

## Sustainable Transportation Practices: Reducing Carbon Emissions through Efficient Load Planning and Transportation

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**Abstract:** Freight vehicles that leave distribution centers partially filled, making repeated trips and operating without proper coordination, silently create a constant and unnecessary stream of carbon emissions in today's transportation systems. This study examines the inefficient planning of loads and bad transportation decisions that exacerbate environmental harm, and how sustainable practices involving targeted inefficiency within transportation operations can be of benefit. We investigate the relationships of logistics planning, vehicle use, and emissions reduction with figures on load consolidation, route optimization, and capacity-aware scheduling as methods of reducing fuel consumption and greenhouse gases. Pulling together evidence from data in existing studies on transportation and logistics and analytical reviews of load planning strategies, this paper highlights how improved loading coordination across supply chain can yield sustainability gains. The analysis examines operational interventions such as maximization of vehicle load factors, elimination of empty backhauls and strategic approaches such as data-related planning models and policies aligned to sustainability. It also points to the importance of decision support systems and planning intelligence in providing the link between economic efficiency and environmental responsibility. The findings show that load planning can significantly reduce carbon emissions by cutting total vehicle miles driven, improving fuel economy and reducing the number of trips that are unnecessary. Beyond the environmental gains, the study shows that there are other benefits in terms of cost savings, as well as service reliability and regulatory compliance, and that sustainability can actually provide value rather than additional cost. This study extends on existing understandings of low-carbon logistics while providing useful guidance for companies seeking to institutionalize sustainability into logistics decision making.

**Keywords:** Sustainable transportation, load planning, carbon emissions reduction, logistics optimization, freight efficiency.

### INTRODUCTION

Freight operations form a critical aspect of the US economy, with trucks moving around 73% of domestic freight by value, amounting to over \$12.4 trillion by the most recent estimates, and handling more than 65% by weight, providing seamless supply chain connectivity from the manufacturers to the consumers (Brajkovic, 2023) (U.S. Bureau of Transportation Statistics, 2024). This critical sector has seen drastic change with advancements in predictive analytics and regulation compliance, as carriers can now make the most of optimal route planning and driver monitoring while ensuring integrity of cargoes with rising demands of e-Commerce. Recent industry projections demonstrate an increase in truck freight volumes to a good 11.27 billion tons in 2025, fueled by 1.6% tonnage growth and market stability following post-recessionary dips (American Trucking Associations, 2025).

As freight volumes surge with trucking projected to move 76.8% of freight market by 2035, operators increasingly turn to data-driven applications such as electronic logging devices (ELD) and even real-time monitoring to stay efficient and remain compliant to standards such as hours-of-service rules (De Leon, 2025). These

technologies are not only critical for streamlining operations but also foundational in meeting Federal Motor Carrier Safety Administration (FMCSA) requirements, including proposed updates to the 2025 speed limiters, automated emergency braking and Safety Fitness Determination analytics requirements (YouAoCargo, 2025). This research draws from existing research studies, carrier reports and case data in order to investigate how such innovations intersect with organizational strategies, revealing patterns in safety enhancements and cost efficiencies.

### Regulatory and Risk Landscape

The regulatory environment governing trucking operations in the U.S. centers on the Federal Motor Carrier Safety Administration (FMCSA), who has the power to enforce core regulations under 49CFR Parts 300-399. These enforcements include hours-of-service (HOS) limits (e.g. 11 hours driving cap within 14 hours on-duty), electronic logging device (ELD) which requires for vehicles larger than 10,001 pounds since 2017, and vehicle inspection/maintenance standards to help curb the number of mechanical failures that are implicated in 30% of large-truck crashes (FMCSA).

Compliance relies on the safety measurement systems (SMS), which is a scoring mechanism for carriers based on seven Behavioral Analysis and Safety Improvement Categories (BASICs) such as unsafe driving (32% weight) and vehicle maintenance (20%), triggering interventions for those carriers exceeding percentiles, with 2025 updates integrating advanced analytics for real-time risk prediction through the SMS Plus pilot (Carpenter, 2025).

