MN, respectively (WI Department of Natural Resources 2021, MN Department of Natural Resources 2021).

In both states, most of the raw forest products transported from the forest to a mill is hauled using truck and trailer systems over multiple road classification types (e.g. in-woods, local, township, county, state) and state-legal loaded log trucks are not allowed to haul on most of the interstate system.

A study was conducted to estimate safety improvements and efficiency gains if state-legal weight limits for commercial motor vehicles hauling raw forest products were increased on selected interstate corridors in WI and MN. Specific objectives included: a) to compare the accident rates for log trucks to other heavy trucks within the lower 48 states, b) to compare available national pavement damage cost estimates for interstate and non-interstate roads. and c) to assess the impact of relaxing interstate weight limits on hauling distance, travel time, safety and pavement damage for hauling timber along selected travel corridors in WI and MN. The University of Minnesota's Institutional Review Board reviewed the protocol for the project and determined it was exempt from further review. Since loading and unloading times are not affected directly by interstate access, they were not considered in this study.

Materials and methods

Comparison of fatality rates for log trucks vs other heavy trucks

Safety information for the lower 48 states was obtained from the National Highway Transportation Safety Administration's Fatality Analysis Reporting System (FARS) (Oak Ridge National Laboratory 2022) and the Federal Motor Carrier Safety Administration's Motor Carrier Management Information System (MCMIS) (US Department of Transportation, Federal Motor Carrier Administration 2019b). FARS provides data about crashes involving motor vehicles traveling on public roads which resulted in the death of a vehicle occupant within 30 days following the crash (US Department of Transportation, National Highway Traffic Safety Administration 2021). MCMIS contains information on the safety fitness of commercial motor carriers (truck and bus) and hazardous material shippers (US Department of Transportation, Federal Motor Carrier Administration 2019a).

Crashes were broken out by state and road functional systems (rural interstates, urban interstates, rural arterial, rural other, and urban other) to estimate crash and fatality rates by state. Crash data was not sufficiently detailed to isolate specific load carrying information for commodities other than logs due to the unique configuration of log trucks. Therefore, we calculated safety risk per load using data from the Commodity Flow Survey (CFS) (U.S. Department of Transportation, Bureau of Transportation Statistics, and U.S. Department of Commerce, U.S. Census Bureau 2020) for all other heavy truck traffic and compared that to risks created by the transportation of timber using log trucks. The CFS is a survey of approximately 100,000 businesses from the industries of mining, manufacturing, wholesale trade, select retail, and service trade industries that ship commodities. A new survey is conducted every 5 years, with the most recent at the time of this study occurring in 2017.

Comparison of pavement damage costs for various road types

The analysis followed the approach used by Conrad (2020), applying the federal nationwide estimates of damage data (Zhao and Wang 2015) with updated 2022 values which were adjusted from March 2003 for inflation using the National Highway Construction Cost Index (NHCCI) (US Department of Transportation, Federal Highway Administration 2021c). An annual inflation rate of 2.03 from a base of 2003 Q1 was used in the analysis.

Assessment of state-legal weight log trucks on the interstate system

The following three wood basket regions in WI and MN were selected based on significant timber consumption and mills

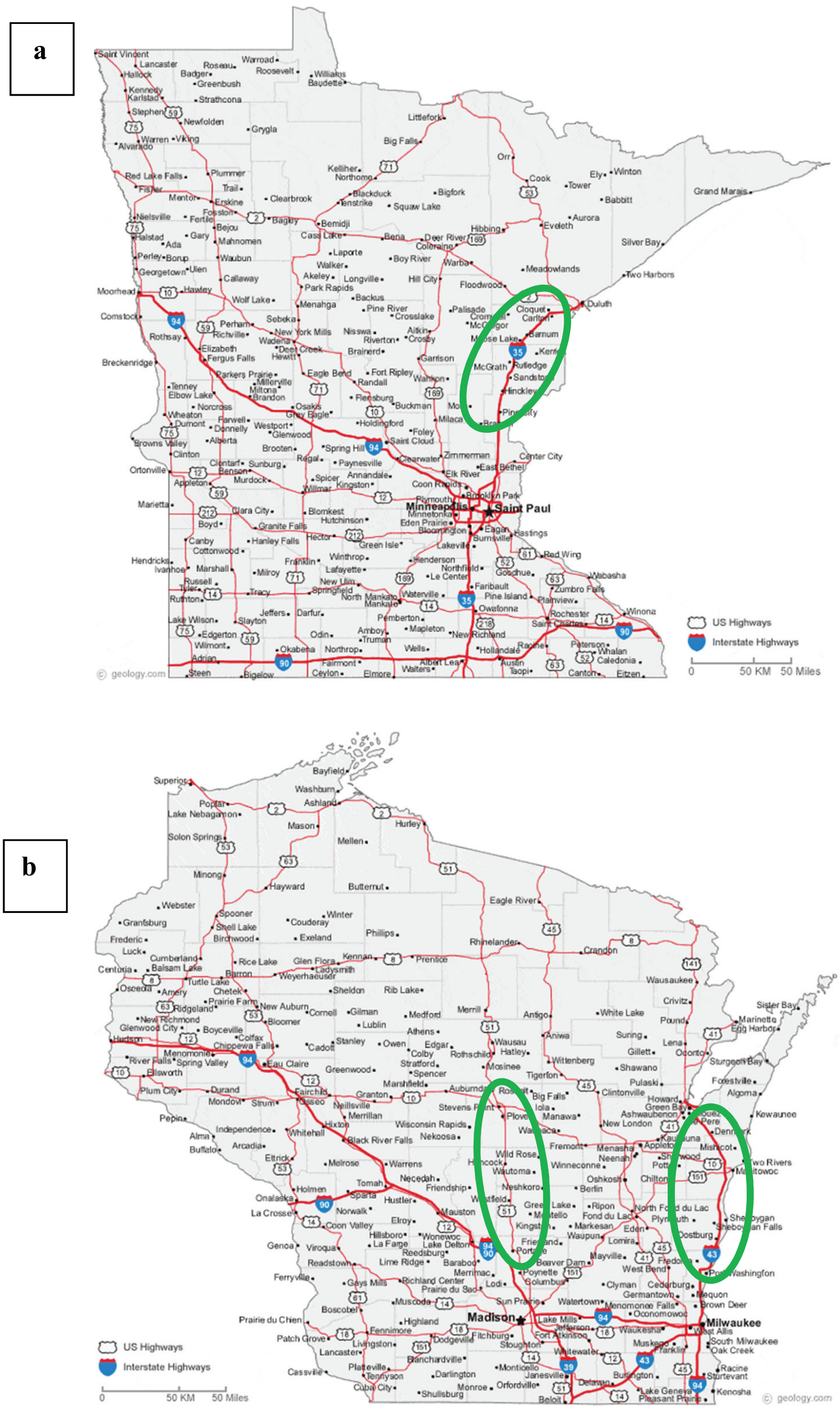

Figure 1. Study locations in a) Minnesota along interstate 35 and b) in Wisconsin along interstate 39 (in the center) and interstates 41 and 43 (on the eastern side of the state).

located near interstate highways (Figure 1). Data were then used to create case studies to demonstrate some of the benefits of interstate access. While it was assumed that interstate access would not be universally beneficial for every trip from a harvest site to a mill, the only case studies selected demonstrated the benefits of allowing state-legal vehicles on interstate highways.

