In collaboration with
McKinsey & Company

Transformation of Industries in the Age of AI

Intelligent Transport, Greener Future: AI as a Catalyst to Decarbonize Global Logistics

WHITE PAPER

JANUARY 2025

Images: Getty Images

Contents

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Reading guide

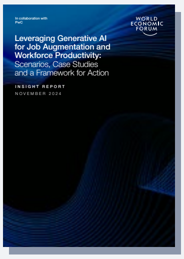
The World Economic Forum's [AI Transformation of Industries] initiative seeks to catalyse responsible industry transformation by exploring the strategic implications, opportunities and challenges of promoting artificial intelligence (AI)-driven innovation across business and operating models.

This white paper series explores the transformative role of AI across industries. It provides insights through both broad analyses and in-depth explorations of industry-specific and regional deep dives. The series includes:

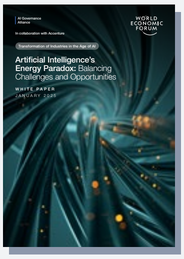
Cross industry

Impact on industrial ecosystems

AI in Action: Beyond Experimentation to Transform Industry



Leveraging Generative AI for Job Augmentation and Workforce Productivity



Artificial Intelligence's Energy Paradox: Balancing Challenges and Opportunities

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Blueprint to Action: China's Path to AI-Powered Industry Transformation

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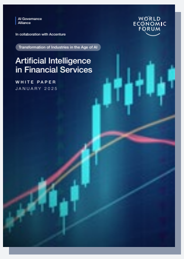
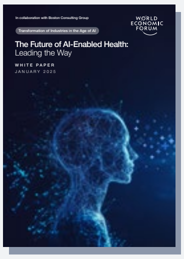


Artificial Intelligence in Financial Services

Media, entertainment and sport

Artificial Intelligence in Media, Entertainment and Sport

Healthcare



The Future of AI-Enabled Health: Leading the Way

Transport

Intelligent Transport, Greener Future: AI as a Catalyst to Decarbonize Global Logistics

Telecommunications

Upcoming industry report: Telecommunications

Consumer goods

Upcoming industry report: Consumer goods

Additional reports to be announced.

As AI continues to evolve at an unprecedented pace, each paper in this series captures a unique perspective on AI – including a detailed snapshot of the landscape at the time of writing. Recognizing that ongoing shifts and advancements are already in motion, the aim is to continuously deepen and update the understanding of AI's implications and applications through collaboration with the community of World Economic Forum partners and stakeholders engaged in AI strategy and implementation across organizations.

Together, these papers offer a comprehensive view of AI's current development and adoption, as well as a view of its future potential impact. Each paper can be read stand-alone or alongside the others, with common themes emerging across industries.

Foreword

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The world urgently needs to accelerate emission reductions, but despite numerous pledges many organizations are lagging behind in meeting their 2030 decarbonization targets. Given that global transportation is responsible for a significant portion of greenhouse gas emissions (estimates range from 16-25%), the sector has a pivotal role to play in global decarbonization.

Making quick gains in this sector with available technologies and continuing to invest in scaling-up less mature decarbonization solutions will be critical to getting on track with a Paris-aligned pathway.

Recent years have seen significant technological developments in advanced analytics, notably in artificial intelligence (AI) and machine learning, with gains in computational capabilities expected to further accelerate the pace of change. This has accelerated in the past 18 months, with widespread adoption of AI applied to quantitative data assets. Such technology can be harnessed to drive decarbonization.

Freight logistics and commercial mass transportation, both data-heavy operations, are well suited to take advantage of these technological improvements. Some industry players are already using AI to improve efficiency, but there is a lot of potential yet to be captured across the sector.

This report looks at how the broad use of AI could help drive global decarbonization. We explore three specific levers demonstrating how it can help stakeholders across the freight logistics sector: through daily operating efficiencies, improving capacity utilization and transitioning to less carbon-intensive modes of transport. Taken together, our analysis suggests that acting on these levers could have significant impact, reducing total emissions from freight logistics by 10-15% if implemented at full-scale potential.

The opportunity is a global one, but action begins at a company level through small incremental improvements. For this reason, the report offers practical guidance and impact examples around how AI can accelerate sector decarbonization, as well as offering steps that business leaders can consider now. Advanced computational applications can be built upon simpler use cases as the starting point within a company. However, success hinges on acting on key enablers, including setting up basic digital infrastructure, fostering industry collaboration and incentivizing sustainable choices among freight logistics customers.

Through incremental improvements, freight logistics companies can not only accelerate decarbonization efforts but also position themselves for long-term success in an increasingly competitive and climate-conscious market. Early technology adopters in freight logistics are likely to realize GHG emission reductions and a competitive advantage in attracting customers aiming to reduce their scope 3 emissions. Other significant benefits will come from enhanced operational efficiency, allowing for lower cost structures and better capital deployment possibilities. AI adoption is poised to be a transformational shift in the industry's journey towards a net-zero future.

This report was developed by the World Economic Forum in partnership with McKinsey & Company and reflects the insights of numerous industry experts and business leaders. Interviews were carried out with stakeholders spanning the transportation and logistics ecosystem including service operators across rail, aviation, trucking and shipping, their customers (including major retailers), AI start-ups, tech player incumbents and academics. We thank our partners and contributors for their valuable contributions to this research.

Executive summary

The freight logistics industry stands at a pivotal moment to significantly contribute to global decarbonization efforts. As a prominent source of greenhouse gas (GHG) emissions, the industry has the opportunity to align with the 1.5°C target set by the Paris Agreement. The substantial emissions gap, projected at 5.5 billion tonnes by 2050, underscores the urgency for innovative solutions. This report illustrates how artificial intelligence (AI) and machine learning (ML) can drive substantial and cost-effective decarbonization of global freight logistics now.

The transportation sector, responsible for 16-25% of global GHG emissions, sees a significant portion (7-8%) coming from freight logistics. AI can be a powerful enabler to drive deep emission reductions by optimizing operations, enhancing capacity use and facilitating modal shifts. Analysis conducted for the paper suggests that three specific levers, outlined below, could reduce total emissions from freight logistics by 10-15%.

Achieving operational excellence with AI

- **Route optimization and asset management:** AI can achieve up to a 7% reduction in emissions through route optimization and efficient asset management. By leveraging real-time data and predictive analytics, AI ensures that every journey is as efficient as possible.

- **Improved capacity utilization:** AI solutions address empty capacity issues by matching supply with demand and tackling market fragmentation. This improved capacity use can cut down on unnecessary trips and enhance overall operational efficiency, reducing emissions by up to 4%.

- **Modal shifts:** AI can identify and implement the most carbon-efficient modes of transportation, shifting freight from, for example, road and air to rail or maritime options. This shift can reduce emissions by up to 4%.

The potential for AI to drive sustainable practices in the freight logistics industry is vast. Companies adopting AI solutions now will not only meet emerging regulatory demands but also position themselves as leaders in a rapidly evolving landscape.

Aligning corporate incentives with sustainability targets can drive meaningful change. Clear communication and demonstration of AI's benefits, such as cost savings and operational efficiencies, can shift organizational and consumer mindsets towards embracing greener choices. Collaboration across the freight logistics ecosystem is crucial. By standardizing data formats and sharing best practices, stakeholders can optimize operations collectively.

Partnerships between logistics providers, tech companies, regulators and governments are essential to drive systemic change. Establishing robust digital infrastructure and incentivizing sustainable practices among stakeholders are foundational for success. Public-private cooperation to enhance rail infrastructure, for example, can help create win-win scenarios for all involved.

While AI offers immediate operational gains, a comprehensive approach that includes long-term strategies, such as investing in railroad infrastructure, fleet electrification and sustainable fuel adoption, is essential. Integrating AI now lays the groundwork for future technological advances and positions early adopters as industry pioneers.

The tools for this transformative journey are available today and the benefits of acting now are clear: significant emissions reductions, enhanced efficiency and a competitive edge in an increasingly climate-conscious market. Some tangible actions and milestones can be adopted in this decade by various stakeholders in the value chain and the report highlights these next steps.

Scope of this paper

This white paper investigates how AI and other advanced analytics tools can enhance operational efficiencies, capacity utilization and modal shifts to decarbonize transportation, with a particular focus on freight logistics.

Artificial intelligence (AI) and machine learning (ML) are subsets of advanced analytics, referring to the use of sophisticated techniques and tools to analyse data and extract actionable insights, enabling improved decision-making and operational efficiency. These technologies can enhance predictive capabilities, optimize operations and support strategic priorities across various industries.

This paper looks beyond the operational efficiency gains that can be made through digitalization alone, for example transitioning from manual administrative processes to computer-based programmes. Throughout the report, AI is used to refer to all computational applications including advanced analytics.

The analysis is focused primarily on freight logistics – in other words, the global transportation of goods or cargo by road, sea, air and rail – as this sector has significant decarbonization potential, addressable operational scope and growing investor and regulatory pressure to decarbonize. The paper includes examples from the passenger rail and commercial aviation sectors, due to their significance in contributing to global carbon emissions and the potential role that digital technologies can play in driving meaningful decarbonization in these sectors in the short term.

However, passenger travel (e.g. passenger cars, motorbikes, passenger boats) has been excluded from the analysis as decarbonization efforts in this area largely depend on behaviour change, which is tied to entrenched consumer preferences.

