

Insights. Shaping Tomorrow.
Your guide to innovation in logistics.
AI & workforce in focus.



The image depicts a futuristic, circular arena or track system. The central area is a large white circle containing the text. Surrounding this is a wide, light blue track with glowing green and blue lines. The track is divided into segments by radial lines. Various figures are positioned around the track: a white humanoid robot at the top, a person in an orange shirt holding a tablet on the right, a yellow and black robotic arm on the right, a person in a green shirt on the right, a small white robot at the bottom right, a yellow and black robotic arm at the bottom, a person in a red and yellow shirt at the bottom left, and a small white robot on the left. A yellow car is partially visible at the top left.

**INSIGHTS.
SHAPING
TOMORROW.**

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Insights. Shaping Tomorrow.

In a volatile, complex, and ambiguous world, competitive advantage increasingly depends on an organization's ability to anticipate change, identify what truly matters, and translate insights into actions. As developments across business, technology, and society accelerate and become more interconnected, supply chains and logistics are evolving from operational necessities into strategic differentiators that shape resilience, customer experience, sustainability, business performance, and ultimately competitiveness.

Artificial Intelligence (AI) stands out as a defining catalyst.

From autonomous decision-making to physical AI in robots, vehicles, and machinery, AI is creating endless possibilities across logistics while unlocking data and insights on an unprecedented scale. Its influence extends beyond logistics operations, changing how consumers discover and purchase products and how companies approach new business models as well as customer and employee experiences. **Yet logistics will remain a people business.** Its future relies on effective collaboration between people and intelligent systems, combining human creativity, judgment, and experience with the speed, precision, and scalability of technology.

The DHL Logistics Trend Radar™ has helped countless customers, colleagues, and partners navigate emerging developments and identify meaningful innovation opportunities. Now in its eighth edition, the Logistics Trend Radar helps organizations distinguish lasting signals from short-lived excitement, understand where value can be created, and explore how innovation can be applied responsibly and at scale. This perspective draws on DHL's global innovation ecosystem, bringing together customers, startups, technology providers, academic institutions, and subject matter experts. Together, we combine foresight with hands-on experimentation to test emerging solutions in real logistics environments and learn what delivers real value.

Ultimately, the impact of the Logistics Trend Radar extends beyond its pages. It can be found in the **conversations, collaborations, and innovations it inspires across the global logistics community.** By creating a shared understanding of emerging developments, the Logistics Trend Radar helps turn insights into implementation and ideas into real-world impact. We invite you to explore the trends, use cases, and opportunities in this edition and join us in shaping the future of logistics...

...responsibly, sustainably, and with people at its center.

"The Logistics Trend Radar 8.0 helps organizations understand technology and workforce interdependencies and focus on the developments that will have the greatest impact on their business and people. The future of logistics will be formed by those that successfully combine technological innovation with human expertise."



Katja Busch
Chief Commercial Officer DHL,
Head of DHL Customer Solutions & Innovation

"The value of foresight lies in making better decisions today. The Logistics Trend Radar helps organizations cut through the noise and focus on innovations that deliver real value at scale."



Dr. Klaus Dohrmann
Vice President, Head of Innovation & Trend Research
DHL Customer Solutions & Innovation

What's New

The DHL Trend Research team has been closely monitoring key technology as well as social and business trends for over a decade. Every two years, the team updates the Logistics Trend Radar to reflect our perspectives on the development of existing and newly emerging trends, and how they impact logistics as a whole.

Since the publication of the previous edition of the Logistics Trend Radar in 2024, we have witnessed several relevant developments that influenced both trend adoption and trend impact – this has changed the position of some trends in the radar. Additionally, through numerous engagements with customers, colleagues, and

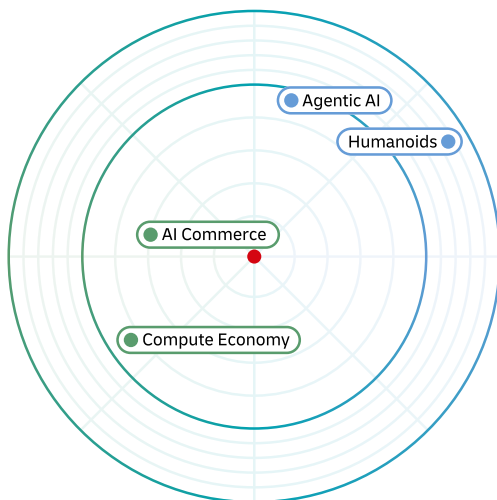
partners around the globe, we have identified new trends relevant for logistics leaders.

These updates shape the latest edition, in particular highlighting significant advancements in artificial intelligence (AI) and people-focused trends.

To further improve the user experience, we have worked on accessibility as well as interactivity of the Logistics Trend Radar website. For the first time, the Logistics Trend Radar 8.0 features RAY, an interactive chatbot that guides users through the content, helping them explore trends, use cases, etc., and find answers to their questions.

Overview of Changes

New Trends



Compute Economy

The Compute Economy relies on digital infrastructure to power AI, cloud, and data-driven services worldwide. As demand grows, the need for scalable computing resources continues to expand.



AI Commerce

AI Commerce uses artificial intelligence to improve buying and selling through automation and personalization. As AI adoption grows, commerce is becoming more efficient and tailored to customer needs.



Agentic AI

Agentic AI enables autonomous systems to perform tasks and make decisions with minimal human intervention. Its growing adoption is driving greater automation and efficiency across industries.



Humanoids

Humanoids are human-like robots designed to perform physical tasks and assist people in a wide range of environments and applications. Their growing adoption can accelerate automation and improve productivity.

Refined Trends

Diversity, Equity, Inclusion, Belonging



Employee Belonging

Workforce Focus



Augmented Workplaces

Vehicle Electrification

SPLIT



Light Vehicle Electrification



Heavy Vehicle Electrification

Advanced Analytics



AI Analytics

Drones



Unmanned Aerial Systems

Our Innovation Approach

It is our core belief that delivering impactful innovation in logistics for efficiency, quality, sustainability, and safety can only be achieved by staying close to customers, close to technology, and close to operations.

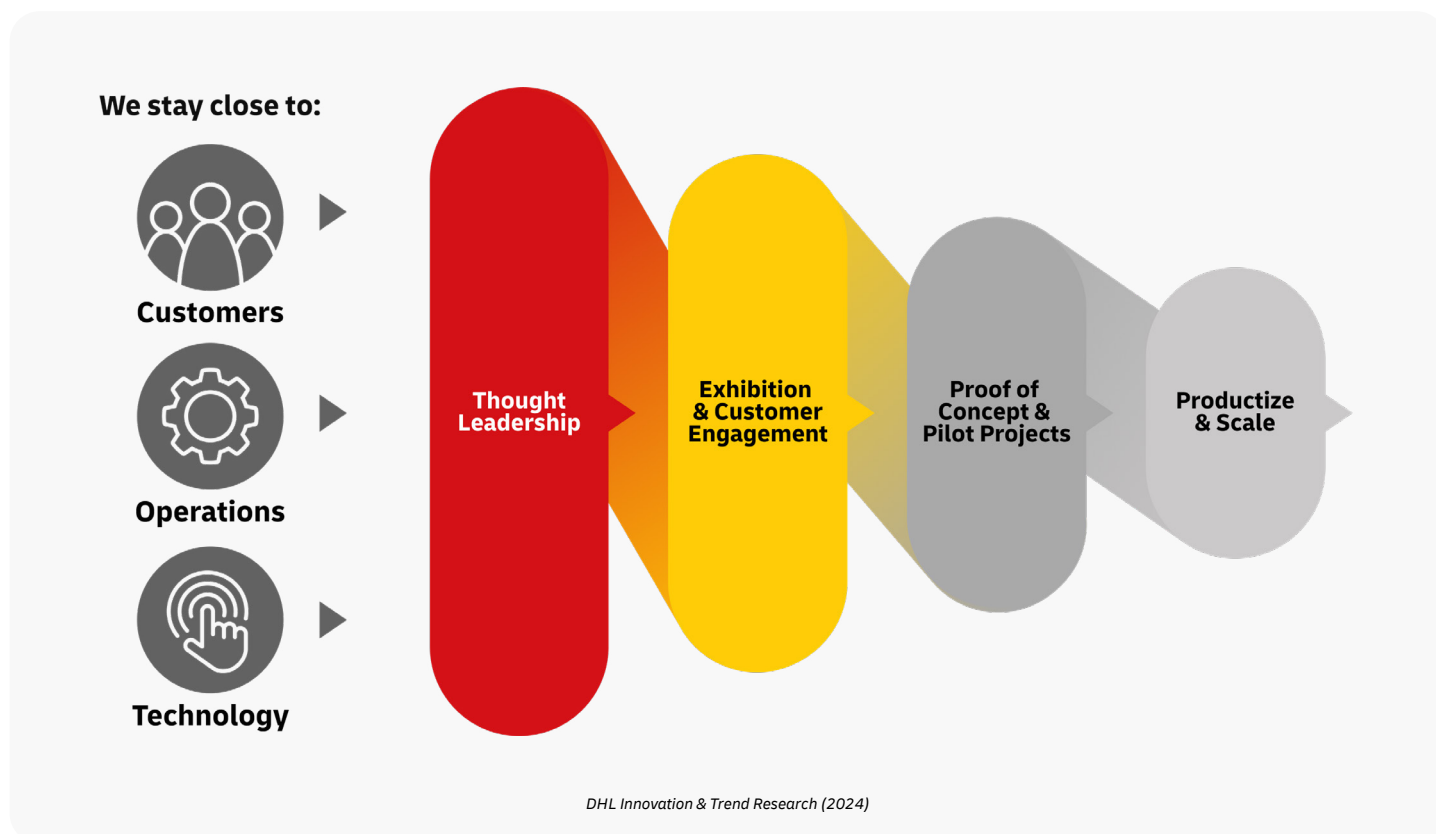
This is the basis of the Logistics Trend Radar, DHL's customer-centric, integrated approach. It empowers us to harness the perspectives of our valued customers along with those of DHL colleagues who are on the ground daily, driving and experiencing the transformation of logistics. We complement these insights using classic research methodologies and incorporate the viewpoints and assessments of multiple experts, including key opinion leaders from influential think tanks, renowned consultancy firms, and top-tier academia from around the world.

We foster open dialogue with our customers to understand their business strategies, future needs, and challenges. This enables us to validate ideas, develop relevant use cases, and apply the right technologies and expertise. Strong customer engagement and collaboration across our innovation ecosystem are key to our success.

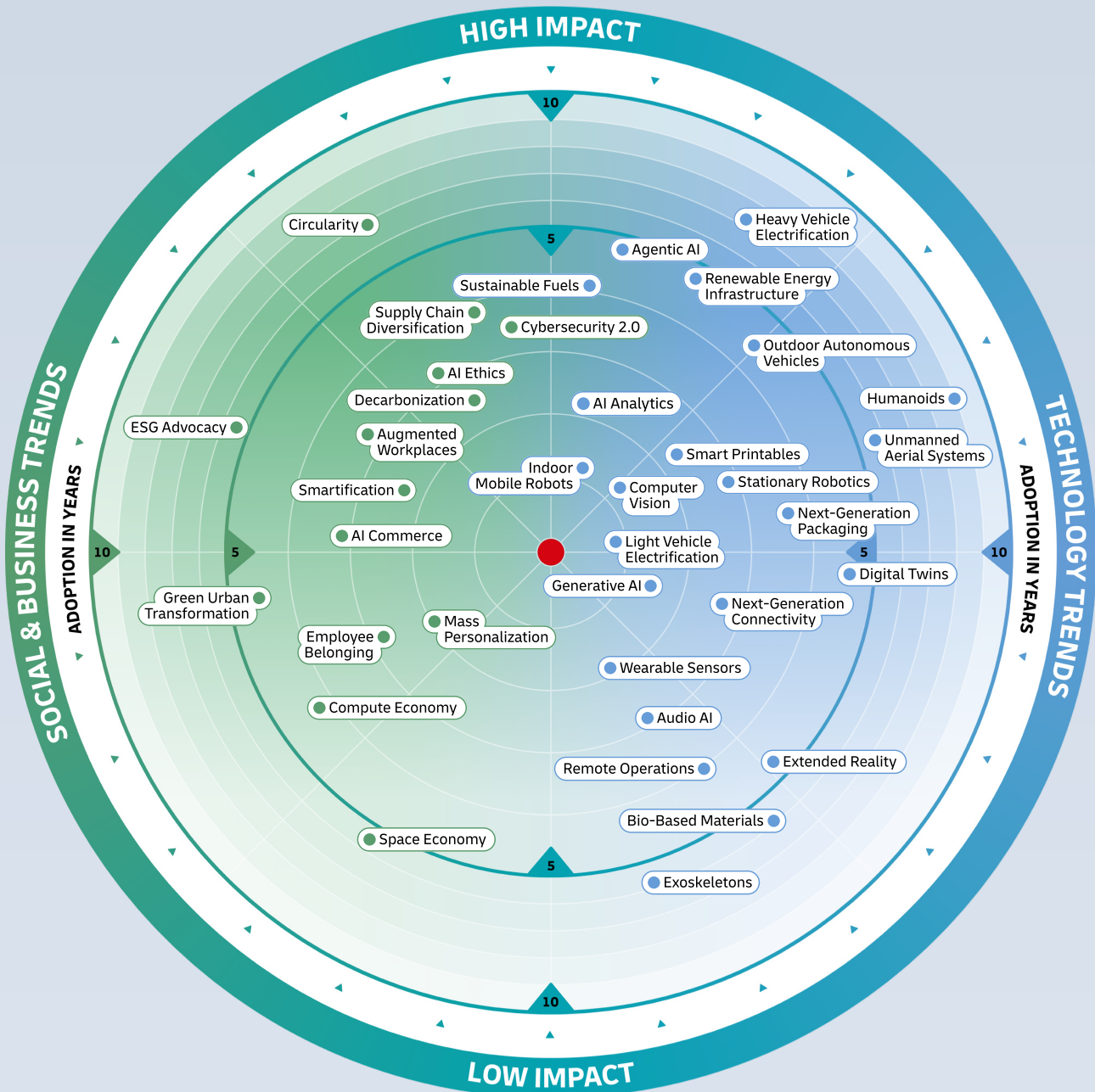
In addition, we are driving the transformation of logistics by tracking and engaging visionary developers and providers across industries covering startups as well as established global providers for us to stay at the forefront of emerging technology and supply chain innovation. Through this, we can identify and co-create new solutions beneficial to our customers and colleagues.

This approach forms the foundation of the Logistics Trend Radar, and many other DHL thought leadership trend reports. With a finger on the pulse of relevant trends, we run proof-of-concept projects in real-world supply chain settings with our customers and within the DHL network of operations to fully understand application benefits and challenges. Successful projects are then scaled and productized, making innovative solutions available across DHL operations and commercially to our customers worldwide.

Trend Research Innovation Funnel



THE RADAR



HIGH IMPACT

Revolutionary applications that are potentially disruptive.

LOW IMPACT

Evolutionary changes with incremental improvements.

ADOPTION

The common way of operating and doing business in logistics.

SOCIAL & BUSINESS TRENDS

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AI Commerce

Trend Overview

Impact:

CONSIDERABLE

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Customer Experience

Trend Clusters:

Artificial Intelligence

Sectors:

eRetail & Fashion



The trend of AI Commerce integrates artificial intelligence (AI) across the entire commerce value chain to create human-in-the-loop shopping experiences that are efficient, predictive, and hyper-personalized. It spans the spectrum from AI-enhanced product discovery to fully autonomous purchasing, with agentic AI applications handling the consumer journey end to end.

Artificial intelligence began in e-commerce as AI-guided assistance for consumers in areas such as brand and product discovery. Now it is expanding into more advanced AI capabilities across the full commerce value chain, including automated product content creation, dynamic pricing and marketing intelligence, and highly tailored personalization. To properly streamline end-to-end operations, it requires machine-readable product pages, pricing, logistics, and fulfillment data. As this evolution continues, it will reshape not just how consumers shop, but how the entire commerce ecosystem functions.

The transition can be understood as a gradual curve of automation, moving away from the current, customer-led search process toward increasing levels of AI influence. In early stages, AI enhances discovery by guiding users toward relevant products and options. This evolves into more agentic behaviors, where AI systems actively scan and compare options on behalf of the user based on predefined criteria and notifying users when conditions are met. Here transactions remain user-approved. Ultimately, once fully autonomous systems are available, they will manage end-to-end purchasing, including selection, negotiation, and checkout. This stage depends on emerging standards, interoperability frameworks, and secure transaction infrastructures, which are currently under development.

Alongside this shift, a new taxonomy is emerging to describe how different types of AI systems shape the shopping journey. “Horizontal systems” integrate the entire shopping experience, ranging from discovery to checkout within general-purpose conversational interfaces such as chat-based platforms like ChatGPT or Gemini. In contrast, “vertical systems” are embedded within specific retail environments, like Ask Macy or Amazon Rufus, enhancing individual platforms with conversational capabilities that support product search, comparison, and decision-making. These two systems illustrate how the trend of AI Commerce is not only transforming the mechanics of shopping but also redefining where and how interactions take place across digital ecosystems.

AI-driven shopping is already generating measurable value. In late 2025, AI-originated recommendations achieved higher conversion rates than traditional referral channels such as paid search and social media. However, fully autonomous AI Commerce remains nascent, with industry experts describing current efforts as early-stage and little mention of it among consumer goods leaders.

Research highlights an important nuance in consumer behavior: people are generally more willing to outsource cognitive effort than to relinquish control. Rather than fully handing over decision-making, consumers tend to prefer systems that reduce complexity, filter options, and provide informed guidance, while still allowing them to retain final authority. The 2026 DHL E-Commerce Trends Report shows that the generation factor directly impacts the adoption curve, with almost a third (29%) of surveyed shoppers (rising to 33% of Gen Z and 36% of millennials) saying they would be happy to hand over control of their shopping to AI and let it make shopping decisions or purchases for them in the next five years.

In the retailer industry, L'Oreal openly shared a direct data partnership with ChatGPT, through which they load their proprietary data so that ChatGPT doesn't have to scrape it, making sure that it is the data they want the consumer to find. This is one of the few concrete, executable actions a brand can take today. The fact that only one company out of 31 CPG brands at the 2026 CAGNY conference mentioned it says how early this trend actually is. Instacart also positioned themselves as not rushing to build a business case around agentic grocery commerce, but, for now, to run tests and observe how partnerships between retailers and AI platforms are influencing business.

What does this all mean for logistics? This gradual curve of adoption places AI Commerce at an early but accelerating stage of impact. While it will likely transform retail and the consumer experience, we see a more moderate but meaningful impact on supply chains, with three key developments taking shape. First, as AI Commerce increases convenience, customer expectations for seamless and fast post-purchase experiences will rise. Second, retailers leveraging AI agents to optimize sourcing and costs may diversify their logistics networks, dynamically allocating volumes across multiple providers. Third, improved demand forecasting through AI could reduce excess inventory and, over time, lower reliance on warehousing capacity.

AI Shopping Use Cases

From Assisted Discovery to Delegated Purchasing

Increasing role & control by AI agent



We are currently here

AI-Assisted Discovery Purchase

Example
Laptop bag for business travel

AI
Searches, compares & shortlists products

Human
Decides & completes the purchase

AI-Enabled One-Click Checkout

Example
Noise-cancelling headphones

AI
Recommends product & executes checkout after confirmation

Human
Confirms the purchase

Autonomous Replenishment Agent

Example
Pet food or household consumables

AI
Selects retailer, price & timing autonomously

Human
Defines needs & spending rules

Fully Delegated Commerce Agent

Example
Everyday household shopping

AI
Manages shopping end-to-end across categories & retailers

Human
Sets preferences & budgets only

AI-mediated shopping is already here, but the future will bring increasing involvement by AI agents, from assisted discovery to delegated purchasing.

ECDB (2026): Global E-Commerce Trends 2026

Relevance to the Future of Logistics



Fully Integrated, AI-Driven Inventory Management

Retailers who adopt AI-enabled market intelligence will continuously track competitor activity and consumer performance data. Such dynamic analyses can generate predictive insights about sales volumes and restocking needs, aiming for the most precise and efficient production-to-shelf ratio.

The leveraging of AI to sharpen demand forecasting can impact supply chains in two main aspects. First and foremost, minimizing surplus stock might, in the long run, decrease the need for extensive warehousing capacity, directly affecting logistics providers' business. Secondly, the increasing velocity of incoming insights from the retailer demands a solid, frictionless, and always-on integration with supply chain networks (e.g., ordering, storing, and picking), so that the investment in intelligence translates into actual operational efficiency. For logistics providers, this connectivity between retailer systems and supply chain networks, involving API platforms, event-driven integration, real-time inventory visibility, data synchronization, and interoperable enterprise platforms, becomes a critical dependency and a differentiating capability. A world shaped by AI Commerce will rely on intelligent, predictive, and agile inventory management and forecasting.

Fulfillment Performance as an AI Visibility Driver

A new layer of competition is emerging around AI visibility: how AI identifies, evaluates, and recommends products and brands. Instead of relying solely on traditional search rankings or paid placement, retailers must increasingly optimize how AI models interpret product attributes, customer experiences, and overall value. In this context, it becomes critical to be "recommended" by AI to generate demand and conversions, which introduces new performance drivers.

When generating recommendations, AI systems weigh multiple factors, including price competitiveness, product relevance, brand reputation, and order fulfillment quality. As a result, achieving visibility in AI-driven interfaces goes well beyond brand reputation to end-to-end operational performance.

An example of this emerging dynamic is Parcel Perform's AI Index, which tracks how AI shopping assistants recommend brands. AI assistants may increasingly recommend based on visibility, ranking, sentiment and after-sales experience signals.

The growing importance of AI visibility has direct implications for logistics. AI-driven product rankings are significantly influenced by fulfillment-related factors such as delivery speed, reliability, and available shipping options. As AI assistants optimize for the best overall customer outcome, logistics performance becomes a key input into recommendation algorithms, elevating logistics from an operational function to a critical lever for securing visibility and competitiveness in AI-mediated commerce.

The same applies to logistics' own platforms, demanding AI visibility enhancement in order to be considered by retailers' agents performing price comparison.



Chat-First Customer Interactions

As AI Commerce evolves, it transforms the shopping experience into a conversational, always-on interaction, with each consumer having a personal AI-enabled digital shopper. Conversation becomes the default layer across the entire customer journey, requiring new services to integrate seamlessly into chat-based interfaces. In doing so, it is beginning to upend traditional formats and could even lead to the disappearance of virtual storefronts. Emerging solutions such as Swap Agentic Commerce Platform already illustrate this shift, enabling “chat-first” e-commerce experiences where discovery, decision-making, and transactions happen natively within conversational interfaces rather than traditional storefronts.

For logistics, this shift extends well beyond basic tracking visibility. Providers will need API-enabled systems that stream real-time, context-aware information directly into conversational interfaces – similar to a live location feature in messaging platforms. This includes dynamic shipment tracking, proactive delay notifications, and the ability to modify delivery options (e.g., rerouting or rescheduling) right in the conversation.

At the same time, conversational AI introduces new forms of decision-making support. Customers and businesses can compare delivery speeds, price options, and sustainability metrics in real time, with AI recommending optimal logistics choices based on preferences and constraints. For enterprise users, this extends to procurement and network decisions, where agents can evaluate multiple carriers simultaneously and suggest trade-offs between cost, speed, and reliability.

As voice and chat interfaces become the default layer for customer interaction, the logistics providers best placed to benefit from this shift will be those that move beyond static, system-based (transactional) interactions to dynamic, API-enabled (conversational) services capable of operating within the chat interfaces their customers already use.



Summary & Trend Overview

Challenges



As AI-guided discovery and fully agentic purchasing raise the bar for convenience and seamlessness, the same expectations extend to the post-purchase experience, placing greater pressure on logistics providers to deliver a matching level.



Poor data quality and gaps in API integration between logistics warehouse management systems and retailer resource planning platforms undermine the quality of AI-generated insights and increase the risk of disruptions and missed estimated delivery dates.



With the shift from website experience to AI-accessible systems and services, retailers must fundamentally rethink their discoverability strategies. The audience moves from human shoppers to AI agents: reachability now requires optimizing for agentic engine optimization (AEO) alongside traditional search engine optimization (SEO).



When agentic AI optimizes retailer supply chains for cost efficiency, it may dynamically distribute volumes across a wider pool of logistics partners, increasing the risk of commoditization and reducing the opportunity for logistics providers to build strong customer relationships and increase their share of wallet.

Outlook

AI Commerce is already reshaping how consumers discover and buy products, naturally also how they select logistics providers, compare quotations, negotiate delivery options, and the autonomous execution of bookings. “Horizontal” agents like ChatGPT and Gemini are becoming primary interfaces for product discovery, guiding users through what to buy and why “Vertical” agents embedded within specific retail environments – such as Amazon’s Rufus and Swap’s conversational commerce solution – are already generating measurable sales impact.

The companies best positioned as AI Commerce matures are those building the necessary infrastructure, securing partnerships, and ensuring they are discoverable within AI-mediated environments.

For logistics providers, the trajectory is comparable. As retailers increasingly use AI agents to scrape data and negotiate with logistics partners, the underlying data infrastructure will need to be structured, accessible, and reliable enough to participate in those automated interactions.



Strategize – This trend has the potential to bring substantial change across logistics with use cases in some applications that can already be addressed today.

Related Trends

Supply Chain Diversification



Agentic AI



AI Ethics



Mass Personalization



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AI Ethics

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Health, Safety & Future of Work

Physical & Digital Security

Trend Clusters:

Artificial Intelligence

Digital Backbone



The trend of AI Ethics represents the embedding of responsible design, deployment, and governance principles into artificial intelligence (AI) systems, ensuring alignment with evolving legal requirements and ethical norms. It also addresses the legislative frameworks governing AI platforms and the implications of data safety and algorithm security.

AI ethics is an evolving, multidisciplinary field concerned with ensuring that AI technologies are developed and deployed responsibly. What began as a conceptual discussion has rapidly progressed into a topic with tangible operational and workforce impact in logistics, as the number, complexity, and autonomy of AI applications within logistics and the supply chain continue to grow.

AI adoption in business functions continues to accelerate. In 2025, 88% of organizations used AI, up from 55% in 2023. This rapid scaling brings ethical risks into sharper focus. According to the US National Highway Traffic Safety Administration (NHTSA), year-over-year incidents involving AI-enabled autonomous vehicles grew 51% from 2024 to 2025 – a concrete indicator of how unresolved accountability questions are translating into real-world consequences. The emergence of agentic AI capable of independent reasoning and decision-making is intensifying these discussions further.

The ethical dimensions requiring attention include bias, privacy, explainability, and transparency, as well as trustworthiness, robustness, and interpretability, as outlined in various Explainable AI, often referred to as XAI framework, an entire sub-field of technology focused on making “black-box” systems human-understandable. These principles are being stress-tested by growing real-world examples of unethical AI use, such as predatory

surveillance practices to enforce unrealistic efficiency targets and misuse of data collected without proper consent, which continue to drive the evolution of legislation and standards. The trend plays a critical role in logistics, as the number, the complexity, and the autonomy of AI applications within logistics and the supply chain continue to grow.

AI ethics standards call for robust data protection measures to safeguard customer information and proprietary data, especially as AI-driven systems operate with greater independence and scale.

Company compliance regulations are also expanding to address the proper use of company data as AI integrates with collaboration tools and company platforms. Here at DHL, we recognize that these regulations must align with national laws while also adapting to emerging AI-driven risks and responsibilities – creating a new domain within compliance, including updated legal clauses and contractual obligations for employees in an AI-enabled workplace.

The speed at which AI ethics will become embedded in logistics operations is accelerating, but integration remains uneven. Most organizations are still navigating the transition from principle-based commitments to auditable, enforceable practices.

However, rising concerns around data privacy and security are driving organizations toward more accountable and explainable, generative AI systems. As expectations continue to evolve, businesses will be under greater pressure to embed responsibility into their AI strategies and operations.

Ethical responsibility is also becoming more complex at the model level, extending beyond individual software providers to entire AI systems and their life cycles. Addressing this requires integrated governance approaches – sometimes exceeding legal requirements – that address development, deployment, monitoring, and continuous improvement.

The regulatory landscape provides the clearest near-term signal. The EU AI Act (2024), certifiable AI management systems like ISO/IEC 42001 (2023), and enterprise-wide accountability mechanisms are becoming central to AI governance, particularly for advanced applications including foundation models and AI agents. Together, these frameworks signal that structured, auditable, and organization-wide governance is moving from a best practice to a baseline requirement.



Effective AI governance must be integrated within a business, demanding an orchestrated systems approach.

Info-Tech (2026): Establish Your Adaptive AI Governance Program: From Principles to Practice

Relevance to the Future of Logistics

Governed Agentic Systems

In logistics, agentic AI systems are increasingly taking responsibility for end-to-end operational decisions, coordinating across multiple functions, and interacting with other agents. This evolution marks a shift from isolated AI-supported recommendations toward autonomous systems that act continuously and at scale. As these systems grow in complexity, governance will need to evolve from focusing on individual decisions to overseeing system-level behavior, including how multiple agents interact, adapt, and influence outcomes over time.

To address these challenges, organizations are implementing real-time governance mechanisms, including continuous monitoring, runtime controls, and fail-safe interventions such as kill switches. Traditional checks and balances are being redefined, particularly in high-stakes scenarios such as financial or operational decision-making, where additional layers of oversight are required. Furthermore, continuous validation processes are gaining traction for ethical assurance, including ethical audits to monitor deployed AI systems for model drift, unintended behaviors, or emerging biases that may not have been evident during initial testing. Such processes give organizations a proactive approach to maintaining system integrity and trustworthiness in dynamic environments.

Underpinning these mechanisms is the principle that human judgement remains integral to AI-governed operations. Human-in-the-loop frameworks are particularly important for decisions with significant operational, financial, or societal impact, ensuring that expert oversight complements automated processes and that organizations can balance efficiency with accountability. Together, these measures reflect a broader transition toward structured, adaptive governance models that enable the responsible use of agentic AI systems in complex logistics operations.



Sustainable AI

In logistics and supply chain management, the concept of sustainable AI is expanding the scope of AI ethics beyond fairness and bias to include environmental impact. The rapid growth of AI adoption is driving a significant increase in energy consumption across digital infrastructure globally. As AI workloads scale, data centers are projected to place growing pressure on electricity demand, raising concerns about alignment with corporate and industry climate targets. In logistics, where data-intensive applications such as demand forecasting, network optimization, and autonomous operations are expanding rapidly, this creates an ethical dilemma: the same AI capabilities that enable more efficient logistics operations require substantial computational resources to run, with associated energy use, water consumption, and carbon emissions that can offset some of the environmental gains.

Despite these challenges, AI remains a powerful enabler of more sustainable supply chains. Applications such as route optimization, load consolidation, and predictive planning can significantly reduce emissions by improving asset utilization and minimizing waste across transportation and warehousing processes. These capabilities are particularly relevant in global logistics networks, where small efficiency gains can translate into substantial environmental benefits at scale.

As a result, ethical AI strategies in logistics are increasingly incorporating sustainability-focused principles. This includes adopting carbon-aware computing practices, prioritizing model efficiency, and selecting infrastructure and deployment approaches that reduce environmental impact. By embedding these considerations into AI governance frameworks, logistics organizations can ensure that innovation not only drives operational performance but also supports long-term sustainability objectives.



AI Regulation & Compliance Frameworks

The regulatory environment governing AI in logistics and supply chain management is undergoing a major structural shift, moving from voluntary principles to enforceable regulation. However, the global landscape remains fragmented, varying widely from region to region. While the EU is leading with binding rules, the United States follows a more flexible approach, and the Asia-Pacific region has yet to establish comprehensive frameworks. This increases complexity for globally operating logistics providers.

The EU AI Act, introduced in 2024, has been a key driver in Europe. It establishes binding requirements and significant penalties of up to €35 million or 7% of global turnover. The regulation classifies several logistics-relevant applications as high risk, including workforce management, safety systems, and biometric use cases. Compliance requires organizations to maintain risk management systems, detailed documentation, human oversight, and ongoing monitoring throughout an AI system's lifecycle.

Alongside regulatory compliance, ethical AI certifications are emerging as compliance and trust signals within global supply chains, including the Ethics Certification Program for Autonomous and Intelligent Systems (ECPAIS), the AI Ethics Impact Group (AIE-IG), and the International Association for Safe & Ethical AI (IAEAI).

International standards are becoming key anchors for harmonization. The first certifiable AI management system (ISO/IEC 42001) covers ethics, transparency, bias, monitoring, and accountability, and is expected to support compliance with regulations like the EU AI Act and customer audits in the coming years.

Agentic and multi-agent AI systems present a particular challenge in this context, with regulations lagging behind the pace of technological innovation. While these systems fall within the broad legal definition of autonomy under the EU AI Act, they struggle to meet its traceability, logging, and human oversight mandates. The industry is preparing for a wave of operational rules, security mandates, and technical oversight standards aimed at closing the compliance gap.



Workforce Impact & Ethical Transition

The growing adoption of AI in logistics and supply chain operations is reshaping the relationship between technology and the workforce. As automation and agentic systems take on more advanced tasks, legitimate concerns are emerging about displacement, the distribution of value created by AI, and the long-term socioeconomic impact on workers. While these debates remain largely conceptual, they are gaining visibility and beginning to influence how organizations approach workforce strategy.

In the near term, the focus is on positioning AI as a tool that augments rather than replaces human capabilities – enabling more efficient planning, safer operations, and improved decision-making across warehouses, transportation, and control towers. Clear employee communication plays an important role in this transition, helping to frame AI as an enabler rather than a threat and supporting adoption across diverse operational environments.

However, effective human-AI collaboration requires investment in people. Reskilling and upskilling are gaining priority as logistics organizations invest in training programs that equip employees to work alongside AI systems and adapt to evolving roles. Legislative efforts aimed at protecting workers' rights in an increasingly automated environment are gaining traction, reinforcing the case for responsible workforce integration as part of broader AI governance strategies.

Summary & Trend Overview

Challenges



Generative AI-driven systems in logistics lack clear mechanisms for understanding, auditing, and explaining the reasoning behind their recommendations and actions, making accountability and transparency difficult to ensure.



Emerging laws are creating unresolved liability questions; providers and deployers remain fully accountable for AI-generated outcomes, even when agents plan and execute actions independently.



As AI ethics shifts from voluntary guidelines to enforceable obligations, many organizations lack the processes and documentation needed to demonstrate compliance in practice.



Governing AI ethics across complex, multi-partner ecosystems is a persistent challenge; agentic systems in logistics increasingly interact across carriers, partners, and platforms and rarely operate in isolation.

Outlook

Over the next five years, logistics and supply chain organizations are likely to face heightened regulatory scrutiny as governments pass legislation and industry bodies introduce guidelines and standards aimed at balancing the efficiency gains of AI-driven operations with the responsibility to protect human rights, ensure data privacy, and maintain environmental sustainability.

Adoption of ethical AI frameworks and best practices is expected to accelerate as organizations seek to mitigate risk, build stakeholder trust, and deploy AI responsibly, embedding principles of fairness, transparency, accountability, and societal benefit across sourcing, manufacturing, distribution, and customer engagement. Companies will increasingly leverage AI to enhance visibility, traceability, and sustainability while addressing ethical concerns such as human rights, environmental stewardship, and employee welfare.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with use cases in some applications that can already be addressed today.

Related Trends

Agentic AI



Generative AI



AI Analytics



Cybersecurity 2.0



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Augmented Workplaces

Trend Overview

Impact:

CONSIDERABLE

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Health, Safety & Future of Work

Trend Clusters:

Bionic Enhancements



The trend of Augmented Workplaces represents work ecosystems where employees and advanced technologies interact synergistically. By integrating intelligent tools and adaptive workflows, strain on workers is reduced and routine tasks are automated, allowing employers to redirect human talent toward high-value oversight, optimization, and innovation.

The business world is undergoing a fundamental shift in how work is designed, supported, and experienced. Augmented workplaces represents the convergence of two complementary perspectives: employee expectations and employer objectives. As digital tools mature, workers increasingly expect technologies that do more than automate tasks. They want tools that enhance their capabilities, reduce cognitive and physical strain, and enable them to contribute at higher levels. For their part, companies are investing in technologies and workflow innovations that augment workers rather than replace them. From wearable technologies such as smart glasses and exoskeletons to AI-empowered decision-making and adaptive interfaces, the augmented workplace blends physical and digital systems into a seamless, responsive work environment.

Fundamentally, the shift toward augmented workplaces involves reconfiguring of how tasks are performed. Traditional linear roles are evolving into dynamic, technology-enabled workflows. Human-robot collaboration is becoming increasingly common, with robots handling repetitive, precision-heavy, or physically demanding activities while humans oversee, intervene, and problem-solve when exceptions arise. This collaborative model not only improves efficiency and safety but also redefines the role of the worker, shifting away from manual tasks toward supervision, judgment, and creative problem-solving.

However, designing augmented workplaces is not straightforward. A readiness gap is already visible: only 35% of workers have received AI-related training, even as 75% of companies are adopting AI. In logistics, a study found that 54% of organizations are automating non-value-added tasks to offset labor shortages, but many have not yet fully trained workers or redesigned roles. This gap has a direct impact on the growing number of tasks that involve human oversight of automated systems. Reliability is a further constraint, with poor data quality and fragmented systems among the top reasons digital logistics transformations underperform, even when systems are technically sound.

Despite these challenges, it's clear that the augmented workplace in logistics is transitioning from pilot projects and point solutions into a foundational operating model. The sector is automating rapidly, and logistics roles will be structurally redesigned as automation, AI, and robotics increasingly handle predictable, high volume tasks. But the next several years may be defined less by the depth of automation and more by how effectively organizations elevate human work.

Optimization & innovation

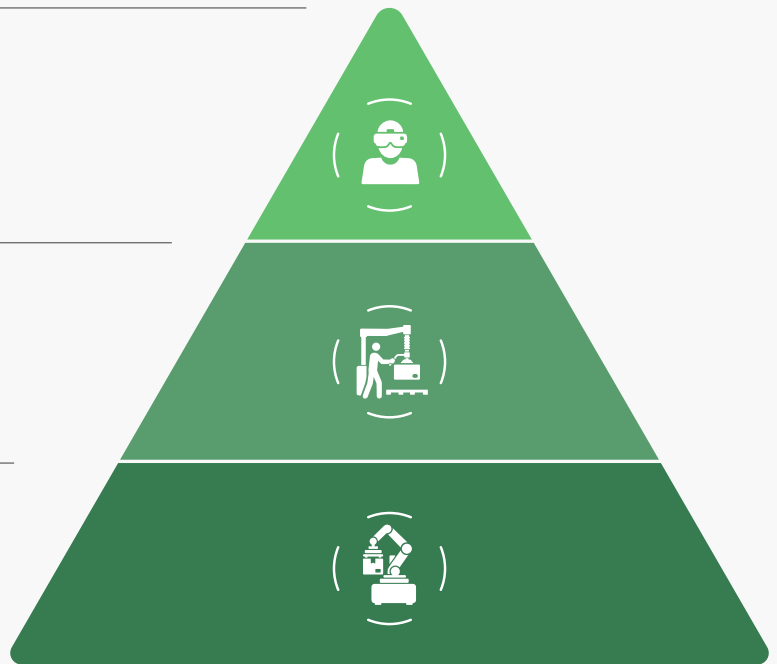
Smart glasses augment reality to allow for total language translation & task training

Exception handling

Tawi technology enhances human ability to lift heavy nonconveyable objects

Repetitive execution (automated)

Boston Dynamics Stretch robot automates container unloading, a notoriously repetitive and arduous task



Automation and bionic enhancement come together to create an augmented workplace where humans and technology collaborate seamlessly.

Deloitte (2026): Using autonomous robots to drive supply chain innovation

Relevance to the Future of Logistics



Tech-Enabled Workplace Inclusion

Augmented workplaces are enabling more people to participate in the workforce. Automation and other intelligent tools allow individuals with varying physical abilities, experience levels, or language proficiencies to perform tasks effectively. Examples include smart glasses that provide live language translation or transcription for workers with hearing impairments and exoskeletons that help workers lift objects. Upskilling and training programs also ensure that employees across diverse age groups and backgrounds have the tools to keep pace with new technology and the skills they need to advance their careers.

Workplace technology also helps attract and retain talent. For example, workers increasingly expect tools that support priorities like the ability to flexibly pick and schedule shifts.



Skill Partnership

Augmented workplaces are enabling collaboration between humans, AI, and physical robots, introducing flexible, adaptive systems where each leverages its unique strengths (e.g., human judgement and machine precision), continuously learns from one another, increasing resilience and operational agility. Research shows that human automation hybrids outperform fully automated logistics operations, reinforcing the case for reliable human oversight over end to end autonomy. Rather than using technology to reach a fixed goal, skill partnerships allow workers to collaborate with it and assume an elevated role.

For example, at DHL we deploy AI orchestrated cobots from Locus Robotics or Carter, developed by Robust.AI, in warehouses and fulfillment centers. These robots work dynamically with human counterparts, adjusting tasks in real time based on human behavior and operational conditions. This creates a continuous learning loop where humans focus on exceptions and optimization, with the system adapting robot actions and improving processes over time.



Task Elevation

As technology increasingly assumes routine execution in supply chain operations, human work is shifting toward elevated tasks. In practice, this means logistics workers move beyond repetitive picking, scanning, or data entry. Instead, they can focus on high-value tasks, such as exception handling (e.g., rerouting a package with an illegible label or resolving a failed delivery), optimization (e.g., adjusting pick paths, inventory placement, or labor allocation in response to congestion or demand fluctuations), and innovation (e.g., identifying recurring inefficiencies in packing or returns and proposing new workflows, layouts, or different technology). These activities depend on human judgment, contextual awareness, and creativity, which cannot be fully predefined within systems.

This shift changes how logistics providers and supply chain managers drive performance on the floor. Workers become active contributors, improving service reliability, throughput, and process efficiency in real time rather than only executing tasks. This leads to more resilient and scalable operations, where human effort is concentrated on resolving disruptions, improving system performance, and continuously refining workflows. While closely related to skill partnerships, task elevation focuses on the worker's role and how the human-in-the-loop can best manage edge cases, exercise expert judgment, and drive ongoing improvement beyond standard processes.

Summary & Trend Overview

Challenges



Skills & Capability Gaps

Shifting workers from manual and transactional tasks to oversight, exception handling, and problem-solving demands digital literacy, analytical thinking, and systems understanding that much of the logistics workforce has not yet developed.



Change Management & Workforce Acceptance

Employee anxiety over job loss, deskilling, and greater accountability can slow or derail adoption where communication, reskilling pathways, and trust-building are weak.



Technology Integration & Reliability

Advanced automation and decision-support systems must be reliable and explainable; unreliable, opaque, or poorly integrated systems across a fragmented logistics IT environment undermine the data quality and human oversight that effective augmentation depends on.

Outlook

The augmented workplace will not appear across global supply chains overnight. In the near term, we see adoption accelerating where variability is high and automation return on investment is clear, such as in warehousing, fulfillment, and planning functions. In the medium term, the augmented workplace will likely redefine job architectures, performance metrics, and leadership expectations across logistics networks.

Leveraging the benefits of an augmented workplace will require proactively redesigning roles, investing in human machine collaboration, and treating augmentation as an operating philosophy, not a technology add on. Organizations that take these steps will be best positioned to scale efficiently, absorb disruption, and attract the next generation of logistics talent.



Strategize – This trend has the potential to bring substantial change across logistics with use cases in some applications that can already be addressed today.

Related Trends



Sources

1. MHI (2026): *Annual Industry Reports*
2. UKG (2024): *2024 Industry Insights Report: Logistics Edition*
3. McKinsey & Company (2024): *Digital Logistics: Into the Express Lane?*
4. Descartes (2024): *Descartes' Study Reveals 54% of Supply Chain and Logistics Operations are Prioritizing Automation to Mitigate Workforce Shortages*

5. Harvard Business Review (2024): *Research: Warehouse and Logistics Automation Works Better with Human Partners*
6. Statista (2021): *Revenue of the Warehouse Robotics Market Worldwide from 2021 to 2030*

Circularity

Trend Overview

Impact:

HIGH

Adoption:

5 – 10 YEARS

Focus Areas:

Customer Experience

Sustainability

Trend Clusters:

Packaging & Containers

Sectors:

Auto-Mobility

Engineering & Manufacturing

Energy

eRetail & Fashion

Life Sciences & Healthcare

Technology



The trend of Circularity seeks to prevent waste and pollution by designing products, materials, and the respective supply chains to retain value across their lifecycles. Circular systems aim to keep products, components, and raw materials in use for as long as practicable through reuse, repair, refurbishment, remanufacturing, recycling, and recovery.

There is gradual but uneven progress toward a circular economy. While many large businesses have committed to Circularity goals, most initiatives remain focused on recycling, packaging, and waste management rather than pursuing broader transformation of products, business models, and supply chains. Increasingly, companies are adopting more advanced circular strategies such as designing products for longevity, reparability, and recyclability, implementing take-back and refurbishment programs, reducing virgin material use, and embracing product-as-a-service or leasing models. They are also exploring innovations such as bio-based packaging materials, reusable transport packaging systems, and AI-enabled lifecycle tracking technologies to support circular operations and compliance. As a result, Circularity is becoming a core consideration within product design and R&D rather than an afterthought.

The Circularity Gap Report 2026 highlights the challenge of scaling Circularity globally. It presents an initial estimate of €25.4 trillion (± €4.7 trillion) in avoidable annual economic value lost through linear material use, equivalent to almost 31% of global GDP. The report describes these figures as an initial estimate subject to methodological uncertainty. These findings reinforce the case for circular economy strategies that extend beyond waste management toward long-term value retention, resource productivity, and resilience.