Central WI

This region is served by Interstate 39 and includes the Domtar, ND Paper, and Expera Specialty Solutions pulp mills, Meister Log and Lumber and several smaller sawmills, a biomass/residue mill, a composite panel mill, and a log building manufacturer.

Eastern WI

This region is served by Interstates 41 and 43 and includes many mills, including Expera Specialty Solutions pulp mills.

East central MN

This corridor is served by Interstate 35 and includes the Louisiana-Pacific composite panel mill and the Sappi pulp and paper mill.

Data collection and analysis in WI

The unit of analysis was a route, the one-way journey or trip between an in-woods harvest site and a consuming mill. Actual route haul data was collected using fleet management Cal/Amp trackers (https://www.calamp.com) between 28 January 2021, through 25 August 2021. Once installed, the trackers collected detailed route information including distance traveled, date and time of delivery, delivery duration from the in-woods location to a mill, fuel and truck maintenance efficiency, engine idle time, and safety events including hard braking, sharp turns, rapid accelerations, and sudden stops. Excessive speed was also collected by the trackers but not assessed.

Cal/Amp trackers are widely used in fleet management systems and measure vehicle information from the vehicle's computer, GPS locations, and acceleration and G forces with an accelerometer (Chen and Ramachandran 2012; Camisa 2017). The Cal/Amp trackers collected data continuously while the truck's ignition was on and aggregated activity every 60 seconds into a data point with a location. Data was transmitted via GMS (Global System for Mobile communications) to a server and retrieved via login access. The fleet management service GPS Trackit (https://gpstrackit.com) was used to receive, collect, log, and convert raw data input into a usable format.

Data captured and stored by GPS Trackit's online data logging system was downloaded and converted into a GIS shapefile. Harvest site and mill locations were manually identified and classified and included in the shapefile.

Routes were analyzed using Esri ArcGIS Route Analysis software. The Truck Time travel mode, which models truck travel by selecting designated truck routes that optimize travel time, was used in the analysis. It estimates travel time using algorithms that allow the user to restrict the route to roads that are open to truck traffic (e.g. avoiding posted weight restriction for bridges) and is capable of modeling travel time specifically for heavy trucks rather than passenger vehicles. Traffic congestion was not considered in estimating travel time.

For each one-way trip within a wood basket, the various factors were compared for the *interstate alternative* and *optimal* routes. Where a route showed a change for a factor as compared to the *interstate alternative*, the average percent difference in the factor was calculated across all qualifying routes. For each factor, the average trip benefit for the *interstate alternative* (e.g. the average reduction in trip time for the interstate alternative as compared to the optimal route) was calculated across all routes. Routes were compared using three different methods: 1) an *optimal* route used current legal road weight limits and was customized to avoid all interstates, regardless of any exemptions or available permits (i.e. analogous to a Google maps shortest route that meets current state-legal road weight limitations on road surfaces and bridges while also avoiding travel on the interstate). 2) an *interstate alternative* route which allowed trucks to access any interstate conditional upon ensuring overall weight limits were not exceeded on connecting arterial roads, and 3) an *actual* route that was the GPS-tracked real route used by the truck. A legal route was defined as the route with the shortest estimated travel time that also complied with legal requirements such as posted bridge weight limits and other requirements.

Some routes were removed from the analysis because of data analysis issues. These included issues when a harvest site occurred too far from an existing road (i.e. ArcGIS was unable to create a route because the software required that the truck first relocate to a road known within its database), route errors that appeared nonsensical due to heuristic solving algorithms used by ArcGIS which led to trucks being routed on an irrational delivery corridor, and routes that exceeded a single day of travel from the harvest site to the mill. Except where the *actual* route was more than 100% of the *optimal* route distance or more than 200% of the *optimal* time, the *interstate alternative* was compared with *actual* routes. When an *actual* route exceeded a single day of travel from the harvest site to the mill and thus was excluded from the analysis, the *optimal* and *interstate alternative* routes were still analyzed.

Data gathered from ArcGIS Route Analysis software included various route and road factors, including estimated one-way trip time in minutes, distance traveled, road classification(s) navigated (e.g. rural highway, rural secondary), roundabouts encountered, and all required turns at stops signs and traffic lights. Fatal crash risk and the cost of pavement damage were estimated using a weighted average based on the distance traveled between harvest sites and mills on each type of road and nationwide crash rates (US Department of Transportation, Federal Highway Administration 2021b; US Department of Transportation, Federal Motor Carrier Safety Administration 2021) and pavement damage costs (Zhao and Wang 2015 updated to February 2022) by roadway type for each *optimal* and *interstate alternative* route. Safety data was not assessed on *actual* routes since it would have required manual tracking of each individual route and no fatal crashes were observed during data collection.

Routes for each WI wood basket were compared with one another and summarized using Microsoft Excel. Within each WI wood basket, differences between the *optimal* and *interstate alternative* were compared using matched pairs t-tests at a significance level of $\alpha = 0.05$.

Data collection and analysis in MN

Due to difficulties in obtaining cooperators who were willing to install project trackers in their trucks, GPS tracker data for the MN wood basket was insufficient to conduct an analysis similar to what was performed in WI. Instead, mill delivery data was used for 6,381 loads delivered during 2018–2020. It represented 172,804 tonnes (190,484 tons) which originated from 70 MN townships that might benefit from access to Interstate 35.

Delivery data from the mill were grouped by township to assess routing impacts. Centroids for each township were located, and all loads within the township were designated as originating from that single point. Route analysis then followed the same protocols described above for WI, calculating the *optimal* and *interstate alternative* routes. *Actual* routes were omitted because GPS trackers were not installed in log trucks. As the data provided for the MN wood basket was provided at the township level, a single route may represent multiple loads from the same township.