While AI could play a role in supporting more capex-heavy transformations, the focus in this report is on non-capex-intensive use cases that leaders can implement in day-to-day operations. In the medium to long term, AI has the potential to fundamentally transform the freight logistics industry in ways that have not even been anticipated. This report focuses on the short-term, low-capex operational gains that companies can make as a no-regret move.

Similarly, AI-powered solutions are only one set of levers that companies can explore in their decarbonization journey. Capital-intensive technological shifts will likely have to be made in the long term to successfully decarbonize transportation, for example through fleet electrification and advanced fuels.

Many industry leaders in freight logistics are already using AI to enhance efficiency, automate decision-making and deliver cost savings, making its adoption a win-win strategic move. This report aims to demonstrate how recent developments in AI and ML can offer cost-effective measures to drive lower-carbon practices in freight logistics, contributing to the broader goal of steering the sector towards a 1.5ºC pathway through technological and operational improvements. While it is also important to consider the just transition in relation to such technological advancements, this subject lies outside the scope of the current paper.

Introduction

Transportation is not on track to meet the 1.5°C target of the Paris Agreement. AI-powered tools can help the sector reduce its projected 5.5Gt emissions gap by 2050.

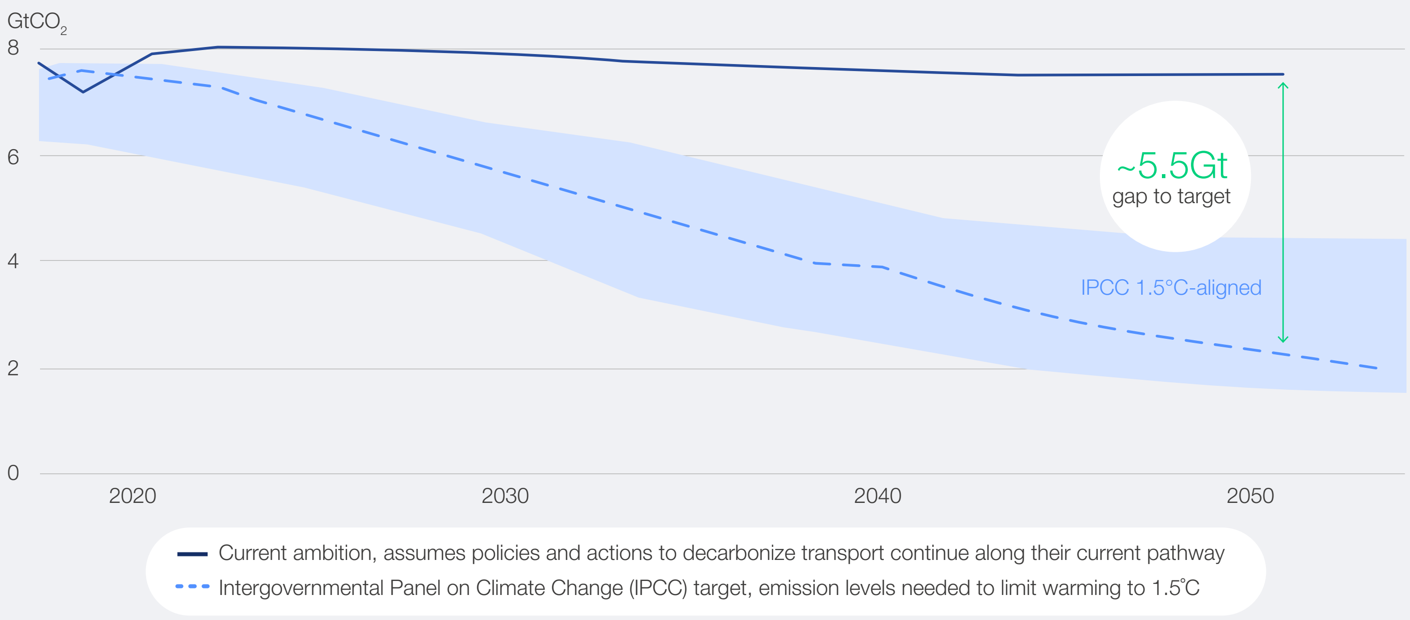
Transportation is a major source of global emissions.[1] However, many technologies for reducing these emissions – sustainable aviation fuels or electrified trucking fleets, for example – are not yet available at scale. At the same time, trends show that even with current decarbonization policies and action plans, the world is not on track to meet the 1.5°C target of the Paris Agreement, with a projected 5.5 billion tonne (Gt) emissions gap for the transportation sector by 2050 (see Figure 1).[2]

To close this gap, the transportation industry needs to reduce emissions by 3% annually, signalling the need for solutions that deliver immediate reductions, alongside steps towards deep decarbonization in the long term.

FIGURE 1 **Carbon dioxide emissions for the transportation sector (Gt)**

CO_2 emissions (Gt) for the transportation sector

To get on track towards net-zero CO_2 emissions by 2050, emissions from the transportation sector need to fall by more than 3% per year. Half of the industry's emissions can be linked to the freight segment.



Source: International Transport Forum.[3]

75% of global shippers and providers either lack clear decarbonization goals or doubt their ability to meet them.

The transportation sector is responsible for 16-25% of global greenhouse gas (GHG) emissions.[4] Freight logistics – the global transportation of goods or cargo by road, sea, air and rail – accounts for nearly half the sector's emissions, contributing 7-8% to global emissions.[5] Innovations and efficiency interventions in freight logistics could simultaneously decrease emissions and save costs.

While a growing portion of transportation companies included in the scope of this paper (namely freight logistics, commercial aviation and passenger rail) have set near-term emission reduction targets, a recent survey suggests that 75% of global shippers and providers either lack clear decarbonization goals or doubt their ability to meet them.[6] AI-powered tools can help to set better goals, prioritize actions and enhance tracking and reporting of progress.

> **The maritime industry has seen a significant shift with about half of vessels now equipped with high-frequency data collection, a stark contrast to just 10 years ago. This advancement is a game-changer for AI's applications in maritime transportation.**
>
> Casimir Morobé, Founder and Chief Executive Office, Toqua

Transportation companies are facing increased pressure from investors, regulators and customers to drive decarbonization efforts. Recent regulations designed to accelerate decarbonization will likely impact not only transportation companies but also businesses that engage transportation and freight logistics services in their upstream or downstream supply chains.

This demonstrates the imperative for transport and freight logistics service providers to decarbonize: they need to meet their own targets and regulatory requirements for direct emissions (scopes 1 and 2) as well as helping their customers across all sectors to meet their scope 3 supply chain commitments, targets and regulatory requirements for 2030 and beyond.

The role of artificial intelligence in addressing decarbonization challenges

Amid growing decarbonization challenges, AI technologies are emerging as powerful and accessible transformational tools, available at an increasingly affordable cost. With vast telematics data generated from cargo vehicles and shipping routes, AI can support operational centralization, optimize route planning, improve fuel efficiency and reduce emissions.

In the freight logistics and commercial travel sectors, AI's potential is pronounced because these networks inherently produce large amounts of actionable data. This data-driven environment is ideal for using AI to optimize variables such as vehicle loads, delivery routes and fuel consumption, all of which can contribute to decarbonization efforts. For example, AI systems may predict demand to minimize empty truck trips, optimize energy use in electric freight vehicles and anticipate maintenance to reduce energy inefficiencies.

While freight logistics is a key area for AI integration, opportunities also exist in the passenger segment, particularly in aviation. Airlines manage large fleets and even small efficiency improvements, such as optimized flight paths, related to contrails for example, or predictive maintenance could lead to significant reductions in fuel consumption and emissions.

Interviews conducted for this white paper revealed a growing recognition that many climate actions are "no regrets" measures that can enhance core business strategies by offering both cost savings and operational benefits. To see meaningful emission reductions in this decade, adopting AI interventions could be one of these "no regret" actions for the sector. Several executives interviewed for this report highlighted the technology's potential to process large amounts of data, reduce computational times and turn data into actionable insights to accelerate productivity gains.

Freight logistics companies have an opportunity to integrate AI into operations and customer experience strategies, among other areas, with the twin interconnected goals of improving efficiencies and reducing emissions.

In the long term, AI could assist in structural changes such as planning efficient charging infrastructure for electric fleets as well as optimizing vehicle allocation, battery health and routing for all-electric autonomous vehicle fleets (already operational and growing in cities such as Phoenix, San Francisco, Los Angeles, Tokyo and Shanghai).

As AI continues to develop at a fast pace, the significance of its impact is likely to grow well beyond 2030 – and the tools to start this journey are available now.

Three key levers to deliver emission reductions

AI offers a unique advantage – it can deliver incremental emission reductions without the significant upfront capital investments often needed to achieve deep decarbonization. This is particularly pronounced in contexts where high-capex decarbonization solutions – such as fleet electrification or green hydrogen fuel – can be challenging to implement and finance, or have limited availability.

> **There is a lot of untapped potential in AI applications. AI can identify complex patterns that may not be visible to the human eye. As AI matures, we can expect accelerated adoption. Key applications of AI such as route optimization and predictive maintenance are particularly promising and can be considered 'low-hanging fruit' for driving both operational efficiency and emissions reductions.**
>
> Massimo Morin, Global Head, Travel, Amazon Web Services (AWS) for Travel and Hospitality

Research for this report shows that these three uses of AI could collectively reduce current global freight logistics emissions by 10-15% relative to current baseline emissions.