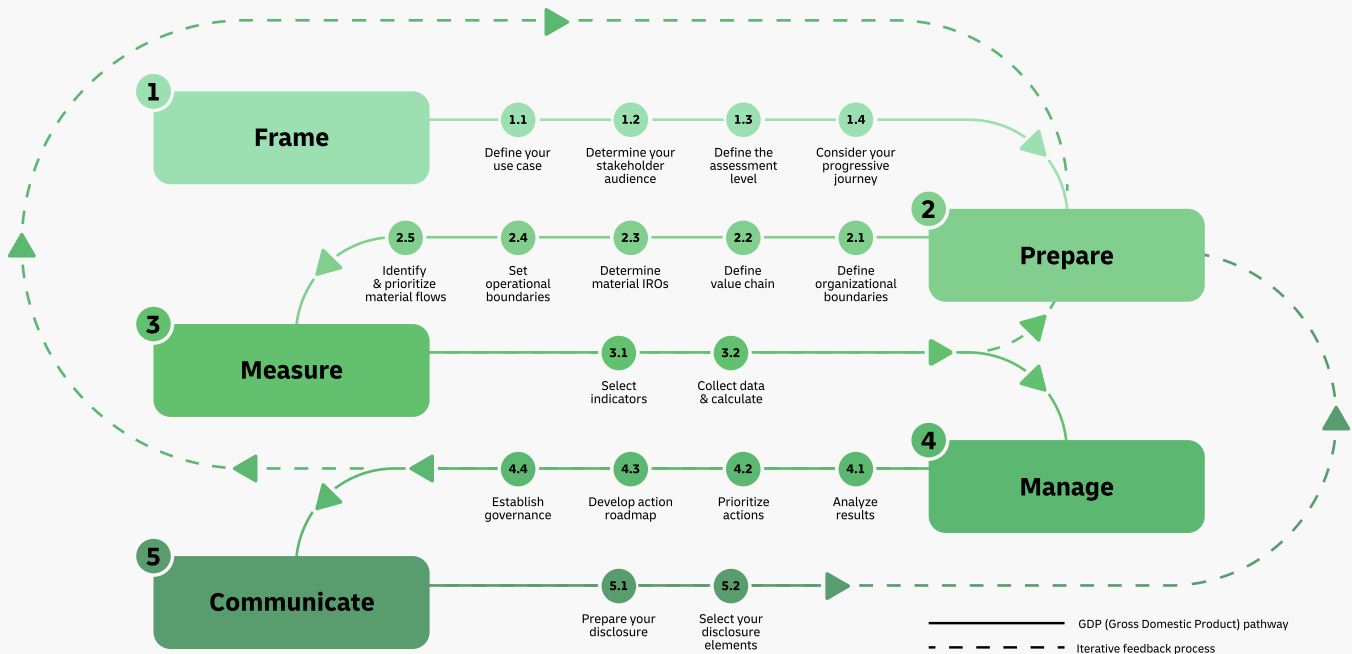
Policymakers are attempting to build momentum. The EU continues to strengthen its Circular Economy Action Plan through initiatives such as the Ecodesign for Sustainable Products Regulation (ESPR), Right-to-Repair legislation, Digital Product Passports (DPPs), and the Packaging and Packaging Waste Regulation (PPWR), which will apply across the EU from August 2026. Complementing this regulatory push, the Global Circularity Protocol for Business (GCP), developed by the World Business Council for Sustainable Development (WBCSD) in collaboration with the One Planet Network coordinated by the United Nations Environment Programme (UNEP), provides a globally aligned framework to help companies measure, manage, and communicate their circular performance through standardized tracking of material flows, impacts, and business strategy alignment.

Overall, the adoption of Circularity principles is progressing gradually but remains a mid- to long-term goal. Most circular initiatives are still limited to recycling and packaging improvements rather than fully circular business models. Significant infrastructure, economic, and operational barriers continue to slow large-scale adoption, and the lack of scalable circular business models and cost-effective product designs means Circularity will likely mature incrementally over the coming years.

That being said, the impact remains high and continues to grow as Circularity increasingly reshapes product design, packaging, reverse logistics, material sourcing, and lifecycle management. New regulations are accelerating the need for circular supply chain capabilities across industries.

Logistics is becoming a key enabler of circular ecosystems. Managing and optimizing the forward and reverse flows of products,

materials, components, and waste across interconnected supply chains is central to making Circularity operate at scale – through reverse logistics networks, reuse and refurbishment infrastructure, and material recovery capabilities.



Effective sustainability management is not a one-time assessment but a continuous, data-driven cycle that starts with clear scoping, translates insights into action, and is reinforced through transparent communication.

Global Circularity Protocol (2026): A global framework to accelerate the transition to a circular economy

Relevance to the Future of Logistics

Recommerce

Recommerce can support value recovery from components and materials and may reduce selected raw-material and waste-disposal costs, depending on product category, recovery yield, and processing requirements. Major retailers and brands such as IKEA, Zalando, Patagonia, and H&M are expanding buy-back, refurbishment, and resale initiatives, while digital platforms increasingly integrate second-hand offerings into existing e-commerce ecosystems. AI-powered grading systems and computer vision technologies are being used to automate inspection, quality assessment, and routing decisions for returned and used products, supporting the operational scalability of recommerce models.



Consumer demand, particularly among younger generations, is reinforcing this momentum. According to ThredUp's 2025 Resale Report, around 68% of Gen Z and Millennial consumers purchased second-hand products in 2024, with nearly half indicating resale platforms are now their first stop when shopping.

Digital traceability and authentication solutions are becoming essential enablers of scalable recommerce ecosystems. Companies such as Entrupy use AI-powered authentication and product fingerprinting technologies to verify the authenticity of luxury goods and resale items, helping retailers and marketplaces reduce counterfeit risk while building consumer trust. As recommerce expands across higher-value products, the integrity of secondary markets will increasingly depend on robust traceability and verification infrastructure.



Circular Packaging

Circular packaging refers to packaging designed for reuse, recycling, or, where suitable collection and treatment infrastructure exists, composting at end of life. It is intended to reduce reliance on linear take-make-dispose models. Two primary forces are driving its adoption: digitalization and material innovation.

On the digital side, Internet of Things (IoT) tracking technologies such as RFID, GPS, and Bluetooth sensors are becoming mainstream in reusable logistics packaging, helping companies improve asset visibility, reduce loss, and optimize return cycles. Digital product passports (DPPs), QR-enabled packaging, and smart labels extend this visibility further – improving traceability across the supply chain, supporting recycling processes, and giving consumers clearer guidance on reuse and disposal. Digital return solutions such as label-free QR-code returns complement these tools by reducing material waste and improve customer convenience.

Material innovation is advancing in parallel. Packaging design is evolving toward mono-material solutions and on-demand right-sized packaging to reduce waste and improve recyclability. Bio-based alternatives such as mushroom- and seaweed-derived materials are gaining traction as compostable substitutes to conventional plastics, though scalability and cost remain barriers to widespread adoption.

For logistics providers, circular packaging creates both operational demands and business opportunity. Managing reusable packing assets – tracking their location, coordinating returns, and ensuring cleaning and quality inspection before redistribution – requires end-

to-end supply chain visibility and reverse logistics infrastructure that many networks are still building. Close collaboration across manufacturers, retailers, recyclers, and logistics providers will be essential to scaling these solutions.

Reverse Logistics

Reverse logistics – the process of moving products back through the supply chain for return, repair, refurbishment, recycling, or disposal – is the operational backbone of the circular economy. Global returns volumes are rising sharply, making reverse logistics an area of growing strategic importance. In some apparel categories, return rates now reach up to 90%, contributing to an estimated US\$62.5 billion global value opportunity in returns management and product recovery. Consumer expectations are also reshaping e-commerce, with DHL's eCommerce Trends Report showing that 79% of shoppers abandon purchases due to poor return policies.

Technological innovation is intended to make reverse logistics faster and more scalable. Automated sorting systems, robotics, and AI-powered returns platforms can support inspection and categorization of returned products. AI applications may automate parts of the returns lifecycle, from return authorization and fraud detection to resale decisions and inventory reintegration. Depending on implementation, these technologies can reduce manual handling, processing costs, and turnaround times for returned products.

DHL is operating more than 45,000 electric vehicles globally in pick-up and delivery, and a network of around 170,000 access points. In the US, where retail returns were estimated at US\$890 billion in 2024, the DHL ReTurn Network provides reverse-logistics services intended to improve return speed and traceability. Any environmental benefit depends on factors including transport mode, route, consolidation, energy source, and the subsequent handling of returned products.

As return volumes grow and circular economy expectations rise, efficient reverse logistics networks are becoming a potential source of competitive advantage for logistics providers and their customers.



Summary & Trend Overview

Challenges



Most products are not currently designed for reuse and recycling, limiting their ability to support Circularity.



End customers face a high barrier to changing their consumption habits and actively participating in Circularity.



The data on the location, condition, and composition of products and materials across supply chains is severely limited, preventing waste from being effectively redirected as raw materials and hampering attempts to close loops.



Implementing supply chain changes to support Circularity, such as circular packaging solutions, can be complex, costly, and time-consuming.

Outlook

Circularity is moving from a voluntary commitment toward a regulatory and business necessity. As legislation and standards continue to take effect across major markets, companies will face growing pressure to redesign products, rethink packaging, and build operational infrastructure for product recovery and reuse. Demand from corporate customers and consumers is reinforcing this regulatory push, accelerating adoption across sectors that have historically lagged.

Logistics will be central to this transition. Reverse logistics networks, reusable packaging systems, and circular supply chain visibility tools are no longer peripheral capabilities – they are becoming core infrastructure for companies operating in a circular economy.

As critical materials become scarcer, supply chain resilience is under pressure. Circularity is emerging as a key lever for securing future resources.



Prepare – This trend has the potential to fundamentally transform or disrupt logistics with developments and use cases on the horizon.

Related Trends

Bio-Based Materials



Decarbonization



Smartification



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2. Interpack Magazin (2026): *Bioplastics in packaging*
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5. TOMRA (2025): *Circular technology trends in 2026: Turning preparation to action*

6. Global Corporate Logistics (2026): *The circular supply chain: Why 2026 is the year of green reverse logistics*
7. DHL (2026): *Reverse logistics goes from cost center to competitive edge, DHL data shows*
8. DHL (2025): *DHL Supply Chain launches return network to transform reverse logistics*

Compute Economy

Trend Overview

Impact:

MODERATE

Adoption:

< 5 YEARS

Focus Areas:

Visibility & Resilience

Trend Clusters:

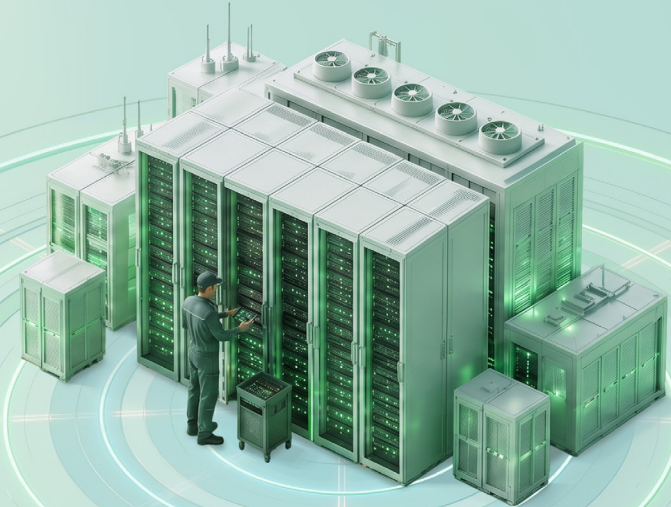
Artificial Intelligence

Internet of Things

Sectors:

Energy

Technology



The trend of Compute Economy reflects a shift towards an economic paradigm shaped by the rapid growth of artificial intelligence, in which computing power has become a critical input factor across industries. This shift is redefining how organizations drive value creation, productivity, resilience, and long-term competitiveness.

Across industries, access to scalable and efficient compute is gaining strategic importance and increasingly determines the ability to develop, deploy, and scale AI. It is as important today as land, labor, energy, and capital were in earlier industrial eras.

Compute has emerged as a core economic input. Global AI infrastructure spending more than doubled from US\$153 billion in 2024 to US\$318 billion in 2025. It is projected to exceed US\$1 trillion by 2029. This growth signals a structural shift in which compute is no longer treated as an operational IT expense but as a long term economic asset central to productivity and competitiveness.

The supply of computing power is concentrated and capital intensive. Five hyperscalers (Amazon, Google, Microsoft, Meta, and Oracle) control approximately 71% of global AI compute capacity. Their combined infrastructure capital expenditure is expected to surpass US\$600 billion in 2026, reinforcing scale advantages and influencing access to AI innovation.

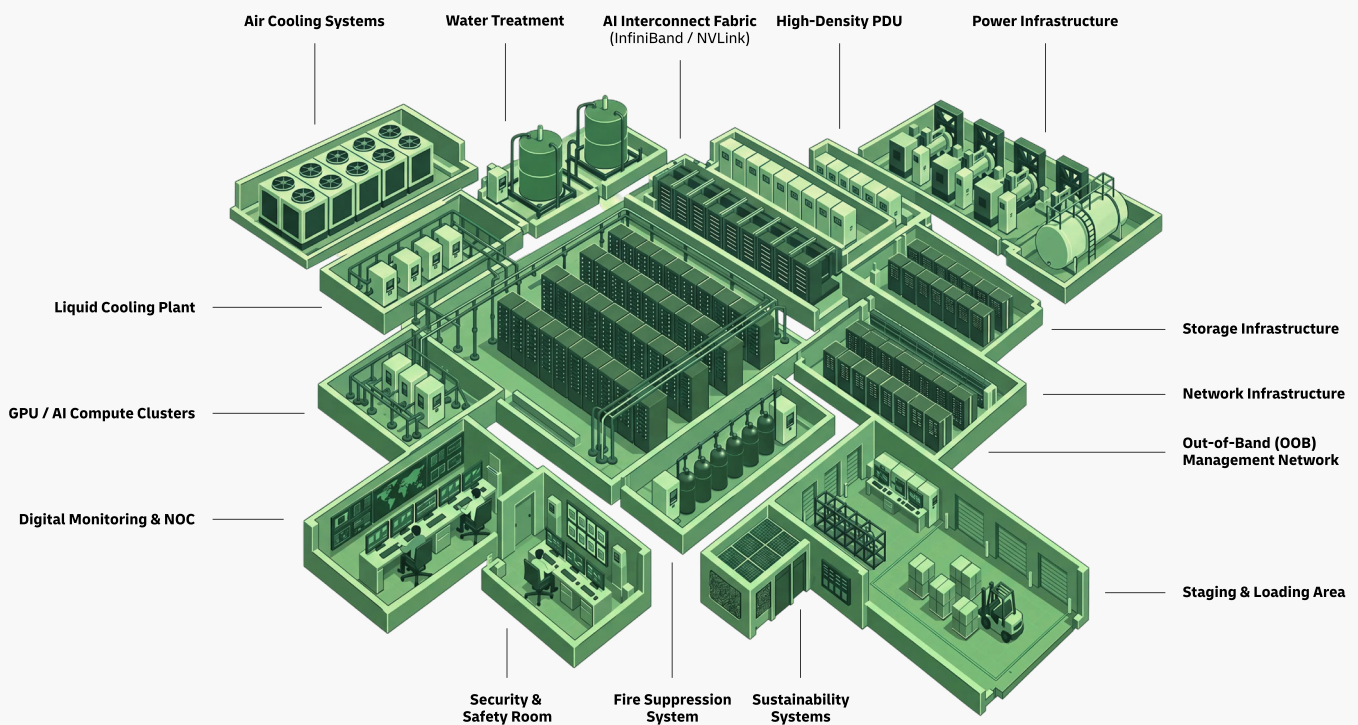
The economic focus is shifting toward infrastructure efficiency. AI inference accounts for an estimated 65 to 90% of total lifetime AI costs. As deployments scale, GPU performance, energy efficiency, and utilization rates increasingly determine returns on investment, aligning AI economics more closely with infrastructure driven industries than traditional software models.

Sovereignty also influences where compute is deployed. Governments are investing heavily in sovereign compute capabilities to strengthen national competitiveness, ensure regulatory compliance, and improve resilience. Initiatives such as Canada's multi-year AI supercomputing program reflect the growing geopolitical importance of domestically anchored compute infrastructure.

The AI driven compute economy is also repositioning logistics as a strategic enabler of AI scale and value creation. As compute infrastructure becomes scarce, capital intensive, and time critical, logistics performance directly impacts deployment speed, system availability, as well as financial and operational risk.

Specialized, time critical, and white glove logistics are increasingly required to deliver compute ready infrastructure across both build and run phases, while minimizing downtime. For customers, service reliability, cost, security, and sustainability are now closely tied to how efficiently compute is transported, installed, powered, and maintained amid rising energy costs and regional constraints.

As a consequence, over the next five years, logistics will form a core layer of the AI value chain. Organizations that can move, deploy, and sustain compute infrastructure faster, safer, more efficiently, and sustainably will gain a decisive advantage in scaling AI and capturing value across industries.



A data center is far more than computing infrastructure – it is a complex ecosystem of power, cooling, networking, security, and physical infrastructure that depends on highly sophisticated logistics throughout its lifecycle.

Chart Industries (2026) & AI generated

Relevance to the Future of Logistics



Compute Deployment Acceleration

The compute economy requires the rapid and reliable deployment of AI infrastructure. In the build phase of a data center, logistics becomes a critical enabler of a capital-heavy and time-sensitive process, directly influencing how quickly capacity comes online and starts generating value.

Requirements include:

- **Time-critical delivery of compute infrastructure**
Secure, accelerated transport of high value components such as GPUs, servers, racks, and power systems to avoid delays and idle assets.
- **Specialized and white-glove handling**
Precision handling, controlled environments, and staged deliveries reduce the risk of damage and on-site installation delays.
- **Synchronized site deployment**
Just-in-time coordination with construction, grid connection, and commissioning schedules to compress build timelines.
- **Cross-border and regulatory orchestration**
Management of customs, export controls, and compliance requirements, particularly for sovereign and regionally anchored compute.

The speed at which compute capacity is deployed will largely depend on how well logistics providers meet these requirements.



Compute Operations Continuity & End-to-End Visibility

Once a data center goes live, logistics remains a key part of operational continuity. Advanced supply chains and white-glove logistics provide end-to-end visibility – continuous tracking, condition monitoring, and secure chain of custody across every touchpoint in the network. Real-time oversight, proactive risk mitigation, and trusted handovers are essential for transporting high-value IT and infrastructure equipment from origin to live data center environments.

Requirements include:

- **Operational continuity and spares delivery**
Secure delivery of spares and replacements maintains uptime and accelerates data center build-outs.
- **Safe handling of sensitive assets**
Trained personnel and controlled processes, including inside delivery and rack and stack services, ensure sensitive assets are handled safely.
- **Scalable, compliant operations**
Operations scale across centralized, edge, and remote sites while strengthening compliance and audit readiness in regulated and sovereign environments.
- **Lifecycle and asset management**
Optimizing lifecycle and asset management supports secure, compliant operations and resilience through fast response capabilities.

In this run phase, the compute economy will rely on logistics providers to keep AI infrastructure operational, efficient, and reliable, directly affecting uptime and resilience.

AI Sovereignty

In the compute economy, AI sovereignty is becoming a key requirement for governments and industries alike as regulations,

geopolitics, and data sensitivity intensify. For logistics operations specifically, this introduces critical operational vulnerabilities. As AI is increasingly integrated in daily operations – from dynamic routing and demand forecasting to automated management – control over where data is processed and where physical compute infrastructure resides is essential. Localizing this digital infrastructure is needed to ensure regulatory compliance, supply chain resilience, and customer trust.

AI sovereignty addresses several critical dimensions across contemporary supply chains:

- **Ensures regulatory compliance and data control**
Regionally anchored compute enables compliance with data residency laws, customer mandates, and public sector requirements.
- **Supports sensitive and cross-border operations**
Sovereign AI is critical for defense logistics, critical infrastructure supply chains, and government contracts where data cannot leave specific jurisdictions.
- **Reduces geopolitical and dependency risks**
Localizing compute lowers reliance on foreign hyperscalers and mitigates exposure to sanctions, export controls, and policy disruptions.
- **Strengthens operational resilience**
Local AI capabilities improve continuity for demand sensing, capacity planning, customs processing, and network control.
- **Creates new logistics demand**
AI sovereignty drives growth in regional data centers near ports and hubs, and in secure, compliant infrastructure deployment services.

As global fragmentation increases, AI sovereignty ensures that the foundational computing infrastructure supporting modern logistics remains secure, elevating logistics providers to strategic enablers of trusted, resilient, and competitive AI driven supply chains.



Summary & Trend Overview

Challenges



As the economics of capital intensive AI compute shift value creation from software to infrastructure, pressure is rising to deploy capacity rapidly and match demand precisely to avoid idle assets and sustain return on investment.



Rising power demand from AI data centers is making energy availability, pricing, and sustainability decisive constraints, with grid access and regulatory limits increasingly determining where compute can be deployed and how fast it can scale.



Scarce specialist skills and fragmented integration are slowing how quickly compute value is fully realized; operating AI infrastructure at scale demands close coordination across compute, energy, facilities, and logistics.



Sovereign compute investment, driven by geopolitical fragmentation and rising regulation, is raising costs and operational friction by separating capacity regionally and adding complexity around data residency, cross border logistics, customs, and compliance.

Outlook

Compute will increasingly be treated as foundational economic infrastructure, with future value driven by efficiency, utilization, and sustainability rather than sheer capacity growth. While hyperscalers will remain central, diversification through sovereign and edge compute is set to expand. How quickly and reliably compute infrastructure can be deployed, powered, and sustained will determine which organizations capture its value. This positions logistics as a critical enabler of the compute economy's growth.



Explore – This trend has the potential to drive meaningful change in specific areas of logistics with use cases in some applications that can already be addressed today.

Related Trends

Agentic AI



Generative AI



AI Ethics



Cybersecurity 2.0



Sources

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Cybersecurity 2.0

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Physical & Digital Security

Trend Clusters:

Digital Backbone

Sectors:

Engineering & Manufacturing

eRetail & Fashion

Technology



The trend of Cybersecurity 2.0 represents the next evolution of cyber resilience in logistics and supply chains, integrating digital and physical security to protect critical infrastructure assets across end-to-end logistics ecosystems. It reflects a shift from reactive, perimeter-based defense toward proactive, autonomous, and predictive approaches that leverage artificial intelligence (AI) and emerging technologies such as quantum-resistant cryptography.

Cybersecurity threats have outpaced conventional defense models. Cybercriminals are faster, more adaptive, and increasingly willing to exploit both digital and physical operations in the same attack. AI and automation have lowered the barriers to mounting complex attacks while simultaneously raising their scale and speed.

Logistics is a high-value target for cyberthreats due to the critical role supply chains play in global trade. The global scale and increasing complexity of today's highly interconnected, multiparty supply chain ecosystems expose it to threats like ransomware, infiltration, malware, and AI-enabled attacks. The digital transformation in the logistics sector has compounded this exposure, expanding the attack surface across transport management systems (TMS), warehouse management systems (WMS), enterprise resource planning (ERP), operational technology, Internet of Things (IoT) devices, and cloud platforms.

Logistics consistently ranks among the top sectors impacted by cybercrime. The IBM 2026 Threat Intelligence Index highlights a fourfold rise in major supply chain or third-party compromises over the last five years and an 89% increase in AI-enabled adversary attacks year-over-year.

AI is no longer an emerging concept in cybersecurity, but a force multiplier actively used by both defenders and adversaries. According to The German National Situation Report on Cyber Crime, AI-based tools are playing a growing role in cybercrime while AI technologies offer new capabilities for IT security and early vulnerability detection. AI enables more targeted and personalized attacks, and keeping pace requires AI-enabled defense: continuous monitoring and cross-system correlation to identify threats in real time.

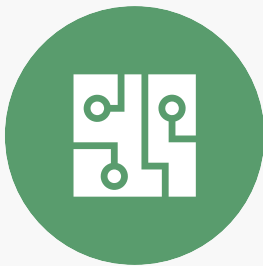
In practice, most major breaches in logistics have involved ransomware and phishing attacks. A cyber assault targeting the UK's postal and courier services disrupted operations for weeks, particularly international deliveries and exports. Ransomware infiltrated operational systems, likely through phishing emails, and froze international operations including parcel tracking.

The M&S ransomware incident also demonstrates the severity of cyberattacks. Attackers used social engineering to impersonate IT support and gain system access. Dragon Force ransomware was used to encrypt data and steal records, causing a weeks-long suspension of online shopping platforms and internal systems.

These cases are two examples of the ripple effect a cyberattack can have across the supply chain. A 2023 Harvard Business Review study found that losses across an affected company's interconnected business ecosystem – including third-party vendors, downstream clients, and upstream suppliers – can be amplified up to 26 times due to cascading disruptions and systemic downtime.

In response, logistics organizations are actively deploying AI-enabled cybersecurity systems. Achieving resilience in today's AI age requires integrating digital and operational security across the full logistics network, with continuous, end-to-end visibility from IT systems to physical operations.

For logistics organizations, Cybersecurity 2.0 represents a response to conditions already shaping operations and outcomes. Consequently, we expect to see continued priority investment in the next five years.



66% increase in attacks by AI-enabled adversaries



Average eCrime breakout time dropped to 29 minutes, a 65% increase in speed from 2024, and the fastest breakout time was only 27 seconds



82% of detections in 2025 were malware-free, up from 53% in 2020



42% increase in zero-day vulnerabilities exploited prior to public disclosure



Valid account abuse accounted for 35% of cloud incidents



37% rise in cloud-conscious intrusions, with 26x increase by state-nexus threat actors

AI-driven and cloud-focused threats are accelerating as attackers move faster and exploit vulnerabilities at record scale.

CrowdStrike (2026): Global Threat Report



Anticipation & Resilience

In complex and digital logistics environments, anticipation and resilience converge to safeguard operations against disruption. This case focuses on identifying and strengthening the weakest links across logistics networks, from IT systems and warehouse operations to transport execution and partner ecosystems, before they can be exploited or fail.

A key challenge is the growing number of actors interacting within logistics operations, including employees, partners, autonomous systems, and AI agents. Each additional actor increases exposure to insider threats, AI-driven cyberattacks, and state-backed espionage, requiring new approaches to monitoring, authentication, and trust management across both human and machine interactions.

At the same time, conventional audit and control mechanisms are becoming insufficient. Next-generation IT and AI-enabled systems introduce new risks, such as opaque decision-making and potential “back doors” embedded in software or models. Future logistics systems will therefore depend on continuous, decentralized verification, where different AI systems independently validate and monitor each other to ensure integrity and compliance.

To address these challenges, logistics organizations are advancing AI-enabled vulnerability management and autonomous security operations. Solutions such as Security Orchestration, Automation, and Response (SOAR) enable continuous monitoring, predictive risk detection, and automated response across distributed networks. Combined with predictive maintenance of physical and digital infrastructure, this allows organizations to anticipate disruptions and ensure operational continuity.

Physical & Cyber Security Convergence

Threats in logistics are evolving from isolated cyber or physical incidents into converged attacks that blend both domains. Criminals increasingly exploit the intersection of digital systems and physical operations, creating more sophisticated and harder-to-detect risks across the supply chain.

A typical example is “fake carrier” or “phantom truck” fraud: criminals infiltrate transport or booking systems, steal identities, and manipulate shipment data. They then arrive at the warehouse posing as legitimate carriers, at the right time, with correct references and forged documentation, and collect cargo without raising suspicion. The theft is only discovered when the shipment never reaches its destination. This threat is rapidly scaling. TAPA reports over 30,500 cargo crime incidents in Europe in 2024–25 with more than €860 million in losses, increasingly driven by identity fraud and digital system compromise rather than traditional theft.

Another vulnerability is the logistics sector’s intrinsic reliance on satellite-based positioning systems (GPS) for the routing, tracking, and timing precision that sustain supply chain continuity. An attack on this infrastructure can cause widespread disruption across land, sea, and air transportation.

In this new threat landscape, cybersecurity and physical security are no longer separate disciplines but interdependent components of a unified risk environment.



Quantum Computing & Data Protection

Quantum computing harnesses quantum mechanics to process information at speeds far beyond the capacity of conventional computers. Not yet commercially available but advancing rapidly, it represents a double-edged development for cybersecurity: a potential tool for stronger defenses and, once sufficiently mature, a serious threat to the encryption standards that protect logistics operations today.

For cybersecurity practitioners, quantum computing can provide an extra layer of digital privacy and security to counteract hacking. For example, the principles of quantum mechanics can be used to create almost unbreakable cryptographic keys and ensure secure communication channels resistant to quantum attacks. Quantum computing can accelerate algorithms used for anomaly detection, pattern recognition, and real-time threat analysis. Furthermore, quantum computers can simulate complex cybersecurity scenarios and potential threats more accurately and rapidly, helping organizations develop proactive defense strategies.

Cybercriminals are sure to apply these tools to enhance their hacking capabilities, putting cybersecurity and cybercrime in a race for the upper hand.

Preparing for the quantum computing era involves assessing current cybersecurity posture and developing transition plans that evaluate the readiness of existing systems and infrastructure for quantum-safe solutions.

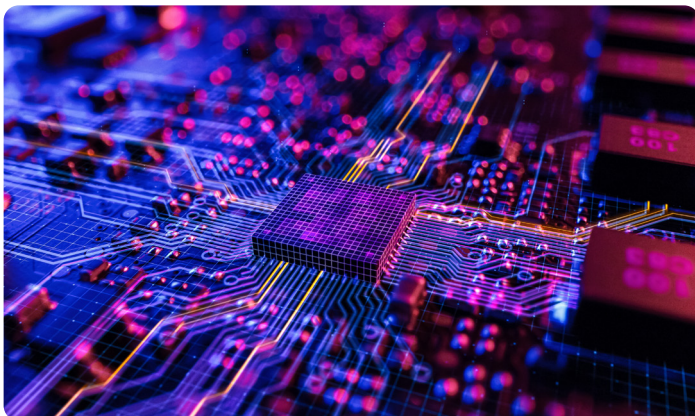
AI Enabled Defense

Logistics runs on interconnected systems and partner networks, creating constant exposure across operations, with every interface a potential weak point. AI-enabled defense shifts from point-in-time audits and static controls toward continuous, adaptive ecosystem security.

Threat detection is changing. Intelligent signal correlation connects activities across TMS, WMS, platforms, and partners. Instead of isolated alerts, risks are identified as patterns across the full flow. Small anomalies in shipment data, user behavior, or system activity can be linked early. This allows intervention before disruption hits operations.

Incident handling is also evolving. Threats can be isolated and contained while operations continue. Compromised accounts are blocked. Suspicious transport orders are stopped. Manipulated data is flagged in real time. This is critical as attacks increase in speed and scale.

AI-enabled defense requires a stronger foundation; this means building AI-enabled cyber resilience by design, with zero-trust architectures across users and systems and strong cross-partner coordination. The workforce will also require new skills to understand and operate AI-driven security tools and navigate an evolving technological landscape.



Summary & Trend Overview

Challenges



The breadth of consequences from cybersecurity failures (e.g., operational disruption, data theft and disclosure, financial losses, and regulatory penalties including fines, sanctions, or loss of licenses) makes it difficult to scope and prioritize comprehensive protection consistently across end-to-end logistics networks.



The rapid growth of AI-enabled threats outpaces the availability of AI -proficient cybersecurity personnel and technological readiness.



Proactive, cybersecurity 2.0 is costly and complex, requiring a dedicated technology stack and organizational orchestration.



Eliminating reliance on single critical software applications requires significant architectural investment and operational redesign – a step many organizations find difficult to address.

Outlook

Cybersecurity has entered the AI age, where attacks happen faster, scale quickly, disrupt operations immediately, and create a ripple effect up and down the supply chain. Threats are also becoming more complex, with increasing interdependencies and emerging risks such as post-quantum vulnerabilities. An AI-enabled cybersecurity strategy is becoming a core capability to block attacks and keep networks and infrastructure running under constant pressure. It is also the foundation of a cyber-resilient organization.

Looking ahead, detection and response will shift to agentic systems that act in real time, identify risks early, and contain threats without disrupting flows.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with use cases in some applications that can already be addressed today.

Related Trends



Sources

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Decarbonization

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Sustainability

Trend Clusters:

Packaging & Containers

Sectors:

Auto-Mobility

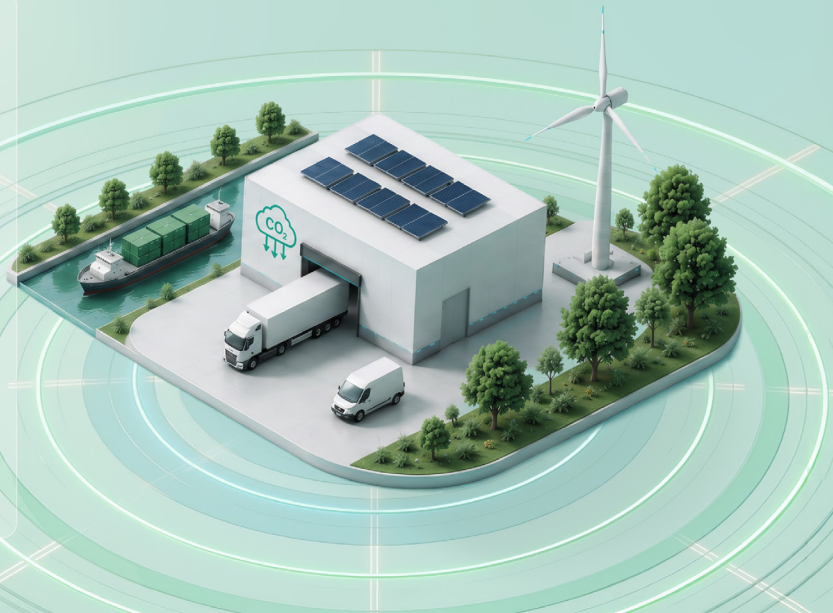
Energy

Engineering & Manufacturing

eRetail & Fashion

Life Sciences & Healthcare

Technology



The trend of Decarbonization is the transformation of the global economy to achieve net-zero greenhouse gas (GHG) emissions. Within logistics, it involves reducing energy demand and fossil-fuel use through efficiency measures, operational changes, electrification, renewable electricity, and lower-GHG energy sources.

Decarbonization has shifted from a long-term ambition to a more immediate priority. Pressure to act continues amid international concern about climate change, evolving policy frameworks, and regulatory obligations such as the European Green Deal and the Corporate Sustainability Reporting Directive (CSRD). The scale of organizational response is already significant: more than 11,000 companies worldwide have validated science-based targets through the Science Based Targets initiative (SBTi).

Decarbonization has sweeping implications for the logistics sector. Supply chains – which span all production, transport, and distribution activity – account for more than half of global GHG emissions, and about 80 to 90% of a product's total emissions derive from its supply chain. Logistics operations alone account for 7 to 11% of global GHG emissions.

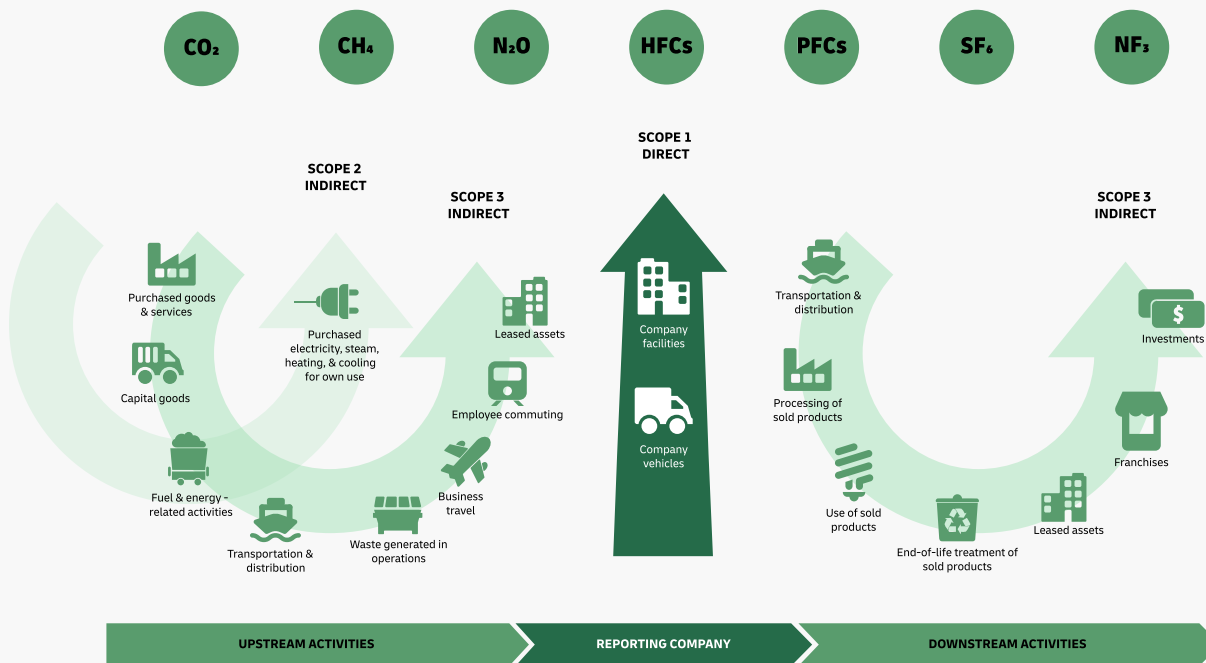
The sector is responding, and a fundamental transformation in supply chain operations is underway – one that is actively supporting decarbonization. Efforts include electrifying transport assets, increasing renewable electricity use at facilities, and scaling Sustainable Aviation, Road, and Marine Fuels.

More granular emissions-disclosure requirements may support decarbonization by improving transparency. However, reliable comparisons between products, services, and providers will depend on consistent system boundaries, methodologies, and data quality.

The trend's impact on logistics is far-reaching, as emissions reduction requires structural change across virtually every segment of the supply chain.

While many business-to-business (B2B) and business-to-consumer (B2C) organizations have net-zero emissions targets and are taking action, progress across global supply chains remains uneven. Differences in infrastructure maturity, regulatory frameworks, and technology availability are slowing large scale realization.

As a result, decarbonization represents a structurally complex transformation for the logistics sector that will depend on coordinated efforts across the supply chain.



Decarbonization in logistics requires eliminating greenhouse gas emissions across the entire value chain, including both upstream and downstream activities.

CrowdStrike (2026): Global Threat Report

Relevance to the Future of Logistics



Carbon Accounting & Tracking

Comprehensive accounting of Scope 1, 2, and 3 emissions (direct, indirect, and upstream and downstream, respectively) remains a challenge. Many businesses rely on secondary data sources and generalized emission factors, and emissions from second- and third-tier supply chain partners remain insufficiently captured. This lack of granularity makes it difficult for B2B and B2C organi-

zations to accurately compare and choose suppliers and service providers on a product- or shipment-level basis.

To address this challenge, carbon accounting and tracking solutions are increasingly integrated into logistics offerings. These solutions enable organizations to measure and report emissions more granularly across trade lanes, including Scope 3 emissions from transport and logistics activities involving third party providers. Book-and-claim approaches can allocate verified emissions-reduction attributes from eligible measures within a logistics network to participating customers, even if the customer's specific shipment is not physically transported using the associated fuel or technology. These approaches are distinct from offsetting outside the transport value chain.

Greater transparency can support compliance and more reliable comparisons across value chains, provided organizations apply compatible methodologies, boundaries, emission factors, and data-quality requirements. The Partnership for Carbon Transparency (PACT), led by the World Business Council for Sustainable Development (WBCSD), provides methodology and technical specifications for calculating and exchanging cradle-to-gate product carbon footprints. In parallel, standards and disclosure

frameworks such as the Greenhouse Gas Protocol, ISO 14064-1:2018, CDP, and California's Climate Corporate Data Accountability Act (SB 253) support organizational GHG accounting and disclosure. The EU Sustainable Finance Disclosure Regulation primarily applies to sustainability-related disclosures by financial market participants and financial advisers.

Looking ahead, carbon accounting will require higher data quality and granularity, supported by advances in digital platforms, emissions calculation software, and sensors that capture primary data for shipment and product level emissions tracking. This improved transparency enables logistics providers and customers not only to report emissions more accurately, but also to identify targeted opportunities for operational decarbonization along the supply chain.

Green Laws & Regulations

Growing awareness of climate change is reshaping the regulatory environment across transport, fuels, and packaging – with direct implications for logistics operations. Public support for environmental measures varies across geographies, particularly where compliance costs risk affecting the cost of living. However, the overall regulatory direction is increasingly influencing logistics investment and compliance planning, and organizations that prepare early may be better positioned as requirements evolve.

Legislation and incentives to electrify fleets have had a profound impact on road transportation operations. These policies range from supporting the transition toward low- and zero-emission vehicles to restricting combustion engine vehicles in specific areas. Examples include China's New Energy Vehicle (NEV) mandate governing automaker production levels and the UK's Zero Emission Vehicle (ZEV) mandate guiding the transition of road transport. Furthermore, zero-emission zones (ZEZs) are increasingly common, restricting or banning certain types of vehicles in urban areas. Depending on their design and enforcement, these zones can reduce local tailpipe emissions and traffic noise and encourage the use of electric vehicles, bicycles, and public transport.

For example, from November 2024, Oslo required taxis operating within the city to have no combustion-engine emissions, subject to an exception for journeys crossing the municipal boundary. A combination of toll rings and emissions-based parking fees is also in force. In Santa Monica, California, a Zero Emission Delivery Zone has been established, providing priority curb access and dedicated loading zones for electric delivery vehicles and cargo bikes.

Regulatory pressure is also increasing in the maritime and aviation sectors. Policy instruments and fuel mandates are increasingly embedding emissions-reduction requirements into global



trade, accelerating the adoption of Sustainable Aviation Fuels and lower-GHG maritime fuels. Examples include the European Union's ReFuelEU Aviation regulation, which introduced a minimum Sustainable Aviation Fuel share from 2025, and FuelEU Maritime, which has applied since January 2025 and limits the lifecycle GHG intensity of energy used by covered ships.

Packaging plays an important role in decarbonization across the entire supply chain given its resource intensity, waste generation, and carbon footprint. Regulations typically target three goals: reducing plastic waste and environmental leakage, cutting the carbon footprint of packaging materials and processes, and improving recyclability and circularity across the supply chain.

For example, the EU's Packaging and Packaging Waste Regulation (PPWR), which entered into force in February 2025 and has applied generally since August 2026, establishes requirements covering packaging minimization, recyclability, reuse, recycled content, labelling, and substances of concern. California's Rigid Plastic Packaging Container (RPPC) law requires manufacturers to meet one of several compliance options, such as using recycled post-consumer materials, designing for reuse, or achieving specific source-reduction targets. In Japan, the Containers and Packaging Recycling Act requires businesses to sort and recycle containers and packaging, placing recycling obligations directly on manufacturers and importers of packaged goods.

Optimizing Operations

With supply chains responsible for more than half of global GHG emissions, the scope for improvement in logistics operations is significant. Realizing that potential first requires a clear understanding of the carbon impact of each logistics component (see Carbon Accounting & Tracking) followed by coordinated action across multiple dimensions – from transport and fuels to facilities and last-mile routing.

On the transport side, battery-electric vehicles and selected hydrogen pilots can reduce operational fossil-fuel use in applicable use cases. Eligible biogas, Sustainable Aviation Fuel, and maritime fuels may also reduce lifecycle GHG emissions relative to specified fossil-fuel baselines in modes where full electrification remains technically or commercially challenging. Optimizing transportation modes and routing can also reduce emissions, such as shifting to ocean and rail instead of air and truck where transit times permit, and calculating optimal routes for last-mile deliveries based on total distance traveled. Greenplan, for example, applies routing algorithms that can incorporate vehicle-specific emissions estimates when planning delivery routes, helping identify lower-emission routing options where operational conditions allow.

Beyond transport and routing, the decarbonization of logistics facilities represents another significant opportunity. This includes developing energy-efficient buildings with increased use of renewable electricity, as well as integrating smart facility management systems to reduce overall energy demand. At DHL, measures include improving building energy efficiency, increasing electricity sourced from renewable sources, deploying lower-GHG heating technologies where feasible, and implementing smart facility management systems.

The initial costs of decarbonization solutions are often higher than conventional alternatives, and implementation can involve operational disruption. Customer and regulatory requirements for emissions information are evolving, and carbon-pricing mechanisms and improved emissions data may strengthen the business case for investment. The financial and GHG-emissions outcomes of early action will depend on technology performance, energy prices, utilization, policy, and implementation conditions.



Summary & Trend Overview

Challenges



Carbon accounting standards remain inconsistent across markets, and the regulatory frameworks governing emissions disclosures are still evolving.



The pace and direction of regulatory change make it difficult to assess the long-term viability of technology and market strategies.



Even where standards exist, the underlying data used to calculate product carbon footprints (PCFs) and logistics emissions is often incomplete, generalized, decentralized, or difficult to verify – limiting the reliability of comparisons across organizations and supply chains.



Many decarbonization solutions carry significant upfront capital costs and require operational adjustments during implementation that can disrupt existing workflows.



Without sufficient scale, the higher cost of lower-GHG logistics measures may be passed through to customers, creating a price premium for services incorporating those measures.

Outlook

The regulatory environment governing emissions across transport, fuels, and packaging is expected to continue evolving, although scope and timing will vary by jurisdiction. Where product- and shipment-level emissions data become more widely available, they may become a more visible consideration in comparisons between logistics providers, subject to consistent methodologies and data quality. While innovation is making the operational levers of decarbonization more accessible, the pace of adoption will remain uneven across geographies and market segments.

Early preparation may help logistics organizations respond to evolving regulatory requirements and customer expectations. With supply chains at the center of global decarbonization efforts, the decisions made now are likely to influence competitive advantage for years to come.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with implementations available for many use cases today.