Case study selection and development

Case studies help illustrate the difference between using haul routes when interstate travel restrictions are in place (*actual* routes) to scenarios when interstate weight limits have been relaxed to allow state-legal loaded log truck traffic (*interstate alternative* routes). Distinctions such as number of intersections, number and difficulty of turns, and average travel speed were summarized to illustrate the cost and safety differences between the routes. Two WI and one MN case study were chosen to illustrate specific individual benefits to increasing interstate weight limits and are not representative of the "average" improvement.

In addition to the route metrics used in the wood basket analyses, additional information was included in the case studies including total road crossings (intersections) encountered, all traffic signals (stop signs and traffic lights) encountered (not just ones where a turn was required), school zones traveled through, bridges crossed, cities or towns that would be passed through, and fuel consumption data. Fuel consumption was calculated using 2.38 km l^{-1} (5.60 mi g^{-1} (mpg)) for travel on interstate highways, 2.08 km l^{-1} (4.90 mpg) for non-interstate rural roads, and 1.59 km l^{-1} (3.75 mpg) for non-interstate urban roads (Conrad 2020).

Results

Comparison of accident rates for log trucks vs other heavy trucks

Within the lower 48 states, the fatality rate per load was lower for log trucks (Column A) than other large trucks (Column B) in 40 states (83% of the states) (Table 1). The eight states where other large trucks were safer in terms of fatality rate per load than log trucks are Connecticut, Louisiana, Minnesota, Mississippi, New Hampshire, North Carolina, South Carolina and Wisconsin. Where interstate grandfathered exemptions exist to allow fully loaded state-legal loaded log trucks on interstates, states with a higher gross vehicle weight for log trucks were safer than other large trucks in 10 of 12 states (83%) (Row 1). The two exceptions were Louisiana and New Hampshire.

Fatality rates per million loads vary across the Lake States (Michigan, Minnesota, Wisconsin) and are the lowest in Michigan where state-legal 74,389 kg (164,000 pounds) log trucks are permitted under a grandfather exemption to travel on interstates on 11 appropriately spaced axles (Table 2).

In the US South, where timber removals represent about 60% of the removals in the US (Oswalt et al. 2019), fatality rates associated with log trucks per million loads were lower than other heavy trucks in eight states (Alabama, Arkansas, Florida, Georgia, Kentucky, Missouri, Tennessee, and Virginia) and higher than for other heavy trucks in four states (Louisiana, Mississippi, North Carolina, and South Carolina).

Comparison of road damage costs for various road types

Updating the national data presented by Zhao and Wang (2015) to February 2022, road impact costs (USD) per 1.61 km (mile^{-1}) from log traffic and other heavy truck traffic of similar configuration are \$0.063 km^{-1} (\$0.094 m^{-1}) for interstate highways, \$0.136 km^{-1} (\$0.220 m^{-1}) for non-interstate urban roads, \$0.167 km^{-1} (\$0.261 m^{-1}) for rural primary roads, and \$2.008 km^{-1} (\$3.232 m^{-1}) for rural secondary roads (Table 3).

Assessment of state-legal weight log trucks on the interstate system

Overview of the two WI wood baskets

Using the GPS tracking technology, nearly one million data points were captured over the course of 7 months (Table 4). These metrics include all the time that the tracking device was on the truck when its ignition was on, including idling,

Table 1. Comparison by state of heavy truck fatality rates per load in the lower 48 states using 2017 data from the freight analysis framework 5.0 (Oak Ridge National Laboratory 2022) and 2017–2019 data from the Federal Motor Carrier and safety Administration (FMCSA) safety and Fitness Electronic records database (US Department of Transportation, Federal Motor Carrier Administration 2019a), assuming 29 tons/load.

	Factor	Log trucks are safer than other large trucks (Column A)	Other large trucks are safer than log trucks (Column B)	Total
Interstate Exemptions	Higher GVW for log trucks (Row 1)	10	2	**12**
	No exemptions (Row 2)	30	6	**36**
	Total	**40**	**8**	**48**

Table 2. Comparison of fatalities per million loads under different interstate limits for log trucks as compared to other large trucks within the Lake states.

		Fatalities per million loads	
State	Interstate GVW limits	Log trucks	Other large trucks
Michigan	74,389 kg (164,000 lbs) on 11 axles	0.59	6.34
Minnesota	36,287 kg (80,000 lbs) on 5 axles	4.48	3.31
Wisconsin	36,287 kg. (80,000 lbs) on 5 axles	6.99	4.32

Table 3. Estimated pavement damage costs ($ USD) for fully loaded log trucks and other heavy truck traffic. March 2003 nationwide estimates of damage data (Zhao and Wang Zhao and Wang 2015) were adjusted for inflation using the National Highway Construction cost index (NHCCI) (US Department of Transportation, Federal Highway Administration 2021b.).

	Pavement damage cost ($ USD)	
Functional road system type	$km^{-1}	$m^{-1}
Interstate highways	0.063	0.094
Non-interstate urban roads	0.136	0.220
Rural primary roads	0.167	0.261
Rural secondary roads	2.008	3.232

Table 4. **S**ummary statistics of GPS tracked data in Wisconsin using a fleet management system.

Description	Quantity
Number of trackers	20
Tracked days (including weekends)	3,157
Total driving time (hours)	13,194
Total Idling time (hours)	2,854
Total distance driven	722,690 km (449,059 mi)
Total observations (drive/idle/other)[1]	993,933
Total driving observations	813,390
Hard brakes/stops	337
Hard turns	408
Rapid accelerations	55

[a]An observation was recorded every 60 seconds when the truck's ignition was on.

backhauling, maintenance, and other local travel. Of the 993,933 observations, 813,390 (81.8%) were captured while the truck was being driven. Total drive distance was 722,690 km (449,059 mi) with 13,194 driving hours logged.

Of the 813,390 observations collected every 60 seconds while the truck was being driven, 337 hard brake/stops (0.04% of all occurrences), 408 hard turns (0.05% of all occurrences) and 55 rapid accelerations (0.01% of all occurrences) were recorded by the trackers. While not zero, those occurrences are one-twentieth of one percent or less of the total occurrences tracked.

After filtering through the GPS data to identify unique routes that could be easily simulated, 3,131 unique routes were identified for comparison of the *optimal* to the *interstate alternative* across the two wood baskets in WI. With these routes 198,052 km (123,064 mi) of timber deliveries were simulated for a duration of 2,275 hours. After eliminating some *actual* routes because of data analysis issues, a total of 2,171 routes were compared for the *actual* to *interstate alternative* analysis.