Significant FMCSA changes in 2025 have reshaped this landscape with elimination of Motor Carrier (MC) numbers, replacing them with a unified U.S. Department of Transportation (USDOT) identifiers as a means to curb fraud affecting 15% of fraudulent registrations (Posea, 2025). Mandatory electronic medical certification uploads to the National Registry became mandatory, slashing paper-based errors in the process by 25%. Phased automatic emergency braking (AEB) requirements target heavy trucks (3-4 years for rollout for vehicles over 10,001 lb), along with speed limiter proposals capping at 68 mph for new trucks. Deregulatory advancements include a set of 18 FMCSA rule changes that simplify compliance by eliminating outdated or duplicative requirements like paper Driver Vehicle Inspection Reports (DVIRs), and mandatory in-cab ELD manuals to reduce paperwork by 20% while preserving and in some areas reinforcing core safety obligations like driver qualification and drug and alcohol controls (U.S. Department of Transportation, 2025).

Risks are not negligible with these evolutions as large truck crashes record claiming 5350 lives in 2023 (down 8.4% from 2022 but up 43% decade-over-decade) and 2523 fatalities in H1 2024 (1-3% decline) as the most prevalent causes of death was led by driver fatigue (13%), speeding (17%) and brake issues (29%) according to NHTSA data. Compliance gaps also exist in large numbers. 93.6% of 2024 inspections revealed acute/critical violations such as being unlicensed operations or failed drug programs. Smaller carriers (less than 50 trucks) experience acute pressures, with out-of-service rates two times higher than fleets, exacerbating a \$91 billion/year crash cost amid 11.27 billion tons projected freight in 2025 (Factually, 2025).

**Telematics in Everyday Fleet Operations**

Telematics adds real-time visibility to the trucking, where drivers are faced with unpredictable road conditions, tight schedules, and fatigue pressures. For DEF Logistics, in North America, managers used to rely on twice-daily phone check-ins, leaving them blind to delays or unsafe driving until problems escalated like a driver speeding through construction zones or sitting in the rest stop for too long. The installation of GPS trackers and dash cams can change this. Dispatchers now have a view of in-cab live routes, braking patterns, and even in-cab drowsiness indicators, triggering coaching via text or calls, turning reactive firefighting into proactive guidance (Bethell, 2025).

**Table 1:** Telematics System Architecture (Bethell, 2025)

Component	Technology	Data Collected	Update Frequency	Key Benefits	ROI Impact
GPS Tracking	Cellular + Satellite	Location, speed, routes	Every 30 seconds	Real-time visibility	\$850K annually
Engine Diagnostics	OBD-II Integration	Performance metrics	Continuous	Predictive maintenance	\$1.2M annually
Driver Behavior	Accelerometer sensors	Driving patterns	Real-time events	Safety improvement	\$980K annually
Fuel Management	Fuel sensor integration	Consumption data	Every minute	Fuel optimization	\$1.8M annually
Route Optimization	AI algorithms	Traffic, weather data	Dynamic updates	Efficiency gains	\$940K annually

In Europe, DHL drivers driving hauling over borders have to contend with different weather and traffic laws. Telematics identifies risky behaviors such as harsh cornering before accidents occur while route adjustments avoid congestion by circumventing high-traffic ports, easing some of the daily grinds of long haul. Operators navigating

pothole-riddled highways, use similar systems to monitor tire pressure and engine heat in real time, preventing breakdowns that could strand drivers in the remote areas (Geotab, 2025).

### **Electronic Logging Devices: From Paper Logs to Seamless Compliance**

Electronic logging devices (ELDs) replace logbooks with automatic hours of service (HOS) tracking, which solves the issue some drivers have when striving to meet their deadlines by hiding their exhaustion. Australian firm Transurban's 5,000 truck fleet has seen voluntarily logged breaks by drivers increase after ELDs were gamified through the use of score boards, nipping in the bud forced violations that turned into fines or crashes on night shifts in the past (Telematica, 2025). In the US small carriers are reporting the supply of ELDs integrating with apps providing live in-nature alerts facilitating HOS compliance during adverse weather situations, helping drivers to avoid fatigue in stringent rural operations such as Midwest grain transport (Sridhar, 2025). Also, India's largest integrated logistics provider, Delhivery, handling 107 million shipments per month with 17.5 million in 24-hours, relies extensively on real-time tracking & route optimization in response to e-commerce growth. Delhivery's driver app makes it possible to mark shifts in vehicles and see the daily usage summary, the company's fleet uses GPS telematics for location and adherence to optimized routes considering traffic, distance and delivery windows, which are critical to managing long-haul demands in India's booming e-com sector (Singh, 2025).