Related Trends

Renewable Energy Infrastructure



Heavy Vehicle Electrification



Light Vehicle Electrification



Sustainable Fuels



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Employee Belonging

Trend Overview

Impact:

MODERATE

Adoption:

< 5 YEARS

Focus Areas:

Health, Safety & Future of Work

Sectors:

Life Sciences & Healthcare



The trend of Employee Belonging describes the emotional experience of being part of a team or organization. Employees feel accepted, valued, and included at work; they are free to be their authentic selves and believe that their contributions matter.

The topic of belonging at the workplace has grown from the recognition that employees want their employers to understand that each individual has their own story to tell and professional mark to make. Modern companies now proactively cultivate a culture of belonging because it not only boosts morale and performance but also helps attract and retain talent: When employees feel accepted and needed – like they belong – they are less likely to leave.

At the individual level, workers increasingly expect more than simply employment. They want to work in a space where they find acceptance, flexibility, autonomy, and psychological safety. An American Psychological Association report found a direct correlation between psychological safety and broad employee satisfaction. Workers who reported higher levels of psychological safety were more content with coworker and manager relationships, work schedules, growth opportunities, and employer support for mental health and well-being. Frontline workers, in particular, value shift choice, schedule fit, and greater control over their work.

At the organizational level, belonging has shifted from a cultural to a business priority. Companies have identified a direct link to performance, particularly in industries like logistics facing labor shortages or high operational complexity. Organizations are shifting toward talent-centric workforce strategies focused less on demographics and more on how work is designed, experienced,

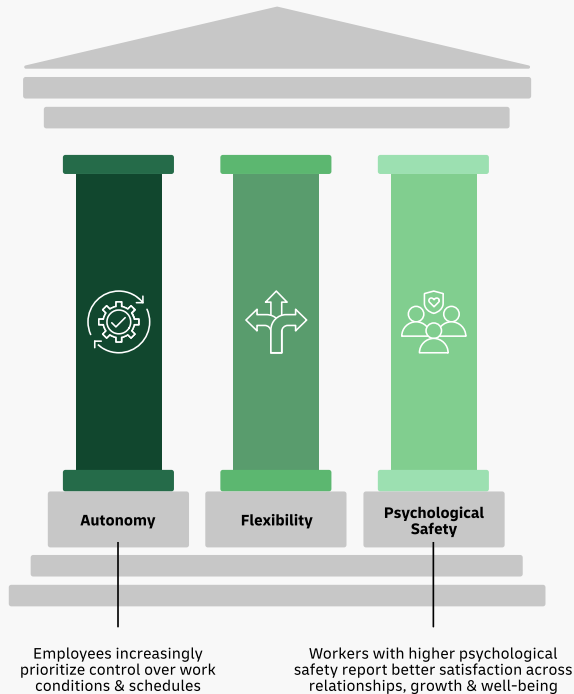
and enabled. In a well-being at work survey from Deloitte, more than eight in ten executives agreed that prioritizing a positive human impact would improve talent attraction, customer appeal, and profitability. Many organizations also cite labor shortage, workforce flexibility, and upskilling as strategic priorities.

In response, companies are reframing inclusion and making structural changes in how work is designed, managed, and experienced. Companies have scaled up formal initiatives for inclusion, flexible work, fair hiring, and caregiver support. Organizations are also using technology and artificial intelligence (AI) to digitalize the workplace, increase automation, and redesign tasks and workflows to make work more meaningful and help workers adapt to change.

While employee belonging is developing as a strategic priority across industries, the transition from treating it as a corporate program to making it a foundation for how work is organized and managed is still in its early stages. Realization at scale is likely to take shape over the medium term as the enabling conditions mature.

At DHL, we believe the potential impact of employee belonging is real. It can directly influence performance through retention, engagement, and culture, especially in a sector like logistics where workforces are frontline-heavy and labor shortages are a persistent challenge.

Employee Belonging today



Autonomy, flexibility, and safety drive Employee Belonging today.

American Psychological Association (2024): U.S. workers adjust to the changing nature of employment

Relevance to the Future of Logistics

Inclusive Workforce Design

Diversity, Equity, and Inclusion (DEI) has been the standard corporate framework for some time now, but inclusive workplaces are increasingly viewed through the broader lens of belonging. Rather than focusing on individual policies or identity categories, belonging emphasizes shared human needs such as feeling valued, respected, and connected. This framing allows organizations to address inclusion in a way that resonates across regions, cultures, and regulatory environments, while supporting a consistent employee experience narrative.

Belonging also serves to connect inclusion with engagement, health, wellbeing, and safety. By clustering these themes, organizations can move away from fragmented initiatives toward a more coherent workforce experience model. This shift supports a more holistic understanding of how people



experience work and how everyday interactions, leadership behaviors, and system design shape organizational culture.

Demographic change further reinforces the relevance of this approach. As workforces age and experienced employees retire,

knowledge transfer, intergenerational collaboration, and life stage awareness grow in importance. Rather than segmenting employees into fixed generational groups, organizations increasingly focus on skills, capabilities, and individual needs across different phases of working life. This perspective strengthens continuity and adaptability while reinforcing a shared sense of belonging.

In this context, belonging ensures inclusion is not a standalone program but embedded in how work is structured and decisions are made. Inclusion is built into the organization by design, with leadership practices, technology, and governance models working together to shape fairness, transparency, and participation.

Employee Autonomy Enabled by Digitalization

Frontline and operational workers place a high value on flexible working models, especially the ability to choose shifts that fit their schedule or create additional income. Schedule control and task ownership also directly shape their work experience. This is why autonomy is emerging as a key driver of belonging in logistics.

Digitalization expands what is possible across frontline and operational environments. Microsoft's research found that frontline workers want better technology for scheduling, automating repetitive tasks, and onboarding – and confirmed that the latest tech can deliver these capabilities. As early as 2024, the company's Work Trend Index found that employees turn to AI to save time and focus on more important work.

Belonging is strengthened when technology improves employees' control over when, how, and on what tasks they work, rather than only increasing efficiency.

Meaningful Work & AI-Driven Work Redesign

AI is changing the nature of work itself and indirectly reshaping how people feel at work. A sense of belonging will increasingly

depend on whether workers experience AI as empowering rather than as a threat to their job security or relevance.

AI is expected to change how tasks are performed within existing roles rather than eliminate jobs outright. With AI handling routine tasks, workers have greater agency over how they work and can concentrate on more value-adding activities. This shifts the focus from job displacement to task evolution, where employees can contribute more meaningfully and find greater purpose in their work.

Employees report that AI helps them save time, focus on their most important work, be more creative, and enjoy work more. However, the same research found that many workers still fear that AI makes them replaceable and that some use it covertly rather than disclosing their use to employers. Many organizations are therefore working to shift this perception, recognizing that positive framing of AI in the workplace is critical to employee acceptance and engagement.

Health & Safety

In logistics, worker wellbeing has historically been defined primarily by health and safety standards. Belonging is changing that by extending health and safety to whether employees feel heard, respected, and able to contribute. This means an employee's sense of belonging is increasingly tied to whether they feel both physically safe and psychologically supported at work.

Workers say increased organizational commitment to "human sustainability" would improve their work experience, engagement, productivity, desire to stay, and trust in leadership. Similarly, higher psychological safety is associated with greater satisfaction, better perceptions of mental health support, and fewer negative outcomes including burnout.

The health and safety dimension of belonging becomes particularly significant during periods of rapid operational change. As logistics organizations introduce new technologies and workforce models, the uncertainty these transitions generate erodes psychological safety, making belonging a determining factor in whether workers navigate change well or experience change fatigue.



Summary & Trend Overview

Challenges



Regulatory uncertainty: An evolving and inconsistently interpreted regulatory landscape creates ambiguity, making it difficult to define and scale clear, future-proof belonging strategies globally.



Organizational response and strategic trade-offs: Heightened legal scrutiny and reputational risk curtail belonging ambitions and slow decision-making because organizations prioritize compliance and risk mitigation rather than long-term cultural transformation.



Fragmented employee experience and impact: Localizing belonging initiatives across regions leads to inconsistent program design and perceived inequities in employee experience.



Unconscious bias: Bias in recruitment and career advancement creates a structural barrier to cultural change that impedes initiatives that support employee belonging.



Employee perception vs. organizational claims: A persistent gap between organizational claims about belonging and employee experience undermines program credibility and erodes trust.



Ensuring AI strengthens rather than weakens human connection: As AI powered technology scales in logistics, the narrative positioning around AI needs revolve around upskilling, as opposed to replacing, human labor and relationships.

Outlook

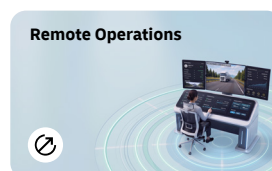
At DHL, we expect investment in belonging to grow as organizations recognize the link to workforce stability and operational performance. Belonging is likely to evolve from a cultural aspiration into an integral part of how organizations design and manage their workforce.

In logistics, as operations digitalize and roles are redesigned with AI, autonomy, flexibility, and meaningful work will be increasingly central to how frontline and operational workers evaluate their workplace experience – and whether they feel accepted, valued, and included at work. Future supply chains won't compete only through technology and automation; they will increasingly compete through their ability to create a workplace where inclusion, physical and mental health, as well as recognition form the backbone of a company's corporate culture.



Explore – This trend has the potential to drive meaningful change in specific areas of logistics with use cases in some applications that can already be addressed today.

Related Trends



Sources

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ESG Advocacy

Trend Overview

Impact:

CONSIDERABLE

Adoption:

5 – 10 YEARS

Focus Areas:

Customer Experience

Sustainability

Trend Clusters:

Packaging & Containers

Sectors:

Energy

Life Sciences & Healthcare



The trend of Environmental, Social and Governance (ESG) Advocacy reflects growing stakeholder expectations that businesses take responsibility for their environmental impact, social obligations, and standards of corporate accountability and transparency. It promotes more holistic decision-making to balance economic performance with the well-being of employees, customers, society, and the planet.

The world is facing an accelerating environmental crisis that extends well beyond climate change. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), biodiversity loss is reaching critical levels, with up to one million plant and animal species projected to face extinction in the coming decades. The International Union for Conservation of Nature (IUCN) has confirmed over 47,000 species as threatened on its Red List. Deforestation continues at 10.9 million hectares annually, and human activity has significantly altered 75% of the terrestrial environment and 66% of the marine environment.

These environmental pressures, alongside growing concerns about labor rights and corporate accountability, are driving a fundamental shift in what is expected of businesses. Logistics providers, operating across every part of the global economy, face these demands with particular intensity.

The environmental footprint of supply chains is multidimensional, spanning greenhouse gas (GHG) emissions from freight, habitat fragmentation from infrastructure development, and packaging waste along major trade corridors. Although many logistics providers are taking measures intended to reduce GHG emissions, broader environmental advocacy requires monitoring

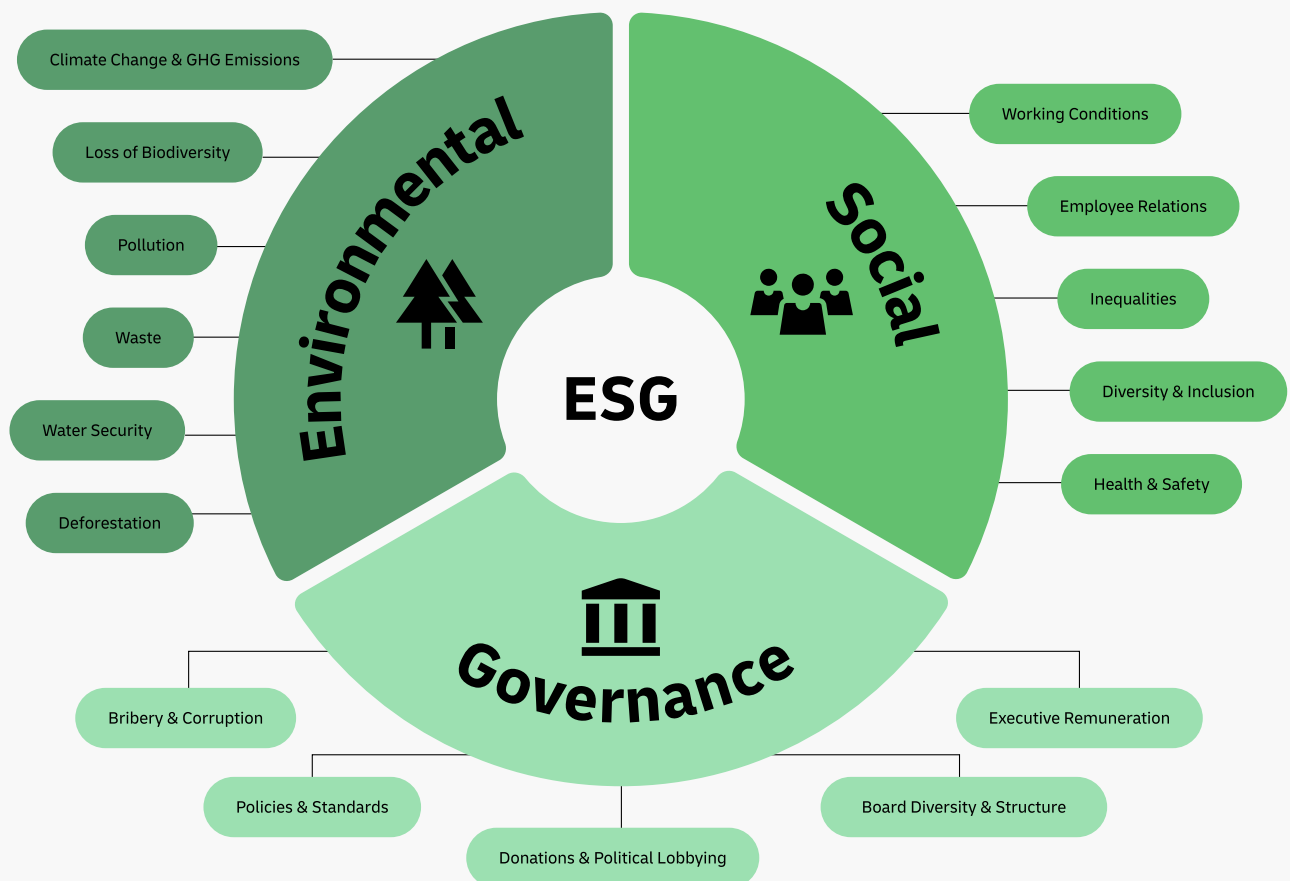
biodiversity-related impacts, ecosystem restoration activities, and lifecycle impacts across defined operational boundaries.

The social risks embedded in global supply chains are equally pressing. Child labor, forced labor, and workplace safety are real problems in parts of the world. The International Labour Organization estimates that 138 million children are engaged in child labor worldwide, while 28 million people are subject to forced labor. And roughly 2.3 million workers die annually from work-related accidents and diseases. Logistics companies sit at the center of these risks, operating across regions where labor protections are often limited and subcontracting structures obscure accountability. Stakeholders now expect active due diligence through supplier auditing, fair wage enforcement, and accessible grievance mechanisms.

Strong governance separates genuine ESG commitment from surface-level compliance. Corporate misconduct and supply chain opacity cost the global economy an estimated US\$4.5 trillion annually. For logistics companies, the fragmented and multi-tiered nature of global freight networks creates significant blind spots around supplier ethics, sanctions compliance, and labor standards. A 2025 Harvard Business Review study tracking 75 global companies found that while 85% have maintained or expanded their sustainability programs, over half are deliberately downplaying their progress, a trend the authors describe as “greenhushing”. This lack of transparency can erode the collective momentum needed to drive industry-wide change. Regulatory frameworks including the EU’s Corporate Sustainability Reporting Directive (CSRD) and Corporate Sustainability Due Diligence Directive (CSDDD) are responding by mandating verifiable, auditable ESG disclosures across entire value chains. Organizations

that invest in governance infrastructure, from digital traceability tools to ethical sourcing frameworks, will be best positioned to meet changing regulatory obligations and the expectations of customers, investors, and the public alike.

ESG advocacy remains a long-term undertaking and full industry-wide adoption is not expected within the next five years, given the complexity of the issues at stake, the evolving regulatory landscape, the current lack of clear reporting standards, and the need for accountability and incentives. While the foundational conditions are being established, proactive investment in reporting infrastructure, supply chain transparency, and cross-sector coordination will drive the shift from compliance-driven reporting toward the genuinely holistic approach to ESG decision-making that the sector's stakeholders now expect.



Business strategies need a holistic perspective on ESG elements to ensure sustainable performance and long-term resilience.

ConceptDraw. (2026). Environmental, Social, and Corporate Governance

Relevance to the Future of Logistics

Consumer Consciousness

Conscious consumerism is reshaping the business-to-consumer (B2C) landscape. Recent research confirms that sustainability remains a growth lever, though price pressure, fatigue, and skepticism have made its influence more selective. Deloitte's 2024 Sustainable Consumer survey found that 29% of consumers stopped buying certain brands or products because of ethical or sustainability concerns, and that scrutiny of green claims has increased, making transparency and substantiation as important as the claim itself. Overall, consumers are increasingly seeking brands that align with their values and expecting genuine commitments to environmental and social responsibility.

This consumer pressure does not stop at the point of sale. It propagates up the supply chain, driving growing demand from B2C companies for greater transparency on emissions and the social aspects of supply chains from their suppliers. To stay competitive in the marketplace, many B2C brands are enhancing their sustainability and social credentials, integrating sustainability into their core strategies, offering more sustainable products and lower-emission logistics, and increasing transparency about their ESG performance.

Business-to-business (B2B) companies also face growing pressure to respond by assessing their entire value chain, evaluating scope 1, 2, and 3 emissions, and accounting for the broader environmental impacts of their own operations as well as those of upstream and downstream partners.

For logistics providers, the impact of consumer consciousness is felt at every link in the supply chain. Logistics sits at the center of global supply chains, touching every tier of the value chain where these transparency demands are being made. Companies that fail to address both their own supply chain sustainability and their relationships with upstream and downstream partners risk ESG-related scandals, reputational damage, and regulatory exposure with material consequences for the business.



Nature & Biodiversity

Nature and biodiversity encompass the living systems and the broader ecosystems on which human activity and global trade depend. Nature provides services such as clean water, climate regulation, and pollination, while biodiversity is the variety of life within those systems at the genetic, species, and ecosystem level. Biodiversity has declined sharply in recent decades, driven primarily by human activity and compounded by intensifying climate change. Research published under the auspices of the United Nations Environment Programme (UNEP) estimates that half the world's gross domestic product (GDP) is moderately or highly dependent on nature.

Logistics operations can adversely affect biodiversity and ecosystems on which supply chains depend, while operational choices may also help avoid, reduce, or remediate specific local impacts. The sector can adopt technologies and practices intended to mitigate air, noise, and soil pollution and reduce associated risks to public health, climate resilience, and biodiversity. Monitoring and managing traffic noise, together with noise-reduction measures, can help limit disturbance to affected species and habitats. Mobility planning and safe handling of hazardous materials can further reduce the risk of environmental contamination.

Logistics can also help prevent the inadvertent spread of invasive species. This may necessitate controlling the introduction of such species through imported goods, packaging, and transport processes as well as curbing the proliferation of invasive organisms (e.g., algae on ocean vessels) once they are present.

Regulatory measures are already in place: since 8 September 2024, ships subject to the International Maritime Organization's Ballast Water Management Convention have been

required to meet the applicable D-2 ballast water performance standard. Broader biodiversity-related requirements affecting logistics may continue to develop.

Biodiversity conservation may appear removed from core business concerns, but companies that integrate it into their operations ahead of regulatory requirements will strengthen their strategic position while contributing to long-term ecosystem stability.



Sustainable & Responsible Sourcing

Sustainable sourcing means choosing suppliers not only based on economic factors, but on their environmental, social, and ethical performance. By applying these criteria across the supply chain, companies can address environmental and social challenges at the source – and respond to the growing expectation from their customers and end consumers that businesses take responsibility for the full footprint of their operations. Active engagement in sustainable sourcing is increasingly recognized as a driver of more resilient and responsible supply chains. However, full adoption is not straightforward: longstanding supplier contracts, limited transparency across the full supply chain, and the often higher costs of sustainably sourced products all present significant barriers.

In an increasingly regulated business landscape, logistics managers are well positioned to drive ESG-conscious sourcing practices by prioritizing transparency, risk management, and stakeholder engagement. Done well, this strengthens their own operations and adds measurable value for their customers.

Regulatory Framework

The regulatory landscape surrounding sustainability indicators and requirements has evolved significantly in recent years, with growing emphasis on carbon accounting, particularly on GHG emissions and nature-related disclosures. Many companies continue to set and pursue climate and ESG targets, even as public communication around these commitments becomes more selective. But in

the absence of a comprehensive framework to address broader environmental impacts such as biodiversity, companies need clear key performance indicators (KPIs), measures, and regulations to guide their analysis and effective alignment of business practices.

Logistics decision makers increasingly need to identify areas of business activity that affect local ecological systems, determining where compensation is required and where it represents only partial mitigation. Standardized quantitative assessment is challenging, as each location is likely to have unique ecological characteristics, making it necessary to add qualitative evaluation of local impacts. Emerging frameworks address this gap: the Taskforce on Nature-related Financial Disclosures (TNFD) offers disclosure recommendations intended to help businesses and financial institutions evaluate, report on, and act on their dependencies on nature, along with associated impacts, risks, and opportunities.

Legislators are increasingly holding companies accountable for their procurement and sourcing practices. For instance, the German Supply Chain Protection Act requires companies with at least 1,000 employees in Germany to uphold basic human rights, combat child labor and exploitation, and address environmental risks across their supply chains.

In Europe, the Corporate Sustainability Due Diligence Directive (CSDDD), as amended, is scheduled to apply to in-scope companies from 26 July 2029. It requires covered companies to identify and address actual and potential adverse human rights and environmental impacts in their operations, subsidiaries, and chains of activities, using a risk-based approach supported by monitoring, complaints procedures, and public communication.

At DHL, we anticipate governments implementing regional and national biodiversity targets, backed by enforceable guidelines. As the regulatory landscape evolves, social requirements are expected to expand alongside environmental ones – holding companies accountable for detrimental practices while also creating incentives for nature conservation and broader human well-being. Companies that get ahead of these requirements, embedding both environmental and social governance into their operations now, will be better positioned to meet future obligations and build long-term trust with customers, investors, and regulators.



Summary & Trend Overview

Challenges



Many companies have yet to move beyond sustainability topics mandated by policymakers and regulators (e.g., GHG reduction) toward a more proactive and comprehensive approach.



The opaque framework for driving and measuring broader sustainability initiatives, which is still being defined, makes it difficult to compare KPIs across industries and use cases and impedes the development of standardized measurement procedures.



Tracking the integrity and the environmental, social, and governance impact of every party within complex supply chains is difficult, limiting full transparency across the network.



Addressing sustainability risks is complicated by ecological diversity across operating locations, insufficient site-specific data on biodiversity hotspots, and significant nature-related impacts in the upstream supply chain.



The dual pressure of allocating budgetary resources toward near-term ESG compliance and investing in broader advocacy measures, including biodiversity conservation, sustainable aviation fuels (SAFs), and fair working conditions, creates financial demands that many companies are not yet positioned to meet.

Outlook

As ESG expectations grow, companies will need to ground stakeholder relationships in demonstrated action rather than stated commitments. Climate change is likely to exert more influence on business strategies in the future, so the industry needs comprehensive guidelines on quantifiable metrics, such as emissions, and more nuanced, harder-to-measure factors, such as impact on biodiversity.

For logistics organizations, monitoring operational impacts on regional ecosystems, including forests, grasslands, and marine environments, is set to become a baseline expectation, given the role intact ecosystems play in climate resilience, food security, and economic stability.

As regulatory frameworks tighten and consumer awareness of sustainability expands, ESG advocacy is becoming both a requirement and a roadmap – guiding companies beyond emissions accounting toward a fuller consideration of their environmental and social footprint, and positioning them to meet obligations, retain customer trust, and build long-term competitive advantage.



Prepare – This trend has the potential to bring substantial change across logistics with developments and use cases on the horizon.

Related Trends

Bio-Based Materials



Circularity



Decarbonization



Sustainable Fuels



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Green Urban Transformation

Trend Overview

Impact:

MODERATE

Adoption:

< 5 YEARS

Focus Areas:

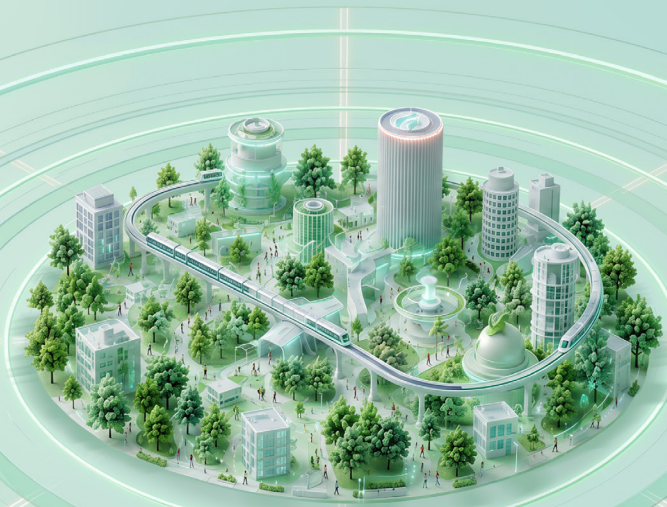
Customer Experience

Sustainability

Trend Clusters:

Digital Backbone

Internet of Things



The trend of Green Urban Transformation describes the shift of urban spaces and cities toward digitally enabled, lower-emission, climate-resilient environments that support behavioral change and improve urban livability. By using digital solutions and regulatory actions, cities can manage established networks, services, and infrastructure more efficiently and in ways that respond to the needs of businesses and residents.

The population shift from rural to urban areas puts pressure on city authorities to manage space, infrastructure, and quality of life efficiently. Cities are responsible for 75% of global greenhouse gas (GHG) emissions and are home to over half of the world's population – a number that will grow to two-thirds by 2050. To mitigate these impacts and ensure long-term viability, modern urban strategy is evolving. Increasingly, the focus is shifting toward urban climate resilience, with cities integrating nature-based solutions such as green roofs, urban forestry, and biodiversity planning alongside their digital initiatives. Artificial intelligence (AI), Internet of Things (IoT) sensors, digital twins, and other technologies are being integrated into core urban infrastructure and services to drive this transformation.

Urban transformation projects involve three layers. The first is a technology base, which includes a critical mass of smart devices and sensors connected by high-speed, high-performance communication networks. The second layer comprises applications that translate raw data into alerts, insights, and actions. The third is adoption by residents, businesses, and city authorities, resulting in behavioral change.

For example, cities are moving from static regulation to dynamic, data-driven traffic management, with residents encouraged to use

public transit during off-peak hours, reduce energy and water use, and adopt preventative health habits to ease demand on the health-care system. The expansion of urban digital twins – which allow the simulation of climate or mobility scenarios for decision-making – is a key emerging capability across all three layers.

Recent proposals to plan entire new cities around integrated digital, mobility, and environmental objectives have attracted significant attention. Nevertheless, Saudi Arabia's NEOM project, which is undergoing a massive strategic recalibration, underscores a broader urban planning lesson: durable green urban transformation must be grounded in incremental development rather than all-at-once master plans.

That being said, progress is being made. Singapore, for example, has long been a benchmark, expanding vehicle-free zones and peer-to-peer renewable energy trading across its public housing estates. In South Korea, the city of Songdo – built on reclaimed land with integrated smart systems – has seen infrastructure investments surpassed US\$40 billion in 2025, with buildings linked to a central management system and waste transported through underground pneumatic networks.

In Europe, urban greening is high on the EU's agenda: the Green City Accord, for example, urges cities to improve air and water quality and expand green infrastructure. Copenhagen has adopted a Climate Strategy 2035 that targets net-zero territorial emissions by 2030 and climate positivity by 2035, supported by implementation plans covering energy, transport, buildings, and municipal operations. Helsinki operates an open 3D city model, also described as the city's digital twin, which supports planning, data sharing, and the visualization of urban change.

Logistics plays both a direct and indirect role in green urban transformation. Logistics providers are simultaneously active participants in urban life and a primary regulatory target. In Europe, public funding and urban-access regulation are supporting measures such as public transport, active mobility, charging infrastructure, and lower-tailpipe-emission vehicles. London operates an Ultra Low Emission Zone in which non-compliant vehicles must pay a daily charge and may receive a penalty for non-payment, while Amsterdam applies low-emission requirements and phased zero-tailpipe-emission rules to specified vehicle categories.

In India, Delhi and Mumbai are piloting clean delivery corridors with electric vehicle (EV) mandates and congestion pricing models. Major metropolitan areas are using a range of measures, including emission-based access rules, congestion charging, and incentives for off-hour deliveries, to manage urban freight traffic and exhaust emissions.

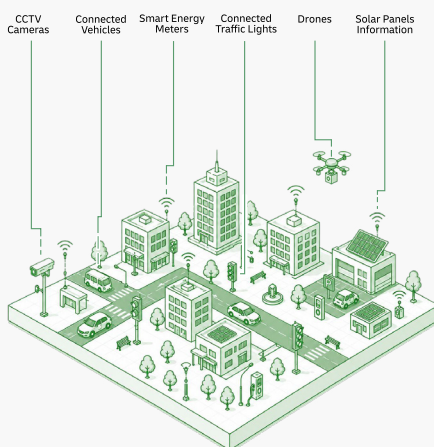
In response to access rules, congestion, space constraints, and service requirements, logistics providers are assessing or deploying EVs, cargo bikes, route-optimization tools, micro-fulfillment centers, and urban consolidation hubs. However, the primary impact of green urban transformation will be a shift toward orchestrated systems. According to the World Economic

Forum, the largest urban logistics gains by 2030 will come from coordinated interventions rather than individual innovations.

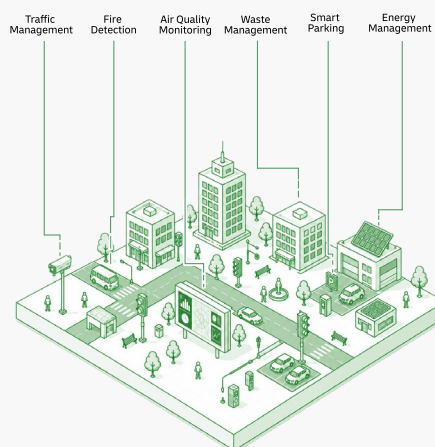
The trend of Green Urban Transformation will continue to vary from country to country and region to region – expanding further in major metropolitan areas and increasingly taking root in second-tier cities, driven by regulatory mandates and falling technology costs.

The next evolution of urban logistics is likely to vary by market, with exhaust emission reduction, congestion, service performance, cost, and access compliance among the principal considerations. While mobility and transportation – especially decarbonizing last-mile delivery – will be the primary goal, expanding efforts to buildings, energy systems, and nature-based infrastructure will further advance the green urban agenda. The transformation will increasingly impact supply chains as logistics remains both a critical lever and a formidable challenge in achieving green urban environments.

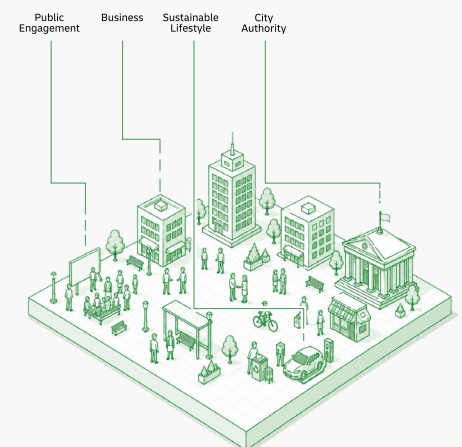
Tech Layer



Application Layer



Adoption Layer



Cities are evolving toward smarter, climate-neutral environments, redefining urban logistics, mobility, and last-mile delivery via three layers: sensors that sense, applications that translate, and public and private players who act and adopt.

DHL (2026)

Relevance to the Future of Logistics



Zero-Tailpipe-Emission Zones (ZEZs)

Urban areas face mounting pressure from traffic congestion and environmental impact, prompting governments to legislate for cleaner, more efficient transportation solutions. Zero-emission zones (ZEZs) are one of the primary regulatory tools in use. A growing number of cities across Europe, Asia, and North America have implemented, piloted, or committed to low- or zero-tailpipe-emission areas, although coverage, vehicle scope, exemptions, and implementation timelines vary.

To meet applicable zone requirements and address limited public space, logistics networks may require revised planning, consolidation solutions, and vehicles that comply with the relevant access and tailpipe-emission rules.

ZEZs are intended to reduce regulated vehicle exhaust emissions within defined areas, but they can increase operational complexity for logistics providers where fleets, charging, routing, and consolidation arrangements are not adapted.

Rather than incremental compliance, logistics providers will need to structurally redesign their urban networks in order to reduce heavy- and light-duty traffic, energy consumption, and emissions. Effective solutions include off-peak deliveries, micro-depots, intra-urban nodes, and consolidation centers on city peripheries served by EVs and cargo bikes. White-label logistics services (which effectively anonymize the logistics provider) are also emerging in ZEZs as a way to consolidate shipments across providers and improve overall network efficiency.

Urban Fulfillment

As green urban transformation progresses, municipalities act as regulators of major logistics flows and often take over control

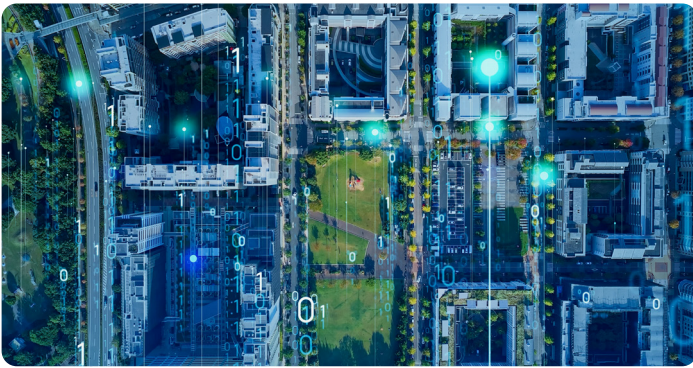
tower functionality. Authorities may also seek to reduce the number of inner-city delivery vehicles by creating white-label hubs – shipment consolidation points, managed by a third party, where multiple logistics providers convene to arrange last-mile delivery (the most expensive segment of the fulfillment supply chain). This is effectively parcel-load pooling and represents a significant shift away from conventional urban fulfillment centers located on city peripheries.

Quick commerce providers are responding by opening “dark stores” (micro-fulfillment centers housed in what used to be retail space) in urban and suburban neighborhoods, reducing travel distances and delivery times. Today, there are many examples of micro-hubs and last-mile delivery services, such as DoorDash and Amazon Now in the US, Talabat, Noon, and Careem Quick in the Middle East, or Blinkit and Swiggy Instamart in India.

Dark stores can shorten picking and delivery times by locating selected inventory closer to urban consumers, although performance and cost depend on order density, assortment, labor, rent, and operating model. Higher urban rents can offset potential fulfillment and transport efficiencies, making the overall economics of dark stores dependent on local demand density, service levels, and operating costs. Dark store ecosystems are also giving rise to new specialized services. Mapbox’s location data platform, for example, helps retailers identify optimal sites for new dark stores.

Beyond dark stores, locker networks are gaining traction: locker-to-locker, consumer-to-consumer (C2C) parcel services are an emerging model in some urban and suburban markets. Their emissions performance depends on factors including parcel consolidation, locker utilization, network design, electricity use, and the trips consumers make to access lockers. The approach moves parcels between automated locker networks and may reduce failed home-delivery attempts and support parcel consolidation, while offering consumers access outside staffed opening hours.





Smart Infrastructure

Municipalities are increasingly integrating digital infrastructure across mobility, energy, heat, water, sewage, and waste systems – a convergence that creates both the data environment and the operational framework for smarter cities. Achieving this requires integrated infrastructure across energy, information, communication technologies, and transportation.

Smart city transportation concepts, in particular, allow cities to provide many valuable services: real-time public transit information and road navigation data, integrated multimodal information, intelligent traffic control, smart parking management, and on-demand micro-transit services. Real-time data also enables congestion pricing, which reduces peak-time traffic and incentivizes alternative forms of transportation.

Logistics providers benefit directly: smart infrastructure enables real-time planning and adjustment of activities such as delivery windows. This is already happening, for example in Helsinki, where the city's digital twin provides a real-time virtual rendering of the city's infrastructure ecosystem. High-quality last-mile delivery will increasingly depend on close collaboration with municipalities and access to shared urban data.



Autonomous Last-Mile Delivery

Autonomous last-mile delivery is emerging as a strategic lever to address rising delivery volumes, urban congestion, and workforce constraints. As cities become denser and regulations tighter, logistics providers are exploring ground-based autonomous solutions for selected delivery tasks within complex urban environments.

Early deployments already demonstrate tangible value. In Finland, Coco Robotics and Wolt have deployed compact sidewalk robots for selected short-range food and grocery deliveries. Autonomous delivery pods could support selected off-peak logistics models, subject to local operating rules, safety requirements, infrastructure, and evidence that vehicle movements are shifted rather than added. These solutions are particularly attractive for cities looking to rebalance freight flows without expanding road capacity.

Despite this progress, deployment remains highly context specific. Regulations, public acceptance, safety requirements, and infrastructure readiness vary widely by city and country. As a result, most near-term value will come from targeted use cases such as short-distance deliveries, controlled operating zones, campuses, and predefined routes rather than fully autonomous citywide delivery.

Urban air logistics – a much-discussed delivery method – is unlikely to play an essential role in the near future. However, first deployments of autonomous drone networks have already moved beyond pilot stage in selected regions. Zipline's drone delivery operations, which Walmart uses for food, grocery, and medical supply deliveries, are demonstrating how autonomy can reduce delivery times and improve access in areas where ground infrastructure is limited. Its potential remains location-dependent, with meaningful application likely only in specific niche use cases.

Overall, autonomous last-mile delivery is best understood as an incremental transformation that complements existing networks, gradually reshaping how goods move through cities as technology, regulation, and urban needs converge.

Summary & Trend Overview

Challenges



Not every region offers the necessary urban infrastructure, such as sufficient grid-level charging, to apply new technologies.



Deploying interactive smart technologies, such as LPWAN and private/public 5G networks, is complicated by fragmented and sometimes incompatible communication infrastructure across urban environments.



Retailers and logistics companies face real estate and access constraints as new transit modes, tightening transportation policies, and the need for smart parcel lockers and urban consolidation centers compete for limited urban space.



A critical mass of participating stakeholders (residents, businesses, and governing bodies) is required to drive behavioral change, with public policy playing a crucial role (e.g., incentives to encourage participation) but unpopular decisions will likely face resistance from voters.



Substantial upfront public funding is required, for example charging infrastructure, telecommunication networks, data spaces, and related technology, which represents a significant barrier to adoption.

Outlook

Green urban transformation is slowly becoming an operating reality for logistics providers. The long term impact will be structural, not incremental, redefining how urban supply chains are designed, digitalized, governed, and monetized. Legislation has a significant impact on the transformation, especially in the last mile of the supply chain. Cities will implement data layers to enable better orchestration of infrastructure, traffic, supply chains, energy consumption, and more. Logistics providers will therefore need to adjust, comply, and participate in the green urban ecosystem. The strategic question is no longer whether the logistics industry adapts, but how quickly and how deeply it integrates into the green urban ecosystem.

Policy and investment are expected to continue supporting lower-tailpipe-emission mobility, vehicle electrification, automation, connectivity, and digital twin applications, although deployment will depend on infrastructure, regulation, cost, and use case suitability.



Explore – This trend has the potential to drive meaningful change in specific areas of logistics with use cases in some applications that can already be addressed today.

Related Trends



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Mass Personalization

Trend Overview

Impact:

MODERATE

Adoption:

< 5 YEARS

Focus Areas:

Customer Experience

Trend Clusters:

Artificial Intelligence

Sectors:

eRetail & Fashion

Life Sciences & Healthcare

The trend of Mass Personalization describes the delivery of highly personalized commercial experiences to individual customers at scale. It operates through advanced, AI-driven analytics of customer data to detect behavioral patterns and offer bespoke products and services.

Personalization differs from customization, which refers to offering customers a choice from a defined set, such as the color of their next sneakers or the location of their seat on a flight. Personalization involves proactively tailoring the customer experience based on individual user and aggregated data such as demographic categories and past customization choices, to make the experience feel more personal and the user feel more special and valued.

Looking across e-commerce markets around the world, Asia has become one of the earliest adopters, driving most purchasing decisions through personalized recommendations. In China, roughly 80% of online purchases started from a search just a few years ago, with only 20% influenced by product recommendations, either from the seller's own system or a third-party platform. Today, the statistics have flipped, with product recommendations now driving 80% of online purchases. For example, the primary conversion engine for many Chinese e-commerce platforms now follows a "goods find people" model powered by algorithms, content, and live video.

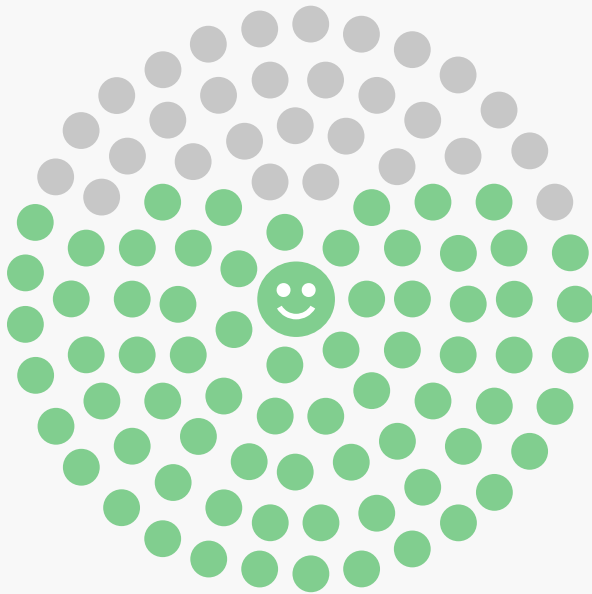
In the near future, the accuracy and relevance of these recommendations will become a competitive necessity. Larger companies especially will adopt generative, analytics-based AI models for deeper engagement with end customers, driving more relevant recommendations and offerings based on end customer needs.

Logistics is not immune to this business-to-consumer (B2C) expectation, and supply chain leaders are already looking for ways to better utilize data to improve the customer experience. Although logistics is primarily a business-to-business (B2B) industry, logistics providers act as enablers of their customers' personalization strategies and must anticipate the shifting agendas of these customers to ensure high-quality service and cost-efficient offerings.

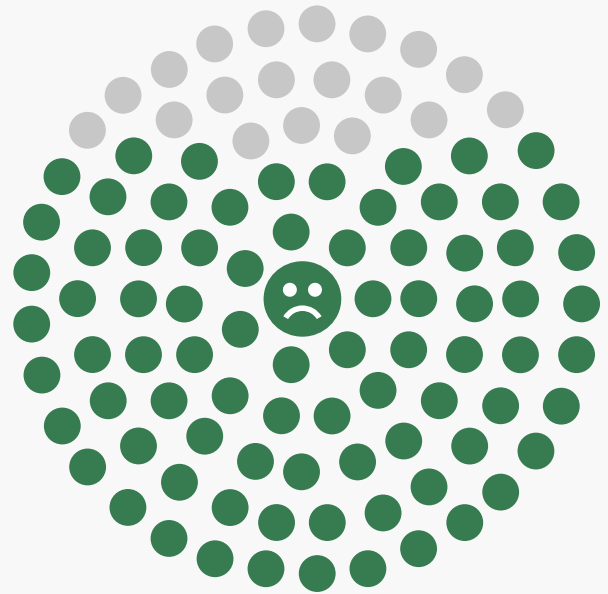
That being said, mass personalization will have a relatively low impact on logistics. While the trend is particularly relevant for B2C logistics engagement, so far we have seen only limited application in B2B logistics relationships.

While supply chains should be capable of adapting to handle more customized products and the complexity that comes with them, we do not expect any operational disruptions to logistics business. However, offering the right logistics services and agile supply chains to e-commerce businesses in the growing world of mass personalization will be necessary to stay relevant for these customers.

The direct operational impact on logistics will continue to grow, as our customers increasingly rely on personalization-driven business models and the strategic importance of logistics providers as enablers of more adaptive, data-driven, and agile supply chain growth.



71% of consumers **EXPECT** personalized interactions.



76% of consumers become frustrated when personalization is **MISSING**.

Research shows that 71% of consumers expect personalized interactions, and 76% become frustrated when personalization is missing, raising the bar for downstream logistics performance as well as for front-end retail experiences.

McKinsey (2021): The value of getting personalization right – or wrong – is multiplying

Relevance to the Future of Logistics

Tailored Logistics Services

As mass personalization gains traction, logistics providers will apply its principles to deliver highly customized B2B and B2C logistics services at scale, increasingly enabled by advances in predictive, generative, and agentic AI. By tailoring services to each customer's operational needs, commercial priorities, and behavioral preferences, logistics providers can strengthen customer retention while unlocking new revenue from value-added, data-driven services.

Customer demand remains a primary catalyst for this shift. As of 2024–2025, 91% of logistics firms report that customers now expect seamless, end-to-end logistics services from a single provider, rather than fragmented offerings across freight forwarding, warehousing, and customs brokerage. In response,

logistics providers are expanding beyond core execution into integrated services such as reverse logistics, e-commerce fulfillment, emissions reporting, and advanced analytics, increasingly underpinned by AI-driven decision intelligence.

Tailored services for B2B customers are not new. Logistics providers have long offered industry-specific solutions based on factors such as product type, regulatory requirements, or network complexity. However, AI-enabled supply chain personalization offers the next level of tailored logistics services. Predictive analytics and machine-learning models are now used to customize risk assessment, demand forecasting, routing, and inventory strategies for each customer, dynamically adapting as conditions change. Gartner reports that 74% of supply chain

managers say the leading driver of supply chain transformation is AI, with decision augmentation and predictive capabilities cited as core sources of competitive advantage.