Analysis of the central WI wood basket

A total of 1,400 routes were analyzed within this wood basket. The average *optimal* one-way route length was 50.1 km (31.1 mi), with an average trip duration of 38 minutes. *Interstate alternative* routes had an average distance of 48.4 km (30.1 mi) with an average trip duration of 33.3 minutes. All *actual* routes had an average one-way length of 104.4 km (64.9 mi) with an average duration of 285 minutes. *Actual* routes used in the analysis had an average one-way length of 66.9 km (41.6 mi) and average duration of 45.6 minutes.

Averaged across the 1,400 routes, the *interstate alternative* routes performed more efficiently and safely than the *optimal* routes (Table 5) and resulted in a statistically significant (p-value <0.05) reduction in time, distance traveled to the mill, roundabouts encountered, stop signs and traffic lights encountered where a turn was required, and fatal crashes. As compared to the *optimal* route, one-way travel time would decrease on 653 routes (46.6% of the routes) by taking the *interstate alternative* and increase for 21 routes (1.5% of the routes) and remain unchanged for 726 routes (51.9% of the routes). The average one-way travel time would be reduced by 16.5% for the 674 routes where there was a time difference. Across the 1,400 one-way trips, the *interstate alternative* route would reduce average travel time by 4.69 minutes load^{-1} and average distance traveled by 1.59 km (0.99 mi) load^{-1}. Also, pavement damage would be reduced by $12.04 (USD) load^{-1}. Across the 1,400 routes, the lower one-way distance associated with the *interstate alternative* would reduce diesel fuel consumption by 993.7 l (262.5 gal) and CO_2 emitted by 2,674.4 kg (5,896 lbs) as compared to the *optimal* route.

The greatest improvement of the *interstate alternative* as compared to the *optimal* route was associated with the various safety factors (Table 5). Where there was a difference between the two routes, the average trip would encounter 72.2% fewer roundabouts and 34.1% fewer stop signs where a turn was required, 48.8% fewer traffic lights. In addition, the interstate alternative would result in 19.6% fewer fatal crashes.

Comparing the *interstate alternative* with *actual* trip data for 876 routes, the *interstate alternative* would reduce travel time and distance on approximately 75% of the routes where there was a difference in the factor, resulting in about an overall 15% reduction for each factor (Table 6).

Central WI case study route

This case study is from an *actual* timber delivery from a harvest site in Portage County, WI to a mill in Endeavor, WI (Figure 2). To comply with current regulations, the log truck traveled Wisconsin Trunk Road 22 rather than I-39. Traveling on I-39 would have allowed the state-legal loaded log truck to bypass the communities of Wild Rose, Wautoma, and Montello, WI. The *interstate alternative* route would reduce (improve) all factors except the number of bridges crossed (Table 7). A single one-way trip using the *interstate alternative* would result in an estimated 14% reduction in fuel consumption with 18.3 fewer kg (40.4 lbs) of CO_2 emitted.

Analysis of the eastern WI wood basket

A total of 1,731 routes were analyzed within this wood basket. The average *optimal* one-way route length was 73.9 km (45.9 miles), with an average trip duration of 55.5 minutes. *Interstate alternative* routes had an average distance of 73.1 km (45.4 miles), with an average trip duration of 51.9 minutes. In comparison, all *actual* routes had an average one-way distance of 117.5 km (73 miles) for an average duration of 367 minutes. *Actual* routes used in the analysis had an average one-way length of 90.1 km (56 miles) and average duration of 60.6 minutes.

The *interstate alternative* routes once again performed more efficiently and safely than the *optimal* route for nearly all factors across the 1,731 routes (Table 8). As compared to the

Table 5. Route change estimated impacts for various factors in the Central Wisconsin wood basket along interstate 39 for 1,400 *optimal* (current legal weight limits limitations which avoid all interstates) versus *interstate alternative* (increased interstate weight limit) one-way routes from a harvest site to a mill. Numbers in parentheses denote the number of routes that meet the specific condition.

	Route changes*			
Factor	Improve	Decline	Average percent change**	Average trip benefit (all routes)***
Time (min)	46.6% (653)	1.5% (21)	16.5%	4.69 minutes load^{-1}
Distance (km)	30.6% (429)	20.5% (287)	4.0%	1.59 km load^{-1} (0.99 mi load^{-1})
Roundabouts	7.0% (98)	0.2% (3)	94.4%	0.14 total load^{-1}
Stop signs****	22.6% (316)	6.7% (94)	40.0%	0.27 total load^{-1}
Traffic lights****	20.6% (288)	0.7% (10)	84.7%	0.26 total load^{-1}
Fatal crashes	42.4% (593)	8.8% (123)	19.6%	0.16 crashes/MM loads
Pavement damage	41.8% (585)	9.4% (131)	27.9%	12.04 $ (USD) load^{-1}

*Percent and number of routes which had a positive (improvement) or negative (decline) change in the factor by using the *interstate alternative* as compared to the *optimal* route. For example, on 653 (46.6%) of the routes, travel time in minutes was decreased using the *interstate alternative* as compared to the *optimal* route and time increased on 21 (1.5%) of the *interstate alternative* routes.
**Average for routes that show either an improvement or decline in the route through use of the *interstate alternative* as compared to the *optimal* route. A positive value indicates a reduction for that factor using the *interstate alternative*.
***Average for all 1,400 routes through use of the *interstate alternative* as compared to the *optimal* route.
****Stop signs* and *Traffic lights* indicate locations where a turn was required, not necessarily all traffic signals encountered during the route.

Table 6. Route change estimated impacts for various factors in the Central Wisconsin wood basket along interstate 39 for 876 *actual* (captured GPS data) versus *interstate alternative* (increased interstate weight limit) one-way routes from a harvest site to a mill. Numbers in parentheses denote the number of routes that meet the specific condition.

	Route changes*			
Factor	Improve	Decline	Average percent change**	Average trip benefit (all routes)***
Time (min)	78.8% (690)	21.2% (186)	14.8%	10.94 minutes load^{-1}
Distance (km)	73.3% (642)	26.3% (230)	16.4%	16.81 km load^{-1} (10.45 mi load^{-1})

*Percent and number of routes which had a positive (improvement) or negative (decline) change in the factor by using the *interstate alternative* as compared to the *optimal* route. For example, on 690 (78.8%) of the routes, travel time in minutes was decreased using the *interstate alternative* as compared to the *optimal* route and time increased on 186 (21.2%) of the *interstate alternative* routes.
**Average for routes that show either an improvement or decline in the route through use of the *interstate alternative* as compared to the *actual* route. A positive value indicates a reduction for that factor using the *interstate alternative*.
***Average for all 876 routes through use of the *interstate alternative* as compared to the *actual* route.

optimal routes, the *interstate alternative* routes resulted in a statistically significant (p-value <0.05) reduction in time, roundabouts encountered, traffic lights encountered where a turn was required and fatal crashes.