The freight logistics sector has traditionally been hesitant to change and adapts at a slow pace, while fragmentation can make it a challenging sector to mobilize. Consequently, cost becomes a key motivator for sustainability transformations. Overall, the investment required for AI solutions at scale can be good for business, regardless of decarbonization effects, as it could help companies stay competitive in a digitally maturing industry.

AI solutions that avoid large capex and unlock operational expense (opex) savings through increased efficiency can be an important value driver for industries with narrow margins, such as freight logistics. For example, in 2022, the economic profit margins for several large freight forwarding companies were in the low single digits.[7] Operational savings can then be reallocated to investments in scaling-up less mature, high-impact decarbonization initiatives such as sustainable aviation fuels. This dual focus makes AI a potentially attractive investment for companies looking to balance sustainability with financial performance.

Three key levers have significant potential for AI to aid decarbonization on a global scale:

1. Enhancing operational efficiencies: Enhancing daily operational practices to reduce emissions and fuel consumption across all transportation modes.

Potential carbon emission reduction: 4-7%

2. Improving capacity utilization: Optimizing the use of space in transportation vehicles to minimize empty capacity and reduce emissions.

Potential carbon emission reduction: 2-4%

3. Optimizing modal shifts: Encouraging the transition to more carbon-efficient transportation modes to significantly cut emissions.

Potential carbon emission reduction: 3-4%

Analysis conducted for this report shows that these three uses of AI could collectively reduce current global freight logistics emissions by 10-15% relative to current baseline emissions (2023). The emissions reduction potential for each lever was calculated by incorporating insights from numerous decarbonization experts, reviewing research and leveraging analysis of baseline emissions. It is important to note that these estimates account for any potential overlaps in impact. For more details on the methodology, see Annex 1.

The three levers are interdependent. Enhancing operational efficiencies could further amplify the benefits of both modal shifts and capacity utilization, while optimizing modal shifts could impact capacity utilization by reallocating freight volumes to more efficient modes. Together, they address key challenges in the industry such as reducing costs, improving service reliability and meeting sustainability targets.

To achieve significant impact, business leaders can start by crafting a bold vision of the full potential impact across these three key levers. They should then act fast to get initial improvements underway and prioritize quick wins. Companies can begin with small, incremental improvements by using these levers to build momentum, setting the stage for broader, long-term transformation.

1 Enhancing operational efficiencies

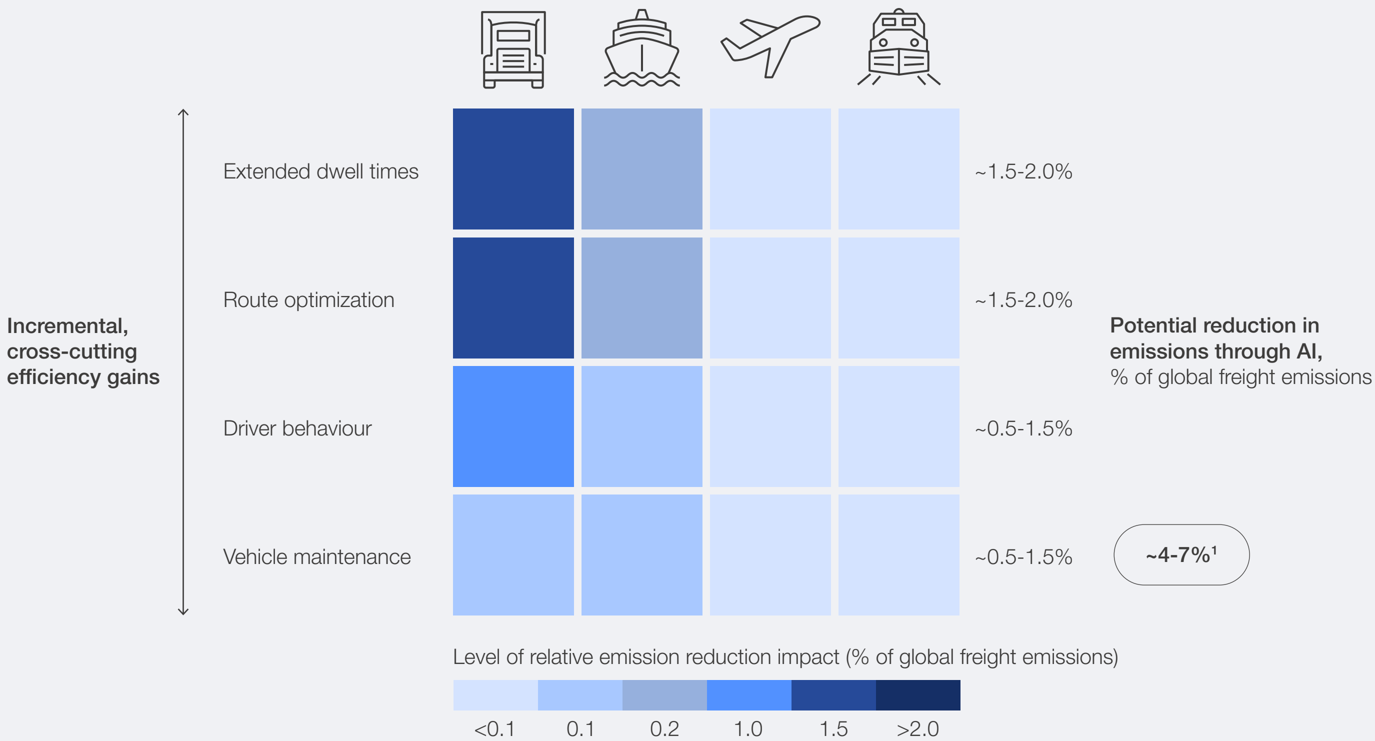
Enhancing day-to-day operations across all transportation modes could reduce emissions from the global freight logistics sector by 4-7% relative to the current baseline.

Four ways AI can reduce emissions through identifying operational efficiencies

Recent developments in AI, including large language models (LLMs), have accelerated computational capacities to process large amounts of data to obtain actionable insights faster. As a result, AI could help companies improve operational efficiency through applications such as real-time data analytics, predictive maintenance and dynamic routing. These technologies could enable more efficient resource allocation, reduce fuel consumption and minimize dwell time. Small, incremental improvements in high-emission areas may have a substantial impact on overall emissions and costs.

Four key areas for potential improvement include dwell time optimization, route optimization, driver behaviour change and vehicle maintenance (see Figure 2).[8]

FIGURE 2: **Operational efficiencies – four ways AI can help reduce emissions**



1. Range calculated considering rounding errors
Source: McKinsey expert interviews.

In the US, inefficiencies in dwell time during loading and unloading cost the trucking industry approximately $3.6 billion in direct costs and $11.5 billion in productivity in 2023.

% global freight sector CO_2 emissions, by mode of transport

Road: 70%

Ships: 20%

Aviation: 5%

Rail: 5%

When looking at global freight sector CO_2 emissions as a whole, road transport (trucking) contributes nearly 70%, ships (maritime services) contribute 20%, while aviation and rail each accounts for just 5% of freight emissions.[9] Therefore meaningful reductions in emissions at a modal level attributed to AI investments could have a notably different magnitude of impact at the overall freight sector level.

While improvements can be amplified through sector-wide collaboration, individual companies can implement these changes independently and benefit from cost reductions. For example, in the US, inefficiencies in dwell time during loading and unloading cost the trucking industry approximately $3.6 billion in direct costs and $11.5 billion in productivity in 2023.[10] Incremental improvements may help drive financial gains alongside emissions savings. The scale of downtime costs alone demonstrates the potential cumulative impact of operational efficiency initiatives driven by AI.

Road transport, responsible for around 70% of global freight logistics emissions, has the potential to benefit from improvements across all four areas outlined in Figure 2.[11] These operational efficiency gains could have a disproportionate impact on the profitability and sustainability of road freight transportation.

In terms of the other freight transportation modes, aviation already leverages technology for route optimization, thereby limiting the additional operational efficiency gains compared to road transport. Optimizing shipping routes involves significant coordination and, among other things, includes avoiding the policy of "sail fast then wait" at ports or congested bottlenecks. For rail freight the gains could also be meaningful, especially across predictive maintenance, scheduling and reliability.

1.1 Operational efficiency #1: dwell time optimization

11 million tonnes

of CO_2 per year emitted by heavy-duty trucks idling during rest periods in the US.

Dwell times refer to the periods when vehicles, drivers or goods are stationary and not actively engaged in transportation or delivery activities. These idle periods can occur during various stages of logistics operations, such as waiting for loading or unloading, handling items or during other delays. Extended dwell times are a source of unnecessary fuel consumption (and therefore emissions) across the transportation sector. In the US, heavy-duty trucks idling during rest periods emit an estimated 11 million tonnes of CO_2 per year, equal to the annual emissions of a small European country such as Estonia.[12]

AI-powered technologies may offer solutions that enable real-time visibility, tracking and optimized scheduling and planning that can reduce dwell time. Furthermore, dwell time optimization is part of a larger momentum for companies and start-ups that are investing in real time visibility platforms (RTVPs) that use AI to combine dwell time minimization with route optimization across networks. For example, in airlines, AI can potentially help optimize airport operations to reduce wait times for planes and improve auxiliary power unit (APU) efficiency to reduce the fuel burn rates when planes are stationary.