### **Operational Routing Strategies**

Operational strategies in freight operations continue to combine human-centered fatigue management with adaptive routing practices to suit the realities of drivers moving daily in different variable road conditions striving to meet tight deadlines and physiological limitations without relying solely on mandates. Carriers understand that fatigue, often manifesting as microsleeps during monotonous rural hauls or after multiple prolonged shifts that gets compounded to poor routing decisions like sending cars through storm-prone corridors during peak hours, creating cascading risks for longitude for safety and compliance (Fatigue Science, 2025).

### **Managing Driver Fatigue Through Behavioral and Tech Integration**

Schneider National, a major carrier in the US, tackled fatigue directly after determining that it was a major driver of accidents throughout their fleet. Rather than simply implementing Hours of Service (HOS) rules, they implemented telematics-connected training, which was able to interpret the personal driving behavior of drivers such as

gradually dropping their speed indicating drowsiness according to their sleep health workshops drivers. This approach turned the blame on the dispatchers, giving them real-time alerts so they could suggest micro-breaks where they knew they were safe, and to be used by long-distance runners, especially those that run across the country because isolation makes exhaustion even more apparent. Within a year, fatigue related incidents saw a 12% reduction as well as measurable dips in reductions in insurance claims as drivers internalized safer driving habits (Psico-smart Editorial Team, 2024).

A mid-sized hazmat trucking company CIRCADIAN Technologies echoed this in an audit they conducted regarding irregular schedules, causing drivers to rotate working night/day shifts resulting in high turnover and near-misses during hazardous material transportation. Using wearables synchronized with ELDs, they introduced predictive fatigue scoring to highlight when drivers fall into a high-risk category 14 days in advance, allowing for a tweak to their schedule or to change their team. As a result, turnover dropped sharply, accidents were reduced, and drivers reported feeling more in control than they were perpetually chasing rest windows amid regulatory pressures (Circadian, 2025).

### **Adaptive Routing Amid Seasonal and Weather Pressures**

BearDown Logistics heavy haulers are a good example of how routing is on the frontline of fatigue prevention during harvest seasons on the northern Plains, where spring thaw restrictions create operation pressures to test driver endurance on the rural roads. As the temperature rises, thawing ground saturates roadbeds, weakening their structural integrity and forcing jurisdictions such as the state of Minnesota to put in seasonal weight restrictions, often with a 25-35% decrease in axle weight at 35 mph speed caps to save vulnerable pavements from hauling of heavy farm equipment. These frost laws force route adjustment around weakened bridges, potholes prone surfaces and variable thawing rates, turning regular oversized tractor or combine transports into fatigue risks as drivers are idling waiting on the restrictions to be lifted or pressured into rushing when restrictions are called off during tight harvest windows. Dispatchers counter this through proactive planning by finding alternate routes around thaw-vulnerable zones, choosing day operations compliant with the terms of their permit rules and buffering schedules for weather delays

generating predictable pacing and integrating opportunities to rest rather than reactive scrambles through slippery, leaf-strewn autumn backroads or sudden winter snow (Clark, 2025).

In fleets with an agricultural focus such as those that take advantage of Konexial's Ag Mode compliance tools, routing merchants harness the HOS exemptions for perishable grain hauls with fatigue safeguards. Iowa-based operators, for example, sequence loads around harvest peaks, using GPS to take detours around flooded backroads and imposing voluntary rest logs that preempt FMCSA violations, transforming seasonal chaos into structured flows that maintain driver performance without burnout (Konexial, 2025).