Overall, these new capabilities are driving a shift from static, contract-based segmentation toward continuously adapting, AI-driven service models. Logistics providers that leverage them, combining customer data, predictive analytics, and generative AI (Gen AI), will be able to offer more personalized, value-added services – differentiating themselves from the competition and improving customer loyalty while increasing revenue across the B2B and B2C segments.

Enabling B2B Customer Personalization Strategies

Many manufacturers and retailers are exploring and implementing mass personalization strategies to enhance the customer journey across a variety of touchpoints. Logistics providers will be expected to be partners in this endeavor, providing innovative and broader services aligned with these customers. In this role, logistics adapts networks, inventory, and last-mile models to execute retailer-defined experiences.

For some logistics organizations, this may mean stocking more products for quicker fulfillment. To illustrate, personalized vitamin subscriptions are gaining traction in many markets. Pre-dosed packets of vitamins and supplements are consolidated and delivered monthly or even daily, tailored to each subscriber's health profile. Players ranging from established brands like GNC and Nature Made to startups like Perelel, Persona, and Ritual are active in this growing market. Unlike typical online vitamin purchases, where products may ship from multiple fulfillment centers, subscription services require concentrated inventory at a single fulfillment center. This demonstrates that while sellers personalize the customer experience upstream, logistics providers must absorb the resulting complexity downstream.

Furthermore, logistics operations may feel increased pressure from B2B customers to offer more sustainable and quicker delivery services. As younger consumers show higher willingness to pay more for sustainable goods, e-commerce retailers are actively seeking greener packaging and delivery mode alternatives to include these as personalized recommendations to customers.



At DHL, we predict that delivery options will become more personalized, based on demographic data and customer needs and preferences. Many digital marketplaces already do this. Options may include flexible delivery windows ranging from free 5-day shipping to premium same-day delivery, as well as the choice to have purchases delivered to a neighbor's address or nearby parcel locker. In order to offer more personalization, retailers will pressure logistics partners to develop and improve these services or seek out the competition if their needs cannot be met.

The trend in this use case is clear and will require expanded logistics service capabilities to meet the evolving needs of customers' personalization strategies.





B2Me: AI-Driven Customer Experience

Business-to-me (B2Me) is a business model in which companies treat every customer – whether a consumer or a business – as an individual rather than a demographic or account. It blends the scale of B2C and B2B models with hyper-personalization focused on each person's immediate needs, context, and preferences.

The Forbes Technology Council describes the emerging B2Me model as a necessary response to consumer expectations for being recognized as individuals rather than segments. Research published by McKinsey substantiates that claim, showing that 71% of consumers expect personalized interactions, and 76% become frustrated when personalization is missing. This raises the bar for downstream logistics performance as much as for front-end retail experiences.

Logistics providers are increasingly enabling the shift from conventional standardized B2C delivery models to personalized B2Me logistics experiences, powered by AI and granular customer data. As shippers and platforms generate richer insights into end consumer behavior, logistics organizations can leverage AI-driven recommendations to proactively configure supply chain services to individual end customer needs, such as fulfillment location, delivery speed, transport mode, and sustainability options. Delivering B2Me at scale requires agile supply chains

that continuously sense demand signals and adjust execution across the network in near real time.

Many logistics organizations already allow consumers to customize delivery, such as selecting delivery windows, pickup locations, packaging options, or carbon impact. Recent advances in AI enable a far more proactive and contextual approach. AI-driven systems can predict customer intent and surface personalized recommendations in real time by analyzing historical preferences, behavioral data, and stated sustainability goals. For example, generative and predictive AI can identify customers with a history of choosing lower-carbon delivery options and proactively recommend a low-carbon shipping product, consolidated deliveries, or cargo-bike last-mile services before checkout.

We already see signs that early adoption is widespread, which indicates potential acceleration. A Deloitte study found that 75% of enterprises had implemented at least one Gen AI deployment in the supply chain function by late 2024.

Summary & Trend Overview

Challenges



The volume and granularity of customer data required to support mass personalization at scale are difficult to acquire, integrate, and maintain accurately without a deep understanding of data analytics.



To help brands keep pace with rapidly shifting customer preferences, logistics providers need agile supply chains that can respond quickly when needed.



The operational complexity of handling individualized and partially customized goods makes it difficult to maintain cost-to-serve parity with standard products.



The pursuit of mass personalization creates pressure to collect increasingly granular customer data, raising the risk of overreach that infringes on data privacy rights and invites regulatory scrutiny.

Outlook

Mass personalization will continue to advance as the customer expectations and demand for tailored experiences grow. AI has advanced the adoption of this trend exponentially in the last two years and is expected to continue doing so as consumer use of AI expands into automated searching and agentic shopping. Logistics organizations can be the enablers of their B2B customers' mass personalization strategies but need to adapt service offerings to these customers and end consumers in order to also fulfill demand for customized logistics services by using the ever-enhancing capabilities of AI-driven analytics.

As B2B customers seek to fulfill the increasingly personalized expectations of end consumers, this may lead to restructuring of supply chains based on anticipated consumer demand or devising fully automated service triggers based on consumer purchases.



Explore – This trend has the potential to drive meaningful change in specific areas of logistics with implementations available for many use cases today.

Related Trends



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Smartification

Trend Overview

Impact:

CONSIDERABLE

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Physical & Digital Security

Visibility & Resilience

Trend Clusters:

Internet of Things

Packaging & Containers

Sectors:

Engineering & Manufacturing

Technology

Life Sciences & Healthcare



The trend of Smartification describes the production of connected devices or retrofitting analog assets with sensor and communication technology. These “smart” assets enable data collection for analysis, performance measurement, simulations, and data-driven decision-making.

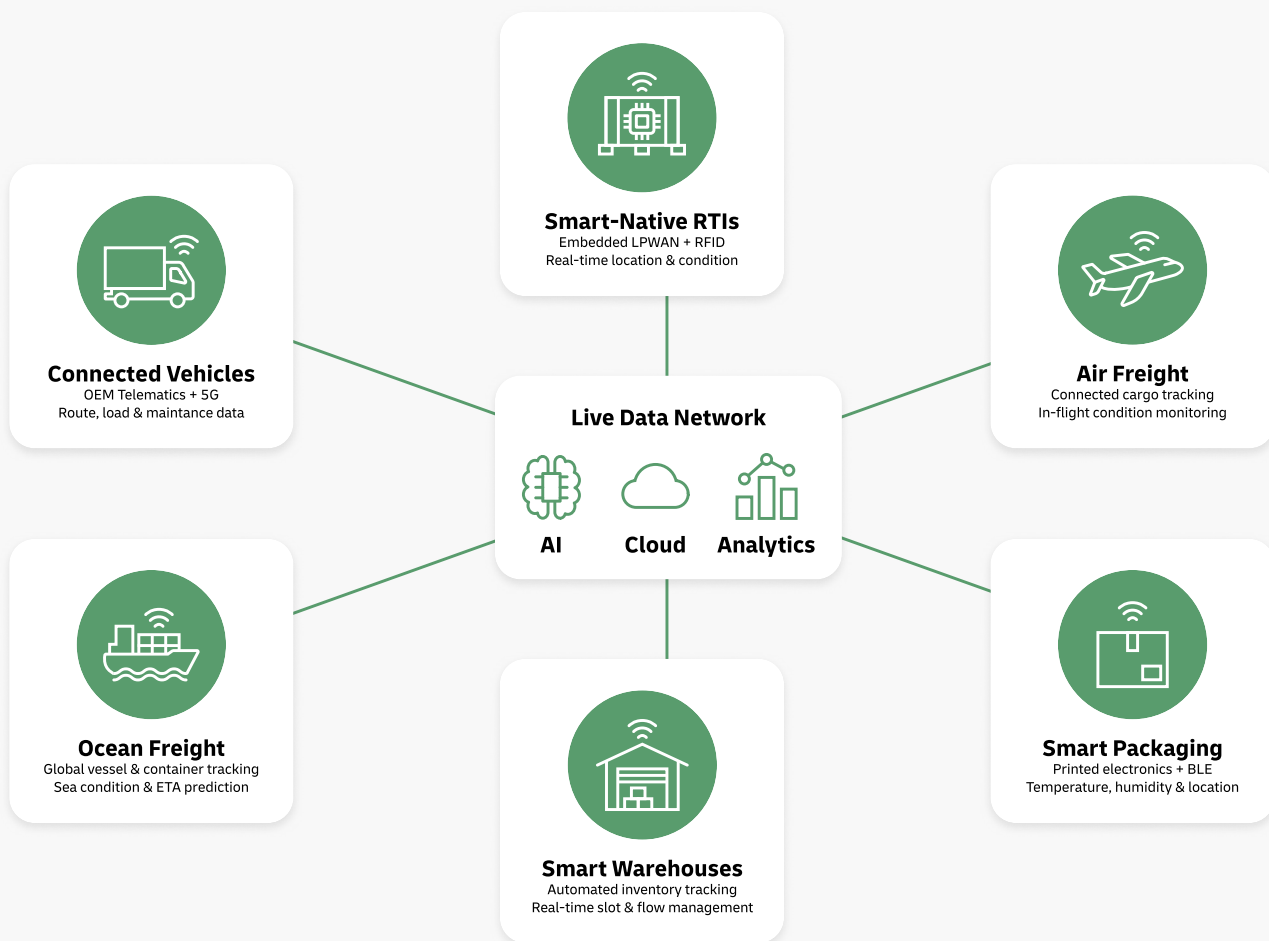
Smart, connected technology has become a standard feature of everyday life, with objects increasingly built to collect, process, and share data. The average number of devices and connections per person globally is roughly 3.6 and continues to climb, reflecting today’s high demand for constant connectivity.

In logistics, the trend is equally significant. The number of active Internet of Things (IoT) devices worldwide (e.g., tools, assets, appliances) reached approximately 21.1 billion in 2025 and is projected to surpass 40 billion by 2034. This growth is driving the shift toward assets that are “smart by default.” However, many assets remain unconnected, making it increasingly important to retrofit them with sensors for comprehensive data collection across operations. This will become easier and more scalable as sensors grow smaller, cheaper, more accurate, and more efficient.

As retrofits accelerate, advances in IoT, edge computing, and next-generation connectivity (e.g., 5G) will drive smartification growth as a whole. These technologies enable powerful ecosystems of smart devices that communicate seamlessly, process data locally, and transmit data efficiently along high-speed wireless networks.

Progress has historically been delayed by retrofitting legacy assets and integrating complex IT systems. However, we anticipate that the shift toward natively connected, smart-by-default equipment will significantly accelerate widespread adoption across industries over the next few years.

At DHL, we expect smartification to have a moderate impact on the logistics industry, improving visibility and transparency to support data-driven decision-making and supply chain optimization.



Smartification transforms the supply chain by embedding intelligence natively into physical assets, creating a fully interconnected network.

DHL (2026)

Relevance to the Future of Logistics

Connected Commercial Vehicles & Trailers

Fleet operators traditionally had to retrofit vehicles with after-market telematics devices to monitor location, fuel efficiency, and driver behavior, which often led to fragmented systems and costly downtime. Today, modern delivery vans, trucks, and trailers roll off assembly lines as fully connected “smart nodes” equipped with factory-installed telematics control units (TCUs) that integrate into fleet management software out of the box. This native connectivity is powered by OEM telematics systems, such as built-in controller area network (CAN) bus access and native 5G modules. Smart trailers also feature integrated load sensing and temperature monitoring devices.

Ultimately, this built-in intelligence provides instant, standardized data streams for predictive maintenance, dynamic routing, and load optimization – drastically reducing integration complexity and hardware costs.





Smart-Native Returnable Transport Items (RTIs)

In logistics operations, it has long been a challenge to keep track of conventional pallets and containers. They are easily misplaced or misrouted. Historically, optimizing the tracking process required manually installing expensive aftermarket tracking tags that often fell off or needed frequent battery replacement.

With smartification, pallets and containers are becoming returnable transport items (RTIs) with tamper-proof IoT sensors and energy-harvesting technologies embedded directly into the structural material. During the injection molding process, manufacturers can insert low-power wide-area network (LPWAN) trackers alongside printed radio frequency identification (RFID) and near field communication (NFC) tags into the plastic.

Logistics providers can leverage these natively smart assets to eliminate manual tagging labor, ensure 100% asset visibility from day one, reduce shrinkage, and optimize inventory pooling without incurring additional hardware deployment costs.

Smart Packaging

Tracking the conditions and location of high-value or highly sensitive goods, such as pharmaceuticals or perishables, traditionally required expensive, bulky external data loggers – devices vulnerable to mishandling and difficult to recover. Today, smartification is transforming packaging materials themselves into tracking devices. Multi-sensor capabilities and communication modules are now printed directly onto the cardboard or integrated seamlessly into shipping labels at the point of manufacture.

Innovations in printed electronics – also known as smart printables – are driving this shift. These include smart labels with integrated Bluetooth Low Energy (BLE) or cellular IoT and ultra-thin sensors capable of detecting real-time location, temperature, and humidity.

Ultimately, smart packaging solutions will provide continuous, automated, item-level visibility that enhances regulatory compliance and reduces spoilage, all without manually attaching or retrieving secondary tracking hardware.





Asset Tracking

Around the world, 10% to 40% of supply chain assets (e.g., pallets, forklifts, containers) are lost every year as a result of misplacement, theft, and breakage. With smartification, these assets can now be tracked and localized, giving organizations the transparency needed to improve usage and distribution – ensuring sufficient availability across supply chains.

Commercially available asset tracking solutions are on the rise. For example, at DHL we have equipped more than 500,000 roller cages with smart long-lifetime trackers made by Alps Alpine to monitor their location and optimize distribution across our supply chain networks.

Shipping company Hapag-Lloyd and IoT-technology provider Nexxiot have partnered to create the world's largest fleet of connected smart containers. By the beginning of 2024, Hapag-Lloyd had installed more than one million solar-powered, cellular asset-tracking devices with a run time of 6 to 10 years in its dry container fleet.

Sewio offers a real-time location system (RTLS) solution for forklift tracking. Vehicles equipped with a tag transmit signals to ceiling-mounted anchors connected to the RTLS server. Each vehicle's position is calculated in real time, within 30 cm (11.8") accuracy. The tags can be powered by the vehicle's battery or by their own battery. The collected data can also be used to measure distance traveled, run time versus stop time, and overall equipment effectiveness (OEE).



Facility Monitoring

In logistics, monitoring environmental conditions within facilities is a critical function, especially when pharmaceuticals, perishables, and sensitive hardware are in transit. It prevents goods from being exposed to extreme heat, cold, and humidity. Facility monitoring also provides insights into energy consumption, allowing organizations to identify and quantify potential energy savings, improve the facility's carbon footprint, and lower energy costs.

Smartification has enabled sensor technology for these tasks. Any facility can be retrofitted with sensors to collect data and enable data-driven decision-making.

For example, Singapore-based BeeBryte offers AI-driven energy optimization and predictive maintenance software for heating, ventilation, air conditioning, and refrigeration (HVAC-R) systems. By analyzing multi-source data (e.g., real-time IoT telemetry, warehouse operational data, and external factors like weather and building occupancy), the system dynamically optimizes operational parameters for peak efficiency.

Summary & Trend Overview

Challenges



The smartification of assets and systems requires new data analytics skills and know-how to leverage the increased volume of data and draw accurate conclusions from it.



Integrating diverse data streams into a unified logistics platform remains a significant hurdle, since manufacturers often embed proprietary sensors and systems into their “smart by default” assets.



The proliferation of embedded electronics in disposable or short-lifespan packaging raises environmental concerns regarding recycling and electronic waste management.



Expanding the number of natively connected devices exponentially increases the attack surface for cyber threats, requiring robust, end-to-end encryption and security protocols built directly into the hardware.

Outlook

Smartification is making the concept of a “dumb” asset obsolete as the cost of microchips and printed electronics continues to approach zero. Native connectivity is now a standard rather than a premium feature.

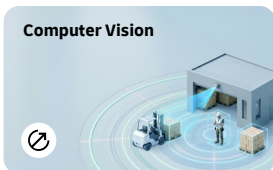
Going forward, innovators will focus heavily on sustainable, biodegradable smart materials and ambient energy-harvesting sensors (e.g., drawing power from radio waves or temperature differentials) that eliminate the need for batteries entirely. Furthermore, the sheer volume of data generated by smart-by-default supply chains will require widespread adoption of edge AI, allowing assets to process data and make autonomous decisions locally rather than relying solely on cloud connectivity.



Strategize – This trend has the potential to bring substantial change across logistics with implementations available for many use cases today.

Related Trends

Computer Vision



Next-Generation Packaging



Smart Printables



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Space Economy

Trend Overview

Impact:

LOW

Adoption:

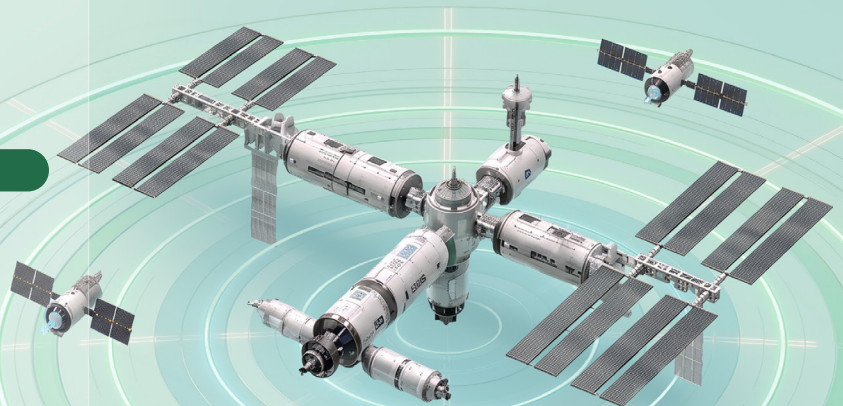
5 – 10 YEARS

Focus Areas:

Visibility & Resilience

Trend Clusters:

Internet of Things



The trend of Space Economy refers to all activities surrounding the exploration, understanding, utilization, and administration of space for various purposes, including science, telecommunications, resource extraction, manufacturing, and tourism. It also encompasses the production, transportation, and storage of related materials and products on Earth, in space, and between the two.

Space Economy is expanding rapidly, driven by increasing public and private investment, and several technological breakthroughs are poised to accelerate this growth further.

According to The Space Report 2025 Q2 by the Space Foundation, the global space economy reached US\$613 billion in 2024, up from US\$570 billion in 2023. Looking ahead, the World Economic Forum and McKinsey estimate the sector could grow to US\$1.8 trillion by 2035 as space-enabled services expand across communications, navigation, Earth observation, and other industries.

Global launch activity has continued to reach new highs. Bryce-Tech analyzed 259 orbital launches and nearly 2,900 spacecraft deployed in 2024, up from 221 orbital launches in 2023, with commercial providers accounting for about 70% of launches and small satellites making up 97% of spacecraft launched.

Key technological breakthroughs will likely accelerate this growth. Reusable launch vehicles, such as SpaceX's Falcon 9 and Blue Origin's New Shepard, and the continued miniaturization of satellites reduce costs for development, launch, and deployment.

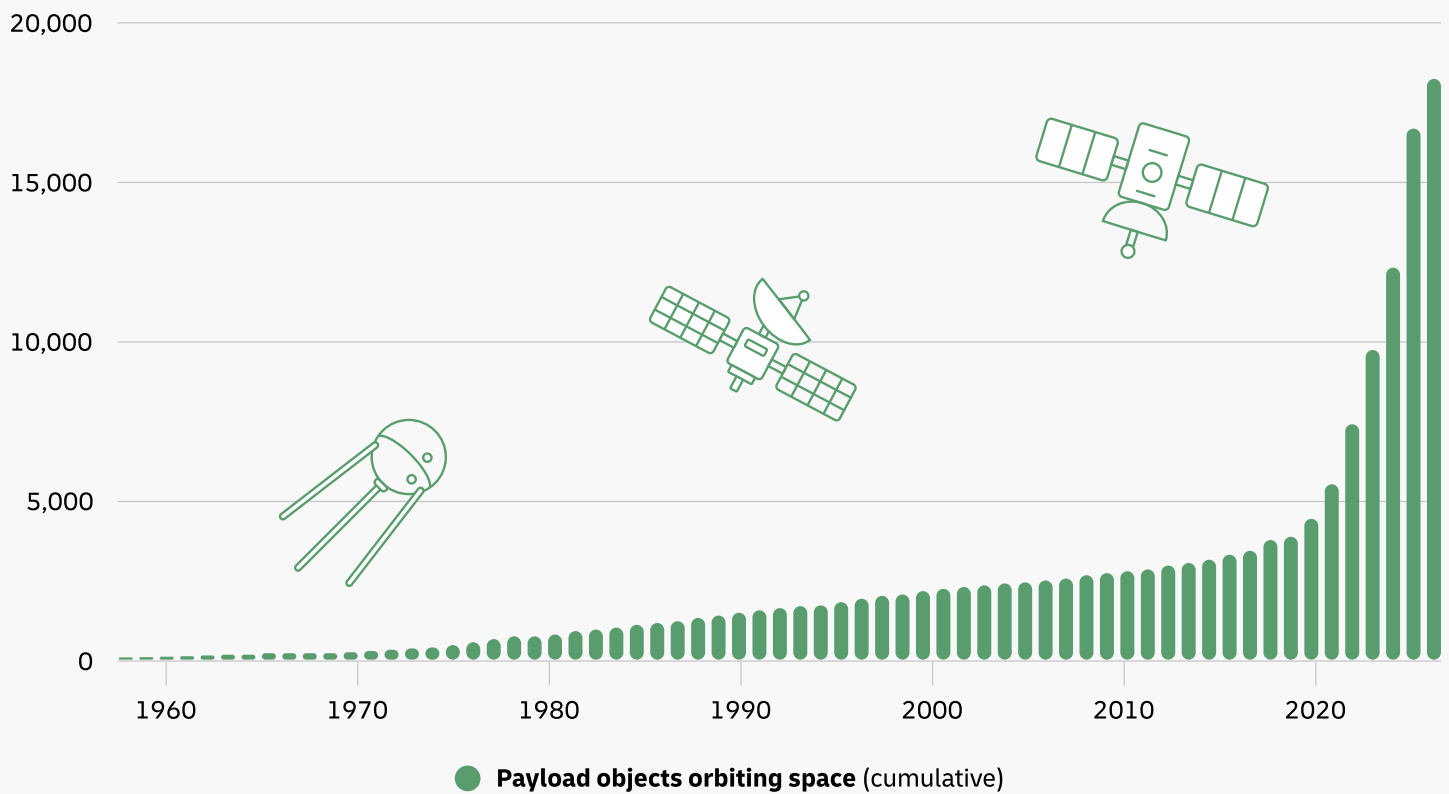
In-space manufacturing is also advancing, with companies such as Redwire Space developing 3D printing and other microgravity

manufacturing technologies. On-orbit servicing, assembly, and manufacturing, including robotic technologies for refueling, repairing, upgrading, and repositioning satellites, is expanding further. Companies are also advancing edge computing in space, enabling satellites to process more data on board before transmitting insights back to Earth.

This trend currently has a low impact on logistics, and widespread adoption remains distant. It represents a tiny fraction of the total throughput of today's supply chains. While it is an emerging niche, the infrastructure, cost, and regulatory conditions for broader logistics involvement are not yet in place.

Number of objects orbiting Earth by year of launch / separation

April 24, 2026



The cumulative number of payload objects orbiting Earth (spacecraft, satellites, etc.) has almost quadrupled since 2020.

Statista (2026): It's Getting Crowded Up in Space

Relevance to the Future of Logistics

End-to-End Satellite Logistics

Tens of thousands of satellites are expected to be launched in the next decade, requiring specialist logistics services to reach their designated coordinates in space. This includes current logistics solutions covering aspects like production, pre-launch, launch, and in-orbit services as well as end-to-end approaches that demand specialized logistics expertise.

End-to-end satellite logistics involve a wide variety of activities, from brokering rocket freight space for customers to deploying specialist teams to satellite manufacturing sites to oversee pickup and delivery to launch sites. Logistics providers are also needed to transport replacement parts and equipment for maintenance as well as the decommissioning process at the end of a satellite's life.

As the space economy expands, it will create demand for end-to-end logistics solutions, though realizing this opportunity will require significant investment to reduce the costs of transporting satellites and other equipment.



Space Cargo Supply Chains

As space activity expands, the growing volume of supplies, such as fuel, equipment, and other materials, will need to be transported into space. Logistics providers will also be needed to move space equipment and supplies between Earth-based facilities supporting these operations.

Logistics infrastructure will be required not only to store but also transport space equipment, which could prove challenging due to stringent space and weight restrictions on rockets and shuttles.

The number of shipments destined for space is likely to grow, along with increased diversification of the products delivered. Here at DHL, we expect modular standardization of packaging and containers to adequately protect products while also minimizing volume and weight.





Satellite-Powered Supply Chains

Global connectivity remains a persistent challenge for supply chains. Many companies experience poor shipment visibility when goods cross borders. Satellite internet has the potential to fundamentally transform connectivity worldwide, extending reliable access to underserved areas and remote regions where ground-based infrastructure is limited.

Satellite-powered supply chains benefit from real-time tracking and monitoring. GPS and other global navigation satellite systems provide precise location data of vehicles, containers, and other assets throughout the journey. The integration of satellites in supply chains can also improve inventory management. For example, satellite imagery can monitor raw material sources, crops, and livestock health, enabling improved demand forecasting and resource allocation. In addition, satellite communication bridges connectivity gaps in remote regions, enabling efficient logistics operations in areas with limited ground infrastructure.

Combining satellite data with other data sources, such as Internet of Things (IoT) sensors and enterprise resource planning (ERP) systems, can generate valuable insights and optimize supply chain performance, enabling companies to make more data-driven decisions on route optimization, fuel efficiency, carbon emission reduction, and more.

Starlink is an example of a low-Earth orbit (LEO) satellite internet constellation providing high-speed, low-latency internet to users around the globe. The international container shipping company Maersk is working with Starlink to use satellite data for tracking container ships, optimizing routes, and improving fuel efficiency.

There is broad potential for satellites in logistics, helping logistics providers collect data that was previously out of reach, optimize supply chains, and provide better services to customers. Satellites will also help to provide network coverage across the globe, eliminating connectivity issues in so-called dead zones.

Summary & Trend Overview

Challenges



Space logistics faces fundamental constraints on the materials and products that can be transported and handled due to the extreme environmental conditions of space and will require highly specialized transportation methods.



It will be difficult for logistics operations to achieve economies of scale due to the payload constraints of launch vehicles in terms of both physical dimensions and weight, which restrict the volume and variety of goods that can be transported into space.



End-to-end logistics services for the space economy are expensive to develop and operate, and their commercial viability remains unproven, requiring significant investment and further technological breakthroughs to cut costs.

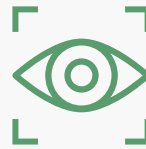


The space economy lacks an established legal framework governing commercial logistics operations in space; as space regulations evolve, there is a risk that emerging rules will not accommodate new business models such as end-to-end logistics services, creating operational uncertainty and potential barriers to investment.

Outlook

The space economy is expanding rapidly, attracting growing public and private investment. As the market for end-to-end satellite logistics continues to evolve, we see promising opportunities alongside significant uncertainties.

The pace of technological advances, regulatory adoption, and cost reductions will likely determine the viability and future landscape of the space economy. For now, the exact impact on the logistics industry remains undetermined, and broad realization of the space economy's potential is still distant.



Consider – This trend has the potential to deliver incremental improvements to logistics with developments and use cases on the horizon.

Related Trends

Next-Generation Connectivity



Digital Twins



Compute Economy



Sources

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Supply Chain Diversification

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Sustainability

Visibility & Resilience

Sectors:

Auto-Mobility

Engineering & Manufacturing

eRetail & Fashion

Life Sciences & Healthcare

Technology



The trend of Supply Chain Diversification describes a proactive strategy that embeds multiple forms of redundancy and optionality across the supply chain network. It involves designing and operating supply chains around one or more of four key dimensions: multi-shoring, multi-sourcing, parallel transport modes, and diversified logistics operations.

Global trade remains strong, demonstrating robust interconnectedness rather than a retreat from globalization. Trade flows remain close to historic highs, and recent analysis shows that global connectedness has stabilized rather than declined following the pandemic. This indicates that globalized supply chain networks are diversifying rather than being replaced, as companies rebalance their footprints across regions while maintaining international linkages.

At the same time, supply chain disruption has shifted from an episodic occurrence to recurring structural patterns. Geopolitical tensions, including armed conflicts, sanction regimes, cyber threats, and economic espionage create persistent volatility that functions as a constant rather than an exception. In 2024, over 90% of global supply chain leaders experienced material disruptions, reinforcing the importance of supply chain diversification as a foundational strategy.

Early post-pandemic responses focused on reshoring; recent activity shows a pivot toward multiregional, Asia-plus strategies. Heavy regional concentration is gradually being reduced, although not eliminated. Organizations are diversifying across Asia, including India and the Association of Southeast Asian Nations (ASEAN), rather than exiting the region. Major technology companies, for example, have significantly expanded their supplier

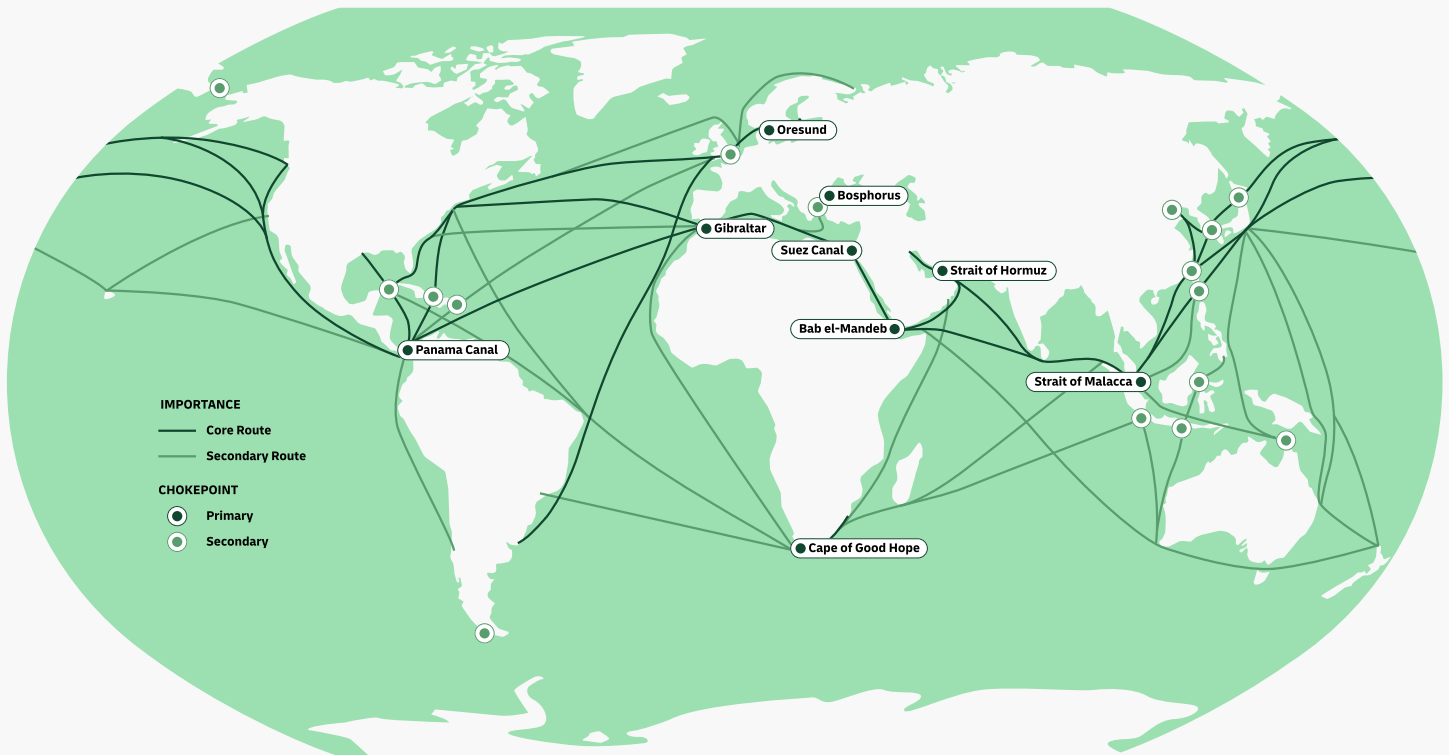
bases across India, Vietnam, Thailand, and Malaysia, while China continues to play a dominant role in absolute terms. This reflects a broader trend of diversification through geographic expansion rather than full-scale relocation.

However, adoption of supply chain diversification strategies remains uneven. While around 73% of companies report progress on dual-sourcing and roughly 60% on regionalization, the rate of new investment in these resilience approaches has flattened since 2023. This suggests that diversification is widely recognized as essential, yet its execution varies significantly across industries and organizations.

Cost efficiency is an important consideration, but decision-making is increasingly guided by economic security, resilience, and operational continuity by reducing dependency risks and maintaining the ability to adapt quickly to disruptions, even when this requires trade-offs in short-term efficiency.

Overall, these dynamics confirm that supply chain diversification is advancing incrementally within an enduring global trade system, shaped by continuous disruption and inconsistent but ongoing transformation. Trade rerouting, not trade reduction, is the dominant pattern, with supply chains becoming more regionally distributed while remaining globally interconnected.

By reducing concentration risks and enabling faster adaptation to disruption, diversification produces supply chains that can bend rather than break, reinforcing the resilience needed to manage persistent volatility.



A disruption of any primary chokepoint would seriously impact global trade.

Port Economics Management (2026): Main Maritime Shipping Routes and Chokepoints

Relevance to the Future of Logistics

4 Dimensions of Supply Chain Diversification Design

The need for supply chain resilience is leading to a shift from isolated sourcing decisions to system-level design. Organizations are increasingly applying the four dimensions of supply chain diversification: multi-shoring, multi-sourcing, parallel transport modes, and redundant/concurrent logistics operations.

Multi-shoring strategies are expanding regional production footprints, with technology firms redistributing manufacturing across



countries such as India, Vietnam, and Thailand while maintaining a partial presence in China. This approach reduces geographic concentration risk while preserving access to established ecosystems.

Multi-sourcing is strengthening supplier optionality. For example, pharmaceutical companies are diversifying the sourcing of active pharmaceutical ingredients across both Asia and Europe to mitigate supply disruptions and regulatory exposure. This layered sourcing strategy enhances flexibility and ensures continuity in critical supply segments.

Parallel transport mode strategies allow companies to switch between sea, air, road, and rail as conditions change. Geopolitical escalation affecting key transit routes like the Strait of Hormuz can disrupt oil, chemical, and container flows. In these scenarios, high-value or time-critical goods are rerouted via air freight from alternative regional hubs to maintain supply continuity.

Redundant/concurrent logistics operations involve establishing multiple distribution centers across regions instead of relying on single centralized hubs. In the life sciences sector, for example, concurrent cold-chain networks ensure compliance and uninterrupted delivery.

Together, these measures illustrate a broader transition toward integrated diversification strategies, where resilience is built simultaneously across sourcing, production, transportation, and distribution layers.

Supply Chain Resilience

Shifting geopolitical dynamics and increasing global instability are reshaping how companies design and manage their supply chains. Diversification strategies such as multi-sourcing and multi-shoring are becoming essential to reduce exposure to concentrated risks. Yet the same diversification that reduces concentration risk also multiplies the number of suppliers, routes, and partners a company must coordinate and monitor, introducing a different kind of exposure.

At the operational level, business continuity management (BCM) and crisis preparedness have become increasingly critical. Research shows that resilience is no longer a secondary consideration but a core design principle. This requires organizations to embed continuity planning into everyday supply chain decision-making rather than treating it as a standalone function. This includes developing structured crisis management capabilities that enable rapid response, recovery, and adaptation. Organizations that integrate these practices are better positioned to maintain service continuity and protect value in today's increasingly uncertain conditions.

In parallel, the threat landscape is expanding across both physical and digital domains, exposing supply chains to cyber risks alongside traditional operational disruptions. This makes being prepared a dual



challenge. Managing cyber risk within supply networks is gaining importance, as vulnerabilities in information systems can propagate quickly across interconnected partners. Physical disruptions caused by infrastructure failures, natural disasters, or geopolitical conflicts also continue to test the robustness of global logistics networks.

Future-ready supply chains will be those that move beyond efficiency optimization toward resilience by design, balancing cost with adaptability in a world characterized by persistent uncertainty.

Software Dependency in Diversified Supply Chains

The growing reliance on single, mission-critical software platforms represents a significant structural shift shaping supply chain operations. Modern logistics networks increasingly depend on deeply integrated digital systems to manage bookings, customs filings, billing, visibility, and compliance. Platforms such as CargoWise have effectively evolved into global freight forwarding operating systems that are embedded in day-to-day operations and process a substantial share of worldwide customs and shipment transactions. Yet even as companies diversify, many continue to coordinate this added complexity through a single digital platform.

This concentration of digital infrastructure creates a new dimension of supply chain vulnerability, one that persists – or even intensifies – after a company has diversified its physical network. The 2024 CrowdStrike outage, which affected approximately 8.5 million Microsoft Windows devices worldwide, including devices used by organizations in the transport sector, demonstrated how a disruption at a single technology provider can cascade across industries and geographies. Similarly, in late 2025, pricing adjustments for CargoWise sparked widespread concern among freight forwarders, many of whom reported limited ability to

transition away due to the complexity and cost of replacing such deeply entrenched systems. These developments show that supply chain diversification may reduce physical concentration risk, but it does not, on its own, reduce dependency on the software platform that coordinates them.

As a result, software dependency is emerging as its own form of supply chain concentration risk, once created in part by diversification itself: coordinating a broader network of suppliers, transport modes, and logistics operations requires a correspondingly capable digital backbone, and many organizations rely on a single platform to provide it. Disruptions, pricing changes, or shifts in capabilities at a single vendor can have consequences comparable to traditional physical bottlenecks, such as port closures or transportation interruptions. This suggests that the context of supply chain resilience gained through physical diversification extends to the digital systems that hold diversified networks together.



Navigating Regulatory Complexity

Regulation is becoming a key driver of supply chain diversification. Environmental policies such as carbon pricing, emissions reporting, and carbon border measures are reshaping sourcing decisions, routing, and landed costs. Trade policy has a similarly direct effect: tariffs have become structural policy tools rather than temporary measures, and sudden tariff adjustments can make an established sourcing strategy economically unviable overnight, pushing companies toward markets not subject to the same measures.

This dynamic works in both directions. As companies diversify across more sourcing countries, transport corridors, and logistics partners, they also take on a correspondingly larger regulatory footprint: customs documentation, product classification, safety rules, and licensing requirements all vary by jurisdiction, and a diversified network must track and adapt to changes in each of them simultaneously. Data localization laws and stricter cybersecurity requirements add a further layer, constraining how logistics and shipment data can be stored and processed across an increasingly dispersed set of operating markets. The result is that diversification, while reducing sourcing concentration, can increase the operational and compliance complexity a company must manage.

Sanctions illustrate this trade-off clearly. They can quickly limit access to markets, partners, or transit routes, and often evolve rapidly enough to raise the risk of unintended non-compliance. Here, diversification provides a genuine advantage: companies can reroute around a newly sanctioned market or corridor, while those with a single, concentrated network have no such option.

Together, these dynamics show that regulation and diversification shape each other: regulatory pressure pushes companies to diversify, while diversification itself expands the range of regulatory regimes a company must navigate. Managing this well requires pairing flexible, diversified supply chain designs with compliance capabilities strong enough to keep pace with a rapidly changing global regulatory landscape.

Summary & Trend Overview

Challenges



Supply chain diversification increases complexity: multi-sourcing, multi-shoring, and additional transportation modes take time and resources to source, pre-qualify, onboard, and manage.



Diversified supply chain setups typically increase operational costs, reducing profitability.



Coordinating a diversified network through a single software platform creates a new risk, since a disruption or pricing change can undercut the resilience diversification is meant to provide.



Expanding the number of nodes, routes, partners, and regulatory requirements within logistics networks can reduce reliability rather than improve resilience unless the added complexity is managed effectively.

Outlook

Supply chain diversification is evolving from risk mitigation to a core operating principle of global logistics. It is redefining how value is created, protected, and scaled in an age of persistent global trade uncertainty and volatility.

In this context, the role of leading logistics providers is expanding, moving beyond execution to become integrators of trade intelligence, risk analytics, and physical network capabilities. Supply chain diversification is the strategy, and they are positioning themselves as the strategic partners that support customers in navigating geopolitical complexity and maintaining stable, resilient supply chains.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with use cases in some applications that can already be addressed today.

Related Trends

AI Analytics



Cybersecurity 2.0



Compute Economy



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Agentic AI

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency Customer Experience
Health, Safety & Future of Work Visibility & Resilience

Trend Clusters:

Artificial Intelligence Digital Backbone

Sectors:

eRetail & Fashion Life Sciences & Healthcare Technology

The trend of Agentic AI describes a class of systems built from autonomous, AI-enabled components that can independently perceive inputs, make decisions, plan and execute tasks, and act toward defined goals. Unlike early AI models that respond to individual prompts, agentic systems pursue multi-step objectives with minimal human intervention, adapting to changing conditions as they interact with environments, data, and tools.

Agentic AI reflects a broad shift in how artificial intelligence is being designed and deployed. While Generative AI (Gen AI) focuses primarily on creating content in response to prompts, Agentic AI extends these capabilities into autonomous, goal-driven systems that require only limited supervision. In this context, content generation becomes one possible activity within a larger autonomous workflow, such as drafting a customer notification and triggering its delivery without human intervention.

In 2025, the global Agentic AI market was valued at approximately US\$7.3 billion and is projected to grow substantially over the next decade, driven by advances in large language models (LLMs), reinforcement learning, and AI tooling.

Agentic AI is best understood as a framework rather than a single technology. AI agents serve as the functional building blocks, each designed to perform specific tasks with a degree of autonomy. When orchestrated together within an agentic system, these agents can collaborate with one another and with human operators, adapt over time, and manage complex processes from beginning to end.

Several key breakthroughs have enabled the emergence of AI agents:

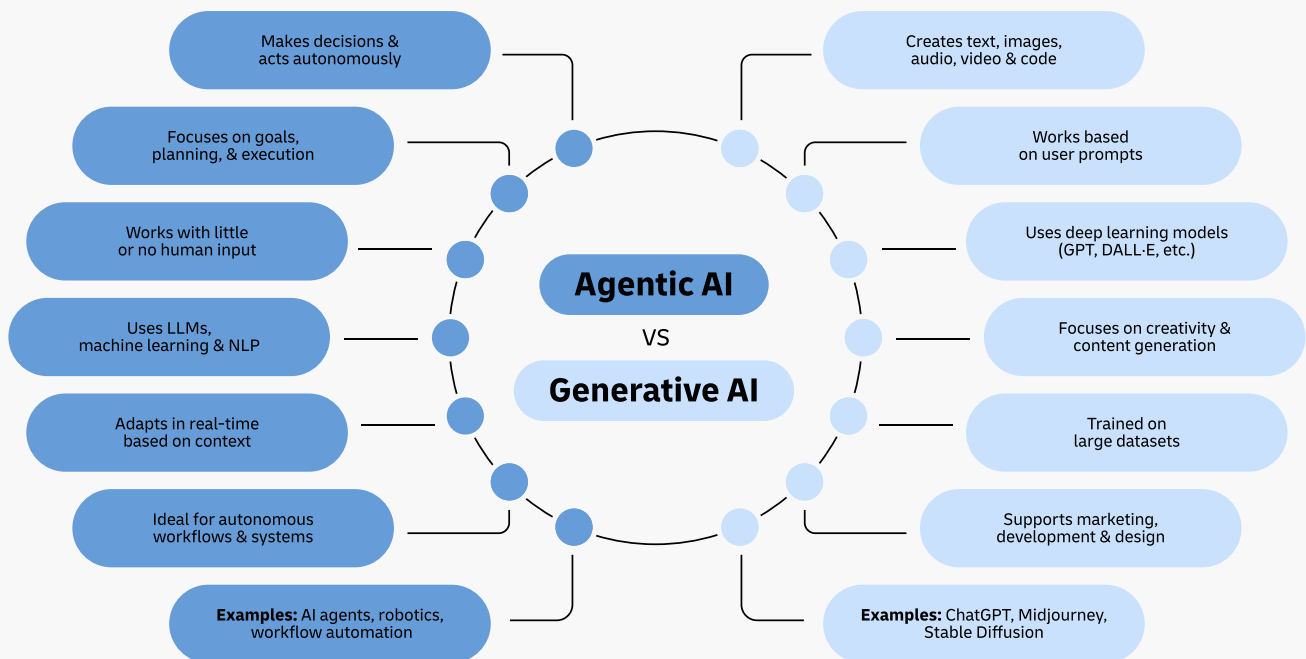
- LLMs that provide general reasoning capabilities.

- Reinforcement learning techniques that allow agents to improve through feedback.
- Structured reasoning approaches that support task decomposition.
- Advances in autonomous tool use that allow agents to interact directly with software systems and data sources.

More recently, shared protocols and platforms, such as Anthropic's Model Context Protocol and Google's Agent2Agent Protocol, have lowered the barrier to building and connecting agents, accelerating enterprise adoption.

At DHL, we foresee Agentic AI having a high impact on logistics, with early implementations already moving beyond pilots into production environments. Unlike earlier automation waves that depended on predefined rules and static workflows, agentic systems adapt dynamically – combining Gen AI, conversational interfaces, contextual memory, and enterprise system integration to execute tasks at speed and scale. This positions the trend closer to realization than previous advances in automation.

The successful adoption of Agentic AI in logistics depends on more than technology readiness alone. Clear governance frameworks are needed to define decision boundaries, embed human-in-the-loop oversight where required, and ensure accountability for autonomous actions. Equally critical are data quality, system integration, and workforce capabilities. Organizations that invest in upskilling staff and redesigning processes around human-agent collaboration are more likely to realize sustainable value from agentic systems.