We use AI to analyse traffic patterns and optimize loading and unloading schedules at the port, reducing idle times and optimizing space usage. Effective algorithms include reinforcement learning for dynamic decision-making and predictive analytics to forecast peak traffic periods. We collect data from sensors, traffic information systems and terminal operations to create accurate models of traffic flow and container movement. This helps reduce waiting times and increases the overall efficiency of our port operations.

Hermann Grünfeld, Head of Traffic Management, Hamburg Port Authority

1.2 Operational efficiency #2: route optimization

Route optimization refers to the strategic planning and management of routes to enhance efficiency and effectiveness in logistics operations. Inefficient miles can result in higher fuel use, more vehicle wear and greater labour costs. Freight logistics operators that have optimized their routes have seen a reduction in their carbon footprints.[13] To put the potential impact into perspective, if route optimization tools were deployed at full-scale across road freight transport globally, the emissions reduction impact could be equivalent to taking approximately 25% of all heavy- and medium-duty trucks in the US off the road.[14] Furthermore, it can play a critical role in supporting the deployment of zero-emission trucks (ZETs). By ensuring strategic route planning, operators can overcome infrastructure limitations and maximize the operational efficiency of ZETs, accelerating the transition to sustainable freight transport.

Route optimization in the context of this section entails day-to-day dynamic routing, rather than network optimization that may require infrastructure investments and which is reflected in the other themes in this paper. While route optimization is not new, the rise of AI and ML in the past five years has revolutionized this field. AI-driven systems use real-time data and sophisticated algorithms to dynamically adjust routes for maximum efficiency and sustainability. They gather data from GPS devices, traffic systems, weather forecasts and historical route performance. Today, freight logistics companies often invest in route optimization tools as add-ons to their existing transportation management system platforms – something many were reluctant to do not long ago. Notable examples of route optimization leading to reductions in fuel consumption and emissions include Alaska Airlines and DHL Express (see Box 1).

Such AI-enabled route optimization solutions are available, relatively easy to implement and can have high impact, making this area a potential priority for transport companies.

BOX 1

Alaska Airlines and DHL Express use AI to optimize routes

Over the last four years, Alaska Airlines, in partnership with Airspace Intelligence, has used an AI-based routing system, Flyways AI, that dynamically adjusts flight paths based on real-time data such as current weather conditions, airspace congestion and route efficiency across the fleet, leading to fuel savings of 3-5% for flights longer than four hours.[15] The AI-based system ingests millions of real-time data points to predict future scenarios and deliver what it calculates as the safest and most efficient flight path. Similarly, Greenplan, a DHL Express funded start-up, developed an AI-based route optimization tool which can achieve up to 20% in fuel cost savings while using 70% less computing time than standard routing tools.[16]

AI-powered route optimization can reduce inefficiencies in real time, significantly unlocking opportunities to reduce carbon emissions.

Alex Nederlof, Director of Engineering, Flexport

1.3 Operational efficiency #3: driver behaviour

Driving styles significantly impact fuel consumption and emissions across all transportation modes, in particular the road sector (e.g. aggressive acceleration and braking) and maritime shipping sector (e.g. "sail fast then wait"). In trucking, such driving behaviour increases emissions by up to 23%.[17] AI could help to address this problem by leveraging real-time data from on-board sensors and machine learning algorithms to monitor driving behaviour and idling, alongside external factors such as traffic, weather and road conditions. These inputs could enable the system to identify inefficiencies and provide drivers with real-time feedback to optimize their driving and reduce fuel consumption.

Over time, AI could refine its recommendations by learning from both historical and real-time data, improving accuracy and effectiveness. In addition to influencing driver behaviour, AI brings greater precision to the monitoring of vehicle health (e.g. tyre pressure, engine temperature), allowing it to alert drivers to potential issues that could lead to breakdowns or fuel inefficiencies. However, while AI can provide access to information, it would require a behavioural shift in organizational culture and ways of operating to fully capture potential gains. As autonomous technologies advance, these suggestions could be implemented in real time, leading to a more fuel-efficient future.

Eco-driving is one of the key advantages of autonomous trucking. Autonomous vehicles can be programmed to perform best practices in driving behaviour. Studies show eco-driving alone can achieve a 4-10% reduction in fuel consumption.

Garrett Bray, former Product Director, Aurora Innovation; alumnus of Centre for Sustainable Road Freight, University of Cambridge

1.4 Operational efficiency #4: asset maintenance

Regular and thorough asset maintenance plays a role in reducing emissions and prolonging asset lifespans. For example, in the road freight segment, a properly maintained engine ensures optimal combustion, while under-inflated tyres or poor alignment increase rolling resistance, requiring more energy to maintain speed and thus consuming more fuel.

AI is enhancing asset maintenance through predictive maintenance solutions that monitor asset health, forecast potential failures, optimize maintenance schedules and monitor and maintain battery health. AI technologies can analyse vast amounts of historical and real-time data to identify patterns that humans could miss, such as engine wear, tyre degradation or brake performance, which could lead to costly repairs or inefficient power use if left unchecked.

In EVs, AI-powered solutions can integrate many complex factors and predict battery lifespan with up to 95% accuracy.[18] A battery management system (BMS) can collect data from temperature, voltage and charge/discharge cycles to predict battery degradation and optimize charging strategies. Several EV manufacturers are already applying this technology and recommending optimal charging and driving behaviour to prevent wear and tear. This is especially critical for electric trucking fleets, which demand high reliability to maximize uptime and enhance margins. For instance, in a tough commercial environment such as over the past two years, where average operating margins for US trucking (excluding less-than-truckload/ LTL) were below 6% in 2023, optimizing fleet performance becomes imperative.[19]

Predictive maintenance has also gained traction with the rise of AI. Such proactive maintenance in the rail sector costs around seven times less than emergency repairs done after infrastructure fails, so AI-driven optimization could help deliver emission reductions and further operational savings (see Box 2).[20] For example, some rail operators use predictive maintenance platforms to prevent train delays by detecting early signs of wear and tear on switches and gears, which are common causes of rail disruptions.

While emission-saving potential in the rail sector is relatively low, given rail transport's already low emissions, a more reliable rail network could encourage a switch from road to rail, a critical step in reducing overall emissions.

BOX 2

BOX 2: Hitachi Rail collaborates with NVIDIA to drive efficiencies

Hitachi Rail is collaborating with NVIDIA to improve rail operations through AI solutions. This partnership aims to reduce maintenance costs, minimize idle times and enhance train scheduling and reliability. Building on Hitachi's existing applications, which analyse data from 8,000 train cars across 2,000 trains, these tools provide computational ability to provide real-time insights into monitoring train fleets and infrastructure more effectively. Previously, such analysis took days to deliver results.

While the emission-saving potential in the rail sector is relatively low given the already low emissions associated with rail transport, the increase in reliability is a crucial benefit. A more reliable rail network could encourage a switch from road to rail, a critical step in reducing overall emissions. This modal shift, while an indirect outcome of predictive maintenance, is a piece of the puzzle in lowering global freight logistics emissions.

2 Improving capacity utilization

Reducing inefficient use of space in freight can lead to a 2-4% reduction in global freight logistics emissions.

2.1 AI can help address empty capacity and reduce emissions

The financial and climate impacts of empty capacity are significant. Analysis conducted for this report indicates that in the US, the trucking industry loses over $150 billion annually due to empty capacity.[21]

Much of this empty capacity problem is around the following structural issues:

- **Trade imbalances**, where reciprocal demand is lacking, means that vehicles return empty after delivering full loads.

- **Specialized cargo requirements** can further exacerbate this issue, as certain freight types may have limited return demand.

- **Strict delivery restrictions** can compel freight operators to depart with less-than-full loads to meet tight timelines, which can reduce overall efficiency.

- **Market fragmentation** is another challenge; smaller freight logistics companies often struggle with limited visibility of regional demand and lack collaboration opportunities to consolidate loads.

- **Volume and load constraints** can prevent effective capacity utilization, as vehicles transporting lightweight goods may operate at full volumetric capacity while underutilizing their weight capacity.

Freight logistics are complicated, involving fluctuating demand, last-minute bookings and the need to efficiently allocate space across various transportation modes. Addressing these issues requires a complex optimization equation. AI-powered solutions can help to predict demand, optimize loading practices, generate capacity demand scenarios and suggest the best routes to minimize empty space. By dynamically consolidating freight loads, these systems may help reduce emissions and improve overall efficiency.