### Challenges and Implementation Barriers

Transportation management systems (TMS) and routing technologies face serious challenges in spite of FMCSA ELD mandates, as legacy infrastructure clashes with modern data demands and operational issues persist amongst small fleets.

### Legacy System Integration Conflicts

Older TMS solutions lack APIs in place for easy integration of ELD/telematics, forcing manual data transfers that delay real-time routing updates during dynamic conditions such as weather reroutes. Small carriers, which are dependent on legacy dispatch software, are faced with the highest barriers. FMCSA reports indicate that revoked ELDs increased by 62% in 2025 due to substandard devices failing self-certification and compelling expensive device replacements within 60 days, while reverting to paper logs. This causes their HOS compliance workflows to be disrupted as fragmented systems cannot automatically sync engine data with route optimization, leaving dispatchers to override algorithms manually and eroding confidence in predictive fatigue tools (Gallagher, 2025).

### Driver Resistance and Training Shortfalls

Drivers frequently perceive in-cab telematics and the use of dynamic rerouting to be an invasion of privacy instead of a safety aid, especially when incidents with ELD violations include roadside violations. FMCSA enforcement data shows that HOS violations persist years after there have been mandates, indicating that an underutilization effect exists because of poor onboarding. Veterans resist non-transparent routing suggestions overriding local knowledge of rural shortcuts while new hires lack training on ELD certification processes that result in daily log edit wars that undermine system

reliability. Fleets skipping phased reskilling report a higher rate of overrides because they are focusing on hardware rather than behavioral change programs due to budget constraints (Factor ELD, 2025).

### Cost Pressures and Regulatory Flux

Initial ELD deployment costs, combined with the FMCSA revocations in 2025 mandating urgent swaps puts strain on small operators who are already dealing with tightening HOS without any corresponding improvements in parking infrastructure. State-specific deadlines such as Wisconsin's intrastate ELD mandate create conflicting changes as carriers jostle between federal registered list with local variances. Cybersecurity gaps in connected routing platforms also leave fleets vulnerable to breaches as well, whilst inconsistent state permitting delays oversize load planning, causing further implementation friction across jurisdictions (Samsara, 2025).

### Future Directions

Carriers need to prioritize TMS platforms with FMCSA certified APIs for seamless ELD/telematics integration, establishing master data governance protocols that standardize driver profiles, route formats, and HOS logs across legacy and modern systems. Fleets who implement centralized data lakes obtain real time consistent inputs for routing algorithms eliminating manual overrides that are currently plaguing 62% of revoked ELD cases. Public-private partnerships should also put together open-source API libraries to enable small operators to plug telematics feeds into any compliant TMS without incurring custom development costs (Gallagher, 2025).

In addition, organizations can structure 90-day onboarding protocols that include ELD certification in conjunction with behavioral training, framing telematics as a collaborative tool instead of surveillance where dispatchers receive explainable AI modules showing routing logic, while drivers access fatigue dashboards with personalized rest recommendations. FMCSA should mandate reskilling credits in SMS scoring, incentivizing fleets to invest in change management rather than just hardware alone, directly addressing the 72% workforce resistance undermining current deployments.

Also, coordinated federal-state ELD timelines are needed by policymakers with dedicated HOS parking infrastructure funding, establishing national rest area APIs linking real time

availability to routing platforms. Carriers must build compliance consortia pooling cybersecurity resources for connected fleets, while WCO aligned standards enable cross-border HOS data portability, structured in the form of annual certification audits rewarding integrated systems with expedited permitting (Varghese, 2024).

## CONCLUSION

This research demonstrates that efficient and sustainable transportation can be achieved through deliberate improvements in load planning and transportation efficiency. By grounding the discussion of sustainability in practical operational decisions, this research demonstrates that the reduction of carbon emission is achievable within existing logistics structures. The results strengthen the importance of efficiency focused approaches as a legitimate route to environmental responsibility in transport systems. In doing so, this research fulfils a more practical understanding of sustainability as a practice in logistics. It concludes that informed data-guided execution of emission cuts rather than radical overhauls of systems is possible. Overall, this research contributes to sustainable transportation towards implementable solutions as opposed to theoretical solutions, creating a firm foundation for further research and policy direction.

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