While Gen AI primarily creates content, Agentic AI drives action, enabling decision-making and execution to solve complex and real-world problems.

Codeflix Global (2026)

Relevance to the Future of Logistics



Customer-Facing AI Agents

Customer service is among the first application areas for Agentic AI to move from pilot to production. Across industries, contact centers are increasingly shifting from human-only channels to AI-powered voice and chat agents that can maintain personalized, context-aware conversations – drawing on internal and external knowledge sources and leveraging generative capabilities for translation, summarization, and response generation. In doing so, Agentic AI is redefining how organizations engage with customers at scale.

In logistics, call centers handle everything from shipment inquiries and appointment scheduling to proactive delay notifications and dispute or claim initiation. Agentic AI enables autonomous management of these interactions, with AI agents completing calls, sending follow-ups, and triggering downstream actions across enterprise systems.

At DHL, we have deployed customer-facing agentic systems across multiple business units, demonstrating how they can improve

service quality, ensure compliance, and deliver more proactive logistics experiences at scale.

DHL Supply Chain uses AI agents from HappyRobot across multiple regions to automate customer communications and operational coordination. These agents handle appointment scheduling, driver follow-ups, and high-priority warehouse alerts, delivering faster responses and freeing frontline teams from routine manual coordination tasks.

For temperature sensitive shipments across Latin America, DHL Supply Chain uses Internet of Things (IoT) sensors to continuously monitor conditions during transport. When a temperature deviates from defined parameters, AI agents automatically trigger notifications, initiate follow up calls, and coordinate next steps without human intervention.

DHL Express has implemented AI agents to conduct proactive customs duty payment calls to non-account customers sending shipments into the United States to prevent customs clearance delays. These autonomous agents contact customers, explain duty requirements, collect missing information, and guide them through payment steps.

Workflow Orchestration

Workflow orchestration is the coordination of interconnected tasks across business applications to ensure smooth and timely execution. Traditional automation approaches relied heavily on robotic process automation (RPA) to handle repetitive and rule-based activities such as data entry and system handoffs. While effective in stable environments, these tools struggle with variability, exceptions, and dynamic decision-making.

Agentic AI introduces a new level of autonomy into workflow orchestration. AI agents can independently assess situations, initiate workflows, adapt execution paths, and coordinate across systems without predefined scripts.

In logistics, this capability can be applied to processes such as request for quotation handling, customs documentation, warehouse

coordination, inventory replenishment, and exception management. Amazon Web Services has introduced Amazon Connect Decisions, an agentic planning and intelligence tool designed to support autonomous decision making across supply chain workflows. The system uses AI agents to analyze data, investigate root causes, and recommend or execute actions on behalf of planners, reducing decision latency and improving planning accuracy.

Large retailers such as Walmart are applying Agentic AI to inventory management, creating a unified view across stores, fulfillment centers, and distribution networks. When unexpected demand shifts occur, AI agents can automatically detect inventory risks, adjust replenishment plans, and trigger corrective actions in real time.

Self-Healing Supply Chains

The most advanced application of Agentic AI for the future of logistics is the concept of self-healing supply chains, in which interconnected agentic systems continuously sense disruptions, diagnose root causes, decide on corrective actions, execute responses within defined guardrails, and learn from outcomes over time. Achieving this requires a tightly integrated ecosystem that combines real-time data from sensors, predictive AI models, enterprise platforms, and automated workflows.

Early examples of self-healing supply chains are already emerging, with some of the most advanced applications found in global freight and shipping. Flexport, for example, uses autonomous agents to manage a growing share of its freight forwarding activities, with specialized agents handling bookings, customs processes, and exception management. During major weather disruptions in Southeast Asia, agents independently rerouted thousands of containers, significantly reducing delays compared with manual intervention.

Maersk has highlighted the use of AI and advanced analytics to support vessel routing, network planning, and container-flow optimization. These capabilities analyze factors such as weather conditions, fuel costs, port congestion, and demand imbalances to improve operational decision making. As agentic technologies mature, they may enable increasingly autonomous coordination and execution across global shipping networks.



Summary & Trend Overview

Challenges



Autonomous agents can unintentionally make errors, expose sensitive data, or create customer and security risks – making robust governance and oversight mechanisms essential.



Explainability, accountability, and incident management remain critical concerns, as organizations must be able to audit autonomous decisions, investigate failures, and clearly define responsibility when agentic systems create operational, compliance, or customer impacts.



Agentic AI requires new skills and roles that cover agent design, orchestration, and supervision as well as effective management of the collaboration between humans and autonomous systems.



Agentic solutions place significant demands on AI infrastructure, as multi-step reasoning, persistent memory, and frequent tool interactions can drive higher compute costs, latency, and system complexity.



Data readiness and legacy system integration remain major barriers, as fragmented data landscapes, inconsistent data quality, and tightly coupled legacy systems can limit the ability of agentic systems to operate reliably at scale.



API lifecycle readiness is critical for Agentic AI adoption. Organizations must establish standardized data contracts, canonical shipment and customer data models, robust error handling, observability, and security controls to enable agents to interact safely and reliably with enterprise systems.

Outlook

Agentic AI is expected to play an increasingly central role in logistics over the next five years as underlying technologies mature and enterprise adoption accelerates. The adoption of Agentic AI will likely occur in phases. Organizations are expected to first deploy assistive AI agents that support employees, followed by supervised workflow agents capable of executing defined tasks. As governance, trust, and system integration mature, companies may gradually enable controlled autonomous actions and ultimately self-healing supply chain processes.

As organizations scale these capabilities, success will depend on striking the right balance between autonomy and control, supported by strong governance, human-in-the-loop oversight, and a workforce prepared to operate alongside intelligent agents.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with implementations available for many use cases today.

Related Trends

Generative AI



AI Ethics



AI Commerce



Compute Economy



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AI Analytics

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Customer Experience

Sustainability

Visibility & Resilience

Trend Clusters:

Artificial Intelligence

Digital Backbone

Internet of Things



The trend of AI Analytics marks the shift from human-guided data exploration to machine-led discovery. It transforms applications into comprehensive, self-learning systems that autonomously process massive datasets to uncover hidden patterns, forecast future scenarios, and prescribe optimal strategies.

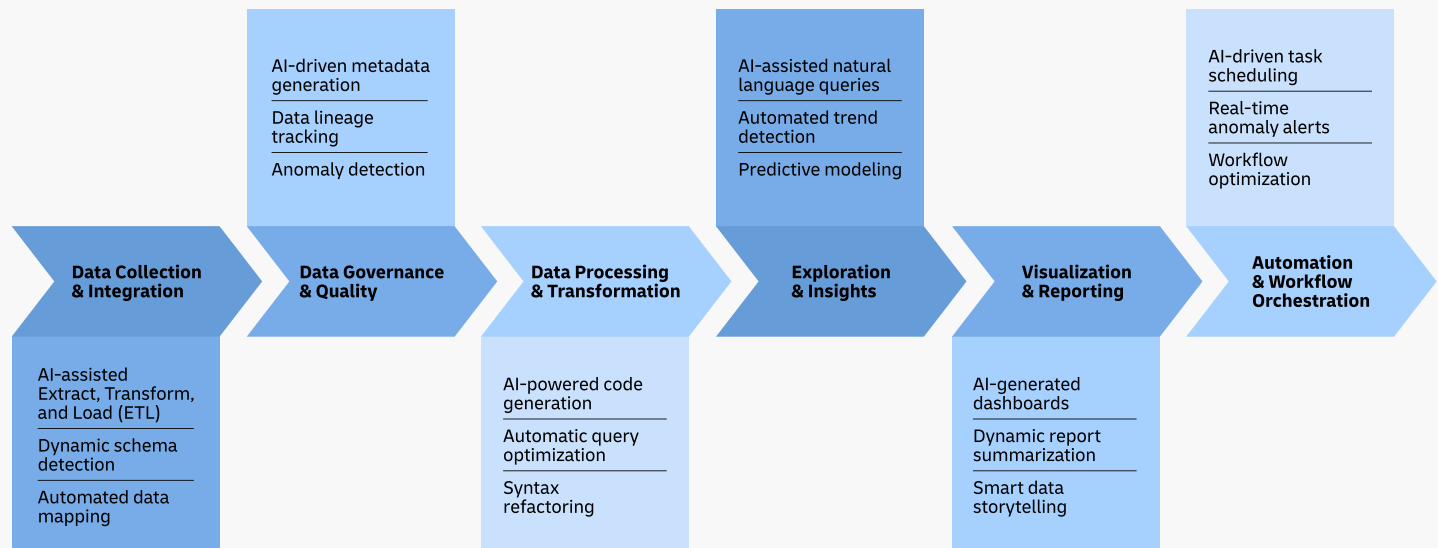
The transition from advanced analytics into AI analytics represents a major leap for supply chain management. Where advanced analytics provided the statistical tools to forecast future events based on historical data, AI analytics introduces self-learning algorithms that continuously adapt, automatically refining their own algorithms by ingesting real-time supply chain telemetry rather than waiting for manual updates.

Machine learning capabilities are now widely integrated into core logistics systems, transforming how organizations handle massive, unstructured datasets. Today's AI models can instantly process complex, multi-layered variables to uncover hidden inefficiencies and dynamically optimize supply chain networks at scale.

The foundational technologies (cloud computing, Internet of Things (IoT), big data) needed for AI analytics are already mature and deployed across the supply chain. Off-the-shelf AI analytics solutions are becoming widely available, highly scalable, and easier to integrate into existing logistics systems via application programming interfaces (APIs), accelerating mainstream adoption.

AI analytics fundamentally transforms supply chain management. It shifts supply chain decision-making from human-directed inquiry, where analysts define the questions and interpret the outputs, to machine-initiated discovery, where systems surface patterns invisible to human analysis, generate recommendations, and, in agentic AI deployments, execute within defined boundaries, with humans in a supervisory role. This will drive cost reductions, risk mitigation, sustainability, and operational efficiency.

AI's Role in the Data Analytics Lifecycle



Integrating AI into data analytics ensures data governance and accelerates time-to-insight at every step of the journey.

Analytics8 | Kevin Lobo (2025): 6 Use Cases for Generative AI in Data Analytics + Best Practices

Relevance to the Future of Logistics

Predictive Demand & Inventory Optimization

Conventional inventory forecasting models rely heavily on historical sales data, a static approach that frequently breaks down during sudden market shifts, weather events, or other disruptions. The result is often costly overstocking or stockouts.

Systems powered by AI analytics solve this issue. With advanced machine learning forecasting models and AI-driven inventory management platforms, such as Kinaxis and o9 Demand Planning, these systems process real-time external variables (e.g., economic indicators, local weather, and market signals) alongside historical data to continuously refine demand forecasts at a granular level. This dynamic approach enables organizations to drastically reduce holding costs, minimize stockouts, prevent waste (especially for perishable goods), and ensure optimal inventory positioning across their global network.





Dynamic Route Optimization & Fleet Management

Static routing and calendar-based vehicle maintenance programs have been standard practice in logistics and fleet management for years. While the digital transformation has improved operations, unnecessary efficiency gaps remain, such as higher fuel consumption, delayed deliveries, and unexpected on-road mechanical failures or other disruptions.

Systems deploying AI analytics close these gaps. To optimize routes, AI algorithms analyze real-time traffic, weather, and delivery windows to instantly recalculate and prescribe the most efficient routes while vehicles are in transit. For fleet management, AI systems analyze live vehicle telemetry and IoT sensor data to detect micro-anomalies and predict mechanical failures early enough to schedule preemptive maintenance.

These systems comprise AI-driven routing engines, telematics with edge AI analytics, and predictive fleet maintenance platforms such as Samsara and Geotab.

Together, these capabilities lower fuel consumption, increase on-time delivery rates, prevent costly on-road vehicle breakdowns, reduce carbon emissions, and maximize asset utilization and vehicle lifespan.



Supply Chain Risk & Disruption Management

Global supply chains are highly vulnerable to geopolitical events, natural disasters, and multi-tier supplier failures, with organizations historically reacting only after a disruption has caused severe bottlenecks.

AI analytics enables a shift from reactive to proactive risk management. These systems continuously monitor diverse data streams (e.g., global news, financial data, and supplier performance metrics) to identify early warning signs of disruptions and automatically recommend mitigation strategies, such as alternative sourcing. Platforms such as Everstream Analytics and Resilinc deliver these capabilities today.

Ultimately, this continuous intelligence enhances end-to-end supply chain resilience, prevents costly operational downtime, and supports business continuity even during major global disruptions.

Summary & Trend Overview

Challenges



Data quality and silos: AI models require large volumes of high-quality, standardized data to function accurately, but many logistics organizations struggle with fragmented, unstructured data trapped in legacy systems across different supply chain partners.



Change management and trust: Employees and planners may resist adopting AI-driven recommendations due to limited understanding of “black box” algorithms or fear of job displacement.



Talent shortage: The market faces a shortage of professionals who combine extensive logistics expertise with a deep understanding of the advanced data science and machine learning skills required to build, contextualize, and maintain these complex systems.

Outlook

At DHL, we see AI analytics driving three transformative shifts in supply chain operations. First, it will increasingly close the gap between prescriptive recommendations and automated execution, laying a reliable, data-backed foundation for future agentic AI systems to act autonomously. Concurrently, data processing will increasingly take place on the “edge” (e.g., trucks, warehouse robots, or shipping containers), enabling instant, localized decision-making without the latency of central cloud processing. Finally, as these AI models become more sophisticated, they will power highly accurate, real-time digital twins of global supply chains, allowing organizations to simulate complex disruptions and test analytics-driven strategies in a risk-free virtual environment before real-world deployment.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with implementations available for many use cases today.

Related Trends

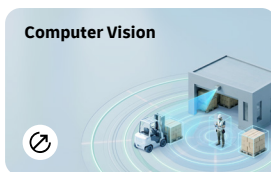
Agentic AI



Generative AI



Computer Vision



Supply Chain Diversification



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Audio AI

Trend Overview

Impact:

LOW

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Customer Experience

Health, Safety & Future of Work

Visibility & Resilience

Trend Clusters:

Artificial Intelligence

Sectors:

Auto-Mobility

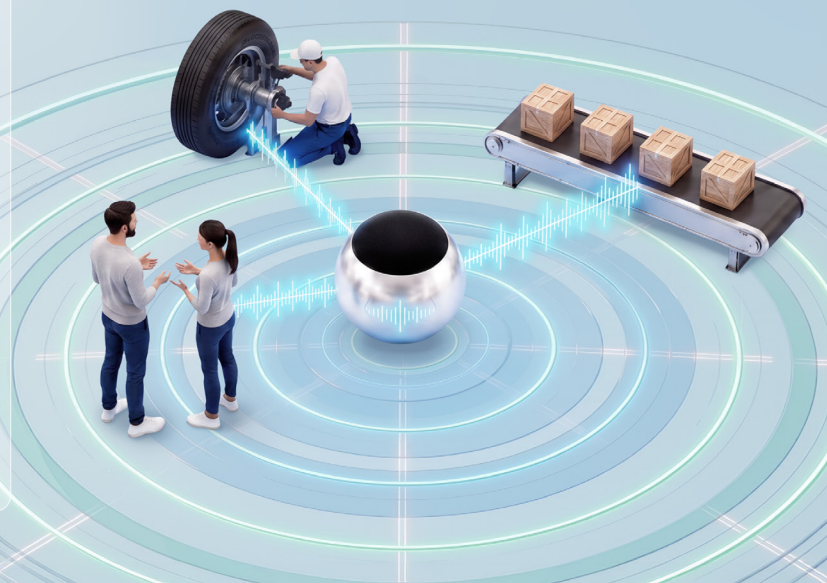
Engineering & Manufacturing

Energy

eRetail & Fashion

Life Sciences & Healthcare

Technology



The trend of Audio AI is the branch of artificial intelligence (AI) focused on analyzing, synthesizing, and interpreting audio signals, whether produced by humans (e.g., voice recognition), machines (e.g., manufacturing equipment), or the surrounding environment. It enables machines to hear and interpret sounds much like the human auditory system.

As a specialized field within AI, Audio AI has applications across a broad range of industries. Sound is present in virtually every operational environment, carrying information that can be captured and interpreted. Extracting meaning from that data opens up a range of applications with direct relevance to logistics.

Two recent developments have significantly expanded the capabilities of Audio AI.

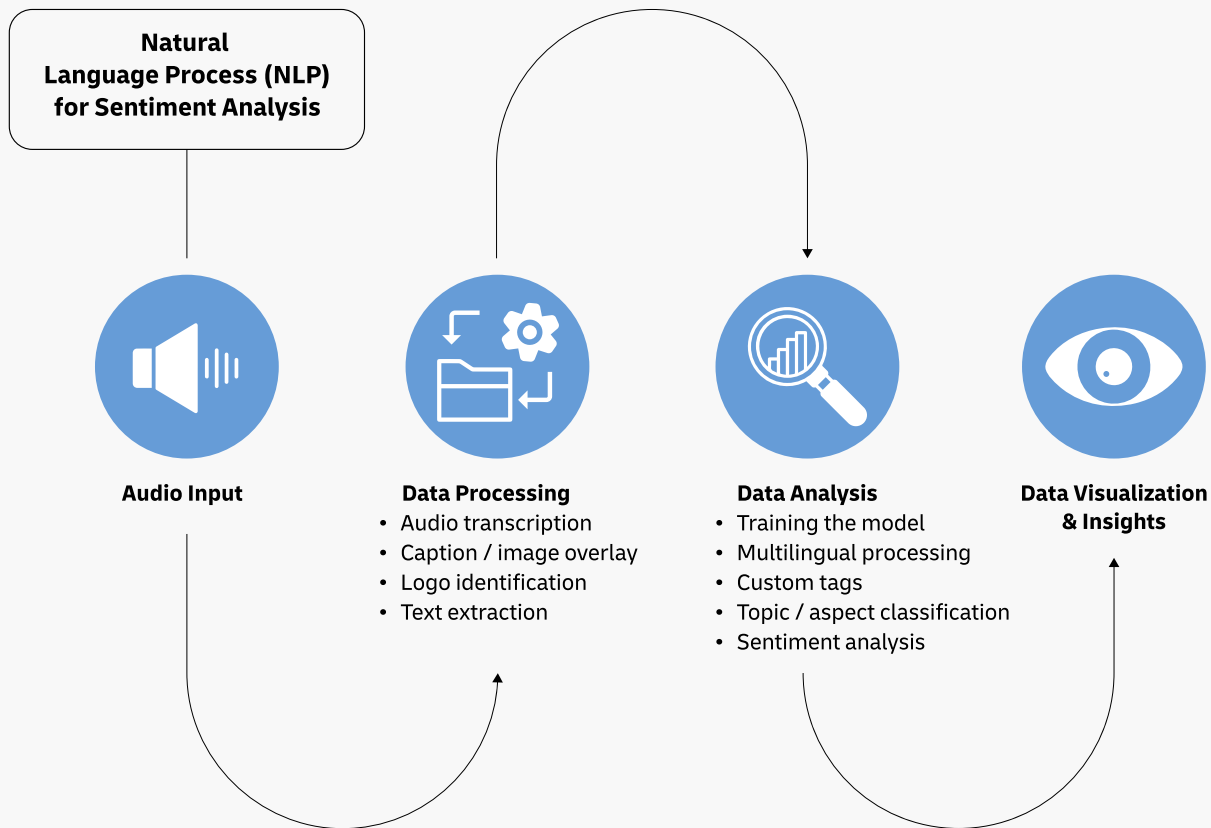
The first is the emergence of Audio Foundation Models (AFMs): large-scale pretrained models that go beyond simply hearing sounds to also understanding and reasoning about them. Unlike traditional machine learning models, which are trained on smaller datasets for specific tasks, foundation models are massive and flexible. This enables the transfer of knowledge learned from one task to another, making them ideal for more expansive domains, including natural language processing (NLP), and speech recognition.

A second significant advance is the shift toward low-latency, on-device sound recognition. Edge AI-powered devices can detect key sounds locally without streaming audio to a remote server, which reduces latency and enables continuous, always-on monitoring.

The sound recognition market illustrates the pace of growth: valued at US\$2.1 billion in 2025, it is projected to reach US\$8.7 billion by 2035, a compound annual growth rate (CAGR) of 15.2%.

Here at DHL, we do not expect the trend of Audio AI to have a very high impact on logistics now or in the foreseeable future. However, we have identified several AI use cases with potential for both office and operations workers, changing the way they perform certain tasks and enhancing certain operational workflows. Examples include predictive maintenance, virtual assistants, and language translation.

While other trends and technologies are likely to have a disruptive impact on supply chains and therefore command the spotlight, Audio AI will function as a supporting technology and frequently appear in user-facing applications such as virtual agents converting spoken commands into system inputs.



Sentiment analysis combines multiple interconnected machine learning and natural language processing tasks into a single, integrated process.

Repustate (2021): Repustate IQ Sentiment Analysis Process: Step-by-Step

Relevance to the Future of Logistics

Predictive Maintenance

In most facilities along the supply chain, heavy machinery creates an environment where the human ear cannot reliably detect auditory anomalies and identify early-stage defects in machinery and equipment. Audio AI changes this. By continuously monitoring machine output and flagging deviations from a trained acoustic baseline, it enables predictive maintenance before equipment breaks down and causes backlogs and delays.

In vehicle fleet operations, Audio AI can analyze the vibrations and sounds produced by trucks, vans, and delivery vehicles while in service. Identified patterns associated with mechanical issues or component degradation are used to predict maintenance needs,



including engine tune-ups, tire replacements, or brake repairs. The result improves vehicle reliability, reduces unplanned downtime, and protects delivery schedules.

Audio AI can also continuously monitor conveyor systems in warehouses and distribution centers. Detecting irregularities, such as excessive friction, belt misalignment, or component wear allows predictive maintenance systems to anticipate potential failures and proactively schedule maintenance tasks, which means maintenance teams can intervene early, minimizing disruption to material flow and maximizing throughput.

Language Translation

Audio AI has clear applications in logistics to support process and workflow guidance through language translation – both in the warehouse and on the road. For example, drivers can receive real-time instructions, traffic updates, and route optimizations in their preferred language, making communications more seamless across multilingual workforces.

For cross-border freight, audio-AI-assisted language translation can help truck drivers, customs officials, and warehouse staff understand instructions and regulatory requirements provided in different languages. This makes compliance easier, streamlines customs clearance processes, and reduces friction at borders.

In customer-facing contexts, automated voice-to-voice translation during service calls (whether handled by a human agent or a chatbot) can improve communication across language barriers and enhance the customer experience.



Voice Pattern Recognition

Audio AI can analyze speech patterns and vocal cues by detecting changes in cadence, tone, and articulation.

In vehicle fleet operations, the technology can be used to identify fatigue or drowsiness in vehicle operators. When early indicators appear, the predictive fatigue detection system can alert both the driver and fleet management that a break is needed or when it will be needed. One example is WOMBATT Fatigue Management, an as-a-service solution originally developed for space engineering that trains its algorithm on each user's voice prior to starting a long-haul shift.

In call center environments, Audio AI can assess vocal cues to predict customer intent and adapt the tone of the interaction accordingly. This capability can be particularly valuable when handling complaints.

Worker Safety & Security

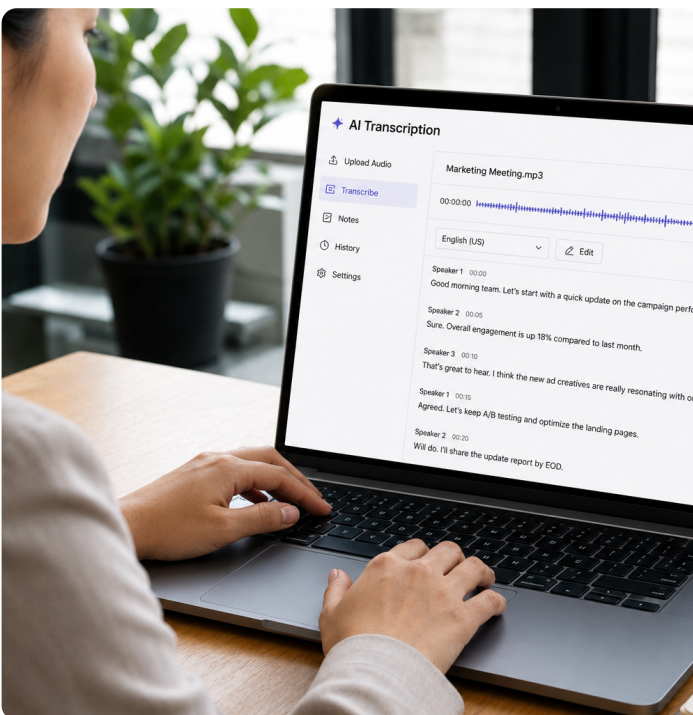
Monitoring sound can add an additional layer of data to workplace safety and security systems. For example, Audio AI-powered edge devices can detect key sounds that signal worker safety or security incidents inside warehouse environments. AI-based classification of screams, shouting, collisions, and glass breaking can trigger real-time alerts to safety personnel, enabling faster response than visual monitoring alone, particularly in areas where camera coverage is limited.



Here at DHL, we also see potential in voice recognition for access control and increased security. By identifying individuals through voiceprints and detecting emotional signals in speech, such systems could flag individuals showing signs of hostile intent before access is granted.

Voice Transcription

Organizations are increasingly using Audio AI for transcription services, which convert spoken language into text.



In digital meetings, automated transcription reduces the burden of notetaking and summarizing action items, freeing participants to focus on the conversation itself. Advancements in accuracy mean less risk of losing crucial information. These tools are becoming standard components of video conferencing platforms, making them widely available.

For in-person meetings, AI-powered wearable devices are available to transcribe, summarize, and in some cases translate. Some devices are pin-sized and have up to 45 hours of battery life.

Human Machine Interaction

AI-powered voice-controlled interfaces give workers a new way to interact with computers and machines. Spoken commands allow hands-free data input that is more convenient, faster, and easier than traditional screens.

In warehouse operations, workers may soon direct autonomous mobile robots (AMRs) using voice commands or receive auditory task lists that guide them through pick paths and workflows without requiring them to look at a screen.

Voice-activated systems also expand accessibility for workers with disabilities. Examples include reading text aloud for those with visual impairments or voice interfaces for individuals with limited mobility.



Summary & Trend Overview

Challenges



Applications using Audio AI must be transparent about whether a voice is human or AI-generated, particularly in customer-facing contexts where the distinction is essential for maintaining trust.



Audio AI systems can struggle to distinguish relevant signals from background noise. In logistics environments, where machinery, vehicle traffic, and human activity compete for attention, isolating the sounds that matter remains a technical challenge.



Audio data collected across logistics operations may vary in quality, format, and labeling standards. This inconsistency complicates the training and deployment of Audio AI models at scale.

Outlook

As AI adoption increases across logistics operations, Audio AI will develop alongside it. Although it won't be a primary disruptor, it will provide a supporting capability that boosts the power of broader AI systems. This will lead to niche deployments in predictive maintenance, voice interaction, and safety monitoring, providing an additional data input layer for larger AI models.



Explore – This trend has the potential to deliver incremental improvements to logistics with implementations available for many use cases today.

Related Trends

Generative AI



AI Analytics



AI Ethics



Digital Twins



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Bio-Based Materials

Trend Overview

Impact:

LOW

Adoption:

< 5 YEARS

Focus Areas:

Sustainability

Trend Clusters:

Packaging & Containers



The trend of Bio-Based Materials encompasses materials wholly or partly derived from biomass, including materials produced through bio-based synthesis processes. Unlike trends focused primarily on end-of-life outcomes, it addresses material feedstocks at the beginning of the product lifecycle and includes both biodegradable and non-biodegradable materials.

Bio-based materials can be integrated into logistics and supply chain applications as alternatives to materials derived from fossil or other non-renewable feedstocks. Their environmental performance depends on factors including feedstock origin, production processes, durability, transport, and end-of-life treatment. Logistics organizations are exploring these materials alongside measures to reduce material use and waste as regulatory, customer, and corporate requirements evolve.

Regulatory requirements are increasing the focus on packaging prevention, reuse, recyclability, and recycled content. The EU Packaging and Packaging Waste Regulation (PPWR) entered into force on February 11, 2025 and generally applies from August 12, 2026. It introduces phased recyclability requirements from 2030, while the requirement for packaging to be recyclable at scale applies from 2035.

A global survey conducted by McKinsey in 2025 confirms that consumer attitudes toward sustainable packaging remain positive but increasingly nuanced. While around 50% of consumers still consider environmental impact important, price, quality, and functionalities like food safety and shelf life now consistently rank higher in purchasing decisions, driven by inflationary pressures and economic uncertainty.

A wide range of potential applications for bio-based materials exists in various supply chain segments, from building construction to packaging.

Although bio-based plastics and materials are technologically mature and commercially available, they still account for only around 1% of global plastics production – a gap that highlights both their potential and current limitations in scaling. Some bio-based materials are already well established in logistics, especially those derived from conventional biomass. Wooden pallets, for example, remain dominant due to their cost-effectiveness, availability, durability, and recyclability. At the same time, innovation in alternative materials continues, including solutions based on bamboo, agricultural residues, mycelium (mushroom-based materials), algae, and emerging bio-composites. New hybrid solutions combining bio-based content with recycled or engineered materials are also gaining traction, particularly in lightweight pallets and transport packaging applications.

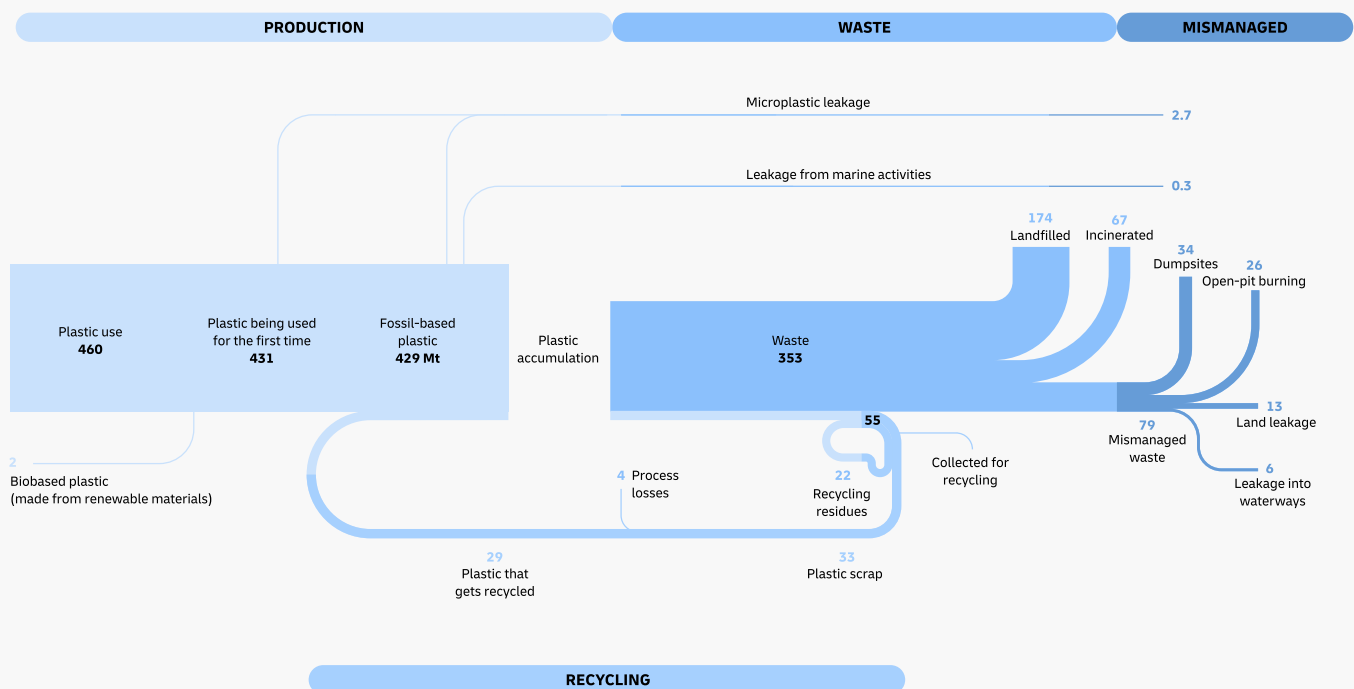
Despite continued innovation, a large-scale transition to bio-based materials in logistics is progressing more gradually than anticipated. A transformative development has not yet emerged, but the properties of bio-based materials have continued to advance toward those of conventional industrialized solutions.

For example, mycelium-based composites are moving from laboratory research into pilot and early commercial applications. Bio-polymers, such as PLA, PHA, and advanced blends, are also gaining traction in packaging, supported by ongoing improvements in performance and the integration of smart functionalities, including sensor-enabled solutions. Bio-based materials are also expanding their presence in sectors such

as construction, where the market share is projected to reach approximately 10% by 2030.

The challenges constraining adoption in large-scale and industrial applications are primarily related to performance. Key barriers include cost competitiveness, feedstock availability, end-of-life infrastructure, and the need for standardized sustainability criteria. Regulatory frameworks are increasing requirements related to recyclability, reuse, and material efficiency. Bio-based materials may contribute where their performance and environmental attributes are substantiated for the relevant application and lifecycle stages.

Over the next decade, the use of bio-based materials is expected to grow steadily, with increased integration into supply chains. However, this is unlikely to fundamentally transform day-to-day logistics operations in the short term. Instead, the impact is expected to be targeted and application-specific, like in packaging applications where certified compostability under specified conditions, lower weight, or documented lifecycle GHG-emissions performance is relevant. The universal replacement of conventional materials remains a longer-term perspective.



In 1900, human-made mass amounted to just 3% of the world's total biomass. In less than two centuries, we have produced more material, including concrete, steel, plastic, and glass, than all living biomass on Earth.

OECD (2023): Global Plastics Outlook 2023

Relevance to the Future of Logistics

Timber in Construction & Logistics

Buildings and construction accounted for 37% of global energy- and process-related CO₂ emissions in 2022. Operational energy use and the production of construction materials, including cement and steel, are significant sources within the sector.

Transport contributes to the lifecycle impacts of construction materials, with the magnitude depending on material weight, transport distance, mode, and supply configuration. Ready-mixed concrete is generally transported over relatively short distances because of handling and setting-time constraints.

Construction industry interest in timber is growing partly because timber products can store biogenic carbon during their service life and may substitute for more emissions-intensive materials in some applications. The resulting lifecycle GHG performance depends on forest management, product design, transport, service life, substitution assumptions, and end-of-life treatment.

Timber construction can create different logistics requirements, including the transport of prefabricated components and coordination with regional processing capacity. Where feedstock and processing facilities are located near the construction site, transport distances may be shorter, subject to the actual supply network.

The DHL Europe Innovation Center in Troisdorf, Germany, opened in October 2025 and was constructed using cross-laminated timber. Any claimed reduction in construction-related emissions should specify the comparison baseline, lifecycle boundary, methodology, and supporting assessment.



Bio-Based Pallets & Logistics Equipment

As global trade and e-commerce continue to expand, the number of warehouses is expected to grow rapidly, along with the critical assets required for logistics operations, such as pallets, racks, and picking bins. This growth brings increased demand for durable and cost-effective logistics equipment that can withstand intensive use while helping organizations meet specified material-efficiency, waste, or emissions objectives.

Wooden pallets are widely used, but durability and repair requirements vary with design, load, handling, and pooling systems. The lifecycle performance of wood, metal, plastic, and alternative bio-based pallets depends on factors including service life, repairability, reuse cycles, transport weight, recycled content, and end-of-life treatment. Logistics organizations are therefore testing material and design alternatives for specific operating conditions.

One example is TGR, which manufactures pallets from miscanthus and a bio-based, formaldehyde-free binder. According to the manufacturer, the pallets are nestable, moisture-resistant, recyclable, and available in configurations designed for specified logistics loads. Claims concerning lifecycle emissions, comparative weight, material toxicity, safety performance, durability, and recyclability require verification against the applicable product

specification, lifecycle assessment, test conditions, and available end-of-life infrastructure.

DHL has participated in pilot testing of TGR pallets to assess operational compatibility, handling, weight, and space efficiency. Any publication of quantified results, including storage-space or weight comparisons and lifecycle GHG claims, should identify the pallet configuration, comparison baseline, test conditions, lifecycle boundary, methodology, and independent verification status.

Pilot testing of bio-based pallet designs can help determine whether specific alternatives meet operational, cost, and environmental-performance requirements at the intended scale.



Packaging & Packing Materials

Packaging is one of the most material-intensive elements of logistics operations, and the industry's reliance on petroleum-based plastics remains a significant sustainability challenge. A growing range of bio-based alternatives is emerging – from algae-, mushroom-, and bamboo-derived materials to novel biodegradable films – with startups and research institutes developing solutions across multiple packaging segments.

One example is the Indian Institute of Technology Hyderabad (IIT-H), which has developed biodegradable nanocomposite films from waste materials, including sewage sludge, eggshells, and shrimp shells. The innovation demonstrates how industrial and food-processing waste streams can be valorized into functional packing materials.

Bio-based feedstocks and biodegradability describe different material attributes and may affect different lifecycle stages. Their environmental performance should be assessed for the relevant application, including feedstock production, manufacturing, use, collection, recycling or composting conditions, and disposal.

Bio-Based Insulation in Logistics

The market for bio-based insulation materials is expanding rapidly as sustainability and energy efficiency gain importance across construction and logistics. Globally, the bio-based insulation market is expected to reach approximately US\$119.34 billion by 2034, driven by rising environmental awareness, demand for low-emission materials, and stricter performance standards across buildings and supply chains.

Bio-based insulation solutions draw on renewable plant and animal sources, including cork, cellulose, hemp, flax, cotton, kenaf, wood fiber, and natural wools such as sheep, alpaca, and goat hair. These materials offer strong thermal and acoustic insulation, support moisture regulation and fire resistance, and represent viable alternatives to conventional fossil-based insulation products.

Bio-based insulation is also being explored in temperature-controlled logistics, where packaging must meet defined thermal-performance and product-protection requirements. DHL operates pharmaceutical and temperature-controlled logistics services. Wool-based thermal packaging is one example of a bio-based insulation format; claims concerning recyclability, compostability, lifecycle GHG performance, and suitability for pharmaceutical shipments should be supported by product-specific test data, applicable collection or composting conditions, and the relevant lifecycle assessment.

Bio-based insulation materials may support energy-efficiency or lifecycle GHG objectives where product performance, system design, operational conditions, and lifecycle assessment demonstrate an advantage for the specific building or packaging application.



Summary & Trend Overview

Challenges



Bio-based materials are not necessarily biodegradable and may still contribute to waste. Whether they perform better than fossil-based alternatives depends on the material, application, lifecycle boundary, and end-of-life system.



The cost of most bio-based solutions remains higher than conventional alternatives; without cost parity or strong regulatory incentives, widespread adoption across logistics operations will be constrained.



Many bio-based alternatives to conventional logistics materials still face performance limitations, including lower durability and reduced load-bearing capacity or moisture sensitivity, limiting their suitability as direct replacements for plastic-based solutions.

Outlook

Bio-based materials are advancing on multiple fronts – from bio-polymer packaging and mycelium-based composites moving toward early commercial scale to bio-based insulation gaining traction in temperature-controlled logistics. Regulatory frameworks such as the EU PPWR are increasing requirements related to packaging prevention, reuse, recyclability, and recycled content. Pilot programs are assessing whether specific bio-based solutions can meet the operational, performance, cost, and environmental criteria of defined logistics applications.

Widespread adoption across the full range of logistics materials remains a medium-to-long-term prospect, constrained by scaling challenges, cost parity, and end-of-life infrastructure. Nonetheless, incremental integration into targeted applications, particularly in packaging and temperature-controlled logistics, is already underway.



Consider – This trend has the potential to deliver incremental improvements to logistics with developments and use cases on the horizon.

Related Trends

Circularity



ESG Advocacy



Green Urban Transformation



Sustainable Fuels



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Computer Vision

Trend Overview

Impact:

CONSIDERABLE

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency Health, Safety & Future of Work
Physical & Digital Security Visibility & Resilience

Trend Clusters:

Artificial Intelligence Robotics

Sectors:

Auto-Mobility



The trend of Computer Vision uses cameras and artificial intelligence (AI) algorithms to interpret images and video, enabling machines to identify objects, track movement, assess conditions, and generate predictions from visual data. More advanced, AI-enabled systems can recognize complex scenes across multiple viewpoints, learn continuously from new data, and identify patterns in dynamic environments, while rudimentary systems are trained simply to distinguish one object from another.

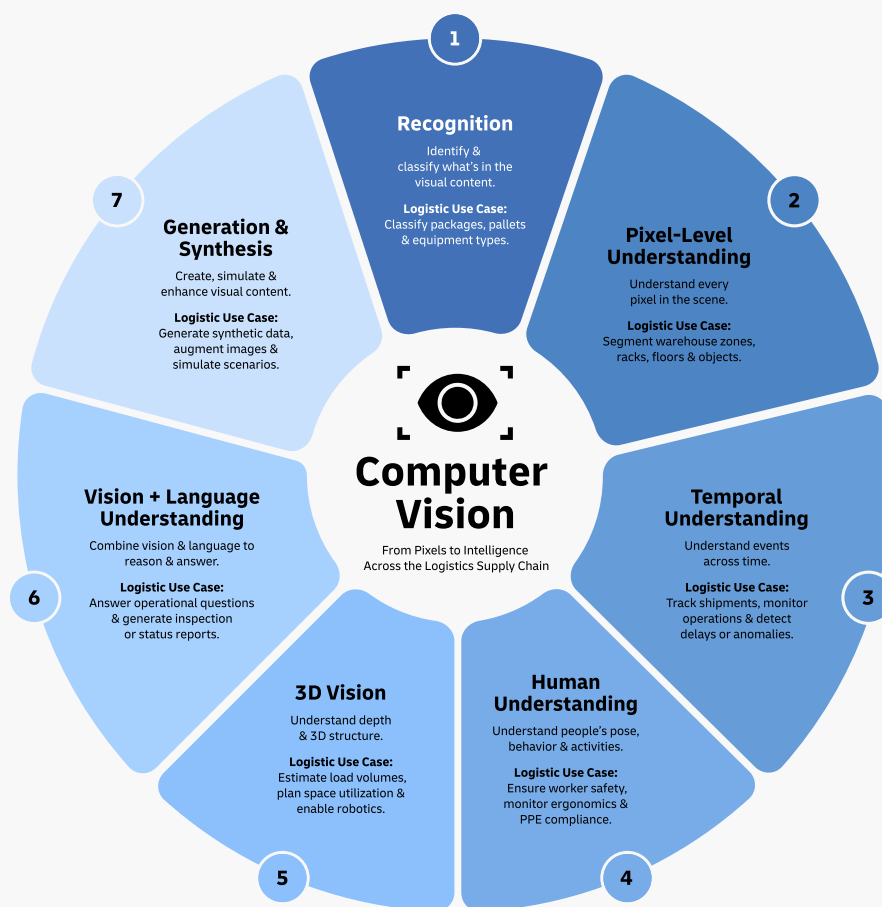
Although often used interchangeably with machine vision, computer vision differs in scope: machine vision typically refers to rule-based, industrial imaging systems designed for highly specific inspection and quality-control tasks, whereas computer vision focuses on AI-driven visual understanding across broad and evolving use cases.

Computer vision systems are increasingly applying sophisticated AI models to interpret and act on visual data. The recent emergence of Vision-Language Models (VLMs) represents a major advance. Combining visual understanding with natural language processing, VLMs enable systems to interpret images and video in response to open-ended instructions, queries, or contextual prompts, unlocking more flexible and scalable applications well beyond the constraints of task-specific models.

Edge computing is accelerating adoption, enabling visual data to be processed directly on devices such as smart cameras or embedded systems, which reduces latency, lowers bandwidth usage, and enhances data privacy by limiting reliance on centralized cloud infrastructure.

In 2025, the global computer vision market was valued at roughly US\$27.4 billion. With the continuous advancement of AI, vision systems, and computer processing, it is expected to grow at a compound annual growth rate (CAGR) of approximately 18.2% through 2034.

Computer vision directly improves operational efficiency, visibility, safety, and automation across core logistics processes such as warehousing, transportation, and last mile delivery. While basic vision applications are already deployed, advanced use cases involving VLMs and fully autonomous decision-making are still maturing and require data integration.



Computer vision transforms raw photos and videos into actionable insights by enabling machines to recognize, interpret, and generate meaningful information.

DHL (2026)

Relevance to the Future of Logistics

Safety & Security Intelligence

AI-enabled computer vision is becoming a core enabler of safer, smarter logistics facilities by turning video into real-time operational intelligence. Instead of simply monitoring people and vehicles, modern systems now detect risk, predict unsafe interactions, and trigger immediate corrective actions that improve safety. For example, they go beyond identifying whether workers are wearing personal protective equipment (PPE) to confirm whether they are wearing it correctly, in the right zones, and under the right conditions, with edge-based alerts that reduce response time and privacy concerns.

Modern systems can also detect unauthorized access, suspicious behavior, vehicle-person conflict zones, and unsafe conditions in real time – then generate alerts or trigger workflows that support immediate action, reducing theft, incidents, and downtime.

Logistics facility managers are moving from passive video surveillance to systems with real-time operational perception, where AI and computer vision continuously monitor risk, behavior, and unsafe conditions and convert those signals into immediate action for measurable reductions in incidents and downtime.