The case study of a European freight forwarder highlighted in Box 3 demonstrates how some of the issues causing empty freight capacity can be addressed. Analysis suggests that if such approaches were adopted across the US trucking industry, empty capacity could be cut by as much as 50%. This could prevent the emission of 43 billion kg of CO_2 annually, equivalent to avoiding the combustion of 16 billion litres of diesel fuel.[22]

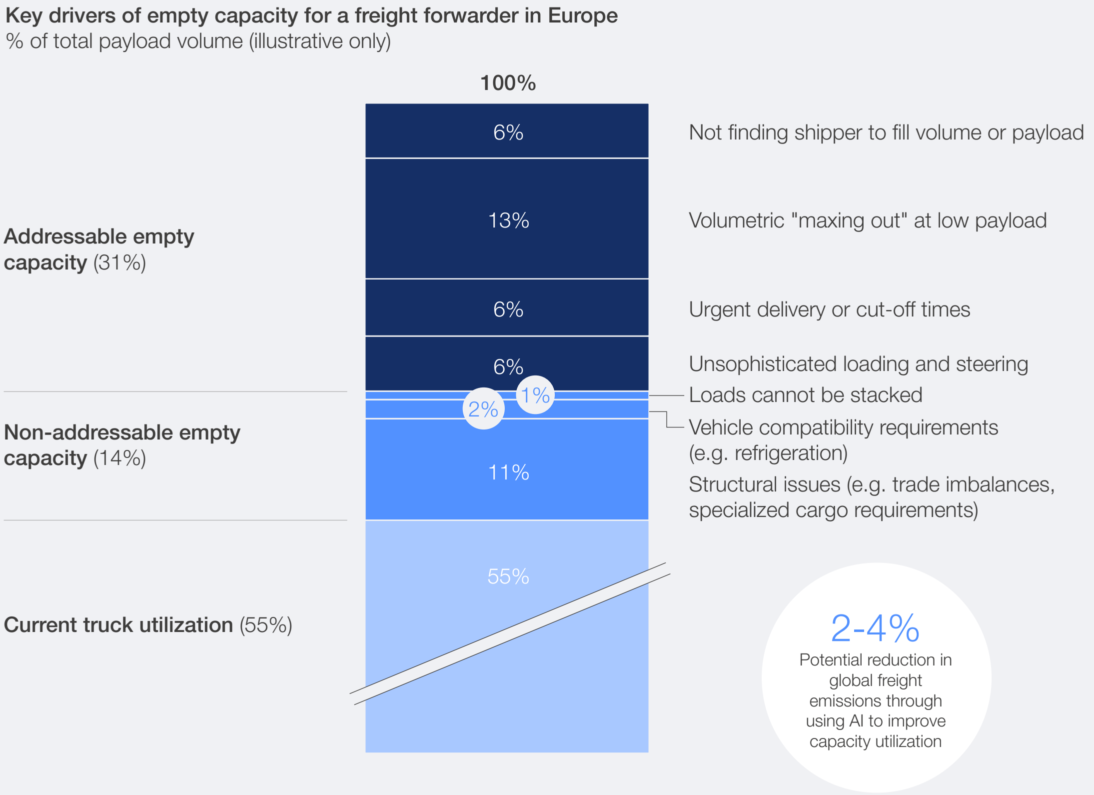
“ We truly see already today in the market that sustainable fuels and electric vehicles are the most scalable and competitive decarbonization levers – reducing GHG emissions by up to 90% per load. At the same time, advanced analytics and AI/ML are generating business opportunities for us, which then drive improvements across the transportation network we operate – including load bundling, load recommendation and predictive load matching. These move the carbon needle at the edge, but primarily improve the business case for our trucking partners, who then generate further opportunities for decarbonization as green business becomes recognized as good business.

Graham Major-Ex, Senior Director of Green Business & eMobility, sennder

BOX 3 | **Key drivers of empty capacity for a freight forwarder in Europe**

In 2020, around one-fifth of total road freight kilometres in the European Union was carried out by empty vehicles.[23] A European freight forwarder interviewed for this report faced an average of 45% empty capacity in its trucking operations (see Figure 3). While about one-third of this was due to structural challenges including trade imbalances, the remainder was caused by factors such as the difficulty of finding shippers to fill available volume, urgent delivery deadlines and inefficient loading. By applying AI solutions for dynamic freight consolidation, intelligent routing and capacity planning, this company was able to significantly reduce empty capacity.

FIGURE 3 | **Capacity utilization – AI can help address empty capacity**



Sources: Eurostat, McKinsey expert interviews.

The potential for AI in optimizing capacity utilization extends to other transport modes. Air freight experiences particularly high rates of empty capacity – often up to 40-50%, according to experts interviewed for this white paper.[24] A cargo division of a large commercial airline addressed this by implementing AI-based demand and capacity management. Using a "show rate estimation" model, the company accurately predicted booked cargo capacity over time, considering fluctuations such as weight changes, cancellations and new bookings. This approach led to an 8% increase in load factor during a 12-week pilot programme. If scaled-up, such an intervention could reduce CO_2 emissions by 80,000 to 85,000 tonnes across all relevant cargo routes.

These examples highlight how AI tools are already helping companies reduce empty capacity and unlock meaningful reductions in emissions, while also lowering costs. On a larger scale, AI may help the freight logistics industry to tackle structural inefficiencies such as consolidating freight loads in trucking or predicting demand in air freight. By leveraging real-time data and predictive analytics, businesses can be equipped to make smarter decisions – with better outcomes for decarbonization and the bottom line. As these technologies continue to evolve, their potential to transform the freight logistics sector and contribute to global climate goals will only grow.

3 Optimizing modal shifts

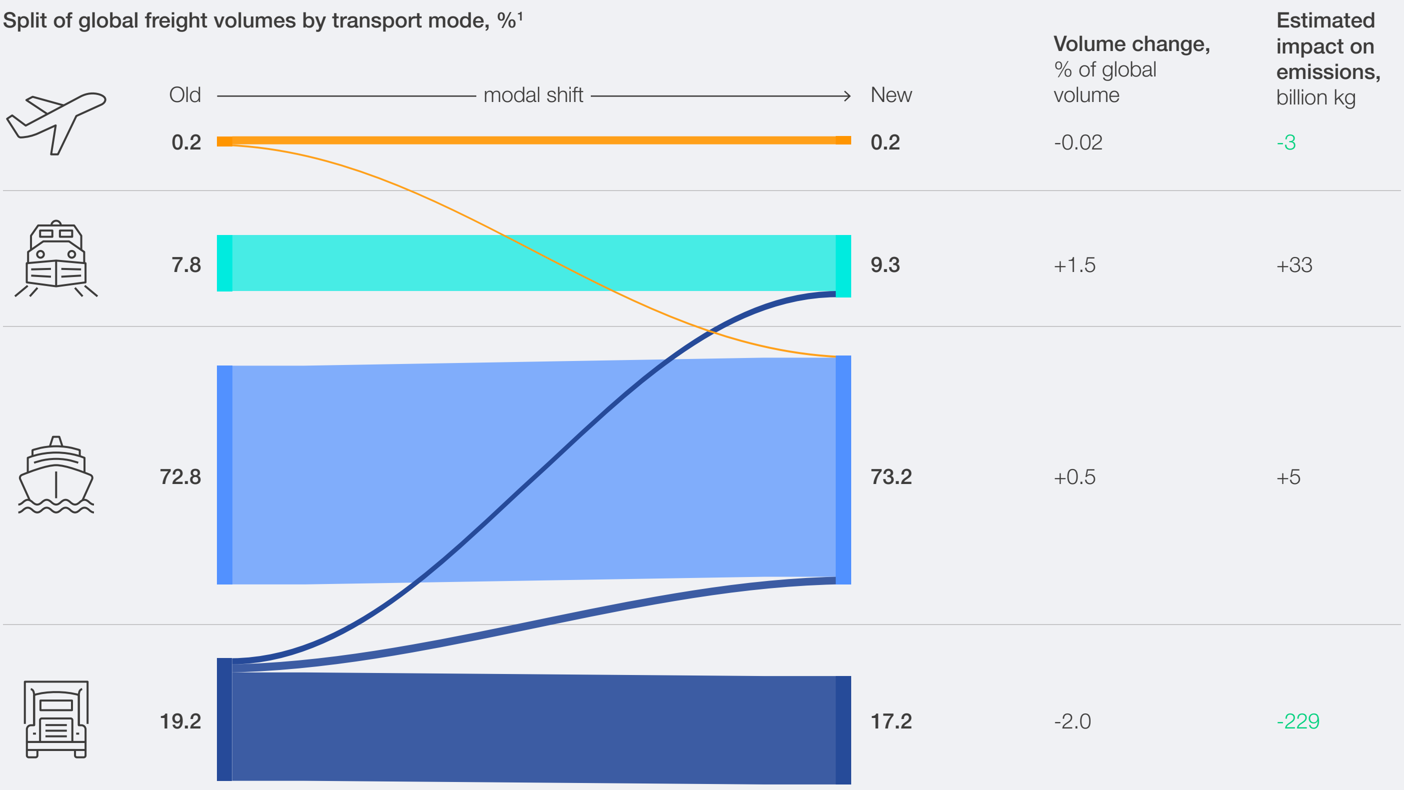
Moving freight to more carbon-efficient modes of transport could reduce global freight transportation emissions by 3-4%.