One-way travel time for the *interstate alternative* would decrease on 517 routes (29.9% of the routes), increase on 36 routes (2.1% of the routes) and be unchanged for 1,178 routes (68% of the routes) when compared to the *optimal* routes (Table 8). The average one-way travel time would be reduced by 11.9% for the 553 routes where there was a time difference. Across all one-way trips, the *interstate alternative* route would reduce average travel time by 3.55 minutes load^{-1} and pavement damage by $3.94 (USD) load^{-1}. While the average one-way travel distance would increase by 0.2% where there was a difference in distance traveled, the average trip distance would be reduced by 0.80 km load^{-1} (0.50 mi load^{-1}). Across the 1,731 routes, that slight decline in distance associated with the *interstate alternative* would reduce diesel fuel consumption by 622.3 l (164.4 gal) and CO_2 emitted by 1,674.7 kg (3,692.1 lbs) as compared to the *optimal* route.

As in Central WI, the greatest improvement by utilizing the *interstate alternative* route was generally associated with the various safety factors. Where there was a difference between the two routes, the average trip would encounter 28% fewer roundabouts and 42.3% fewer traffic lights where a turn was required and 22.1% fewer fatal crashes would result. However, where there was a difference between the two routes, there was an overall 25.8% increase in the number of stop signs encountered where a turn was required for the *interstate alternative*.

Comparing the *interstate alternative* with *actual* trip data for 1,295 routes, the *interstate alternative* would reduce travel time and distance on approximately 75% of the routes where there was a difference in the factor, resulting in about an overall 15% reduction for each factor (Table 9). Across all 1,295 routes, the average travel time would be reduced by 12.38 minutes load^{-1} and travel distance by 22.48 km (13.97 mi) load^{-1}.

Eastern WI case study route

This example is from an *actual* route from a harvest site in Sheboygan County, WI to a mill in Manitowoc, WI (Figure 3). To comply with current regulations, the log truck traveled Wisconsin Trunk Road 42 rather than I-43. Traveling on I-43 would allow the state-legal loaded log truck to bypass the communities of Manitowoc, Kellners Corner, Howard's Grove, and Elkhart Lake, WI. The *interstate alternative* route would reduce (improve) all factors except the distance traveled and the number of bridges crossed (Table 10). The *interstate alternative* would require crossing 30 bridges as compared to 12 on the *actual* route. A single one-way trip using the *interstate alternative* would result in an estimated 6% reduction in fuel consumption with 6.1 fewer kg (13.5 lbs) of CO_2 emitted.

Analysis of the MN wood basket

The number of loads within the 70 Minnesota townships ranged from 1 to 512 (average 90 and median 43). The *interstate alternative* performed more efficiently and safely than the

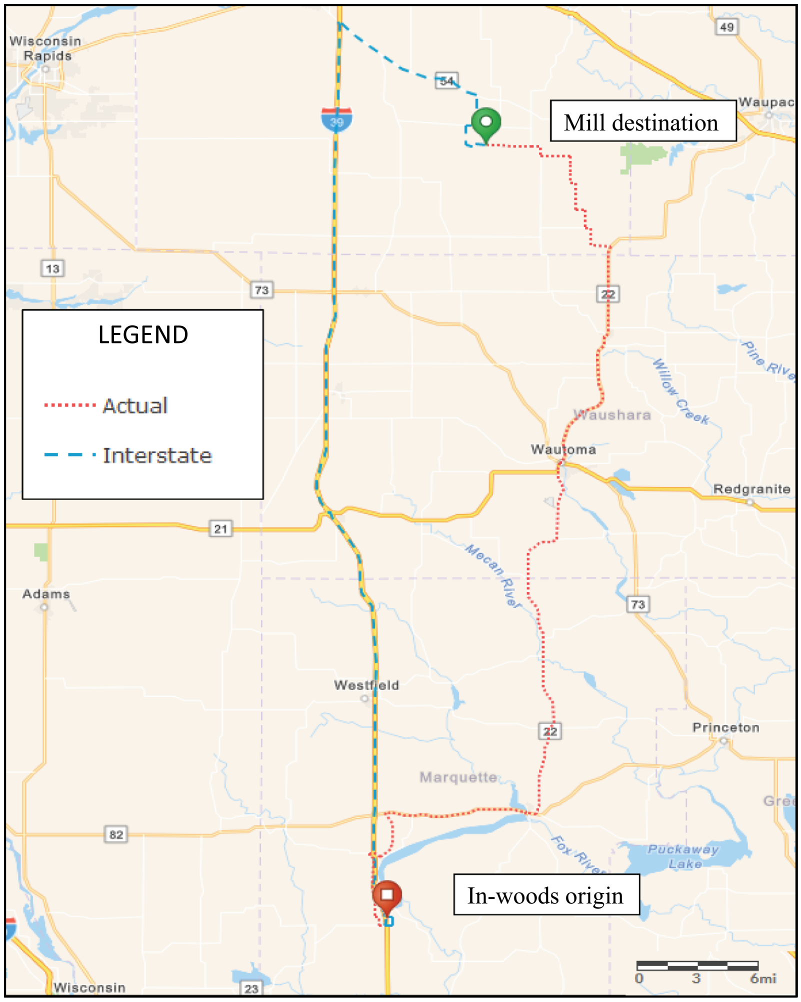

Figure 2. Central Wisconsin case study map showing the *actual* and *interstate alternative* routes.

Table 7. Summary of various factors for the Central Wisconsin case study for the *interstate alternative* and *actual* routes.

Factor	*Interstate alternative* route I-39	*Actual* route WIS-22	*Interstate alternative* benefit
Travel time (minutes)	1 hr 05 min	1 hr 24 min	22%
Distance (km)	98.8 km (61.4 mi)	100.6 km (62.5 mi)	2%
Average travel speed (kph)	90.1 kph (56 mph)	72.4 kph (45 mph)	24%
Number of intersections encountered*	28	127	78%
Stop signs and traffic lights encountered**	4	11	64%
Towns/Cities encountered	1	6	83%
School zones encountered	0	4	100%
Bridges crossed	21	16	−31%
Fuel consumption	42.8 l (11.3 gal.)	49.6 l (13.1 gal.)	14%

*All intersections/road crossings encountered.
**All stop signs and traffic lights encountered (not just ones where a turn was required).

optimal route for all factors (Table 11). Average *optimal* route length was 97.7 km (60.7 mi), with an average trip duration of 69.5 minutes. *Interstate alternative* routes had an average distance of 82.4 km (51.2 mi), with an average trip duration of 53 minutes. The greatest improvement by utilizing the *interstate alternative* route was associated with the various safety factors. For the 6,381 loads modeled in the analysis, as based on mill delivery data for 2018–2020, the interstate alternative would reduce diesel fuel consumption by 43,090.5 l (11,383.3 gal) and CO_2 emissions by 115.9 tonnes (127.8 tons) as compared to the *optimal* route.