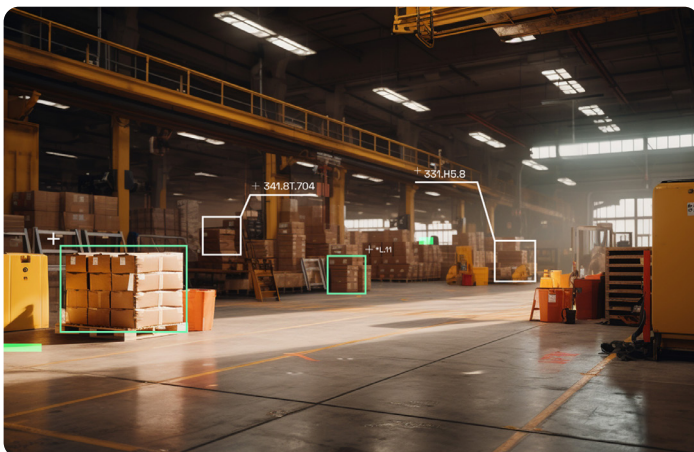
Workforce & Operations Efficiency

Accurate measurement and efficient processing of packages are fundamental to storing, handling, and transporting goods across the supply chain. Computer vision leverages fixed or mobile 3D measurement systems to automatically capture package dimensions. Integrated AI-powered dimensioning stations can dynamically measure and weigh items ranging from small packets to full pallets while simultaneously reading barcodes and capturing images, enabling faster and more accurate logistics operations.

With computer vision, supervision moves from reactive observation to continuous, data driven operations management. Computer vision systems automatically track people and vehicle movement, task duration, and activity distribution across zones without compromising privacy. This data is increasingly combined with machine learning and digital twin logic that can simulate and suggest better workflows in real time.

One example is camera-based analytics for head counting, occupancy control, and heatmap analysis. Another is feeding live camera streams into a real-time decision layer that optimizes pick paths, adjusts layout suggestions, and flags imbalances in workforce allocation. These tools can also enforce safe occupancy limits and support dynamic shift planning without relying on manual counting.

The main supply chain benefit is greater operational efficiency with the same or potentially fewer people. Productivity improves because travel time, avoidable congestion, and misallocated tasks are reduced. Overall, operations become more predictable, safer, and more responsive to daily workload changes.



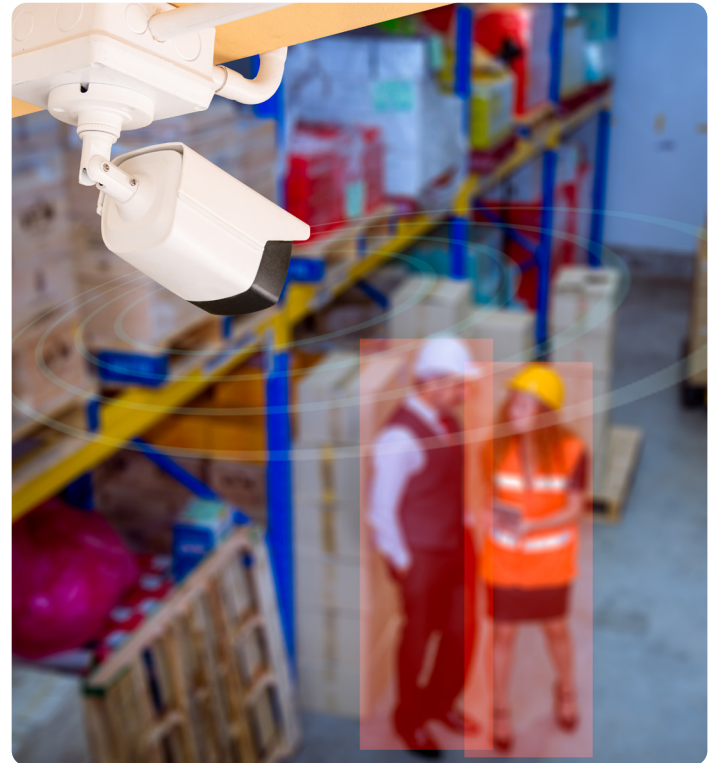
Visibility, Quality & Compliance of Goods

Accurate measurement and efficient processing of packages are fundamental to storing, handling, and transporting goods across the supply chain. Computer vision can use fixed or mobile 3D measurement systems to automate package dimensioning, improving capacity planning, load utilization, and overall efficiency.

Computer vision can also support quality assessment and compliance by detecting damage, label errors, and barcode issues early in the flow of goods. This helps companies reduce costly exceptions and protect brand reputation. One example is Dockware – a fully autonomous solution built for high-volume docks that captures data in real time, including package dimensions, case and unit counts, and damage detection.

Computer-vision-enabled parcel handling and sorting systems can speed up parcel classification and routing, improving accuracy and throughput even in mixed, non-standard, and cluttered logistics flows. They can also enhance capacity planning by assessing available cargo space inside trucks, containers, and warehouses against pallet dimensions, orientation, and load density, reducing wasted space and improving utilization.

Overall, computer vision translates physical items into measurable, readable, and sortable digital signals that strengthen visibility, quality control, and compliance across the flow of goods in logistics operations.



Assets, Yard & Facility Performance

From forklifts and trailers to docking bays and yard space, logistics assets have traditionally been managed reactively, with condition and usage data captured only after an incident, delay, or manual inspection. Computer vision changes this by enabling continuous, automated monitoring of assets, yard areas, and facilities. For predictive maintenance, vision systems issue alerts when early signs of wear or malfunction are detected, allowing maintenance teams to intervene before failure occurs and managers to schedule repairs and upkeep proactively, preventing downtime and prolonging asset life.

Terminal and yard operators are deploying computer vision enabled gate and surveillance systems that identify vehicles and trailers, log entry and exit times, measure dwell and idle time, detect visible damage, and restrict access to authorized assets. These systems go beyond the condition monitoring traditionally performed by humans to capture how assets are used – tracking interactions, handling behavior, and operating patterns to identify factors that influence asset performance, safety, and lifespan.

For supply chains, the result is a shift from reactive oversight to proactive control: longer asset lifecycles, reduced downtime, more predictable maintenance planning, and real time awareness of space usage and asset movement that improves capacity utilization and throughput while lowering congestion and delays. Overall, this visibility enhances security, safety, and compliance while reducing losses and operational risk.

Summary & Trend Overview

Challenges



Workplace surveillance methods perceived as invasive may lower employee morale, increase work-related stress, and cause counterproductive work behaviors.



Cameras may not see everything; for example, if the field of view is obstructed during capacity assessment, perhaps by a stack of goods waiting to be packed, a workflow change may be needed.



Environmental factors such as poor lighting, shadows, and reflection may challenge the capabilities of computer vision, in which case a manual process could also be needed.



Oversensitive computer vision systems may generate excessive alerts for minor or non-critical anomalies, which can overwhelm operations teams, reduce trust, and lead to critical alerts being overlooked if not properly calibrated.



Data privacy compliance may pose challenges, as computer vision systems capturing employee-related data must adhere to regulations (e.g., GDPR), requiring strict governance, transparency, and safeguards to avoid legal risks and maintain trust.

Outlook

Computer vision technology has matured significantly in the last two years, driving growth in deployment and expanding applications in logistics operations. The next phase will move beyond detection and monitoring toward autonomous action, where visual insights directly trigger maintenance workflows, yard orchestration, and capacity reallocation. Continued investment in AI will accelerate this shift, positioning computer vision as a core operational intelligence layer rather than a standalone tool.

While computer vision has proved its value in dimensioning, health and safety, and other applications, challenges remain. These include technology acceptance, data privacy compliance, cybersecurity, hardware upgrades, and material identification. Despite these hurdles, computer vision remains integral to the automation and digitalization of logistics for more efficient and sustainable operations.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with implementations available for many use cases today.

Related Trends

AI Analytics



AI Ethics



Cybersecurity 2.0



Digital Twins



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3. Global Market Insights (2025): *Computer Vision Systems Market Size & Share 2025 – 2034*

Digital Twins

Trend Overview

Impact:

MODERATE

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Visibility & Resilience

Trend Clusters:

Digital Backbone

Internet of Things

Sectors:

Auto-Mobility

Engineering & Manufacturing

Technology

Life Sciences & Healthcare



The trend of Digital Twins encompasses virtual models that accurately mirror the real-time conditions and behaviors of physical objects or processes. A digital twin enables functions such as visualization, diagnosis, analysis, prediction, simulation, and optimization, without requiring direct interaction with its physical counterpart.

Digital twins are evolving into AI-powered decision engines, driven by the emergence of agentic AI, which are systems capable of autonomous, goal-directed action. Once confined to pilot projects and simple monitoring, digital twins are increasingly being used to take action in operational environments. Machine learning, agent-based simulation, and prescriptive analytics now enable automated recommendations and dynamic optimization, reducing reliance on manual intervention and accelerating responses to disruptions.

The convergence of cloud and edge computing is accelerating this shift. Cloud infrastructure provides the scalability needed for complex simulations, and edge computing delivers low-latency responsiveness across distributed environments. This combination supports mission-critical use cases and allows organizations to balance performance with cost efficiency.

Accessibility is also improving. Low-code/no-code platforms now allow non-technical users to build and modify digital twin workflows without specialist support, enabling faster deployment and broader adoption – with small teams supporting large user bases. One example is Lyric's four-layered platform, which allows users to create and modify digital twins through a mix of AI, apps and drag-and-drop workflows.

Despite these advances, challenges remain in data integration, interoperability, and cybersecurity. As digital twins take on greater operational control, the reliability and security of these systems will be increasingly critical. Overall, digital twins are becoming foundational to intelligent, adaptive supply chains.

Barriers to adoption are decreasing due to the developments in technology described above. Low-code platforms lower the technical threshold and AI integration enables more advanced predictive and limited autonomous decision-making. However, adoption still depends on the quality of the underlying data and the maturity of system integration.

Here at DHL, we expect the impact to be moderate. Digital twins are improving optimization and decision-making, but mainly by enhancing existing operations rather than disrupting them.

Digital Twins + AI

Real-Time Mirrors for Smarter Decisions



Digital twins are evolving into AI-powered decision engines, driven by the emergence of agentic AI systems capable of autonomous, goal-directed action.

Nitin Gupta (2026): Digital Twins and AI: The Future of Real-Time Decision Making

Relevance to the Future of Logistics

Stress Testing Resilience

Global supply chain managers are operating under extreme pressure, navigating disruptions to meet increasing demand and handle ongoing volatility. Events such as the Covid-19 pandemic and geopolitical tensions have underscored the need for more resilient supply chains. Digital twin simulations offer a direct means of stress testing entire supply chains to help build that resilience.

Logistics and supply chain organizations can use digital twins to simulate disruptions across global networks, including natural disasters, cyberattacks, and sudden market shifts. These simulations provide a comprehensive view of potential impacts on service levels, cost to serve, and supply chain integrity, without affecting real-world operations. Logistics planners can then identify vulnerabilities and refine their response strategies in real time. Scenarios



can also be modified and rerun to test different strategic adjustments, systematically strengthening resilience across the network.

This proactive approach enables logistics teams to make more informed decisions and strengthen logistics operations before disruptions occur, rather than reacting to them afterwards.



Optimizing Logistics Processes

Virtually all processes within supply chains stand to benefit from digital twins. From workload allocation to the management of inbound and outbound flows, digital twins support logistics optimization through end-to-end visibility.

As AI agents mature, digital twin solutions are evolving beyond visualization and optimization into systems with defined autonomy, further automating operational workflows.

Two early examples illustrate this shift. PepsiCo is deploying physics-based digital twins and AI as co-designers to simulate, validate, and optimize facility layouts before any physical construction begins. Samsung Electronics has announced plans to implement digital twin simulations across its manufacturing processes and deploy specialized AI agents dedicated to quality control, production, and logistics.

Digital twins can also help companies achieve sustainability goals. As organizations seek to balance cost reduction with carbon emissions targets, digital twins can be used to monitor and optimize emissions by refining routes or redesigning logistics networks. Specialized AI agents can further automate decision-making in this area.

Together, digital twins and AI agents have the potential to deliver measurable reductions in cost, time, and resource consumption across each stage of the supply chain.

Predictive Maintenance

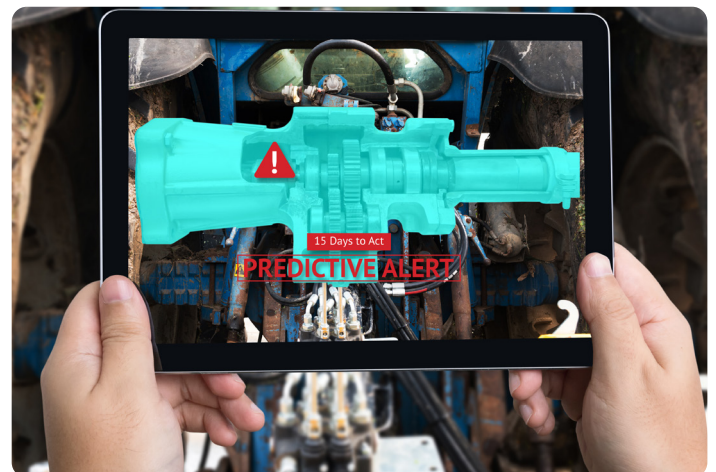
Unplanned downtime is disruptive and expensive, consuming an average of more than 15 hours per week for industrial manufacturers and costing the sector over US\$50 billion a year. With equipment failure causing almost half of all stoppages, a system that can anticipate wear and flag assets for repair before they break or fail has become essential. Predictive maintenance cuts costs and increases productivity for manufacturers and logistics providers alike.

Digital twins are well-suited to this application. By providing real-time visibility into the condition of physical assets, they enable maintenance teams to act early and even monitor facilities from afar.

TATA Steel in India offers a substantive example. Operating from a control center in Jamshedpur, roughly 350–400 km away from its mines and manufacturing plants, the company supervises and controls its facilities via digital twins. TATA Steel has built a comprehensive AI ecosystem of 650 narrow AI and generative AI models to optimize its entire steel manufacturing value chain, and has shifted from condition-based and time-based maintenance to predictive and prescriptive.

Digital twins can also be applied at the individual asset level, not just whole facilities. Leading logistics companies and equipment service providers are building digital twins of individual robots, forklifts, trucks, and other assets – tracking the condition of each and detecting wear that should be addressed before it causes a breakdown.

By using digital twins to facilitate predictive maintenance, logistics providers can reduce reactive maintenance by about 40% in any given year, boosting operational throughput and reducing costs.



Summary & Trend Overview

Challenges



Digital twins require high-quality, real-time data; demanding or prohibitive environmental conditions can limit data collection and reduce accuracy.



Digital twins require considerable upfront investment in sensor infrastructure, integration platforms, and APIs.



Some complex assets have properties that are extremely costly or difficult to replicate accurately, such as chemical, electrical, or thermal states; users are often forced to design digital twin models based on generalizations and simplifications, which reduces accuracy.



Because digital twins connect directly to physical objects, they pose a security risk, giving cybercriminals potential entry points to monitor, manipulate, or disrupt operations.

Outlook

While digital twin technology has existed for decades, it is now approaching a tipping point where widespread adoption in logistics is likely within the next five years. Four forces are driving this trajectory: the proliferation of connected sensors across supply chains, the widespread adoption of APIs and cloud platforms, the emergence of low-code/no-code development tools, and the rise of AI agents. Digital twins are set to become an indispensable tool for modern supply chain management.



Explore – This trend has the potential to drive meaningful change in specific areas of logistics with use cases in some applications that can already be addressed today.

Related Trends

AI Analytics



Smartification



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5. ScalaCode (2025): *The Future of Digital Twins: Trends to Watch in 2025 and Beyond*

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Exoskeletons

Trend Overview

Impact:

LOW

Adoption:

5 – 10 YEARS

Focus Areas:

Health, Safety & Future of Work

Trend Clusters:

Bionic Enhancements

The trend of Exoskeletons involves wearable devices designed to support or enhance human physical capabilities. Passive exoskeletons absorb energy from movement and release it as support when needed, while active devices are externally powered and can sense and respond to specific body movements in real time.

Over 1.7 billion people worldwide are affected by musculoskeletal disorders (MSDs), and they are one of the most common work-related health issues in the logistics and supply chain sector. Originally developed for applications in healthcare and military industries, exoskeletons for use in logistics operations appeared on the market more than a decade ago, designed to reduce physical strain, mitigate worker fatigue, improve ergonomics, and prevent injuries and MSDs.

Over the years, performance, usability, and wearability have improved across both active and passive industrial exoskeletons. More recently, costs have fallen as providers standardize their products and scale up production.

Market growth is expected to continue. Industrial exoskeleton shipments are projected to reach 181 million units by 2030, generating US\$2.2 billion in revenue. Market segmentation studies show that manufacturing remains the dominant deployment sector for active industrial exoskeleton installations, followed by construction and automotive assembly. Logistics and warehousing together account for fewer deployments, mostly limited to pilot programs and constrained use cases.

Logistics organizations are becoming increasingly interested in exoskeletons to reduce physical strain on the human body.

Facing an aging workforce and growing labor shortages, many companies are seeking to limit the industry's particularly high sick leave rates per full-time equivalent (FTE).

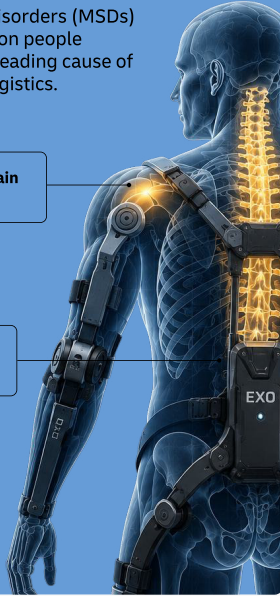
However, we have not yet seen large-scale deployments in logistics. This is largely because currently available devices typically support only specific sets of movement while restricting others (such as walking), limiting their application to niche use cases. Furthermore, efficacy remains unproven: no long-term studies of large-scale deployments exist to substantiate the expected health and safety-related benefits or risks or the impact on talent attraction and retention. Results from multiple ongoing studies are still pending, including research examining whether passive back exoskeletons reduce muscle activity and improve user well-being over time without compromising productivity.

Exoskeletons in Logistics

Musculoskeletal Disorders (MSDs) affect over 1.7 billion people globally and are a leading cause of lost workdays in logistics.

reduce physical strain & prevent injuries

improve health, safety & well-being



Frequent Bending & Lifting Tasks



Overhead Work Tasks



Standing Workstation Tasks



Exoskeletons provide task-specific support for worker health and safety.

DHL (2026)

Relevance to the Future of Logistics

Frequent Bending & Lifting Tasks

Lower back pain is the main contributor to musculoskeletal burdens and among the most common workplace injuries and illnesses. It's the leading cause of disability in 160 countries worldwide, resulting in days and even weeks away from work per employee.

Manual handling activities are among the main risk factors for lower back pain. Workers who frequently lift items can benefit from exoskeletons specifically designed for lower back support. The key requirement is that the task must involve a bending movement.

There are a wide range of products currently on the market. They include passive devices using spring systems, such as IX BACK from SUITX by Ottobock, and fully textile solutions using elastic bands, such as the Apex 2 from HeroWear. There are also actively powered systems such as the Apogee from German Bionic. DHL



has been piloting with various providers such as EASE to support the development and refinement of passive exosuit products. All serve the same core purpose: helping supply chain organizations improve workplace health and safety and reduce costs from preventable injuries.

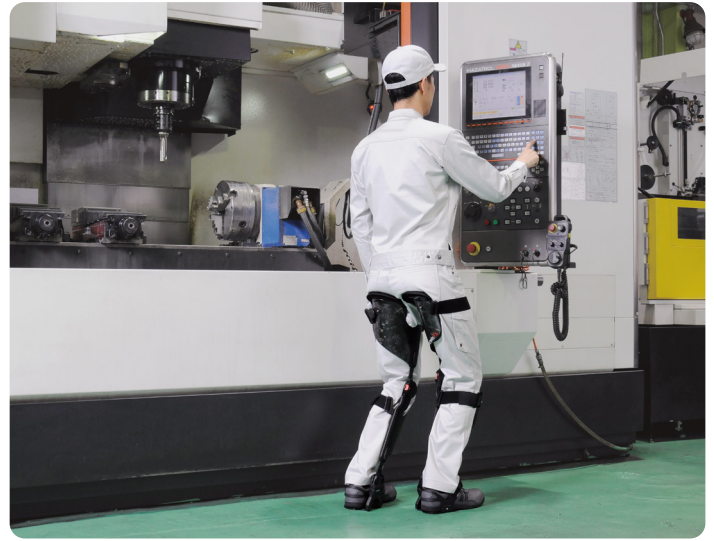


Overhead Work Tasks

The neck and shoulders are among the body areas widely affected by MSDs. Major risk factors for injury include activities involving static overhead work, such as inspecting and repairing the underside of delivery vehicles, and sustained handling of weight above shoulder height, such as loading or unloading the upper tiers of containers.

Passive devices such as the IX SHOULDER AIR from SUITX by Ottobock are specifically built for these type of activities, acting as support structures for the upper arms to reduce strain in the neck and shoulders.

The task-specific design of these devices limits their applicability in logistics, where few use cases consist exclusively of overhead handling.



Standing Workstation Tasks

Many facilities along the supply chain do not accommodate seating in workspaces due to space constraints or operational safety requirements. As a result, workers must remain on their feet throughout their shift, which adds to the physical strain over long hours.

Tech companies such as Noonee and Archelis have developed space-saving solutions often referred to as ‘chairless chairs.’ Nimble attached to the worker’s legs, these devices fold out when the worker squats, providing chair-like support for resting, and retract when the worker stands up again.

The cumulative impact of ‘chairless chairs’ in logistics is not yet clear, but one benefit is already evident: like other exoskeletons, they can help make physically demanding roles accessible and appealing to a broader pool of candidates.

Summary & Trend Overview

Challenges



Productivity impacts, cost savings from reduced sick leave, and other quantifiable data are missing but are essential to prove the business case and eliminate doubts about medical efficacy.



Implementation is more demanding than it appears: user acceptance of exoskeletons requires well-organized onboarding and personalization, making rollout more like a change management project rather than a hardware installation.



Most available exoskeletons are not entirely effortless to wear, creating a trade-off: support for certain movements may come at the cost of restriction or added burden for others.



Without long-term evidence from large-scale deployments, early adopters carry the risk of investing in technology with unconfirmed health benefits (or potential risks), creating a first-mover burden that slows adoption among organizations unwilling to act without established proof.

Outlook

Large-scale adoption of industrial exoskeletons in logistics operations remains some way off. Here at DHL, we recognize ongoing product improvements in performance and usability, though today's available devices still tend to serve only very specific subsets of movement.

While interest is growing, the long-term medical effectiveness of exoskeletons remains unproven, making the business case difficult to establish. As workplace health and safety moves to the top of the agenda, and logistics organizations face mounting pressure to attract and retain operational staff, the potential value of exoskeletons becomes harder to ignore. These devices have the potential to improve workforce health and safety, expand the pool of candidates for physically demanding roles, and make the logistics workplace more attractive overall.

The recent drop in cost for many exoskeletons is likely to accelerate testing and, in turn, broader adoption.



Consider – This trend has the potential to deliver incremental improvements to logistics with developments and use cases on the horizon.

Related Trends

Augmented Workplaces



Wearable Sensors



Smartification



Sources

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2. NIH (2025): *Effectiveness of an Occupational Passive Back-exoskeletons on the Biomechanical Load of Warehouse Workers*

Extended Reality

Trend Overview

Impact:

MODERATE

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Customer Experience

Health, Safety & Future of Work

Trend Clusters:

Bionic Enhancements

The trend of Extended Reality (XR) encompasses three categories of immersive technology: augmented reality (AR), virtual reality (VR), and mixed reality (MR) – each delivering a distinct mode of interaction between the digital and the physical worlds. AR enriches the physical world with purely visual digital elements or overlays in the right place at the right time; VR provides fully immersive virtual environments; and MR sits at the intersection of both, infusing interactive virtual content within the real world.

XR is gaining traction in enterprise and logistics contexts, supported by a decade of operational deployment and, more recently, by significant advances in mixed reality and spatial computing. As the most established form of XR, AR has been used in enterprise contexts for more than a decade to overlay digital information onto the physical world. Logistics and industrial applications have focused primarily on hands-free information access, workflow guidance, and immersive training scenarios, particularly where tasks are complex, safety-critical, or difficult to replicate in reality. In logistics specifically, XR is being used increasingly to support guided operations, immersive training, and remote expert collaboration. XR also enables early-stage exploration of spatial computing applications, including layout simulation, workflow optimization, and interaction with digital twins.

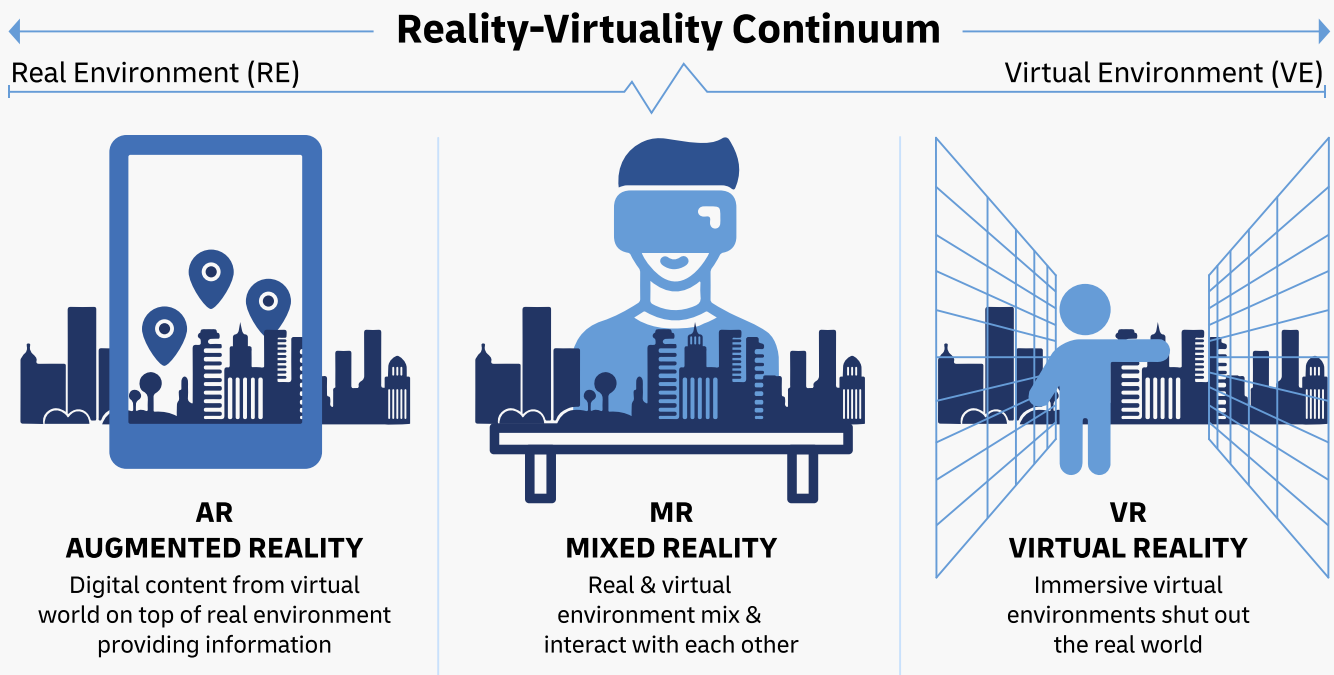
More recent XR developments have been driven by advances in MR and spatial computing. Devices such as Microsoft HoloLens and, more recently, Apple Vision Pro place virtual three-dimensional content within the physical environment, enabling users to interact naturally with both physical and digital elements. While these capabilities open new possibilities for interactive training, simulation, and remote collaboration, broad enterprise adoption

remains selective in 2026, primarily due to hardware cost, device ergonomics, and the effort required to integrate XR into existing IT and operational landscapes.

XR headset shipments offer one indicator of the trend's adoption trajectory. Following the pandemic-driven peak, XR headset shipments declined significantly before stabilizing again as new devices entered the market in recent years. The launch of high-end spatial computing devices, most notably Apple Vision Pro, renewed attention around XR and contributed to a partial recovery in shipments; however, overall volumes have remained well below pandemic peak levels.

In logistics, some XR use cases are now well-established, mature solutions such as workflow guidance for the warehouse picking process or immersive training. However, the industry has not yet tapped into the full potential of XR technology. Therefore, XR will likely have a moderate impact, with broader adoption anticipated within the next five years – driven by the maturing use cases and improving hardware already visible in logistics today.

At DHL, we do not expect the wider application of XR to revolutionize logistics operations, but it will most likely deliver many benefits. For example, we see clear opportunities to enhance the employee experience, increase safety, improve training and onboarding effectiveness, reduce error rates, boost productivity, and enable flexible information sharing across the organization.



The continuum from reality to virtuality includes technologies like AR, MR, and VR that help enhance real-world operations.

Carrasco, Moisés & Chen, Po-Han (2021): Application of mixed reality for improving architectural design comprehension effectiveness

Relevance to the Future of Logistics

Guided Operations & Vision Picking

In logistics operations, reducing human error and accelerating employee onboarding are central challenges – particularly in environments where tasks are complex, safety-critical, or difficult to replicate in training.

The use of AR or MR headsets with dedicated software enables companies to provide hands-free, step-by-step instructions to employees while they are performing operational tasks.

Here at DHL, we were an early mover in using smart glasses for workflow guidance in the picking process, with pilot projects completed as early as 2014 and a productized solution that has since been scaled globally across multiple sites. What has worked for the picking process can be replicated in other operations, such as upskilling employees to work on more complex, value-added tasks and onboarding new employees faster.

No-code application platforms are now widely available, making it easier to digitalize workflows and run them on smartphones,

tablets, and smart glasses. Using MR to guide employees through a workflow (e.g., via Microsoft HoloLens) provides enhanced user experience for tasks that benefit from spatial alignment of digital content with the physical environment. However, not all workflows require this level of integration. For many logistics applications, step-by-step guidance delivered via smartphones or tablets is sufficient. MR has clear applicability in logistics for tasks such as maintenance of complex machinery, and further use cases are emerging as the technology matures.



Remote Support & Collaboration

Logistics operations frequently depend on specialist expertise that is not always available on site – for maintenance, troubleshooting, or complex process execution. AR technology enables a remotely located expert to be connected to an on-site operator wearing smart glasses via a live video call. This allows both people to see the same things at the same time, and it keeps the operator's hands free. With dedicated software, the expert can provide instructions, sketches, and annotations to guide the operator. The combination of workflow guidance and remote support promises significant gains for maintenance, service, and any other process requiring expert knowledge not always available locally.

For example, Siemens has deployed AR-based remote expert support solutions to connect on-site technicians with centrally located specialists, enabling faster maintenance, troubleshooting, and commissioning of industrial equipment while reducing travel and downtime. Similarly, in aerospace manufacturing, companies such as Boeing have used AR-enabled remote assistance to support technicians during assembly and inspection tasks, allowing experts to provide guidance remotely and reducing errors in complex workflows.

Some software platforms are specifically designed for remote collaboration with a user wearing smart glasses and support automated report generation for documentation purposes. Where higher levels of collaboration are required, VR and MR headsets offer additional possibilities. In logistics planning and design, for example, teams in multiple locations can meet in a shared virtual space and use 3D holograms to design processes and solutions. A more general example would be a virtual conference or event, with participants using VR headsets to meet and interact as avatars.



Training & Simulation

While AR and MR add virtual content to reality, VR can be used to create immersive training experiences, simulating realistic scenarios in a fully virtual environment. Our experience shows that participants in a fully immersive VR training session learn four times faster than in a classroom setting, a difference attributed in part to the higher emotional engagement that immersive environments create.

For years, DHL has been using VR as a training and engagement tool for employees and external audiences, covering immersive training for internal processes and hazardous or complex operational scenarios. One application uses a gamified approach in which people learn how to load pallets and containers with shipments, earning more points for optimal space utilization and attention to special-handling labels.

Using VR for training is well suited for simulating real-world situations, allowing people to learn and make decisions in a safe environment, and it can also ensure a fun experience. Here at DHL, we see potential to use VR for operational health and safety (OHS) training within logistics, given the ability to deploy training content consistently across global operations. A few startups, such as Pixaera and Next World, have recognized this potential early on and are offering easily customizable, almost ready-to-use library modules to cover standard OHS topics such as line-of-fire training and working around forklifts.

MR and spatial computing capabilities have advanced to the point where virtual content can be integrated into the physical environment with sufficient fidelity to support hands-on training in real-world settings, rather than requiring a fully immersive virtual space.

Beyond immersive training scenarios, XR – combined with spatial computing and digital twin technologies – is increasingly used for spatial planning, layout simulation, and interaction with virtual representations of facilities and assets. In logistics, this includes visualizing warehouse layouts, simulating material flows, validating ergonomic workplace design, and reviewing infrastructure changes before implementation. While these applications are still emerging and not yet widely deployed at scale, they illustrate how XR can extend beyond training toward planning, simulation, and decision support in the future.

Summary & Trend Overview

Challenges



Most XR use cases involve specific hardware and deploying at scale requires significant investment in both the technology and employee onboarding.



Time, effort, and often significant investment are needed to create content for both fully immersive and workflow applications.



Mobile network coverage and bandwidth may be insufficient for the connectivity demands of XR applications, particularly for live video calls and streaming fully immersive 3D content.



Integrating XR solutions into existing IT systems, learning platforms, and operational workflows often requires significant investment, change management, process redesign, and cross-functional coordination – all of which can slow broader adoption.

Outlook

Here at DHL, we expect new XR applications to continue emerging over the coming years. Developer activity around spatial computing platforms has increased following the launch of the Apple Vision Pro, particularly for niche and enterprise focused use cases. While mass adoption of MR and spatial computing is not yet evident, selective implementation in industrial and operational contexts is expected to progress as organizations identify clear business cases.

The barrier of content creation is also falling as more software companies offer no-code solutions and ready-to-customize library content – a development we already see reducing one of the key entry hurdles to creating XR experiences. Advances in spatial computing are also expected to take remote collaboration to a new level of capability, enabling geographically distributed teams to work together more effectively through shared virtual environments.



Explore – This trend has the potential to drive meaningful change in specific areas of logistics with use cases in some applications that can already be addressed today.

Related Trends

Exoskeletons



Wearable Sensors



Augmented Workplaces



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Generative AI

Trend Overview

Impact:

MODERATE

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency Customer Experience
Health, Safety & Future of Work

Trend Clusters:

Artificial Intelligence Digital Backbone

Sectors:

Energy



The trend of Generative Artificial Intelligence (Gen AI) describes AI techniques that autonomously produce new content based on patterns learned from existing data. Using algorithms and neural networks, these systems generate original outputs (e.g. images, text, audio, synthetic data, code, or apps) that reflect the style or characteristics of their training data.

At its core, Gen AI operates through a continuous lifecycle of training, tuning, and generation. During training, large foundation models (e.g. large language models or LLMs) learn by predicting patterns across vast datasets, developing complex neural networks that enable coherent outputs. To improve accuracy and relevance for specific tasks, these models are refined through techniques such as fine-tuning on labeled data or reinforcement learning with human feedback. In deployment, outputs are continuously evaluated and enhanced through feedback loops or techniques such as retrieval augmented generation, which draws on external knowledge sources to sharpen performance.

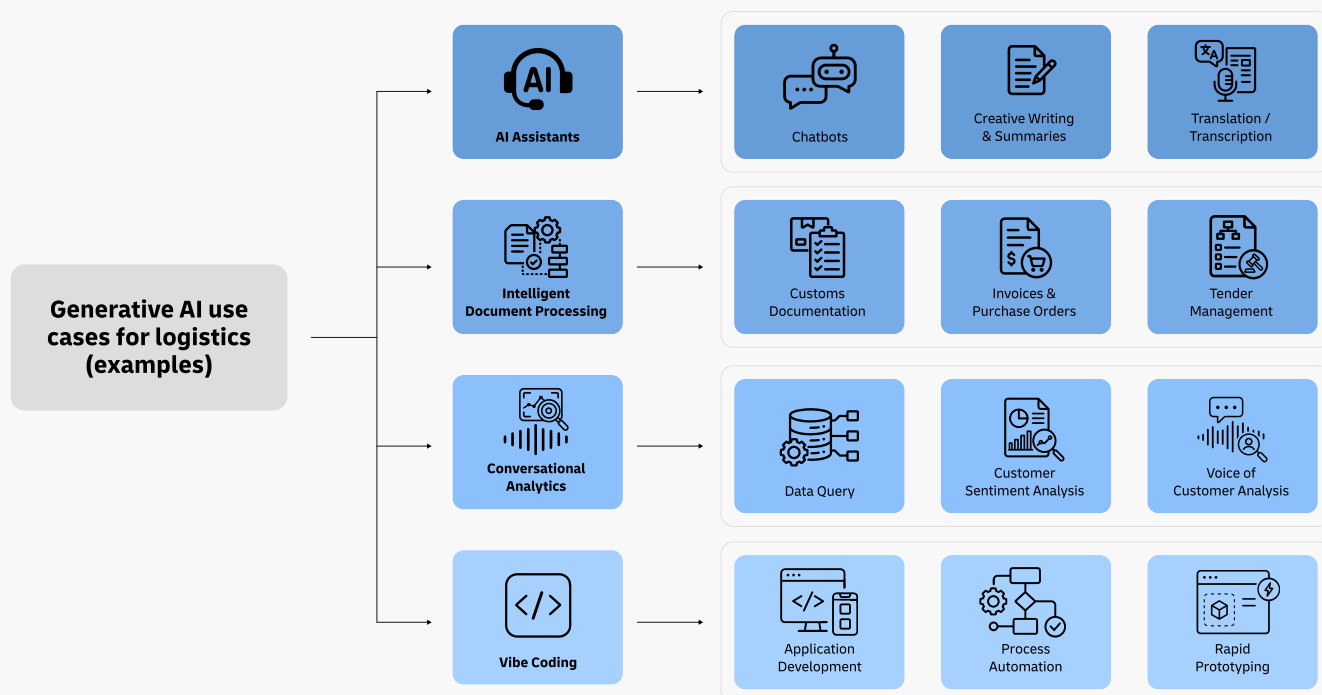
While Gen AI excels at producing insights, recommendations, and content, it serves primarily as an enabling capability and does not independently make decisions or execute actions. It is thereby distinct from Agentic AI, a separate trend on the Radar, that builds on Gen AI to autonomously make decisions, plan workflows, and carry out tasks with minimal human intervention.

Recent advancements have significantly accelerated adoption. Gen AI is projected to generate up to US\$1.6 trillion in technology-related revenue by 2032, driven by widespread enterprise and consumer adoption. A McKinsey industry survey indicates that nearly 80% of organizations are already experimenting with or deploying Gen AI across at least one business function, highlighting

its rapid transition from emerging technology to mainstream capability. Improvements in algorithm efficiency have also reduced computing requirements, making models more scalable and accessible. One study estimates the pace of algorithmic improvement at roughly 400% per year, meaning today's results can be achieved a year later at one-quarter the computing requirement. New hybrid reasoning models such as IBM Granite 3.2, Anthropic's Claude 3.7 and Gemini 2.5 Flash, further balance performance with cost efficiency, enabling broader enterprise deployment.

Gen AI is expected to have a moderate impact on logistics, with many applications already piloted or deployed and broader adoption anticipated within the next two to three years. Its position reflects both its maturity and its role as a foundational technology underpinning more advanced capabilities such as AI assistants, intelligent agents, and conversational analytics. However, despite strong momentum and widespread experimentation, organizations are also facing the "Gen AI paradox": while nearly 80% of companies report adopting Gen AI, a similar proportion have yet to realize meaningful financial impact, highlighting the gap between experimentation and scalable value creation.

In logistics operations, Gen AI enables the automation of repetitive and document-intensive workflows across both front-line and knowledge work, freeing employees for higher-value decision-making and customer engagement. At DHL, we are integrating Gen AI across the logistics value chain to automate processes, improve data-driven decision-making, and support our Digital by Default strategy.



From customer interactions to back-office processes, Gen AI unlocks efficiency, accuracy, and scalability across logistics operations.

DHL (2026)

Relevance to the Future of Logistics



AI Assistants

AI assistants represent one of the most immediate and widely adopted applications of Gen AI, enabling users to interact with systems through natural language to retrieve information, generate content, and execute tasks. These assistants rely on conversational AI capabilities, allowing them to understand prompts, respond contextually, and support a broad range of knowledge and productivity tasks. While most AI assistants operate within defined prompts and session-based memory, recent

advancements are increasingly enabling them to reference prior interactions and deliver more relevant and personalized outputs.

In a logistics context, AI assistants address a fundamental challenge: accessing and processing large volumes of fragmented data across systems. By simplifying how users interact with information, they allow employees to extract insights, compare documents, and generate outputs without requiring advanced technical skills. For example, sales personnel can use AI assistants to analyze and compare key information across vendor tenders or request-for-quotation documents, significantly reducing manual effort and improving decision speed. This ability to translate unstructured inputs into actionable insights enhances both operational efficiency and decision quality across supply chain functions.

Enterprise tools such as Microsoft Copilot and Anthropic's Claude illustrate how organizations are leveraging Gen AI at scale. Many companies are using these solutions as general productivity enablers, while others are developing custom AI assistants tailored to specific processes and datasets. At DHL, our people are empowered to use Microsoft Copilot to support day-to-day activities, including drafting emails from rough notes, summarizing lengthy documents or email threads, and generating clear recaps of meet-

ings based on transcripts. These capabilities reduce administrative workload and allow employees to focus on higher-value tasks.

Beyond internal use, AI assistants are also transforming customer interactions in logistics. At DHL, we have deployed customer-facing solutions such as the VIVA chatbot at DHL Freight, handling a wide range of customer inquiries, including shipment tracking, product information, and complaint management. These systems provide around-the-clock support, generate human-like responses, and are scalable across multiple markets. Similarly, voicebot solutions have been implemented at DHL Post and Parcel, where approximately 16 million calls are received annually. These voicebots supplement human agents and improve service availability.

AI assistants serve as a key interface between users and complex logistics systems, enabling faster access to information, automating routine tasks, and enhancing both employee productivity and customer experience. Their ability to operate across internal and external use cases makes them a foundational building block for the broader adoption of Gen AI in supply chains.

Intelligent Document Processing

Logistics operations depend on a continuous flow of structured and unstructured documents – invoices, bills of lading, customs declarations, and delivery receipts – exchanged across multiple stakeholders throughout the supply chain. Errors, inconsistencies, and manual data entry can lead to delays, compliance risks, and operational inefficiencies. Traditional document processing approaches relied heavily on template-based extraction, predefined rules, and classical machine learning, which required extensive configuration and struggled to adapt to variations in document formats.

Gen AI fundamentally transforms this capability by enabling systems to understand context rather than simply recognizing patterns. By leveraging LLMs, modern intelligent document processing solutions can extract, classify, and interpret information from highly variable and unstructured documents without relying on fixed templates. This shift from rule-based to intelligence-based processing allows organizations to achieve near-human levels of accuracy even in complex scenarios, while significantly reducing the time and effort required to train and deploy document models.

At DHL, we have demonstrated the practical impact of this approach through our Intelligent Documents Capture solution known as iCAP, an in-house system designed to automate the processing of shipment documents. The solution extracts and classifies information from booking requests and customer documentation, automatically triggering downstream actions such as notifying stakeholders and creating entries in back-office systems. Operating at scale, it processes more than 140,000 shipments per month with near-perfect data extraction accuracy.



Further validation of this approach can be seen in a proof of concept we conducted at DHL Supply Chain, where intelligent document processing was applied to purchase order validation and data extraction. These documents presented significant variability in format, structure, and content, including both printed and handwritten elements. Despite these challenges, leading solutions demonstrated high accuracy rates of up to 95% for structured data and strong performance on unstructured inputs with minimal training, illustrating the flexibility and scalability of Gen AI-driven document processing.

Beyond DHL, industry examples reinforce the transformative potential of this technology. Audi, for instance, applied intelligent document processing to automate the comparison of tender documents, a process that previously required extensive manual effort due to large document sizes, inconsistent supplier formats, and the risk of human error. By combining LLMs with semantic search and human oversight, the company significantly reduced manual workload, accelerated evaluation timelines, and improved overall decision quality, resulting in thousands of man-hours saved.

By automating data extraction and interpretation across diverse document types, Gen AI-driven document processing reduces processing times, improves accuracy, and enhances supply chain visibility – supporting faster decisions and more reliable service delivery.

Conversational Analytics

Conversational analytics is the use of artificial intelligence to analyze, interpret, and extract insights from natural language interactions across channels such as chatbots, voice calls, emails, and messaging platforms. By leveraging natural language processing (NLP) and Gen AI, it enables organizations to understand context, sentiment, and intent at scale, transforming everyday conversations into actionable insights that support improved decision-making, customer experience, and operational performance.

In logistics, conversational analytics addresses the growing complexity and volume of communication data generated across customer interactions and internal operations. Traditionally, extracting insights from this data required manual effort or



technical analytical skills, limiting accessibility and speed. Gen AI changes this by enabling automated collection, processing, and interpretation of conversational data from multiple sources, including chat logs, call recordings, and messaging systems. The result: faster pattern recognition, more actionable insights, and better-informed decisions across the organization.

This capability is particularly valuable in customer support and operations. By analyzing interactions between customers and service agents or virtual assistants, companies can identify common issues, improve response quality, and ensure consistent service delivery. Conversational analytics also plays a key role in voice-of-customer analysis, where large volumes of feedback can be categorized and evaluated to understand customer preferences, pain points, and sentiment trends. In addition, it enables operational teams to explore performance data using natural language queries, reducing the reliance on technical specialists and accelerating access to insights.

At DHL, we have implemented several solutions that demonstrate the practical value of conversational analytics. The Talk to Your Data solution developed by DHL Supply Chain allows users to query complex datasets using natural language. Users pose a question in plain language and the system generates the appropriate query and returns results in a clear, human-readable format. This empowers teams to independently access insights and make faster decisions without relying on data specialists.

Another example is the Voice of Customer tool used at DHL eCommerce, which processes more than eight million customer feedback entries annually. By leveraging Gen AI, the solution automatically classifies feedback and analyzes customer sentiment, enabling teams to visualize trends, prioritize issues, and take targeted actions to improve customer satisfaction. Similar approaches are seen in solutions such as Amazon Connect, where Gen AI is used to generate post-call summaries and improve contact center performance, as demonstrated by companies like Priceline.