3.1 Shifting freight to lower-carbon modes of transport can reduce emissions

Currently, a portion of goods is transported using high-emission modes such as road and air, even though less carbon-intensive alternatives such as rail and sea are available. Shifting even a small fraction of freight from road to rail or sea through AI-powered solutions could lead to significant emission reductions. For example, moving cargo from long-haul trucks to rail could reduce fuel consumption per mile for the same tonnage by up to 75%, while switching from air freight to sea could cut emissions by as much as 95% per kilometre for the same tonnage.[25]

Figure 4 demonstrates that even a modest shift in global freight volumes from high-carbon to low-carbon modes of transportation could result in approximately 195 billion kg of CO_2 emission reductions. However, despite the clear environmental benefits, various structural and logistical barriers have prevented widespread adoption of more sustainable modes of transport. AI could play a meaningful role in overcoming these structural barriers and enhance decision-making processes around the type of transport used.

FIGURE 4: **Modal shifts – impact on emissions of shifting freight to lower-carbon transport**



Total estimated reduction in CO_2 emissions (in billion kg) from strategic and feasible modal shifts **-195**

1. Rounded to one decimal

Sources: MIT,[26] McKinsey expert interviews.

> **Moving cargo from long-haul trucks to rail could reduce fuel consumption per mile for the same tonnage by up to 75%, while switching from air freight to sea could cut emissions by 95% per kilometre for the same tonnage.**

3.2 Key challenges with modal shifts and potential solutions

The main challenges facing modal shifts are as follows:

- **Infrastructure limitations:** many regions do not have the necessary rail or port capacity to handle large volumes of goods currently moved by road. Rail networks are often concentrated in certain areas and expanding them is restricted by geographical and urban development constraints.
- **Geographical factors** further complicate the issue, especially for landlocked countries that lack access to ports, limiting their ability to shift from road to sea transport.
- **Modal flexibility** is a barrier, as modern supply chains rely on adaptable solutions for first-mile and last-mile deliveries. Trucks remain essential for this flexibility, especially in e-commerce, where deliveries need to be highly responsive. Whilst modal flexibility is crucial for goods including direct-to-consumer deliveries which depend on road transport, a share of bulk items such as raw materials or heavy equipment could be moved to lower-emission modes such as rail or shipping.
- **Specialized goods**, particularly high-value or time-sensitive items (e.g. temperature-controlled pharmaceuticals) require secure and fast modes such as air transport. Nevertheless, less time-critical imports and exports could potentially shift from air to sea for scalability and cost effectiveness.

AI has the potential to allow much more efficient planning and scheduling, which will allow modal shifts and flexibility. This power of AI is why we must make sure there are powerful incentives to cut emissions – so that optimization includes emissions. Failure could lead more use of AI to higher emissions modes of transport.

David Victor, Professor of Innovation and Public Policy, Global Transformation Chair in Innovation, University of California, San Diego

Large retailers have made significant public commitments to achieve net-zero carbon emissions between 2030 and 2040, reflecting a broader industry trend towards sustainability driven by increasing consumer demand and investor push. Such companies are setting standards for environmental stewardship and operational efficiency, aiming to reduce their own carbon footprints and influence the entire retail and logistics ecosystem. Modal shifts, such as moving from air to ocean freight, have become viable levers for reducing carbon emissions due to advancements in storage and handling technology, improved reefer (climate controlled shipping container) capabilities and increased reliability through predictive berth planning.

Despite structural barriers, there is room for improvement – and AI could play a critical role in overcoming challenges around modal flexibility. AI-powered solutions can manage the vast data and complexity associated with optimizing global transportation networks, making it possible to integrate lower-emission modes without compromising business efficiency. This could allow companies to make dynamic adjustments, identifying opportunities to shift from road or air to rail or sea, maximizing carbon savings without increasing costs or delivery times and consistently making the most rational emissions-reducing decisions.

We extensively consider all three modalities for our customers while developing the solutions. Modal shifts are a huge lever for both cost reduction and decarbonization.

Carsten Lützenkirchen, Senior Vice President, Commercial Operations Customer Solutions & Innovation, DHL

3.3 Use of predictive analytics to enable modal shifts

Predictive demand analytics, powered by machine learning, forecast where and when demand will peak, helping companies pre-emptively allocate resources across more sustainable modes. This level of forecasting enables better bundling of shipments, making full use of available capacity in rail and sea freight. AI could also play a critical role in optimizing logistics hubs and intermodal connections. By streamlining how goods transfer between modes, AI may mitigate the inefficiencies that arise in first-mile and last-mile deliveries – where trucks are often necessary – ensuring that goods move as efficiently as possible through lower-carbon routes (see Box 4).

BOX 4 **Optimizing modes of transport across Europe to reduce costs and emissions**

DHL worked with one of its customers in Europe, a large automotive OEM company, to use AI to optimize modal shifts. The OEM, which transports car parts from the Czech Republic and Spain to Germany using large trucks, sought a more sustainable method that would maintain similar lead times while also offering transparency about bottlenecks in the supply chain. DHL devised a multi-modal solution, integrating optimized trucking operations with existing train routes between the Czech Republic and Germany, as well as Spain and Germany. This operational change was implemented within a few weeks. The project led to a 13% cost reduction on the Spain-Germany route and a 4% reduction on the Czech Republic-Germany route. Additionally, the overall carbon emissions per tonne-kilometre per trip decreased by approximately 58%, significantly contributing to the OEM's sustainability goals.

In another case, several European businesses have begun using AI to address the challenge of first-mile and last-mile inefficiencies in rail transport. By integrating AI-driven logistics platforms, they can synchronize transport schedules and reduce idle time, making rail a viable alternative, even for goods that require precise delivery timelines. The European Union (EU) Green Deal recognizes that while 75% of inland freight is carried by road, the region has advanced rail infrastructure, so a significant portion of road freight could shift to rail and inland waterways. Digitalization and AI-powered solutions could support this massive transition.[27]

As more companies adopt AI-powered solutions, the capacity to make transportation both greener and more efficient will likely continue to grow, driving progress towards global climate targets while supporting business growth. However, despite the high potential of modal shifts to increase decarbonization, this lever is more likely to be driven by increasing demand from customers to reduce scope 3 emissions across the value chain. As large retailers make a greater push towards net-zero emissions, modal shifts will gain momentum across the freight logistics industry.

“ AI is already essential for the efficient routing of shipments across the oceans. We see further potential to minimize CO_2 emissions and reduce costs through AI, especially if combined with an even closer integration across all transport parties.

Bernhard Hersberger, Head of AI Hub Hamburg, Hapag-Lloyd

4 Critical actions needed to embrace the AI opportunity

Maximizing the power of AI to help decarbonize freight logistics will take changes in behaviour, collaboration across the ecosystem and commitment from business leaders.

4.1 Behaviour change is key to maximizing the impact of AI

The green logistics market is estimated to grow from $50 billion in 2025 to $350 billion by 2030.

Despite end-consumers, business customers and regulators signalling a desire for lower emissions, the green logistics market remains in its early stages. Research shows that over 67% of logistics customers are unwilling to pay more than a 10% premium for greener options, with only 10% willing to pay a 20% premium.[28] On the corporate side, internal incentives often need to align more closely with stated sustainability targets, but as companies approach deadlines for their net-zero commitments, we are seeing a gradual shift. The green logistics market is estimated to grow from $50 billion in 2025 to $350 billion by 2030, indicating a growing demand for greener solutions.[29]

What sets AI applications apart from traditional sustainability strategies is their ability to deliver results without requiring immediate behavioural shifts from consumers or corporate clients. AI-driven improvements do not rely on convincing customers to pay more for sustainable choices. However, maximizing any AI-powered gains will still require some mindset and behavioural shifts at the end-user level.

For example, live recommendations from an AI-powered truck maintenance system on braking would still require drivers to change their behaviour. Similarly, consumers could be encouraged to play their part by not opting for same-day delivery for less urgent purchases. To unlock the full potential of AI, companies may potentially consider a more drastic rethink. For example, instead of network optimization, companies could leverage AI for network redesign in the long-term.

4.2 Collaboration across the freight logistics ecosystem is crucial

To fully capture the AI opportunity in decarbonizing the freight logistics sector, two types of cross-industry collaborations are essential to consider:

– Vertical collaboration, such as shippers (customers) and carriers (transport/logistics providers) working together for more intermodal solutions

– Horizontal collaboration, such as trucking companies partnering with each other towards shared goals.

As the use of AI becomes more and more prevalent, data-sharing among stakeholders to foster greater data collaboration and transparency will become increasingly important. Cross-ecosystem collaboration on best practices for data management, training and transparency could drive the further development of data sets to train these algorithms and in turn improve overall performance. Collaboration in each direction may come with challenges, but the rise of AI has provided incentives for cross-industry collaboration. Every actor will have a unique role to play. While start-ups will push the frontier of innovation, incumbents will have to drive the changes needed to deliver greater sustainability.

Vertical collaboration

Competitiveness across transportation modes presents a key challenge. AI can optimize low carbon-intensity modes such as rail, but customers may only transition to these modes if they remain competitive on both cost and performance compared to higher-emission alternatives such as trucking.

Strategic partnerships and data-sharing agreements could align incentives across the value chain. For example, the European Clean Trucking Alliance (ECTA) demonstrates how collaboration between shippers, carriers and logistics providers can lead to sustainable transport solutions.[30] By sharing data and resources, they can optimize routes, improve load efficiency and collectively invest in cleaner technologies.

“ Start-ups can showcase what is possible with the data, have a positive impact on the industry’s acceptance of technology and increase the sentiment to adopt AI across the sector.