MN case study route

This example is from a contrived timber delivery from a harvest near McGrath, MN to a mill in Cloquet, MN. To comply with current regulations, the log truck was assumed to travel on MN Highway 27 and County Road 61 rather than I-35. Traveling on I-35 would allow the state-legally loaded log truck to bypass the communities of Moose Lake, Barnum, Mahtowa, Otter Creek, and Carlton, MN. As compared to the *optimal* route, the distance traveled on the *interstate alternative* route is decreased by 16%, travel time is 23% lower and it would encounter 48% fewer intersections, 67% fewer stop

Table 8. Route change estimated impacts for various factors in the Eastern WI wood basket along interstates 41 and 43 for 1,731 *optimal* (current legal weight limits which avoid all interstates) versus *interstate alternative* (increased interstate weight limit) one-way routes from a harvest site location to a mill. Numbers in parentheses denote the number of routes that meet the specific condition.

Factor	Route changes* Improve	Route changes* Decline	Average percent change**	Average trip benefit (all routes)***
Time (min)	29.9% (517)	2.1% (36)	11.9%	3.55 minutes load^{-1}
Distance (km)	18.6% (322)	19.1% (330)	−0.2%	0.80 km load^{-1} (0.50 mi load^{-1})
Roundabouts	18.6% (322)	6.4% (110)	32.7%	0.41 total load^{-1}
Stop signs****	10.3% (179)	10.0% (173)	−16.1%	0.01 total load^{-1}
Traffic lights****	14.0% (242)	2.7% (47)	57.6%	0.11 total load^{-1}
Fatal crashes	33.1% (573)	4.6% (80)	22.1%	0.24 crashes/MM loads
Pavement damage	28.4% (573)	9.3% (161)	0.2%	3.94 \$ (USD) load^{-1}

*Percent and number of routes which had a positive (improvement) or negative (decline) change in the factor by using the *interstate alternative* as compared to the *optimal* route. For example, on 517 (29.9%) of the routes, travel time in minutes was decreased using the *interstate alternative* as compared to the *optimal* route and time increased on 36 (2.1%) of the *interstate alternative* routes.
**Average for routes that show either an improvement or decline in the route through use of the *interstate alternative* as compared to the *optimal* route. A positive value indicates a reduction for that factor using the *interstate alternative*.
***Average for all 1,731 routes through use of the *interstate alternative* as compared to the *optimal* route.
*****Stop signs* and *Traffic lights* indicate locations where a turn was required, not necessarily all traffic signals encountered during the route.

Table 9. Route change estimated impacts for the Eastern Wisconsin wood basket along interstates 41 and 43 for 1,295 *actual* (captured GPS data) versus *interstate alternative* (increased interstate weight limit) one-way routes from an in-woods location to a mill. Numbers in parentheses denote the number of routes that meet the specific condition.

Factor	Route changes* Improve	Route changes* Decline	Average percent change**	Average trip benefit (all routes)***
Time (min)	79.8% (1,033)	20.0% (259)	15.9%	12.38 minutes/load
Distance (km)	75.5% (978)	24.4% (316)	14.7%	22.48 km load^{-1} (13.97 mi load^{-1})

*Percent and number of routes which had a positive (improvement) or negative (decline) change in the factor by using the *interstate alternative* as compared to the *optimal* route. For example, on 1,033 (79.8%) of the routes, travel time in minutes was decreased using the *interstate alternative* as compared to the *optimal* route and time increased on 259 (20.0%) of the *interstate alternative* routes.
**Average for routes that show either an improvement or decline in the route through use of the *interstate alternative* as compared to the *actual* route. A positive value indicates a reduction for that factor using the *interstate alternative*.
***Average for all 1,295 routes through use of the *interstate alternative* as compared to the *actual* route.

signs and traffic lights, 63% fewer towns, and avoids all school zones (Table 12). The *interstate alternative* would reduce fuel consumption by an estimated 7% and result in 10.2 fewer kg (22.5 lbs) of CO_2 emitted.

Discussion

Safety

In the assessment of state-legal weight log trucks using the interstate system, many of the WI analyses compared the *optimal* route to the *interstate alternative*. As the *optimal* route was similar to a Google maps shortest route that avoided interstate access, some of the *actual* routes were longer and required more travel time. While the safety factors (fatality rates, and traffic control structures) associated with the *actual* routes were not assessed as it would have required manually tracking each route, the safety benefits reported from the *optimal* vs *interstate alternative* analyses likely would be greater than for a comparison of *actual* to *interstate alternative* routes because of the longer average travel time and distance associated with the *actual* routes.

In general, log trucks tend to have lower fatality rates than other large trucks based on the Federal data used in the analysis. In 40 of the lower 48 states (83%), log truck fatality rates are lower than the rates for other large trucks on a per load basis. In Maine, Oregon, Vermont and Washington, where logs are the highest or second highest tonnage commodity hauled by trucks (Oak Ridge National Laboratory 2022), those states have grandfathered weight exemptions for log trucks (US Department of Transportation, Federal Highway Administration 2019b), allowing them to haul timber products and commodities on interstates above federal weight limits. In each of those four states, fatalities per million loads were lower for log trucks than other large trucks. In six of the other eight states with grandfathered exemptions, fatalities per million loads were lower for log trucks than other large trucks. Thus, the Federal data indicate that the percentage of states with a lower fatality rate for log trucks than other large trucks did not increase where grandfathered exemptions allowed higher GVW for log trucks.

In both WI and MN, the *interstate alternative* would reduce the number of routes where a roundabout and/or traffic light would be encountered where a turn would be required as compared to the *optimal* route. However, it would increase the number of stop signs encountered in Eastern WI where a turn would be required as compared to the *optimal* route. Based on road type and nationwide crash rates, it was estimated that the *interstate alternative* would reduce the number of fatal crashes in both states as compared to the *optimal* route. Similar results were noted by Conrad (2020). The reduction of traffic control structures at intersections is important as they are where fatal log truck crashes frequently occur.