By enabling organizations to understand interactions at scale – turning large volumes of conversational and operational data into accessible insights – conversational analytics enhances customer experience, improves operational visibility, and supports more agile and informed decision-making across the supply chain.

Vibe Coding

Vibe coding represents an emerging approach in software development enabled by Gen AI, where users describe their intent in natural language and AI systems translate these instructions into executable code. Rather than relying on traditional programming practices that require deep technical expertise, vibe coding emphasizes speed, creativity, and accessibility, allowing individuals to focus on desired outcomes while the AI handles the technical implementation. This approach lowers the barrier to application development and enables faster experimentation across business functions.

In a logistics context, vibe coding offers the potential to bridge the gap between business needs and technical execution. Employees who are closest to operational challenges can rapidly prototype solutions without waiting for dedicated development resources. For example, workflows such as employee onboarding or purchase order approvals can be automated by describing the process in plain language, with the AI generating the underlying logic. Similarly, vibe coding can be used to develop lightweight tools for sales and customer support, including virtual assistants or automated response systems tailored to specific logistics use cases.

Another area of application lies in compliance and risk management. Vibe coding can be used to create monitoring tools that flag anomalies, generate checklists, or trigger alerts for potential compliance issues in areas such as financial reporting or data protection. Yet the same speed that makes vibe coding attractive introduces risk: in highly controlled environments like logistics, applications developed without careful validation and oversight can fall short on reliability and regulatory compliance.

Vibe coding also introduces several other challenges that organizations must manage. AI-generated code can become difficult to interpret, leading to potential duplication of logic or maintenance issues over time. Legacy system integration adds further complexity, with additional concerns around security and governance. To address these risks, organizations are beginning to establish structured approaches, such as creating sandbox environments for experimentation, defining clear handoff processes before production deployment, and implementing governance frameworks to ensure quality and consistency.

Vibe coding is still maturing, but its potential to democratize application development – enabling a broader range of employees to prototype and contribute digital solutions – makes it a technology worth watching for logistics organizations.

Summary & Trend Overview

Challenges



Data security and privacy remain critical concerns, as risks such as prompt injection, API misuse, and compromised training data can expose sensitive information.



The quality of underlying data is critical, as poor data can lead to inaccurate or misleading outputs (e.g., hallucinations).



The evolving landscape of AI governance and regulation presents an additional challenge, as regional frameworks and standards continue to develop and diverge.



Integrating Gen AI into existing logistics systems is operationally complex, touching infrastructure, workforce capability, and change management simultaneously.



The financial investment required to implement and maintain Gen AI solutions is substantial, and many use cases have yet to demonstrate a clear or immediate return.

Outlook

Gen AI is expected to continue advancing rapidly, driven by improvements in data availability, computational power, and model design. As these systems become more sophisticated, their role in logistics will deepen – accelerating automation, sharpening decision-making, and opening new service and business models across the logistics industry.

At DHL, we see Gen AI as a key enabler of our long-term strategy, supporting digitalization and sustainable growth. By focusing on strong data foundations and expanding AI capabilities across the organization, we aim to unlock new efficiencies and deliver greater value to customers. As adoption accelerates, Gen AI will shift from an emerging capability to an integral component of how logistics operations are designed and executed.



Explore – This trend has the potential to drive meaningful change in specific areas of logistics with implementations available for many use cases today.

Related Trends

Computer Vision



AI Ethics



Agentic AI



Compute Economy



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Heavy Vehicle Electrification

Trend Overview

Impact:

HIGH

Adoption:

5 – 10 YEARS

Focus Areas:

Sustainability

Sectors:

Auto-Mobility

Engineering & Manufacturing



The trend of Heavy Vehicle Electrification comprises the adoption of battery electric, fuel cell electric, and hybrid propulsion systems particularly in heavy duty trucks, but also aircraft, trains, and waterborne vessels to decarbonize freight operations. Advances in battery performance and the gradual expansion of charging and hydrogen infrastructure are beginning to make electrification viable across select corridors and use cases, with the pace and pathway varying significantly.

Electrification of heavy-duty transport across land, air, and water has progressed more slowly than in lighter vehicles, constrained by stricter operational demands and technology limitations, particularly in long-haul use cases. Recent advances in battery performance and the gradual expansion of alternative fuel infrastructure, including EV charging and hydrogen networks, are beginning to unlock targeted applications in select segments.

The market is responding to these developments. Global sales of electric medium- and heavy-duty trucks surpassed 90,000 units in 2024, marking the third consecutive year of growth and a year-on-year increase of nearly 80%. While widespread adoption remains constrained, the sector is steadily moving from early experimentation toward broader commercialization in select segments.

The path to electrifying heavy freight will be gradual and uneven across transport modes.

- Heavy duty trucks: Electric truck production is scaling and gaining momentum. Deployment of megawatt charging infrastructure will take time while simultaneously placing additional strain on already stressed power grids.

- Waterborne transport: Stronger government intervention will be essential, as demonstrated by Norway's strict zero-emission mandates for ferries, which have accelerated adoption.
- Aviation: Progress will remain slow. Several high-profile program delays and company pivots signal that the technology gap between ambition and viable deployment remains wide.
- Rail: Already the norm in some regions. However in most other regions, rail faces structural barriers, where legacy infrastructure, long deployment timelines, and high capital costs make widespread electrification challenging.

However, the long-term impact for logistics is significant. Heavy freight accounts for roughly 8% to 10% of global greenhouse gas (GHG) emissions, making electrification one of the more consequential decarbonization levers available. Despite near-term constraints, as technologies mature and infrastructure expands, even partial electrification across key corridors and use cases can deliver meaningful emissions reductions while reshaping how global logistics networks operate.

300–500 km
Already Disrupting Freight

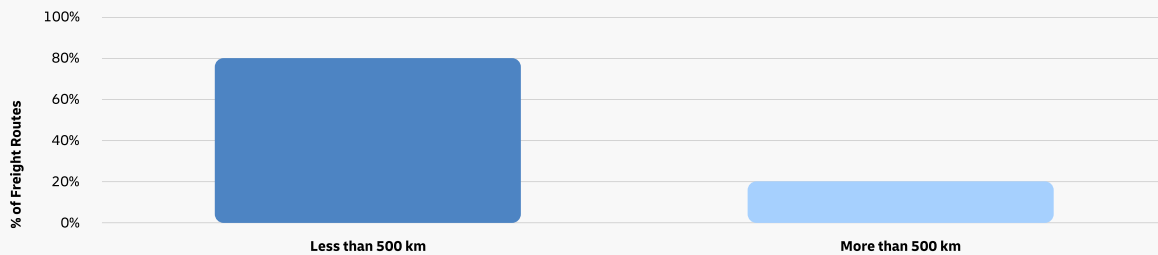
Covers the majority of daily freight routes today.

500–600
Psychological Threshold

The number everyone watches. But not where the impact begins.

700–800 km
Diesel Replacement Zone

Enables total route flexibility & true diesel parity.




Daily & Regional Deliveries
< 300 km



Medium-Haul
300–500 km



Long-Haul Main Corridors
500–600 km



Extended Long-Haul
600–700 km



Maximum Range Flexibility
700–800+ km

A benchmark EV range of 600 km (370 mi) is not necessary for most logistics organizations – a significant majority of freight routes are less than 500 km (300 mi).

EV Curve Futurist (2026): Electric Trucks Unleashed. Freight Enters New Age

Relevance to the Future of Logistics

Regional & Long-Haul Road Freight

The decarbonization of regional and long-haul road freight is accelerating. Battery-electric vehicles (BEVs) are the primary solution, supplemented by hydrogen fuel-cell electric vehicles (FCEVs) and battery swapping solutions. Each pathway presents distinct advantages and trade-offs, shaping how logistics networks will transition away from internal-combustion engines.

Battery-electric trucks have made the most visible progress to date, supported by effective incentive schemes and stronger investment momentum. Historically constrained by charging time, battery weight, and limited range, recent advancements in Megawatt Charging Systems (MCS) and battery capacity are beginning to turn the tide. Volvo reports a maximum range of 700 km for its 2026 models. With MCS, trucks can recharge from 20% to 80% in 40 minutes, thus significantly reducing charging



times, paid waiting times and idle time. Aligning MCS charging with mandatory driver rest periods can be a bonus. Together, extended range and fast charging are making battery-electric trucks increasingly viable not only for regional routes but also for long-haul corridors with adequate infrastructure. Tesla's announcement of 64 additional MCS locations (beyond two already operational) signals growing private investment in this charging ecosystem.

Hydrogen fuel-cell trucks offer a different value proposition: faster refueling and more reliable performance in cold climates, where battery efficiency can degrade. However, adoption remains limited due to infrastructure gaps and cost competitiveness, with hydrogen refueling stations far less widespread than EV chargers. Innovations such as Saathi GreenTech's hydrogen retrofit solutions highlight ongoing experimentation, but large-scale deployment still faces systemic challenges.

Looking ahead, a hybrid ecosystem is likely to emerge. Battery-electric trucks are well suited for urban and regional operations, or for long-haul corridors supported by megawatt charging, while hydrogen may serve niche scenarios such as remote routes or extreme climates. As charging technology advances, battery solutions have increasing potential to dominate broader use cases, further accelerating the transition toward low-carbon logistics.



Waterborne Transport

Electrification in waterborne transport is progressing more slowly than in road freight, but recent developments signal a meaningful though uneven shift. While we are seeing moves to electrify short-range and inland vessels, decarbonization in deep-sea shipping continues to rely heavily on drop-in fuels (sustainable marine fuels) and look to hybrid-electric solutions as a viable pathway.

Short-distance and fixed-route applications, such as ferries and inland waterways, are emerging as the most viable entry points because predictable schedules and access to shore-side charging infrastructure make battery-electric solutions more practical here than in open-sea or variable-route contexts. Developments in Norway provide compelling proof points:

battery-powered, fully electric ferries such as the MF Ampere (the world's first all-electric car and passenger ferry), MS Medstrøm (the world's first fully electric fast ferry), and MF Vargsund (the world's northernmost fully electric car ferry) have demonstrated reliable electric propulsion, even in demanding Arctic conditions.

Longer and regional routes are expected to rely on a combination of low- or zero-carbon fuels, such as methanol, complemented by shore power and onboard battery systems to support energy needs and port operations. This hybrid approach reflects a pragmatic transition pathway as the industry balances operational constraints with sustainability goals.

Technology is advancing on multiple fronts. Battery-electric vessels are progressing rapidly, with high-capacity systems and ultra-fast shore charging enabling efficient, reliable operations. Large-scale applications are also emerging. China's Ningyuan Diankun is the country's first 10,000-ton pure-electric container vessel, combining high-voltage charging with battery swapping to maintain operational uptime. In inland shipping, the Blue Marlin, launched in mid-2025, is the world's first hybrid solar-powered inland cargo vessel.

Solar and wind integration are also gaining attention. Captain Arctic's 35-meter solar sails, fitted with 2,000 square meters of solar panels, double as physical sails to harness wind energy. SolidSail's retractable, rotatable sails are designed for vessels of various sizes and are projected to reduce fuel consumption by 1,000 tons per rig per year.

Overall, electrification in waterborne transport is gaining traction, but no single technology dominates. Deep-sea shipping remains the hardest segment to decarbonize, but the breadth of innovation underway signals that the trajectory is firmly toward lower-emissions operations.

Air Freight

Air freight accounts for approximately 5% of total logistics-sector emissions, yet it is the most complex segment to decarbonize, constrained by strict safety regulations, certification requirements, and fundamental technology limitations. Compared to road and waterborne transport, aviation electrification remains at an earlier stage, with viable solutions still under development rather than near-scale deployment.

Battery-electric aviation faces the most significant constraints. Fully electric propulsion is currently feasible only for very small aircraft over short distances due to the gap in energy density between batteries (approx. 300Wh/kg) and traditional jet fuel (approx. 12,000 Wh/kg). One example is Pipistrel's Velis Electro



two-seater training aircraft. Batteries also add considerable weight, directly reducing payload capacity and range. For cargo aviation, where high utilization and payload efficiency are critical, these limitations – including long charging times – make full electrification commercially unviable in the near to medium term. Operational fully electric cargo aircraft are unlikely within the next decade.

Hybrid-electric aircraft offer a more incremental pathway. By combining conventional engines with electric propulsion support during taxi, climb, and auxiliary operations, they can deliver modest efficiency gains while maintaining operational flexibility. These systems are better suited for short-haul and regional routes, though development remains limited and certification pathways are still evolving. For example, while numerous hybrid hydrogen-electric aircraft are in development, the Diamond HK36 “Super Dimona” is the only aircraft to even hold a type certification. The hydrogen fuel-cell propulsion system itself has not yet been certified.

Hydrogen represents a longer-term alternative with stronger theoretical potential. It has a higher energy density by mass (approx. 33 kWh/kg) than jet fuel (approx. 12 kWh/kg), making it an attractive candidate for aviation. In practice, however, implementation is highly complex. Airbus has postponed the launch of its ZEROe hydrogen aircraft to the second half of the 2040s, reflecting the scale of the technical challenge. Hydrogen requires entirely new aircraft designs, specialized cryogenic storage systems, and robust safety frameworks – challenges that mean hydrogen-powered aviation remains firmly in the experimental stage.

Overall, air freight electrification is likely to follow a gradual, multi-pathway transition. In the near term, incremental improvements through hybrid systems and sustainable fuels will dominate, while breakthrough technologies such as hydrogen will define longer-term transformation.

Rail Freight

Rail is already one of the most energy-efficient and electrified transport modes, yet full electrification remains uneven. Passenger rail has historically attracted the bulk of electrification investment, where dense, high-frequency routes justify the capital outlay for the

required infrastructure. Rail freight, by contrast, is a lower frequency, higher payload service running on privately owned networks, which means investment decisions are closely tied to return on capital. Continuous electrification across long rural corridors is economically unviable in most cases. In recent years, this dynamic has pushed the sector toward a more pragmatic approach, concentrating electrification on high-density corridors between major ports and inland hubs where volume justifies the investment in infrastructure.

The sector is also moving toward “discontinuous electrification” – selectively installing overhead line equipment in economically viable segments such as stations or flat sections, while relying on onboard energy systems elsewhere. This hybrid infrastructure model allows operators to capture electrification benefits without incurring prohibitive system-wide costs.

Recent developments illustrate this transition. Battery-electric locomotives are being tested in heavy-haul environments where routes are predictable and regenerative braking can partially offset energy consumption. For example, BHP is testing Wabtec battery-electric locomotives with 7 MWh systems on iron ore routes in Australia; Rio Tinto and Roy Hill are pursuing similar programs there as well. In China, 1,000-kilowatt battery-powered locomotives are operating in industrial rail networks, demonstrating near-term viability in controlled settings.

Hydrogen-powered rail is also emerging as an alternative for non-electrified lines. Alstom’s Coradia iLint and Coradia Stream H trains have demonstrated that hydrogen can replace diesel in passenger service without requiring continuous overhead infrastructure. In freight, Canadian Pacific Kansas City has introduced a high-powered hydrogen locomotive into mainline service, signaling early momentum beyond passenger applications.

Overall, rail freight electrification is advancing through selective infrastructure investment and onboard propulsion alternatives. This pragmatic approach enables near-term progress without waiting for full network electrification – accommodating the economic realities of freight operations while building toward a lower-emission rail system.



Summary & Trend Overview

Challenges



While electric propulsion is gaining traction in road and rail transport, adoption in maritime and other energy-intensive applications remains more dependent on future advances in energy storage, charging infrastructure, and grid capacity.



Heavy vehicle electrification shifts spending from fuel to infrastructure, transforming operating costs into upfront capital investment. It demands high-capacity power connections, from megawatt to gigawatt scale, along with grid upgrades, new substations, and harmonized standards across transport modes.



Battery-electric propulsion reduces payload capacity because battery systems add substantial weight, which negatively impacts heavy vehicles designed to move large cargo volumes over long distances.



For optimal performance, electric systems require fixed routes, predictable schedules, tight management and planned downtime – conditions that are not always guaranteed in heavy freight operations, and where fossil fuels offer flexibility that electrification cannot yet match.



Long certification timelines, immature standards, and conservative regulatory frameworks (particularly in aviation) extend time to deployment and add cost and uncertainty.

Outlook

The electrification of heavy vehicles rests on infrastructure: the availability of charging networks, refueling stations, and grid capacity will directly determine the pace and scale of adoption across all transport modes. At the same time, the industry is converging toward a portfolio approach, matching propulsion choices to operational needs, such as distance, payload, route predictability, and infrastructure availability. Battery-electric, hydrogen, and drop-in fuels will each serve distinct roles rather than competing as a single solution.

This shift reframes the trend: no longer purely an energy challenge, it is becoming a broader systems and coordination challenge that will require alignment across charging technologies, interfaces, and stakeholders. Successful electric ecosystems will depend on integrating vehicles, infrastructure, and standards seamlessly. The players best positioned to lead will be those who simplify this complexity.



Prepare – This trend has the potential to fundamentally transform or disrupt logistics with developments still needed and use cases still being explored.

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19. XINHUANET (2025): *China's first 1,000-kW battery-powered locomotives rolled out in Dalian*
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Humanoids

Trend Overview

Impact:

CONSIDERABLE

Adoption:

5 – 10 YEARS

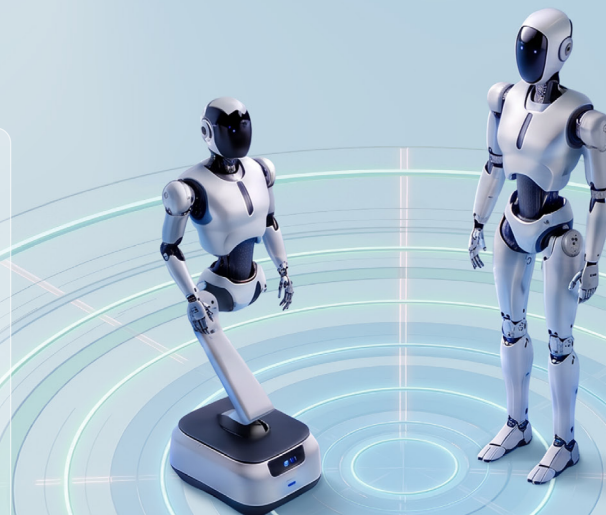
Focus Areas:

Automation & Efficiency

Physical & Digital Security

Trend Clusters:

Robotics



The trend of Humanoids refers to the development of mobile robots with human-like morphology, designed for general-purpose use in human-centric environments. These robots perceive the world around them through integrated sensors and cameras, processing inputs via neural networks and a central computing system to execute tasks.

Often seen as a physical manifestation of artificial intelligence (AI), human-like robots have long captured human imagination – from ancient mythology to modern science fiction. Today, this vision is rapidly materializing as developments make humanoids increasingly viable for real-world operational applications, including logistics.

Underpinning humanoid development is physical AI – the capability to perceive, understand, reason, and act within the physical world. It enables autonomous mobile robots to continuously interpret surroundings and respond dynamically to unpredictable conditions.

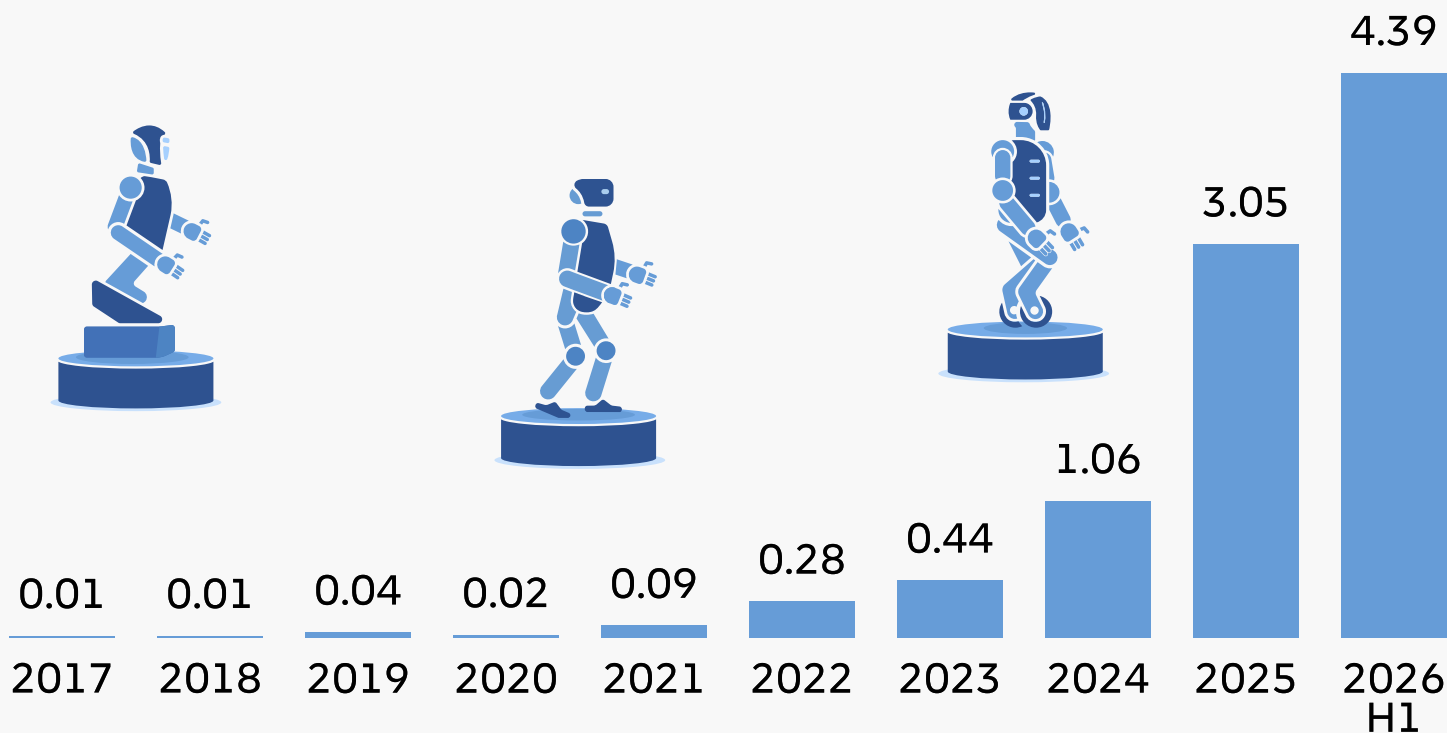
Recent advances in machine learning show how far this capability has come. Paired with Figure AI's O1 humanoid, OpenAI's speech-to-speech reasoning showed the robot processing live inputs, generating context-aware responses, and translating them into real-time actions. This demonstrates that robotic development is bridging the gap between cognition and execution.

Investment in humanoid robotics is accelerating. The year 2025 saw more than 600 deals spanning venture funding, strategic partnerships, and early commercial collaborations. Market forecasts indicate growth from approximately US\$2.16 billion in 2026 to nearly US\$8.78 billion by 2035.

Early deployments suggest that value will first emerge in manufacturing and logistics settings with repetitive and moderately complex tasks in low variability environments. The human-like structure of humanoid robots is a key advantage, allowing integration into existing brownfield logistics environments without expensive rebuilds, new tools, or redesigned workflows.

Humanoids are expected to play a significant role in future logistics and supply chain operations, but several critical challenges remain as the technology matures. Safety in shared environments, task range, and operational reliability all require further development before broad deployment is available. Durability of initial product offerings also remains in question, with actuator stress, rapid battery degradation and extreme internal heat as primary mechanical constraints to humanoid robot longevity. Subsequent design iterations across the vendor landscape indicate that system durability is progressing steadily. High upfront costs – with entry-level platforms starting around US\$30,000 and advanced systems reaching US\$150,000 to US\$250,000 – also underscore the importance of demonstrating measurable productivity gains to support long-term economic viability.

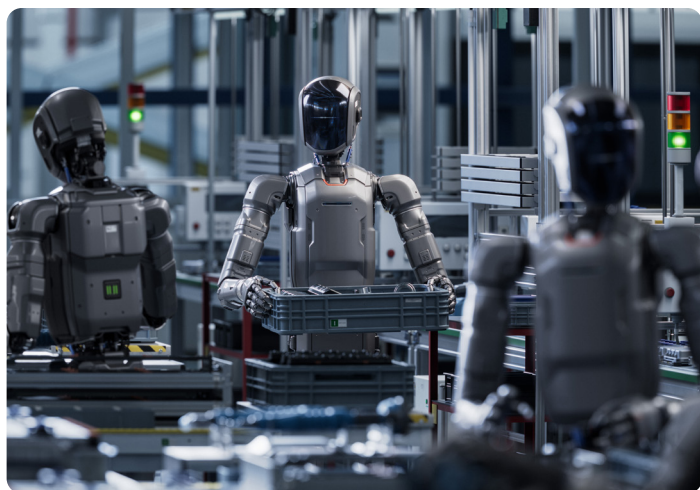
Investments in humanoid robotics startups worldwide in billion U.S. dollars 2026



The humanoid landscape is rapidly diversifying as manufacturers expand capabilities and seek to identify use cases in industrial settings.

Tracxn (2026): Humanoid Robot Sector

Relevance to the Future of Logistics



Manipulation & Dexterity

Automation has long been used in logistics to optimize movement and routing within warehouses and distribution centers, but autonomous interaction with physical items remains a complex challenge due to the variability of shapes, materials, and packaging conditions. As a result, the scope of humanoid deployment in logistics hinges directly on the ability to reliably grasp and handle objects.

Many logistics workflows, such as picking, palletizing, packing, and singulation, involve inconsistent inventory and require dexterity, adaptability, and judgment. Human hands offer more than

20 degrees of freedom; most industrial robotic arms operate with six to eight, limiting their adaptability in unstructured settings. As a result, these workflows still rely primarily on human labor. As robotic dexterity improves, humanoid robots can close this “flexibility gap,” scaling automation from structured, repetitive tasks to more dynamic processes.

Recent developments have moved humanoid technology closer to this goal. Advances in end effectors, the physical devices at the end of robotic arms, are expanding the handling range beyond simple, rigid objects toward more complex and variable items. Environment-specific constraints like extreme temperature tolerance in manufacturing and insulation from dust and debris in material handling, present additional need for customization in end-of-arm tools based on the desired application. Despite such limitations, improved sensing capabilities are allowing robots to better understand how to grasp and manipulate items with various textures and fragility in real time, improving reliability and reducing errors. For example, platforms like Haply Robotics’ Inverse 3 replicate real-world physical objects so that operators can “feel” digital objects, speeding up training and improving control for robotic grasping. These developments are bridging the gap between perception and action, accelerating progress toward more adaptive and capable humanoid systems.

Continued advances in robotic dexterity are expected to unlock broader deployment of humanoid robots across supply chain operations. As these capabilities mature, they will enable more flexible automation that can work alongside existing infrastructure, handle a wider range of tasks, and better complement human workers in increasingly complex fulfillment environments.



Locomotion Platform

Logistics environments span a wide range of conditions. How a humanoid robot moves determines where it can operate and what it can do. In practice, there are two primary locomotion platforms: wheeled mobility and legged mobility, each with distinct trade-offs in speed, stability, and adaptability. While both are evolving to address different supply chain contexts, hybrid designs that combine both approaches are now emerging.

Legged humanoids are designed to navigate human-centric infrastructure (e.g., stairs, uneven surfaces, and confined spaces) enabling deployment within existing facilities with minimal modification. They also typically boast a smaller physical footprint than wheeled alternatives, though the bipedal form can introduce higher intervention rates due to higher engineering complexity. In contrast, wheeled systems offer greater stability, higher payload capacity, more energy-efficient movement, and a simpler, lower-cost design – making them well suited for consistent, high-throughput transport tasks such as point-to-point pallet movement and line-side replenishment on flat, predictable surfaces.

Some hybrid locomotion approaches include feet with embedded wheels so the robots can move efficiently across warehouse floors on wheels, switching to legged motion to step over obstacles or reposition as needed. Manufacturers such as Boston Dynamics and Unitree have demonstrated this approach, reflecting a broader industry effort to combine the strengths of both approaches.

Locomotion will remain a key determinant of where and how humanoid robots can be deployed. The market is likely to maintain a mix of designs, with each platform optimized for specific operational requirements. This reinforces the role of humanoids as complementary systems that extend automation into new areas, rather than replacing existing solutions outright.

Perception & Sensing

Reliable perception is central to how humanoid robots transition from controlled demonstrations to real-world deployment. Perception and sensing systems combine cameras, sensors, and AI models to transform raw inputs (e.g., images, distances, and motion) into an actionable understanding of the physical world, enabling robots to detect objects, interpret conditions, recognize patterns, and make context-aware decisions. In logistics operations, where workflows often involve variability, safety risks, and incomplete information, these capabilities allow robots to operate with greater autonomy and take on roles that have traditionally required human judgment.

Atlas, the humanoid robot by Boston Dynamics, combines advanced vision systems, AI-driven perception models, and real-time localization capabilities to identify objects, understand their spatial relationships, and execute precise manipulation tasks in complex industrial environments. This enables robots to continuously interpret and respond to dynamic surroundings, transforming robotic operation from pre-programmed task execution into a more adaptable, perception-driven process. More broadly, AI-powered vision systems are evolving toward “scene-level understanding,” allowing robots to interpret complex environments, recognize relationships between objects, and respond to changing conditions in real time.

These capabilities unlock new opportunities in security, inspection, and monitoring workflows across the supply chain. Humanoids equipped with these systems can continuously monitor facilities, detect safety incidents, and trigger real-time alerts for proactive risk management, while also performing routine equipment inspections – reducing reliance on manual checks and improving data accuracy over time.

As these capabilities mature, perception and sensing technology is expected to play a central role in extending automation beyond structured processes, enabling more responsive and resilient supply chain operations.



Summary & Trend Overview

Challenges



Humanoid safety standards are still evolving, limiting deployment in mixed environments and requiring controlled or segregated operations.



Limited battery life constrains continuous operation, reducing overall system utilization.



Despite their general-purpose form, current humanoid systems remain limited to a narrow set of simple, repetitive tasks.



Current humanoid systems fall short of the uptime and reliability requirements of warehouse operations, often requiring higher rates of human intervention and maintenance than established automation.



Perceived risks and uncertainty around human-robot interaction continue to limit acceptance among both the public and logistics workforce.

Outlook

Scaled deployment of humanoid robots over the next three to five years will likely remain limited to targeted use cases, given the technical and operational barriers that remain. Continued advances in AI, sensing, and hardware are expected to drive broader innovation across robotics and automation, gradually expanding the role of humanoids from early-stage applications toward more general-purpose deployment in supply chain operations.



Prepare – This trend has the potential to bring substantial change across logistics with developments still needed and use cases still being explored.

Related Trends

Stationary Robotics



Computer Vision



Generative AI



Sources

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6. Agility Robotics (2024): *Why Humanoid Robots Need Legs*
7. Asian Robotics Review (2026): *Feet or Wheels? Answer depends on the application... and a lot more*
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9. World Metrics (2026): *Ecommerce Delivery Statistics*
10. PrimeVision (2026): *Robotic Sorting Solution Enables Flexible Peak Operations for DHL*
11. Gartner (2025): *Garner Unveils Top Emerging Technologies to Support Autonomous Business*

Indoor Mobile Robots

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency Health, Safety & Future of Work
Physical & Digital Security

Trend Clusters:

Robotics

Sectors:

Auto-Mobility eRetail & Fashion
Engineering & Manufacturing



The trend of Indoor Mobile Robots encompasses movable robots that transport and sort materials, goods, and inventory primarily inside facilities. They typically operate without direct human control while safely collaborating in shared workspaces with human personnel.

Automated mobility has advanced from two-dimensional (2D) lidar autonomy to three-dimensional (3D) visual autonomy, which has increased accuracy and capabilities. The robotics component market has expanded as a result – from automated guided vehicles (AGVs) that follow predetermined visible or invisible paths to next-generation autonomous mobile robots (AMRs) that use real-time path planning and can more freely move around obstacles.

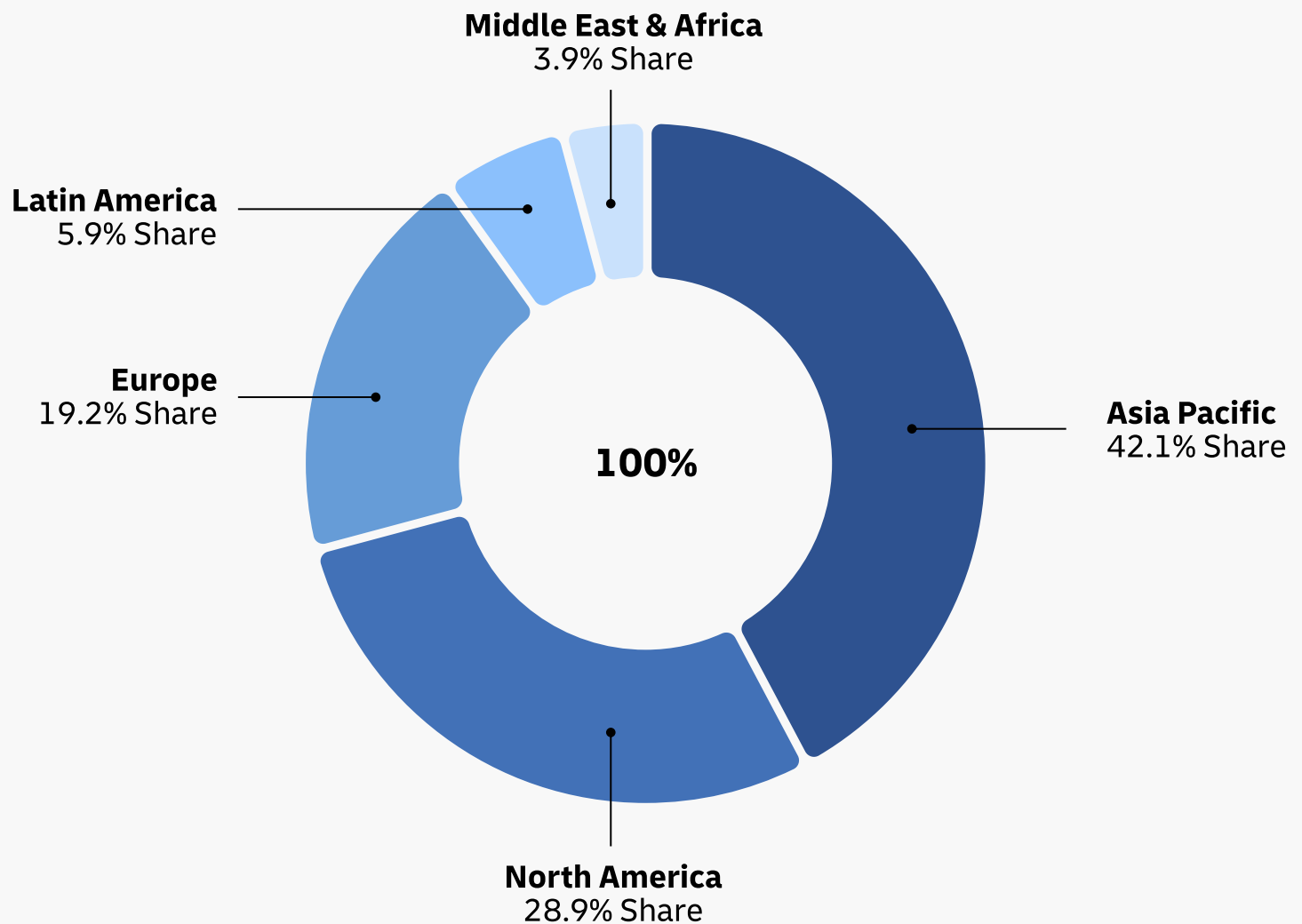
In 2025, the AMR market was valued at US\$3.1 billion. It is expected to grow at a compound annual growth rate (CAGR) of 19.5% to US\$17 billion by 2035. For logistics, the primary market drivers are global e-commerce growth, enhanced safety, and increased efficiency. At DHL, we expect up to 30% of our material-handling equipment worldwide will use some form of robotic process automation by 2030.

In markets with high labor costs, logistics providers have accelerated the adoption of robotics to meet rising consumer expectations for rapid order fulfillment. Today's indoor mobile robots not only help automate warehouse processes, but they also provide real-time insights, which improve inventory management and make delivery-time estimates more accurate.

While cost remains a barrier to widespread adoption in some regions, a number of specific AMR applications have reached considerable maturity and scale in demand-intensive markets. In recent years, we have seen significant, market-wide development of robotic logistics applications, such as case handling, container unloading, and robotic orchestration across multiple fleets or systems.

At DHL, we anticipate indoor mobile robots will have a high impact on logistics and supply chains. As the number and application range of these solutions continue to grow, their efficiency and ability to meet increasing customer demands will increase.

Mobile Robots in Logistics Market by Region Value 2025



Asia Pacific dominates the market for mobile robots in logistics with over a 40% global share, significantly outpacing North America and Europe.

Tracxn (2026): Humanoid Robot Sector

Relevance to the Future of Logistics



Point-to-Point Transportation & Sortation

Moving goods between predefined locations within a warehouse is an essential yet highly repetitive, time-consuming process. Inbound and outbound inventory sortation represents a large subsection of the point-to-point transport tasks across distribution operations. Manual inventory sorting processes are highly labor-intensive and prone to mis-sorts, particularly under high order volumes and SKU proliferation, leading to downstream inefficiencies across packing and shipping operations. Indoor mobile robots are an effective way to save resources because fewer people are needed to oversee a fleet of robots, which frees up other workers to perform value-adding tasks.

Indoor mobile robots for point-to-point transportation are divided into two distinct categories by their perception technology and operating capabilities: horizontal and vertical transport robots. Horizontal transport robots (e.g., jack lifts, pallet jacks, or tugging robots) operate strictly within a two-dimensional grid along the warehouse floor. They pick up goods at floor level, move them across the room, and drop them off at floor level. Vertical transport robots (e.g., forklifts) add a third dimension, the Z-axis. In addition to moving goods from place to place at the floor level, they can also lift payloads up and down. Both horizontal and vertical transport robots help automate point-to-point material handling tasks in warehouses. Companies like Agilox, Seegrid, and Vecna have robotic horizontal pallet jacks and tuggers as well as autonomous vertical counterbalance forklifts on the market. New vendors like Filics have attracted significant attention with a horizontal pallet jack with a low-profile, skateboard-like design that can operate in tight spaces like staging lanes and narrow aisles.

As international e-commerce markets grow steadily, fulfillment centers can experience order volume spikes of up to 250% across

peak seasons. Mobile sorting robots can automate product sorting, further insulating supply chain and distribution networks from demand volatility, peak intensity, and workforce shortages. Unlike fixed infrastructure, these AMR solutions can be flexibly configured to evolving facility layouts and scaled up or down in line with demand requirements. One example is Robin, made by PrimeVision, which can handle and sort both standard e-commerce orders and non-machinable packages weighing up to 35 kg. Sorting solutions like Robin, which are also available as a “Sorting as a Service” model, help organizations maintain high operational flexibility for peak demand without capital investment.

Global supply chain networks are also exposed to operational realities such as pallet type and quality variance, which can cause friction in the adoption of autonomous transport solutions. Despite these requirements, we’ve seen tangible benefits through improved operational efficiency, enhanced safety and risk mitigation, and real-time inventory visibility. The market for automated point-to-point transportation solutions is already quite mature, with many use cases significantly reducing repetitive work and walking distances.



Container Loading & Unloading

Loading and unloading containers and loose-load trucks are some of the most physically demanding activities in logistics. Workers can be exposed to harsh weather conditions and must rapidly and repeatedly move heavy goods in confined spaces to ensure downstream operations continue seamlessly. Indoor mobile robots are designed to reduce the burden on workers.

Stretch, made by Boston Dynamics, is an autonomous robot developed for a range of warehouse tasks; it is initially being deployed for unloading floor-loaded containers and trucks. Stretch consists of three components: a lightweight robotic arm that can lift cartons of up to 22.7 kg (50 lb), a relatively small mobile base designed to easily fit inside trailers and containers,

and a perception arm with depth sensors and 2D cameras. The sensors help Stretch perceive its operational environment and identify cartons of different shapes and sizes. Future models may be capable of loading, building pallets, and depalletizing. In January 2023, DHL Supply Chain became the first company to commercially deploy Stretch for truck unloading.

Autonomous forklifts made for pallet unloading have improved significantly, increasing throughput and reducing intervention rates over the past five years, making them a viable option for logistics organizations. This progress stems primarily from more robust onboard perception hardware and enhanced navigation software – upgrades that have also improved workplace safety. Crucially, vendors like Gideon & Fox robotics have also extended their product capabilities to include autonomous loading of pallets into trailers. The expanded scope of these autonomous units demonstrates machine intelligence in 3D spatial planning, load stability and distribution, and higher placement accuracy than required in palletized container unloading.

Currently deployed AMR solutions are primarily for handling uniform cartons or pallets. Autonomous robotic loading and unloading of unstructured, mixed cartons remains a complex task; further development is needed to achieve broad commercial scale. However, rapid advances in robotic software and computer vision are accelerating the transition to autonomous mobile piece manipulation.

Order Fulfillment & Assisted Picking

In analog warehouse environments, order fulfillment workers can walk an average of up to 14.5 km (9 miles) each day. This puts a physical burden on people and presents a compelling case for indoor mobile robots. Picking robots can shorten the distance walked by humans and reduce time between picks, driving efficiency in the order fulfillment process.

Fully automated solutions are now emerging, with “robot-to-goods” (R2G) order picking robots such as the Locus Array. The Array can autonomously navigate storage areas, retrieve items, and transport completed orders to downstream pack-out stations. This solution can further insulate operations from labor shortages and inefficiencies attributed to stock-keeping unit (SKU) growth within a facility.

While full autonomy is only in early deployment, assisted AMR technology such as the Locus Origin has already been deployed commercially at massive scale. DHL Supply Chain uses the Origin across more than 40 managed sites worldwide, leveraging the robots to increase units picked per hour and reduce training time



by 80%. In February 2026, a Locus Origin bot completed the one billionth robot-assisted pick at a DHL Supply Chain facility.

Carter, made by Robust AI, is another example of how indoor mobile robots are uniquely equipped to help optimize order fulfillment. The collaborative mobile robot blends artificial intelligence (AI) and advanced robotics to create a flexible material handling solution that works alongside humans. Carter is equipped with camera-based visual simultaneous localization and mapping (vSLAM) for intelligent localization, a force-sensitive handlebar for seamless manual operation, and an adaptive put-to-light system to minimize errors and improve picking efficiency. DHL Supply Chain and Robust AI have established a global strategic partnership, with early deployments and scaling efforts focused across DHL’s Latin American operations to drive higher productivity through collaborative, human-centric automation.

Using AMRs to support order fulfillment allows workers to focus on picking accuracy while significantly reducing walking distance and travel time.

Facility Support

For sprawling warehouse and cross-dock operations, maintaining high facility standards for cleanliness, security, and maintenance is paramount for keeping an operation safe and efficient. However, such standards are both resource-intensive and costly. Developments in robotic mobility & perception technology, coupled with AI and machine learning, have driven costs down while increasing the viability of facility support robots in supply chain applications.

Many traditional original equipment manufacturers (OEMs) of cleaning solutions, like Karcher, have added autonomous product lines to supplement their manual equipment offerings. The Karcher KIRA bot, for example, deploys cloud-based AI to support a smarter cleaning process; KIRA can learn and improve

over time. Additionally, smart detection systems let the bots navigate safely around people and obstacles.

The massive footprint and decentralized layout of modern logistics facilities increase security infrastructure requirements and risk of theft. In the US alone, losses from cargo theft have risen nearly 50% since 2023, with an average loss of more than US\$202,000. Autonomous security robots (ASRs) can be deployed to monitor and control these facilities. Use cases range from automatic license plate recognition to video surveillance and the detection of blacklisted or suspicious mobile devices.

The four-legged mobile robot Spot, made by Boston Dynamics, can be equipped for security with additional cameras and a sensor suite to physically inspect a defined area. Designed to walk stairs and uneven terrain, Spot can patrol multiple levels, following pre-mapped routes or operated remotely via a tablet.

Indoor mobile robots for warehouse cleaning and security remain limited, but they are likely to play a significant role in intelligent facility support infrastructure in the future.



Automated Inventory Management & Mobile Sorting

In warehousing and distribution, active inventory management is a complex and often inefficient operation. Inventory inaccuracies across warehouse management systems drive stockouts and inefficient space utilization, ultimately causing lost revenue.

Purpose-built indoor robots can automate tasks like inventory cycle counting and sorting inbound products or outbound orders. Indoor mobile robots are helping digitalized organizations

maintain real-time visibility into inventory levels using two primary form factors: aerial scanning drones and ground-based autonomous mobile sensing robots.

Dexory's vertical mast robot, for example, leverages cameras to scan up to 10,000 pallet locations per hour, with integrated AI that can flag misplaced stock, damaged items, and general non-compliance issues. Inventory data from scans are continuously fed into DexoryView, a digital twin platform that provides a visual representation of warehouse inventory and operations. The application of Dexory has led to improved inventory accuracy because of daily scans, directly enabling a reduction in inventory shrinkage and immediate feedback on operational errors.

Inventory management robots are helping transform static warehouse inventories into dynamic, continuously monitored assets. By combining autonomous data capture with AI-driven analytics and digital twin platforms, these solutions provide greater operational transparency, enabling faster issue resolution, improved storage utilization, and more informed decision-making across warehouse operations.



Summary & Trend Overview

Challenges



Large-area AMR solutions require sufficient Wi-Fi or cellular network coverage that meets IT security requirements throughout the facility.



Deploying a large fleet of automated robot solutions from different manufacturers requires a robust software platform enabling efficient route planning and mission dispatching.



Crowded facilities with many people and obstacles can prevent indoor mobile robots from integrating seamlessly into operations.



The wide variety of warehouse management platforms in use can make it difficult to integrate and scale indoor mobile robot systems.