Andreas Loy, Founder & Vice Chairman of the Board, KONUX

There's a lot of regional variation in preferences, policy, economic capacity and technological infrastructure. The future world could be even more of a patchwork of policies than today. Profound changes are unlikely to emerge from global consensus, which is getting harder to forge, but from places that are willing to lead with higher standards that set new benchmarks that spread widely. This fragmented approach, while not ideal, reflects the complex realities of international coordination and the diverse capabilities of different regions.

David Victor, Professor of Innovation and Public Policy, Global Transformation Chair in Innovation, University of California, San Diego

Similarly, the EU's Technical Specification for Interoperability (ITS) defines the standards needed for seamless data exchange between operators, promoting rail system efficiency.[31]

In another example, the International Union of Railways (UIC) promotes rail transportation across regions through research and the development of technical standards. It brings together rail operators from different countries to establish common frameworks and ensure interoperability between national rail networks as they expand. UIC plays a role in creating standard technical specifications for rail equipment and promotes data-sharing protocols, ensuring that infrastructure development aligns with standardized data handling and communication systems globally.[32] For the AI emissions opportunity to be captured, data standards and governance need to be embedded in global coalition conversations.

Horizontal collaboration

Horizontal collaboration within the freight logistics industry also faces challenges. Trucking companies, for example, often operate in highly competitive environments where sharing data and resources with competitors can seem counterintuitive or raise proprietary data security concerns. This competition can hinder the adoption of AI-powered solutions that require extensive data integration and cooperation to optimize routes, reduce empty miles and improve load factors. Additionally, the lack of standardized data formats and interoperability between different companies' systems further complicates collaboration.

Companies can be reluctant to share data, thinking of it as a competitive edge. However, data collaboration can unlock much wider benefits of AI. There is potential to create an industry-wide "data lake" with low-risk parameters to foster collaboration. To unlock the full potential of AI in reducing emissions, companies could overcome these barriers by establishing trust, standardizing data practices and creating frameworks for mutual benefit. The potential for collaboration between the industry, governments and tech platform providers is evident – with strong oversight to ensure that any concerns about anti-competitiveness are mitigated.

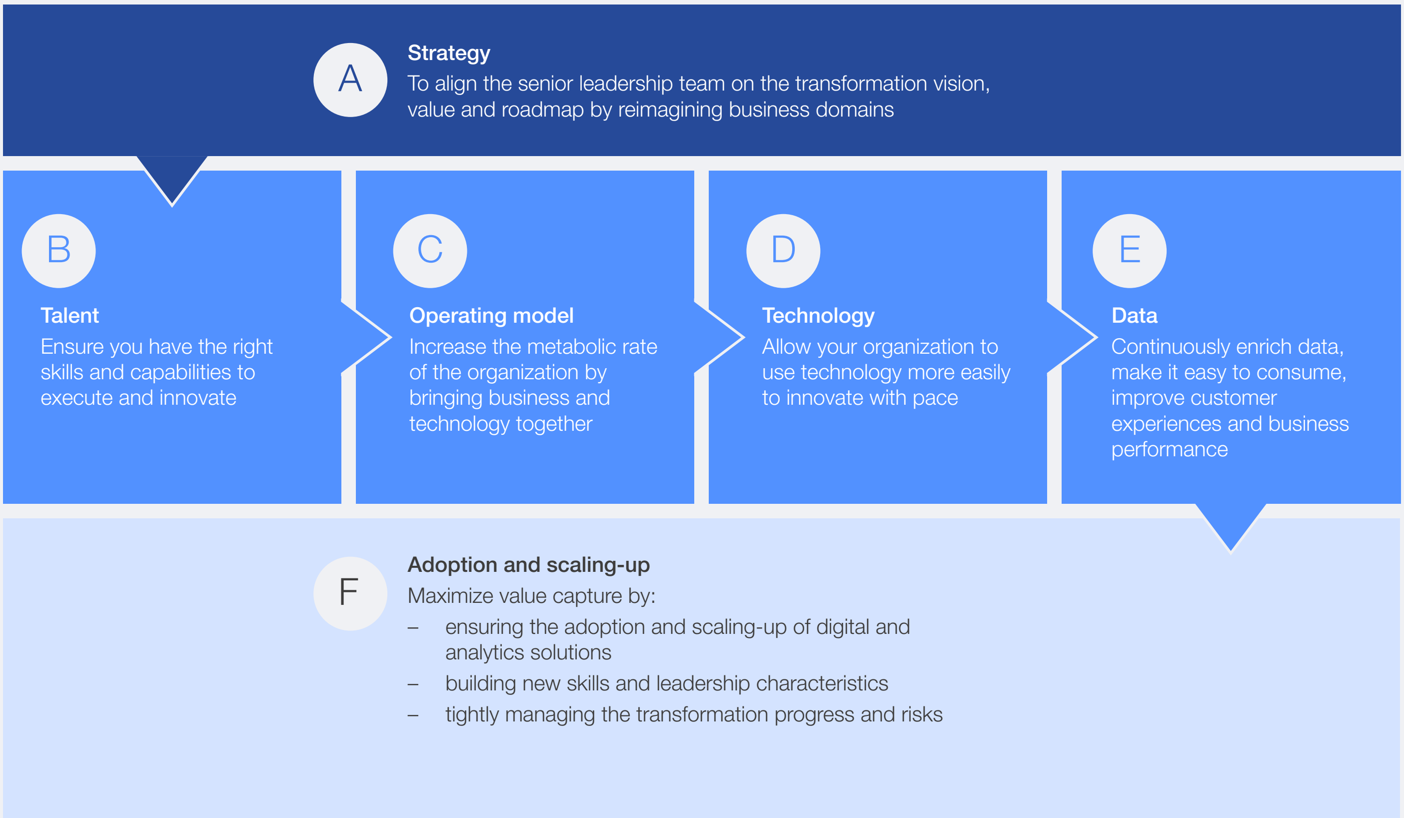
Data is most useful when abundant, but companies often think retaining it means retaining their power. There needs to be more data sharing for us all to be successful.

Tobias Fischer, Deutsche Bahn, Tech and Innovation

4.3 Integrating AI needs vision from leadership and bottom-up action

Findings from two surveys by the EU's Digital Economy and Society Index on digital adoption and use of AI show that, overall, the transportation sector has low digital maturity.[33] The surveys cite a lack of digital talent and the fragmented nature of the industry as reasons for falling behind. This underscores the need for businesses to invest in best practice when digitalizing their operating models or using AI solutions to enhance decarbonization (see Figure 5).

FIGURE 5 **Strategic framework to enhance digital maturity in organizations**



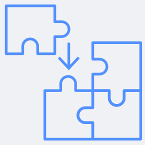
Once a clear vision has been set by business leaders, it is important to encourage a bottom-up approach to experiment with ways in which AI can deliver tangible results at company level.

Typically, companies adopt one of three approaches towards AI (see Figure 6), with some companies going on an AI journey that starts with being a "taker" and grows towards becoming a "shaper" or a "maker".

AI should be supported from the top but enabled with a bottom-up approach. Companies have to set up training and awareness for leadership and provide access for operational teams to AI applications. You need to give the people in the business the opportunity to develop ideas, given their understanding of operations and processes.

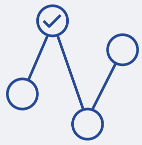
Sven Deckers, Director Sustainability, Innovation and Partnerships, Dubai Airports

FIGURE 6 | **Three approaches to adopting AI**



Taker

Integrate commercial off-the-shelf AI/ML solution into workflows as-is, with little to no customization



Shaper

Augment existing AI/ML models for specific geographic, sector and business case needs, leveraging proprietary data and insights

Maker

Develop a new foundational model from scratch, tailored to the organization

Source: McKinsey & Company.

Deploying AI for decarbonization clearly involves costs, but the benefits of proactive action could outweigh these expenses in the long run. For instance, prioritizing decarbonization could maintain investor confidence and improve financial stability. Equally, tightening regulation will increase the costs of GHG emissions. For example, given that the annual cap on EU carbon allowances (EUAs) – which allow companies to emit a certain amount of CO_2e under the Emissions Trading System (ETS) – will tighten towards 2030, pushing the projected price per tonne over €150, early investment could mitigate future costs.[34]

However, when looking at AI solutions, companies will have to factor in the carbon emissions associated with using AI itself, as the technology requires large data centres that require huge amounts of energy. Training an LLM can emit around 284,000 kg of CO_2 – as much carbon as five cars emit in their lifetimes.[35] It is important for leaders to implement AI responsibly to maximize its impact on sustainability.

Globally, there has been a significant push from large technology companies to decarbonize AI operations. For example, Google has set a target of operating 24/7 on carbon-free energy by 2030[36] and Microsoft intends to have 100% of its electricity consumption matched by zero-carbon energy purchases by 2030.[37] So the deployment of AI to reduce emissions must be evaluated against its cost and impact to ensure it makes the most sense for any given application.

Companies across the freight logistics ecosystem could consider the actions summarized in Table 2 to kickstart or accelerate adoption of AI in support of their decarbonization goals.