In MN, the *interstate alternative* would reduce the number of those traffic control structures encountered by 82.5% as compared to the *optimal* route. Where there was a difference

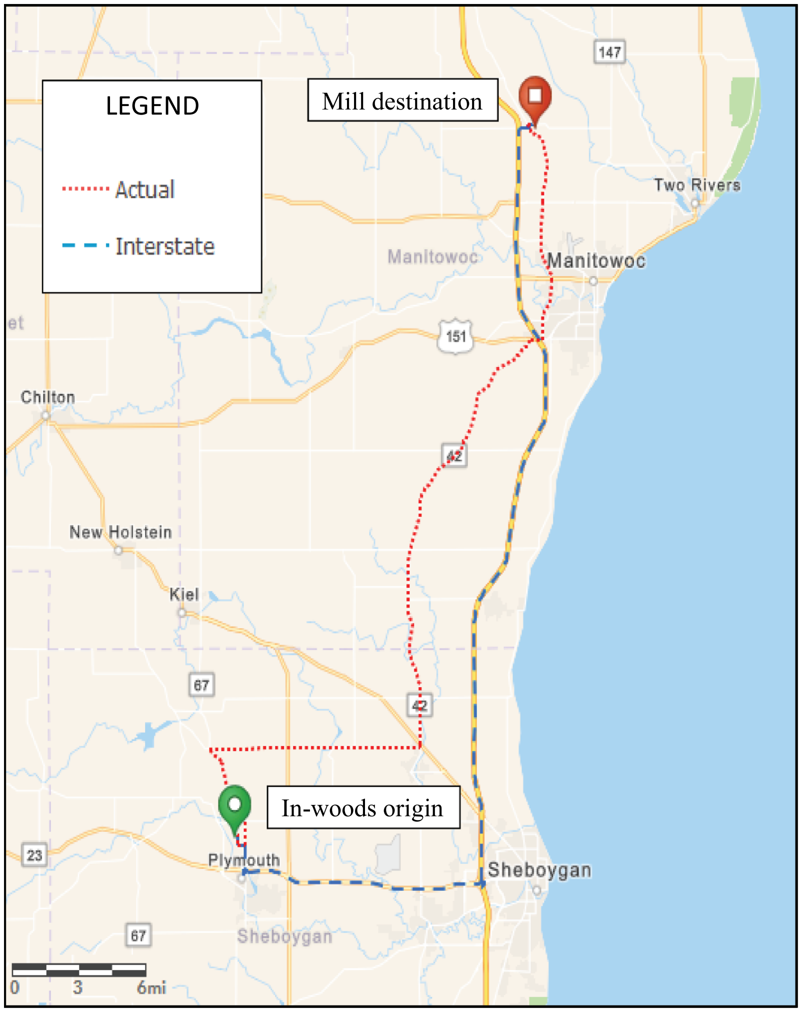

Figure 3. Eastern Wisconsin case study map showing the *actual* and *interstate alternative* routes.

Table 10. Summary of various factors for the Eastern Wisconsin case study for the *interstate alternative* and *actual* routes.

Factor	*Interstate alternative* route I-43	*Actual* route WIS-42	*Interstate alternative* benefit
Travel time (minutes)	43 min	58 min	26%
Distance (km)	75.0 km (46.6 mi)	71.3 km (44.3 mi)	−5%
Average travel speed	104.6 kph (65 mph)	74.0 kph (46 mph)	41%
Number of intersections encountered*	13	110	88%
Stop signs and traffic lights encountered**	4	16	75%
Towns/Cities encountered	1	6	83%
School zones encountered	0	1	100%
Bridges crossed	30	12	−158%
Fuel consumption	33.3 l (8.8 gal.)	35.6 l (9.4 gal.)	6%

*All intersections encountered.
**All stop signs and traffic lights encountered (not just ones where a turn was required).

in the fatal crashes modeled between an *interstate alternative* and *optimal* route, the *interstate alternative* would reduce the number of those incidents by 43.7% as compared to the *optimal* route. Conrad (2020) reported that there would be a reduction in fatal crashes by allowing state-legally loaded log trucks on the interstate in the US South.

Efficiency

Average *actual* haul distances ranged from 104.4 km (64.9 mi) in Central WI to 117.5 km (73 mi) in Eastern WI which are both longer than the 77 km (48 miles) reported by Conrad (2020) for eight wood baskets in the US South. The difference in data collection techniques between the two studies may account for some of the difference. While GPS trackers were used on all WI trucks to track their *actual* route, only about 12% of the data in Conrad (2020) came from a GPS truck tracking system with the remainder from GPS coordinates of harvest sites and mill location information with travel time and distance modeled to determine the quickest legal route. Also, markets in the Lake States may be farther apart than in the US South.

Table 11. Route change estimated impacts for the Minnesota wood basket along interstate 35 for 70 *optimal* (current legal weight limits which avoid all interstates) and *interstate alternative* (increased interstate weight limit) one-way routes from an in-woods centroid location within a township to a mill. The centroids for 70 townships were located and all loads were designated as originating from that single point. Numbers in parentheses denote the number of routes that meet the specific condition.

Factor	Route changes* Improve	Decline	Average percent change**	Average trip benefit (all loads)***
Time (min)	78.6% (55)	0.0% (0)	21.6%	16.47 minutes load^{-1}
Distance (km)	71.4% (50)	8.6% (6)	10.2%	15.2 km load^{-1} (9.44 mi load^{-1})
Roundabouts	2.9% (2)	1.4% (1)	33.3%	0.11 total load^{-1}
Stop signs****	44.3% (31)	10.0% (7)	9.6%	0.31 total load^{-1}
Traffic lights****	20.0% (14)	2.9% (2)	75.0%	0.20 total load^{-1}
Fatal crashes	80.0% (56)	0.0% (0)	43.7%	1.13 crashes/MM loads
Pavement damage	70.0% (56)	10.0% (7)	34.4%	20.19 $ (USD) load^{-1}

*Percent and number of routes which had a positive (improvement) or negative (decline) change in the factor by using the *interstate alternative* as compared to the *optimal* route. For example, on 55 (78.6%) of the routes, travel time in minutes was decreased using the *interstate alternative* as compared to the *optimal* route and time increased on 0 (0%) of the *interstate alternative* routes.

**Average for routes that show either an improvement or decline in the route through use of the *interstate alternative* as compared to the *optimal* route. A positive value indicates a reduction for that factor using the *interstate alternative*.

***Average for all 70 routes through use of the *interstate alternative* as compared to the *optimal* route.

****Stop signs* and *Traffic lights* indicate locations where a turn was required, not necessarily all traffic signals encountered during the route.

Table 12. Summary of various factors for the Minnesota case study for *interstate alternative* and *optimal* routes from 70 township central locations.

Factor	*Interstate alternative* route I-35	*Optimal* route MN-27 and Co Rd 61	*Interstate alternative* benefit
Travel time (min)	53 min	69 min	23%
Distance (km)	82.4 km (51.2 mi)	97.7 km (6.7 mi)	16%
Average travel speed	98.2 kph (61 mph)	9.1 kph (56 mph)	9%
Number of intersections encountered*	13	25	48%
Stop signs and traffic lights encountered**	1	3	67%
Towns/Cities encountered	3	8	63%
School zones encountered	0	1	100%
Bridges crossed	31	14	−121%
Fuel consumption	51.5 l (13.6 gal.)	55.3 l (14.6 gal.)	7%

*All intersections encountered.

**All stop signs and traffic lights encountered (not just ones where a turn was required).

In contrast to Conrad (2020) where interstate access did not reduce average haul distance, the *interstate alternative* generally reduced the travel distance as compared to the *optimal* and *actual* routes in all three WI and MN study areas. Similar to Conrad (2020), the average travel time was shorter on the *interstate alternative* as compared to the other routes. Both travel time and distance traveled would be reduced through the *interstate alternative* for approximately 22% of the WI routes. Conrad (2020) reported that transportation efficiency and cost savings would occur on approximately two-thirds of the harvest sites through interstate access. Increased weight limits combined with enhanced efficiency through reduced travel time and/or haul distance through interstate access would potentially increase fuel efficiency and the ability to transport more loads per unit of time with existing trucks.

The largest benefit from the *interstate alternative* for haul time and distance was in MN. That may be due to the difference in assessment method used in MN (modeled from a centroid within a township) as compared to knowing actual harvest site locations in WI. Each state and study area also has its own unique forestry and road infrastructure. In addition, each MN township was weighted equally, regardless of the number of loads brought to the mill, while each load in WI was recorded. Also, the two interstates studied in WI are relatively close to each other, potentially negating some of the benefit of interstate travel as compared to the one interstate in MN.

Pavement damage

Roads in the US are largely funded by state, local and federal motor fuel taxes (Boesen 2020). According to the national data, pavement damage costs from fully loaded log trucks and other heavy truck traffic increase as one moves from interstate highways to collector (non-interstate urban and rural primary roads) to local roads (rural secondary roads) where it is 34 times as great as on an interstate highway. Allowing state-legal loaded log trucks access to the federal interstate system will likely decrease overall road damage and the associated pavement damage costs, which agrees with findings reported by Conrad (2020),

President Biden signed into law the Infrastructure Investment and Jobs Act in November 2021. The bill includes $110 billion (USD) in new funds for roads, bridges and other major projects in the US to address 278,417 km (173,000 mi) of highways and major roads and 45,000 bridges that are in poor condition (The White House 2021). While these investments are important, they may not do much to improve many of the state, county and local roads through which state-legally loaded log trucks travel in most states because they cannot access the federal interstate highway system.

Reduction in CO_2 emissions

As the transportation sector generates the largest share of GHG emissions, the US Environmental Protection Agency published a proposed rule that would set new, more stringent standards to reduce pollution from heavy-duty vehicles and engines starting in model year 2027 (US Environmental Protection Agency 2022b, 2022c). While the fuel savings in the three study areas during the study period appear to be relatively small, an unknown percentage of all the log trucks in WI that might benefit from interstate access were outfitted with GPS trackers and other MN mills not included in the study also might benefit from interstate access. As Tunnell (2009) and Alshayeb et al. (2021) reported that changes in vehicle speed associated with encountering traffic control structures result in increased fuel consumption and GHG emissions, the total reduction in GHG emissions by allowing interstate access is potentially much larger than reported here.

Optimal vs actual routes

Most of the WI analyses reported in this summary compares the *interstate alternative* to the *optimal* route which mapped the shortest route between the harvest site and the mill destination while also meeting current state-legal road weight limitations on road surfaces and bridges and avoiding travel on the interstate. The WI route travel times and distances were commonly shorter for the *optimal* routes as compared to the *actual* routes in this study. An *actual* route may be longer than the *optimal* route for a variety of reasons including taking a loaded truck home at night to make a delivery from there on a - subsequent day after the truck had warmed up or stopping along a route (e.g. to refuel, eat, for a comfort stop, maintenance) while leaving the engine running. Thus, those deviations from the *optimal* route add distance (not the shortest route) may add time and interactions with traffic control structures (roundabouts, stop signs, traffic lights), and increase the potential for a fatality and pavement damage due to increased travel distance. It is also possible that the driver chose the *actual* route knowing that it was not the shortest route but that it avoided potential interactions with communities and traffic control structures.

Conclusions

On a per load basis, log trucks tend to have lower fatality rates than other large trucks in 83% of the lower 48 states. That trend is consistent where there is an exemption to allow state-legal, loaded log trucks access to the interstate highway system. Due to the higher design standards, pavement damage costs are lowest on the interstate system as compared to other road types.

Allowing state-legal, loaded log trucks access to federal interstate highways would improve the overall safety and efficiency of timber transportation while reducing pavement damage costs and CO_2 emissions in MN along Interstate 35 and WI along Interstates 39 (Central WI) and 41 and 43 (Eastern WI). The safety benefits generally exceed the efficiency benefits. Reducing the number of routes that incur two-way traffic and traffic control structures, some of which require sharp turns which increase the potential for a rollover, will likely result in fewer accidents, injuries and fatalities.

There were few recorded hard brakes/stops, hard turns or rapid accelerations from more than 800,000 observations collected by GPS trackers installed on 20 log trucks in two WI wood baskets. Despite the safe conduct already present in log truck deliveries, increased weight limits on interstates will likely provide safer roads for log trucks to travel. Interstate access will also reduce travel times from in-woods sites to mills in many cases.

The three case studies demonstrate that the alternative interstate route would decrease the number of areas where potential accidents could occur (i.e. intersections, stop signs and lights, communities, school zones) by moving log trucks on those routes away from state, county and local roads to the interstate.

While the gains in efficiency and reduced CO_2 emissions by increasing interstate weight limits are relatively minor relative to the safety benefits, they are still important. When there was a difference in travel time or distance between an *interstate alternative* and *optimal* routes in both WI and MN, the *interstate alternative* route would have reduced the average travel time by at least 11.9% and distance would be reduced by at least 4% in all but Eastern WI where the *optimal* distance was 0.2% less than the *interstate alternative*. Shorter travel distances and avoiding instances where intersections with traffic control structures require deceleration, stopping and/or acceleration back up to the speed limit will have an overall effect of reducing fuel consumption as well as GHG emissions.

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