TABLE 2: Key actions for freight logistics providers, customers and stakeholders before 2030

Actions for freight logistics service providers	**Identify quick-win use cases:** – Start with AI use cases that are simple to implement, to build conviction and demonstrate savings; then scale-up from there to more complex initiatives. – Focus on quick-win, high-impact potential levers, such as operational efficiency gains that deliver rapid returns on investment while reducing carbon emissions.
	Build AI capabilities and an implementation roadmap: – Develop an AI implementation roadmap for the short to medium term. – Build a strong technological foundation by investing in training for relevant teams (e.g. strategy and procurement teams). – Create the right tech stack and introduce an actionable initiatives roadmap (including measurable KPIs).
	Seek cross-collaboration data-sharing opportunities: – Recognize that company-wide data can enable significant AI gains, but industry-wide data can unlock greater opportunities for emissions reduction. – Promote data-sharing and establish transparency in supply chain and process emissions, scheduling, congestion and routing data between key industry stakeholders (e.g. ports, ship operators, fleet owners, shippers and customers) to optimize operational efficiencies, load volumes and capacity utilization.
	Set up robust processes to measure carbon emissions: – Ensure mechanisms are in place to accurately measure the baseline for carbon emissions from operations. – Regularly measure and track carbon reduction associated with AI initiatives, AI use and the impact on operations.
Actions for customers of freight logistics services (e.g. retailers)	– **Evaluate carbon intensity of the existing network:** – Assess the carbon emissions within the existing logistics partner network. – Evaluate modal shift options to reduce carbon emissions and optimize cost in the process. – Apply AI tools for increasing transparency around the most rational and emission-reducing choices.
	Leverage demand power to accelerate decarbonization: – Encourage logistics service providers to increase the transparency of their sustainability strategies, especially short-term initiatives. – Consider making sustainability and/or AI-enablement a more central element of contract negotiations (e.g. a competitive dimension of RFP criteria) to incentivize transport operators to double-down on decarbonization.
	Communicate the full picture to enable customers to evaluate trade-offs: – Develop applications with AI that increase transparency about potential carbon emission impacts to empower customers to make an informed choice. – *For example:* display the environmental impact of same-day delivery compared to regular shipping via a more environmentally friendly mode.
Actions for industry decision-makers, investors and stakeholders across the ecosystem	**Explore collaborative initiatives to accelerate AI solutions:** Introduce support mechanisms, establish focus groups or identify investment opportunities to support AI implementation in hard-to-abate sectors. *For example:* pool knowledge – and potentially investments – via cross-sector sharing or even a green AI fund.
	Incentivize sustainable transportation: Consider incentivizing the sustainable transportation of goods and services through targeted programmes and funding opportunities. *For example:* incentivize the use of rail instead of road for transporting goods.
	Standardize processes: Explore opportunities to streamline trade processes and reduce cross-border challenges and delays. *For example:* align document formats regionally to reduce dwell/wait times, reducing fuel consumption.
	Collaborate on industry-wide standards: Develop responsible AI (RAI) usage and governance and provide guidance to operators for assessing and building AI trust and risk management capabilities, particularly as regulatory attention in RAI grows across many countries and regions of the world.

Conclusion

With support from AI, the freight logistics sector could potentially reduce its emissions by 10-15%, while increasing both efficiency and service levels.

The global transportation industry is responsible for up to 25% of all greenhouse gas emissions, with freight logistics accounting for 7-8% of global emissions. Consequently, there has been an increase in customer demand, regulatory pressure and investor interest for the transport sector to decarbonize. The industry now stands at a critical juncture in its bid to reduce carbon emissions.

The past few years have seen a significant inflection point in AI development, investment and adoption around the world, but AI has not yet fully made its mark on the transport sector. This shift in computational power has enabled the integration of AI across several previously technologically immature and underpenetrated industries. The freight logistics sector is one such industry, but there is now a significant opportunity to bend the emissions curve with support from AI. The technology is here today but is unevenly used. The sector can now take a big step forward towards integrating AI and achieving its full potential to reduce both costs and emissions.

The freight logistics industry has the potential to leverage AI for decarbonization across three interconnected themes, each of which could achieve significant emission reductions (see Figure 7):

1. **Enhancing operational efficiencies** to streamline day-to-day operations across all transportation modes could reduce emissions in the global freight logistics sector by 4-7%.

2. **Improving capacity utilization** has the potential to reduce global freight emissions by 2-4%.

3. **Optimizing modal shifts** to more carbon-efficient transportation could reduce emissions by 3-4%.

When such interventions are combined – taking into account that road freight is responsible for ~70% of all freight transport emissions – the freight logistics industry could potentially reduce its emissions by 10-15%, while increasing both efficiency and service levels.

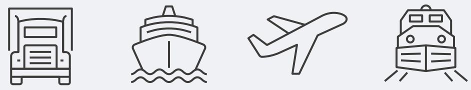
While the freight logistics sector has historically been under-digitalized, starting with quick-win use cases can help build momentum for AI, demonstrating tangible benefits for stakeholders and enhancing profit margins. Internally, companies should focus on implementing robust data management processes, incorporating AI into pricing and scheduling models and optimizing cargo space utilization to achieve early gains while building a strong foundation for further efforts.

To make this a reality, the freight logistics ecosystem could come together to seek cross-collaboration opportunities, establish uniform data norms, and measure and track decarbonization progress.

The benefits of using AI are clear: cost savings and a high degree of decarbonization potential. Early adopters of leveraging AI could potentially unlock a strategic edge on operational efficiencies and overall competitiveness. As the global economy faces a transformational shift in the way companies work with AI, the freight logistics industry is well placed to embrace AI and lead the world towards a low-carbon future.

FIGURE 7 | **Three key levers to reduce emissions across the global freight sector**

Road freight has the highest impact potential, responsible for ~70% of freight transport emissions



Enhance operational efficiency	4-5%	0-1%	0-1%	0-1%	~4-7%
Improve capacity utilization	2-3%	0-1%	0-1%	0-1%	~2-4%
Optimize modal shifts[1]	4-5%	0% to -1%	0-1%	0% to -1%	~3-4%
					~10-15%

Estimated potential reduction in emissions through AI,
% of global freight emissions[2]

Level of relative emissions reduction impact (% of global freight emissions)

<0% | 0-1% | 1%-3% | 3%-5%

1. Assumes a modal volume shift from road and air to rail and maritime for calculations, resulting in a reduction of emissions in high-intensity modes (air, road), but an increase of emissions in low-intensity modes (maritime, rail – hence negative values shown in white squares).
2. Totals might not equate exactly to values in heatmap graphic due to rounding to one decimal place.

Note: Discount factor assumptions were applied to the decarbonization impact potential of each initiative to account for possible double counting across levers. For example, a reduction in dwell times would allow for better capacity utilization for perishable goods, while routing optimization would aid in enabling modal shifts.

Source: McKinsey expert interviews informed modelling.

Annex 1: Methodology

The range of decarbonization potential reflects low and high ranges to account for uncertainty around the exact level of current AI penetration across the logistics sector and transport modes. Additional variables that will determine the full decarbonization impact potential of AI initiatives include the implementation effectiveness of organizations (e.g. employee behaviour change) and how the economics evolve for deploying AI tools and how advanced those AI tools are (e.g. basic programmes vs most advanced available).

Calculations and assumptions for the three categories of emission reductions considered in this report are below:

Empty capacity impact:

Empty capacity impact = Share of baseline emissions by transport mode that are attributed to empty capacity x Discount factor to account for less fuel consumption per mile when transport modes are lower weight (i.e. lower capacity) x Share of emissions that can be reduced through AI/ML levers (as not all will be abated through AI/ML).

Modal shift impact:

The % of logistics trips, broken down by transport mode and by cargo volume was the starting baseline. Assumptions of the shift in cargo volume across transport modes enabled by AI initiatives was then applied to this baseline (e.g. reducing air freight and adding to rail) to get a new optimized modal split of cargo volume by transport mode. Transport mode specific emissions factors were applied to the baseline and new cargo volumes. The delta is the decarbonization impact potential estimate.

Operational efficiencies impact:

This is the sum of decarbonization impact compared to baseline emissions that AI can address across four operational levers (driver behaviour, route planning, dwell time, predictive maintenance). The figure is discounted for an overlap in impact to avoid double counting across levers (e.g. route planning is only effective if driver behaviour is also enacted). The total impact across these four levers equals total operational efficiency levers.

All the above assumptions were validated and refined with experts as well as triangulating with public research reports and expert interviews. A high and low range was used to reflect discrepancies in expert input and reflect uncertainty in projections of AI/ML's full-scale potential.

Where sources reference McKinsey expert interviews, this analysis is based on interviews conducted by McKinsey & Company with 10+ AI and transportation experts from September to November 2024, in addition to leveraging learnings and data analysis from numerous relevant logistics client engagements.

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Acknowledgements

The World Economic Forum and McKinsey & Company would like to express special gratitude to the following individuals for their contribution and insights shared during interviews. The paper does not necessarily reflect the views of these individuals and/or their companies. Expert advice is purely consultative in nature and does not imply any association with the takeaways or conclusions presented within this paper.

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We would also like to thank the individuals below for their overall insights, stimulating discussions and peer review of this report.

Devendra Jain
Initiatives Lead, Frontier Technologies for Operations, World Economic Forum

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Editor

Endnotes

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