The complexity of navigating in close proximity to humans requires a comprehensive safety and risk analysis before deploying indoor mobile robots alongside personnel.

Outlook

Logistics providers worldwide are implementing indoor mobile robot solutions. However, leveraging the entire suite of today's indoor mobile robot technology is not yet feasible. Scaling solutions across a variety of applications requires more mature technology. In addition, decision-makers need more verification so that robots can be deployed safely for mission-critical tasks.

However, the trajectory toward full warehouse orchestration is clear. Together with stationary robots, indoor mobile robot solutions will soon enable automation of a significant portion of warehouse operations.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with implementations available for many use cases today.

Related Trends

Computer Vision



Outdoor Autonomous Vehicles



Stationary Robotics



Humanoids



Sources

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Light Vehicle Electrification

Trend Overview

Impact:

CONSIDERABLE

Adoption:

< 5 YEARS

Focus Areas:

Customer Experience

Sustainability

Sectors:

Auto-Mobility



The trend of Light Vehicle Electrification describes the transition of manned and autonomous light-duty logistics vehicles from conventional powertrains to power-assisted or fully electric propulsion systems. These vehicles range from vans and cargo bikes to micro-mobility fleets, and are typically deployed in urban, suburban, and private property environments, where short and predictable routes, emerging zero-emission zones, and rising sustainability requirements create strong demand for electrification.

The electrification of light vehicles in logistics is one of the most mature segments within the broader transition to sustainable transport. Adoption continues to accelerate, driven by strong policy support, improving economics, and expanding charging infrastructure, particularly in urban logistics and last-mile delivery. Global sales of commercial light electric vehicles (LEVs) grew by more than 40% in 2024, surpassing 600,000 units and increasing market share to roughly 7%, led by China and Europe.

Advancements in battery technology have further strengthened the business case for electrification. For example, new chemistries have the potential to significantly reduce operating costs. Sodium-ion cells are on average less expensive than lithium-ion cells, costing roughly US\$59 per kWh compared to US\$74 per kWh. Sodium-ion batteries also perform better in cold weather, making electric vehicles (EVs) more viable across a wide range of operating conditions. In real-world winter trials, global battery manufacturer CATL reports that its Naxtra sodium-ion battery maintained 90% of its range at -40°C (-40°F) and retained stable power delivery at temperatures as low as -50°C (-58°F).

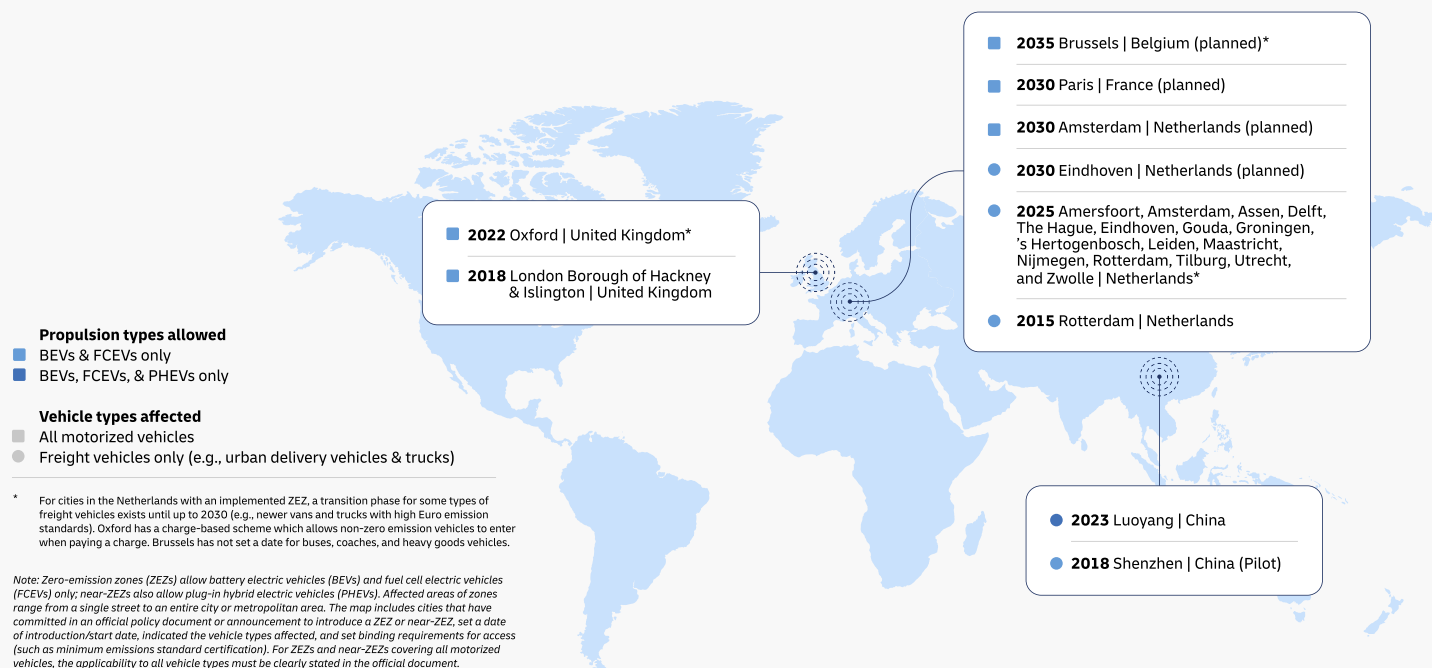
The development of solid-state batteries (SSBs) also promises significant improvements in range, with next-generation technology aiming for over 1,000 kilometers per charge compared to an average of 500 kilometers in 2024. Dongfeng Motor has announced plans to mass-produce SSBs in late 2026. With range anxiety, charging frequency, and total cost of ownership still significant barriers to adoption, SSBs are well positioned to address these concerns.

Overall, light vehicle electrification is rapidly transitioning from early adoption to large-scale deployment. Electric material handling equipment is now standard and electric two-wheelers and vans are quickly becoming the norm for urban deliveries, especially in larger cities. The growing number of zero- or low-emission zones permitting only electric commercial vehicles is accelerating adoption further.

This trend has the potential to transform last-mile logistics by reducing emissions, lowering operating costs, and enabling more efficient and scalable delivery models. The more than 40,000 robovans – autonomous delivery vehicles – now operating in China are strong evidence of this trajectory.

At DHL, we see the trend of Light Vehicle Electrification as a cornerstone of low-emission urban and last-mile logistics networks.

Implemented and planned zero-emission zones (ZEZs) & near-ZEZs globally



The adoption of light electric vehicles is being accelerated by the growing number of zero- or low-emission zones that permit only electric commercial vehicles, especially in Europe.

The International Council On Clean Transportation (2025): Zero-emission vehicle phase-ins: Zero-emission zones (April 2025)

Relevance to the Future of Logistics



On-Site Logistics

On-site logistics leveraging LEVs are emerging as a highly impactful and readily scalable use case in logistics operations. Also known as shunting or switching, on-site logistics covers all on-site vehicle movements inside logistics facilities such as warehouses, distribution centers, ports, airports, and industrial campuses, where vehicles operate in controlled environments with predictable routes and centralized charging. These conditions enable efficient energy use, simplified infrastructure planning, and consistent operational performance, making electrification particularly attractive.

Electrification in this space is already well advanced, with a strong foundation established for wider adoption across more vehicle types. Many organizations have already electrified material handling equipment such as forklifts, and are now extending that transition to yard trucks and shunting vehicles. In the US, we have been expanding our fleet of Orange EV electric yard trucks for on-site transport.

Electrifying on-site logistics delivers clear operational benefits, including reduced fuel consumption, lower emissions, quieter operations, and improved air quality. In busy or enclosed areas, it can enhance workplace health and safety while supporting sustainability goals.

Automation is accelerating the transition, with outdoor autonomous vehicles now capable of operating within controlled

environments, where fewer regulatory barriers exist compared with public roads. Companies can deploy solutions faster and experiment with new operating models more freely. For example, in Singapore we deployed Zelos' unmanned platform to move palletized goods between two on-site warehouse buildings.

Together, electrification and automation are transforming yard operations and on-site logistics into a cleaner, safer, and more efficient system.

Micro-Mobility

Micro-mobility encompasses small, lightweight electric or power-assisted vehicles designed for short distances, typically under five kilometers. It is becoming an increasingly important component of urban logistics, particularly in dense and congested environments. These vehicles, mostly two- and three-wheelers, are especially suited for the "last mile" of delivery in areas with restricted vehicle access such as city centers, pedestrian zones, or apartment complexes. They can bypass congestion and reach locations inaccessible to conventional delivery vans, making hyperlocal deliveries agile and emissions-free.

The micro-mobility market is highly mature, supporting widespread adoption that continues to grow. Globally, more than 9% of two- and three-wheeled delivery vehicles were electric in 2024, making them the most electrified segment in road transport. Micro-mobility vehicles are a natural fit for scaling sustainable urban delivery, particularly in tier 1 and tier 2 cities where food delivery and quick commerce are expanding rapidly. The lower cost, ease of use, and minimal charging requirements further strengthen the business case.



Parcel couriers on electric cargo bikes are now a common sight in urban areas. They offer the flexibility of a micro-mobility solution combined with high payload capacity without added physical strain on couriers. At DHL, we have deployed cargo bikes around the world, such as the Chariot FS2 in Belgium and the Rytte Move3 in Germany. The DHL Express Belgium fleet of FS2 cargo bikes, each with a 1,500 liter volume, 200 kg payload, and 50 km range per day, has a lower cost of ownership than a fleet of electric vans.

New technologies are expanding the scope of micro-mobility beyond manned vehicles. Autonomous delivery robots are re-defining last-mile delivery through fully automated, on-demand services. Examples include Serve Robotics in the US and Meituan in China. These systems have been deployed for food delivery and even hotel room service in some markets, especially China.

Overall, micro-mobility is proving central to faster, cleaner, and more decentralized urban logistics networks, complementing the trend in heavy vehicle electrification and supporting the shift toward sustainable last-mile delivery.



Urban Logistics

Urban logistics involves vans and small trucks and sits between micro-mobility and heavy-duty freight transport. LEVs are rapidly becoming the foundation of sustainable last-mile delivery and city-wide distribution networks in this space. Electric vans and small trucks offer a balance of payload capacity, range, and operational flexibility.

The shift toward electrification in urban logistics is accelerating quickly. While internal combustion engine (ICE) vehicles still dominate overall sales, global sales of electric light commercial vehicles grew by 40% in 2024 to exceed 600,000 units and is expected to continue experiencing strong growth in the coming years.

These vehicles are a strong operational fit, which is further driving adoption. Electric vans typically cover up to 300 kilometers per day, closely matching average urban delivery distances. The latest battery technology offers up to 400 kilometers per charge, extending their range for citywide parcel delivery and business-to-business distribution. Integration with depot-based charging systems enhances fleet efficiency and predictability, and reduced noise and zero tailpipe emissions enable extended delivery windows, such as early mornings and late evenings that ease congestion during peak hours.

Adoption is already visible at scale. In 2025, sales of electric light commercial vehicles grew 45% year-on-year, though largely concentrated in Europe and China. In our own operations, we have electrified 46.2% of our last-mile fleet (as of 2025), and others are following suit.

Overall, we see strong progress toward sustainable urban logistics. LEVs are becoming the default solution, enabling cleaner, quieter, more efficient, and compliant delivery systems in increasingly emission-restricted cities.

Summary & Trend Overview

Challenges



Grid infrastructure upgrades still lag behind charging infrastructure installations.



EVs often have reduced payload capacity due to the weight of their battery systems.



Compared to conventional vehicles, EVs generally have higher upfront costs but lower operating costs, creating a financial barrier to fleet transition for many logistics companies.



Despite the clear sustainability advantage over conventional vehicles, EVs present environmental challenges, such as the extraction of natural resources used in batteries, the energy-intensive manufacturing process, and immature battery recycling and disposal systems.



Policy uncertainty, tariffs, and fuel subsidies can distort total cost of ownership economics, slowing the adoption of electric vehicles relative to internal combustion alternatives.

Outlook

Light vehicle electrification is expected to continue its strong upward trajectory, although ICE vehicles will remain dominant in the near term. Rapid year-on-year growth in electric van adoption, combined with increasing investment in on-site charging infrastructure, is accelerating the transition across logistics fleets. As a result, electric vans will become the default in tier 1 and tier 2 cities, while ICE vehicles are likely to persist in rural and lower-density areas where infrastructure and economies of scale remain limited.



Strategize – This trend has the potential to bring substantial change across logistics with implementations available for many use cases today.

Related Trends

Heavy Vehicle Electrification



Renewable Energy Infrastructure



Sustainable Fuels



Green Urban Transformation



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Next-Generation Connectivity

Trend Overview

Impact:

MODERATE

Adoption:

< 5 YEARS

Focus Areas:

Physical & Digital Security

Visibility & Resilience

Trend Clusters:

Digital Backbone

Internet of Things

Sectors:

Life Sciences & Healthcare

Technology

The trend of Next-Generation Connectivity is the development and implementation of advanced communication and connectivity technologies and their supporting infrastructure. It draws on various frequencies and bandwidths across the electromagnetic spectrum to extend connectivity to people, devices, and assets across the globe.

Connectivity is the backbone of modern logistics. As next-generation technologies come online and coverage expands, new opportunities and operational challenges emerge across global supply chains.

Logistics organizations now have access to a broad spectrum of network types tailored to specific use cases, ranging from low-power Internet of Things (IoT) networks and stationary infrastructure to mobile and long-range connectivity – gradually closing the remaining white spots across global supply chains. New connectivity models, particularly low Earth orbit (LEO) satellite networks, are playing a critical role in bridging gaps where terrestrial infrastructure remains limited, with an expected additional 70,000 LEO satellites to be launched by 2030.

Where connectivity already exists, network capabilities are continuously being upgraded. Fifth generation (5G) mobile networks are designed to support significantly higher device densities, data rates of up to 20 Gbps, and ultra-low latency down to around one millisecond, far surpassing previous 4G LTE capabilities.

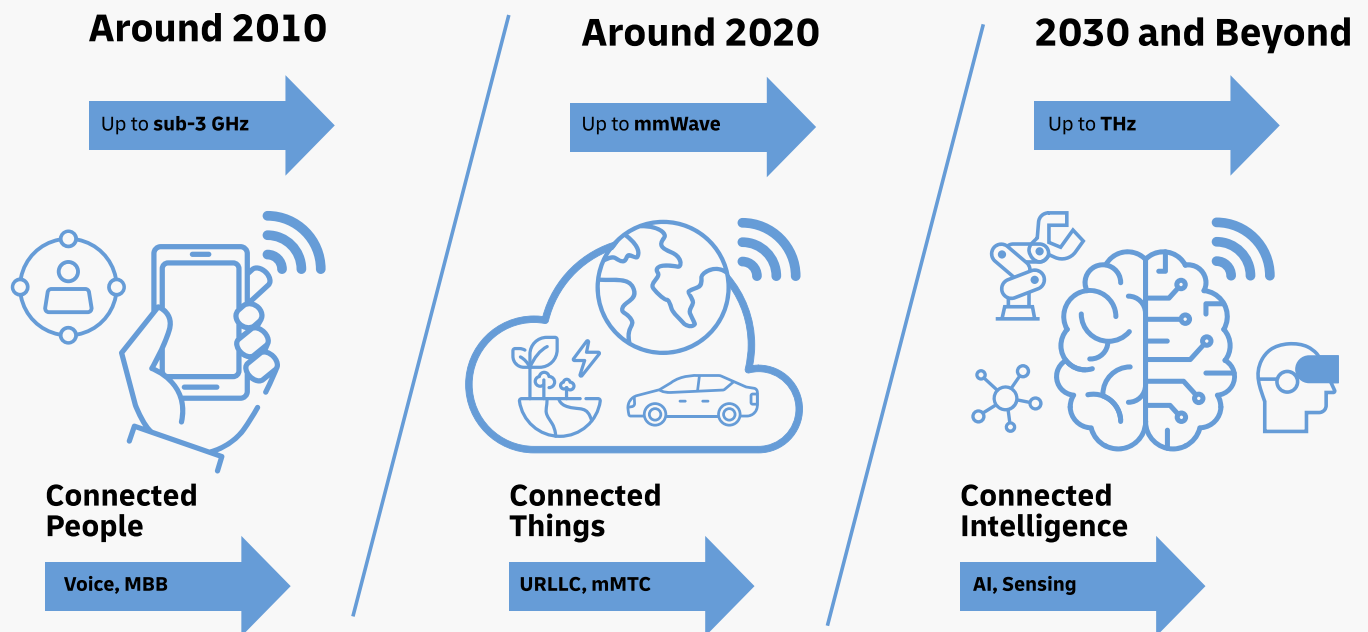
These performance improvements enable data-intensive and time-critical logistics applications such as automation, real-time analytics, and remote operations at scale.

At the same time, the growing diversity of logistics use cases is driving a shift away from one-size-fits-all connectivity. Instead, companies are increasingly adopting hybrid connectivity strategies that combine multiple radio access technologies, including cellular, satellite, and Wi-Fi, to build more resilient, scalable, and cost-efficient network infrastructures capable of supporting heterogeneous environments.

As connectivity ecosystems become more complex, edge computing and artificial intelligence (AI)-driven network optimization are gaining importance. By analyzing network data in real time, AI can help IT teams proactively identify anomalies, performance bottlenecks, and root causes, enabling more stable operations and ensuring that critical logistics applications receive the connectivity quality they require.

The trend of Next-Generation Connectivity forms the foundation for logistics, delivering significant benefits through instant and continuous communication both within logistics facilities and across global supply chain networks. Improved visibility of shipments, assets, and inventory – extending beyond the reach of traditional networks – combined with additional indoor connectivity capacity, will support a data-driven and agile supply chain. Logistics organizations are investing in these technologies, and adoption continues to accelerate across all supply chain segments worldwide. The required technologies already exist and are maturing steadily, pointing to near-term realization across a broad range of logistics applications.

From connected people & things to interconnected intelligence



MBB: mobile broadband URLLC: ultra-reliable low-latency communications mMTC: massive machine type communication GHz: Gigahertz mmWave: Millimeter Wave THz: Terahertz

These technologies form the foundation for the evolution from connected people and things to interconnected intelligence.

Huawei (2021): 6G: The next horizon

Relevance to the Future of Logistics

Wi-Fi 7 & 8

Wi-Fi 7 was officially launched on January 8, 2024, and is now being rolled out across enterprise environments and expected to become the standard for indoor connectivity. The global Wi-Fi 7 market is projected to grow at a compound annual growth rate (CAGR) of 61% from 2025 to 2030.

Building on Wi-Fi 6, Wi-Fi 7 delivers a new level of performance and reliability. It is up to 5x faster compared to previous Wi-Fi generations with a 4x lower latency and 5x greater capacity. Wi-Fi 7 introduces 4096-QAM (Quadrature Amplitude Modulation), increasing the number of data bits encoded per symbol from ten in Wi-Fi 6 to 12. This translates to roughly a 20% increase in data transmitted per symbol.



In logistics, these enhanced Wi-Fi capabilities help accelerate the deployment of indoor mobile robots and other warehouse automation systems that require low latencies for real-time data processing. The increased capacity also allows more handheld scanners and IoT devices to connect simultaneously without impacting network performance.

While the implementation of Wi-Fi 7 is still ongoing, Wi-Fi 8 is being developed with an estimated release date around 2029–2030. The focus of Wi-Fi 8 is not increased speed but ultra-high reliability, delivering consistently more throughput and lower latency than previous generations.



Satellite-Based Connectivity

In 2025, the global low Earth orbit (LEO) satellite market was valued at about US\$15 billion. Investors expect the market for LEO satellites to grow to about US\$108 billion by 2035.

LEO satellites orbit the Earth at altitudes of 160 to 2,000 kilometers. While costs remain relatively high, they are cheaper to operate than higher-orbit systems such as GPS, which circle the Earth at between 2,000 and 35,786 kilometers. LEOs are gaining popularity in IoT applications for their extensive coverage, ability to reduce delays, and high reliability.

Current applications include disaster recovery and resilience in remote areas, where LEO satellites can maintain communication links during natural disasters and other emergencies that disrupt terrestrial networks. Another important application is IoT and machine-to-machine (M2M) communication, as LEO satellites can provide ubiquitous, low-latency coverage.

Capabilities continue to expand. For example, in early 2024, T-Mobile announced that SpaceX launched the first set of Starlink LEO satellites with direct-to-cell capabilities, enabling communication even in cellular “dead zones.”

In logistics, maritime shipping is already benefiting from new tracking capabilities and global connectivity to smart containers. In 2023, Maersk partnered with Starlink to track container ships, optimize routes, and improve fuel efficiency via satellite data, with plans to extend this connectivity solution to broader vessel digitalization.

Beyond cellular connectivity, new approaches are emerging that further lower the barrier to satellite enabled IoT. Early demonstrations showed that Bluetooth Low Energy (BLE) signals can be detected and processed by LEO satellites in orbit. This opens up the possibility of using widely deployed, ultra low power Bluetooth tags for global asset tracking without relying on cellular or dedicated satellite terminals. While still at an early stage, satellite based BLE connectivity could significantly reduce costs and energy consumption for large scale logistics tracking use cases, particularly for low value or high volume assets.

Private Network Slicing & Sharing

Next-generation connectivity enables private network sharing and slicing, dividing a single network into isolated channels to serve multiple purposes simultaneously, improving security and enhancing the user experience.

One example of this is Amazon Sidewalk, designed to extend the coverage and functionality of smart home devices by pooling a small portion of users’ internet bandwidth. Apple AirTags follow a similar model, drawing on the shared network formed by all Apple users.

With 5G and beyond, network slicing allows a single physical infrastructure to be divided into multiple virtual networks, providing greater flexibility in the allocation of network resources. This can support a wide range of services and applications, including enhanced mobile broadband, IoT services, mission-critical communications, and industrial automation.

Here at DHL, we anticipate industrial deployments will feature more use of existing networks, infrastructure democratization, and network slicing. Together, these capabilities offer meaningful benefits for logistics operations, including tailored service levels, efficient resource utilization, enhanced security, and greater resilience.





Ambient IoT

Ambient IoT is a class of connected devices that draw energy from naturally available sources such as electromagnetic fields, light, thermal differences, motion, and vibration. By harvesting these ambient energy sources, these devices can significantly reduce dependence on batteries and, in some cases, eliminate them altogether. This enables more flexible form factors, lower bill of materials costs, and substantially longer product lifetimes.

Using widely available Bluetooth or cellular networks, these devices leverage existing connectivity infrastructure. The result is ambient connectivity that is persistent, low maintenance, and largely invisible, yet capable of fundamentally transforming transparency, efficiency, and control across logistics and supply chains.

In logistics, a reusable transport container or a case of pharmaceuticals can automatically share its location, condition, and lifecycle data without the need for manual scanning or human intervention.

Recent applications include Walmart's deployment of millions of ambient battery-free IoT sensors throughout its U.S. supply chain. This deployment is expected to cover an estimated 90 million pallets, tracking them across distribution centers and stores.

5G & 6G

5G is on track to become the primary cellular network globally. The shutdown of legacy 2G and 3G networks across many regions – alongside early plans to phase out 4G in parts of the world during the early 2030s – is accelerating this transition. By the end of 2025, 5G networks covered an estimated 55% of the global population. Adoption, however, remains uneven. North America, Europe, and East Asia are leading with close to nationwide coverage, while much of Africa and parts of South Asia and Latin America continue to lag significantly behind. For example, only around 12% of the African population was estimated to be covered by 5G by the end of 2025.

When 5G first rolled out, expectations for its transformative potential on logistics were high. While some early promises have taken time to materialize, 5G is increasingly proving its value as a foundational enabler rather than a standalone breakthrough. Its low latency, high reliability, and ability to connect large numbers of devices are improving visibility, resilience, productivity, and decision-making by seamlessly connecting people, vehicles, assets, and infrastructure across supply chains.

In logistics operations, 5G enables a new generation of real-time, data-driven use cases. One prominent example is 5G-enabled fleet telematics, which allows operators to optimize routes, maintenance schedules, and delivery performance based on live operational insights. In addition, 5G supports advanced safety applications such as real-time hazard alerts, video analytics, weather intelligence, and AI-powered driver assistance systems, contributing to reduced accidents and lower operational risk.

Within logistics facilities, 5G is expected to further enhance automation and digital operations. Its low latency and high bandwidth support advanced warehouse automation technologies for picking, packing, and sorting, as well as AI-driven warehouse management systems. Combined with robotics and edge computing, these systems enable more efficient multistory warehouse operations and create the potential for continuous, around-the-clock operations.

Despite ongoing progress, barriers remain. The absence of universal standards across countries and network providers complicates scaling and cross-border deployment, while high infrastructure and operating costs can deter adoption even where coverage is available. Nevertheless, as 5G rollouts continue and capabilities mature, the technology is moving steadily toward mainstream adoption.

Looking ahead, research into sixth generation mobile networks is already underway, with early introduction expected in the 2030s. 6G promises to shift the current paradigm of connected things toward one of connected intelligence, where end-to-end mobile communication systems are tightly integrated with AI and machine learning. This evolution is expected to further amplify the role of connectivity as a core enabler of intelligent, autonomous, and resilient logistics networks.

Summary & Trend Overview

Challenges



A lack of global standards and organizational alignment on frequencies is a barrier to interoperability across regions.



Network and infrastructure security is a critical barrier to this trend, as each connected device can act as a gateway for cybercriminals.



Fragmentation across supply chain participants – in both device deployment and network infrastructure – can result in redundant tags and sensors per shipment and data registered across multiple communication networks.

Outlook

The trend of Next-Generation Connectivity continues to evolve, opening new ways to connect people and assets and close persistent gaps such as white spots. It also enables broader communication, including machine-to-machine (M2M), with lower deployment barriers.

Across logistics, many connectivity technologies are already deployed. Some are complementary, but others are redundant, adding unnecessary cost. Leveraging existing connectivity alongside its convergence with automation, big data, and AI is likely to expand the range of viable use cases. With new developments, especially the launch of satellite connectivity, the trend of Next-Generation Connectivity is positioned not only to enable the connected intelligence ecosystem but to enrich all aspects of logistics operations.



Explore – This trend has the potential to drive meaningful change in specific areas of logistics with implementations available for many use cases today.

Related Trends

Smart Printables



Indoor Mobile Robots



Smartification



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Next-Generation Packaging

Trend Overview

Impact:

CONSIDERABLE

Adoption:

< 5 YEARS

Focus Areas:

Customer Experience

Sustainability

Visibility & Resilience

Trend Clusters:

Internet of Things

Packaging & Containers

Sectors:

Life Sciences & Healthcare

The trend of Next-Generation Packaging encompasses the evolving world of packaging designed to improve material efficiency, circularity, functionality, and technology-enabled visibility. This includes bio-based, biodegradable, recyclable, and reusable materials alongside sensing and connectivity technologies that enable packaging to monitor and react to changes in the environment, the packaged contents, and the integrity of shipments.

From the continued growth of e-commerce to the global drive for sustainability, the world increasingly needs smarter and cost-efficient solutions for primary, secondary, and tertiary packaging with a strong focus on the reduction of carbon footprints. Consumers are demanding recyclable, reusable, compostable, and biodegradable packaging, with growing interest in antimicrobial packaging. Market pressures are also driving improvements in traceability and condition monitoring.

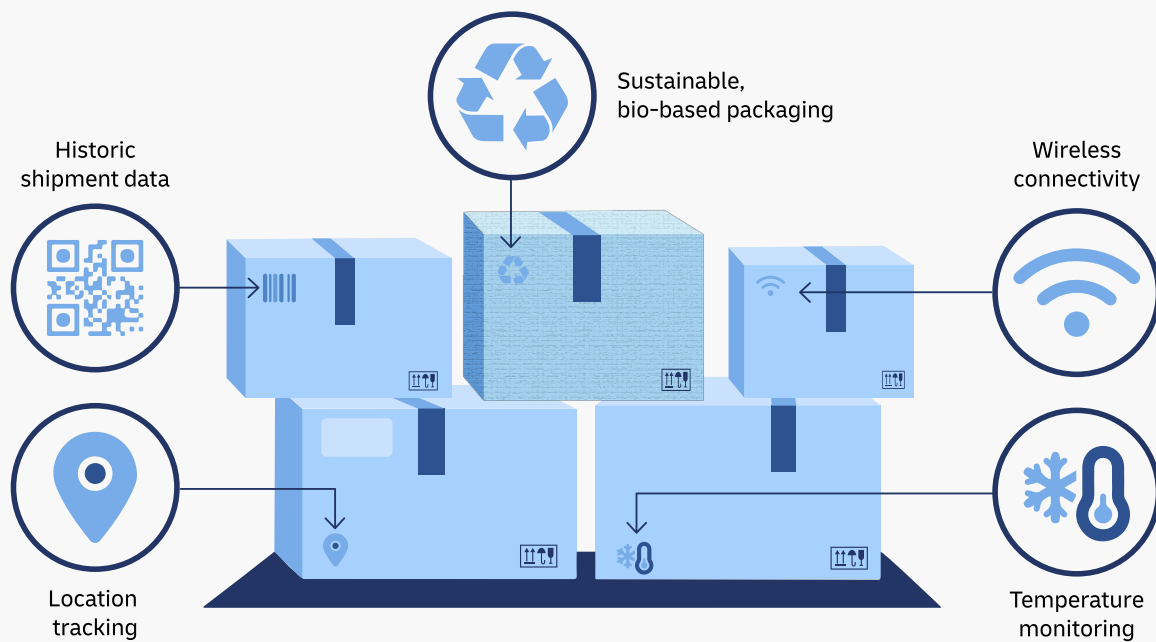
Furthermore, packaging solutions increasingly need to be designed for compatibility with automated and connected logistics operations, ensuring they can be processed efficiently by conveyors, scanners, sorting systems, and robotic handling. Recent advances in packaging technology include the incorporation of radio-frequency identification (RFID) tags, other Internet-of-Things (IoT) sensors, and content condition sensors, as well as redefining the way packaging materials are sourced.

The global next-generation packaging market has grown steadily in recent years, propelled by population growth, technological innovation, and evolving consumer expectations. In the mid-2020s, the market was valued at approximately US\$15 billion. By mid-

2030, it is projected to grow at a compound annual growth rate (CAGR) of around 6.5% and reach roughly US\$27 billion.

With developments in this trend expected to continue over the next five years, more companies are reconsidering the materials and technology used in their primary, secondary, and tertiary packaging. This shift has operational implications for logistics organizations: new packaging formats and embedded technologies must be compatible with existing handling systems so that packaged contents can be monitored during transit and arrive undamaged.

Nonetheless, the cost of packaging remains a factor that is a significant constraint to broad adoption. Especially during unstable economic periods, companies may opt for a cheaper solution rather than more expensive sustainable and technology-enabled alternatives.



Recent advances in technology have enabled packaging to become smarter, more connected, and more sustainable.

Packmojo (2024): What is Smart Packaging & How Does it Work?

Relevance to the Future of Logistics

Active Packaging & Tracking

Active packaging incorporates additives that interact directly with the contents or internal atmosphere to maintain or extend product quality, safety, and shelf life. With a global market share of around 40%, it is the largest segment within next-generation packaging and is expected to remain dominant over the coming decade. Examples of active packaging include antimicrobial packaging, heating/cooling packaging, gas-emitting and scavenging systems, moisture- and odor-control packaging, corrosion inhibitors, and spoilage-retardant formats.

These types of packaging are engineered to respond and react to changes in the external and internal atmosphere of a package and are therefore particularly relevant to the pharmaceutical and nutraceutical industries and to shipments containing lithium-ion batteries. Logistics organizations are required to maintain fresh-chain and cold-chain operational capabilities that meet customer standards and align with applicable legislation.

Logistics companies are developing more solutions to improve active temperature retention and eliminate reliance on dry ice or liquid nitrogen which are subject to dangerous goods handling

requirements, particularly in air freight operations. They are increasingly using IoT sensors and systems to monitor a variety of product and shipment condition parameters such as temperature, shock, light, humidity, inversion, tilt, location, and thermal runaway. However, active trackers use batteries and are classified as dangerous goods, adding complexity to air freight operations.

Looking ahead, Bluetooth trackers represent a cost-effective alternative. They can be monitored using existing infrastructure like smartphones, and their small batteries are not classified as dangerous goods. However, some Bluetooth tracker designs are intended for single use and may add to e-waste. Reusable active trackers can support circular-use models when they are recovered and used across multiple rotations.



Intelligent Asset-Monitoring Solutions

Intelligent packaging systems monitor the internal condition of packaged goods to give information on quality during transport and storage. Simply defined as packaging that senses and informs, these systems integrate hardware components such as time-temperature indicators (TTIs), freshness and ripening sensors, and RFID and other tags. This helps maintain product quality and reduce waste.

Intelligent packaging has become essential to a broad range of sectors, where product integrity and high-level supply chain visibility are vital. Healthcare and pharmaceuticals are two fast-growing markets. In fresh and cold chains, monitoring solutions ensure temperature stability during transit and enable shipment status checks upon arrival. Integrated real-time monitoring can further reduce the risk of spoilage, damage, and costly compliance issues during transit.

Previous active tracker generations were mostly used for tracking location, but today the demand for temperature stability monitoring is greater than ever. The Digital Shipping Label & Asset Tracker made by British startup Envio can even help shippers remotely track and re-label shipments using an e-ink digital shipping label. It also sends out notifications when a shipment is opened, dropped, or exceeds a temperature threshold.



Modified Atmosphere Packaging

Modern global shipping operations enable the rapid transport of perishable goods and atmosphere-sensitive products around the world. This complex process involves continuous monitoring and potential modification of the internal conditions of the storage container or packaging to ensure products arrive in best condition. Modified atmosphere packaging (MAP) offers this capability and has become an essential solution for transporting sensitive goods effectively.

MAP technology reduces global food wastage, extending shelf life by days and even weeks, leading to a more profitable and secure global food supply chain. For example, by actively replacing oxygen with nitrogen, MAP solutions can be used to protect nutraceuticals, which are nutritional supplements and functional food products that tend to deteriorate through oxidation. Other examples include formats that incorporate dry ice or other active cooling elements.

The growing shipment volumes and regulatory requirements in the pharmaceutical and life sciences & healthcare (LSHC) sectors have reinforced the importance of MAP for maintaining atmospheric conditions during transport.

Green Packaging Alternatives

Packaging alternatives focused on material efficiency, circularity, and defined environmental attributes include bio-based, biodegradable, recycled, or reusable materials, optimized packaging formats, and circular or refillable systems. However, there are notable challenges to the adoption of these packaging approaches in the logistics and business-to-business (B2B) sectors, with limited integration beyond specific industries. For example, reusable formats need return logistics that often do not exist, and sustainable alternatives typically cost more than conventional packaging. DHL eCommerce research shows that customers worldwide are evenly split: 28% are willing to pay for sustainable packaging, and an equal 28% are not.

Across the industry, companies are actively exploring innovative alternatives – including water-soluble, edible, plantable, and biodegradable formats – to address packaging sustainability challenges. To remain viable for sensitive products, these alternatives must replicate the required protective properties of conventional packaging and be assessed against clearly defined environmental criteria.

A growing number of companies are also embracing minimalist packaging approaches, such as unbleached kraft boxes and optimized package sizes, to reduce shipment size and packing materials. Where supported by lifecycle and transport data, these approaches may also reduce associated greenhouse gas emissions. For example, IKEA reduced plastic packaging for consumer goods by 47% within two years by shifting to fiber-based and right-sized packaging solutions, reducing material use and potentially improving transport efficiency across its global supply chain.

Regulations and legislation, such as the EU's Packaging and Packaging Waste Regulation (PPWR), are shaping the evolution of packaging design and material choices. While the PPWR sets binding packaging reduction targets (5% by 2030, 10% by 2035, and 15% by 2040), its requirements include defined exemptions and implementation provisions relevant to specific packaging uses. As a result, innovation is increasingly focused not only on material substitutions, but also on smarter packaging design, reuse where feasible, and efficiency gains across the supply chain.

Cargo Security & Tamper-Evident Packaging

The increasing value density of goods moving through global supply chains, combined with rising cargo theft, counterfeiting, and diversion risks, is driving demand for packaging solutions that actively protect shipment integrity. Advanced cargo security and tamper-evident packaging focus on safeguarding goods against unauthorized access or manipulation throughout transportation and handling, providing an added security layer beyond traditional tracking and monitoring.

These packaging solutions integrate physical and digital security mechanisms such as tamper-evident seals, break-indicating closures, smart locks, and sensor-enabled packaging that can detect opening events or abnormal handling. When combined with connectivity, such systems can generate alerts or verifiable event records when shipment integrity is compromised, enabling faster response and investigation.

This use case is particularly relevant for high-value, regulated, or sensitive goods including pharmaceuticals, medical devices, electronics, luxury products, and critical industrial components. In these sectors, maintaining proof of shipment integrity is essential not only to reduce financial losses, but also to meet regulatory, safety, and compliance requirements. Tamper-evident packaging can support chain-of-custody verification and demonstrate that products have remained secure from origin to destination.

As global supply chains become more complex and risk-exposed, logistics organizations are increasingly required to incorporate cargo security considerations earlier into packaging design and operational planning. Advances in material design, sensor miniaturization, and low-power connectivity are steadily expanding the viability of security-enabled packaging across a broader range of applications, though cost, scalability, and standardization remain challenges.



Summary & Trend Overview

Challenges



Next-generation packaging sometimes includes components such as batteries, sensors, displays, and circuits which are challenging to recycle. The long-term viability of such solutions may depend partly on their environmental performance and available end-of-life handling options.



Different regulations apply in various countries and regions, and evolving sustainability rules increasingly include sector-specific exemptions or adaptations, requiring continuous monitoring and interpretation to ensure compliant and operationally viable packaging solutions.



The successful adoption of sustainable and circular packaging solutions requires substantial investments and collaborative efforts across multiple supply chain stakeholders.



Integrating next-generation packaging into existing logistics operations requires that new materials, formats, and embedded technologies remain compatible with automated handling, sorting, and transport systems – a constraint that increases in complexity across global supply chains.

Outlook

Next-Generation Packaging has the potential to enhance visibility, improve cargo security, and increase supply chain reliability, particularly for temperature-sensitive and high-value shipments. As enabling technologies mature, these packaging solutions are expected to play a more active role in protecting shipment integrity while improving efficiency and resilience across logistics networks.

Future developments in sustainable and smart packaging will focus on reliability, durability, pricing strategies, and regulatory guidelines to reduce dependence on unrecycled single-use plastics and non-sustainable packaging. Financing and bringing closed-loop and reusable packaging systems online are likely to be critical to advancing circular economy models, reducing waste, and supporting a more resilient and economically viable packaging landscape.

Here at DHL, we see next-generation packaging as a key enabler of greater visibility, material efficiency, and circular-use models in logistics.



Strategize – This trend has the potential to bring substantial change across logistics with use cases in some applications that can already be addressed today.

Related Trends

Bio-Based Materials



Circularity



Smart Printables



Smartification



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Outdoor Autonomous Vehicles

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Trend Clusters:

Robotics

Sectors:

Auto-Mobility



The trend of Outdoor Autonomous Vehicles (AVs) encompasses the range of self-driving vehicles operating primarily on land and water, both within private property and on public rights of way. The trend covers vehicles that are either completely driverless or highly automated, with occasional control by a human driver or remote operator.

Advances in artificial intelligence (AI), sensor technologies, machine learning, and remote monitoring are accelerating the development and commercial viability of outdoor autonomous vehicles. In 2025, the global AV market reached US\$3.36 trillion, with strong growth expected over the coming decade as technology capabilities mature and regulatory frameworks continue to evolve. Improving regulatory conditions and expanded pilot programs are enabling autonomous vehicles to move beyond controlled testing into real-world deployment across a growing range of industries. A number of high-visibility deployments are building public trust and validating autonomous capabilities in practice.

Robotaxis represent one of the most mature applications of AV technology. In the US, Waymo has scaled commercial robotaxi operations in 11 cities, offering fully driverless rides to the public and completing millions of passenger journeys under real-world conditions. In China, Baidu operates the world's largest robotaxi fleet by ride volume, with more than 14 million rides completed across several major cities and trials now expanding internationally to Dubai, Switzerland, and the UK. These large-scale deployments validate core autonomy capabilities such as perception, decision-making, and remote fleet supervision, while giving regulators practical operational experience.

In the maritime sector, autonomous ships offer a parallel signal of progress. The Yara Birkeland, a fully electric and highly automated container vessel, has been operating regular commercial routes between fixed ports since 2021 with reduced human intervention. Hyundai Heavy Industries' Avikus division has equipped commercial vessels with autonomous navigation systems supporting collision avoidance, route optimization, and fuel efficiency, with contracts in place to deploy systems on up to 70 vessels.

The potential of AVs is being actively tested and deployed across a wide range of industries. Public transportation systems are deploying autonomous buses and trains on fixed routes. The construction, mining, and agriculture sectors are using autonomous machinery to improve safety and productivity in hazardous or hard-to-staff environments. Airports and ports increasingly rely on autonomous tractors, tuggers, and patrol vehicles. Logistics and transportation companies are integrating autonomy into yard operations, long-haul freight movement, and point-to-point cargo transfers – and last-mile delivery in urban areas and campuses is emerging as a key application area for autonomous delivery robots and vans.

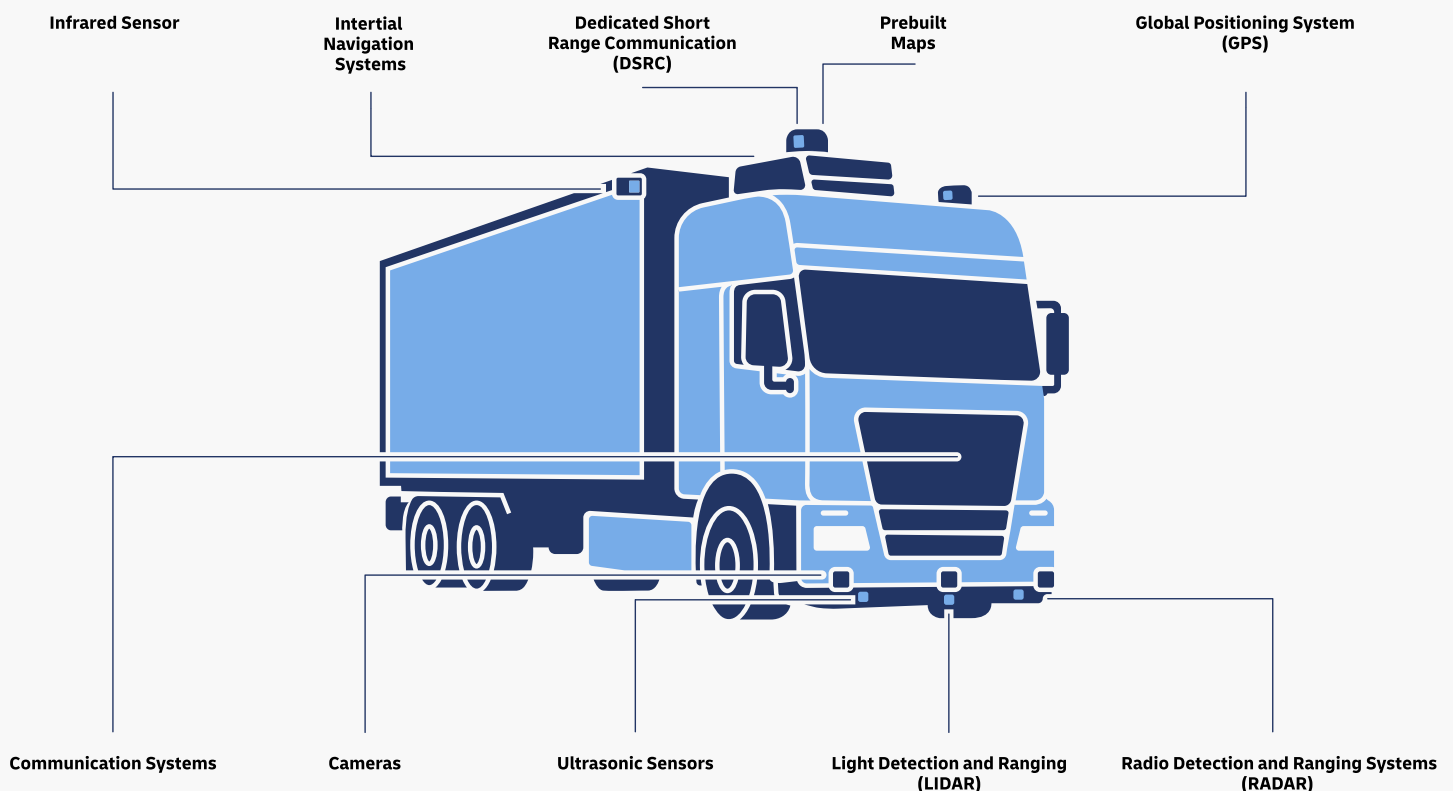
Vehicle-to-everything (V2X) communication is also strengthening autonomy, enabling vehicles to exchange real-time data with infrastructure, other vehicles, and digital systems. This connectivity helps autonomous vehicles anticipate traffic conditions, respond to hazards, and coordinate movements within complex logistics environments such as ports, yards, and transport corridors.

Together, these developments signal a broader transition from experimental autonomy toward scalable operational use. While

deployment conditions differ across industries, the underlying technologies, governance models, and operational lessons are directly relevant to logistics. These parallels reinforce the role of outdoor autonomous vehicles as a foundational capability that will increasingly shape how goods move across global supply chains.

The adoption of the trend of Outdoor Autonomous Vehicles in logistics is expected to accelerate over the next five years, though timelines vary significantly by use case and geography. While core technologies such as sensor fusion, autonomy software, and vehicle platforms continue to improve, large-scale deployment remains influenced by regulatory clarity, liability frameworks, and public acceptance. As seen with other automation-driven trends, controlled and private environments are reaching maturity faster than open and highly complex public road operations.

The potential impact on the logistics industry is substantial. AVs can directly address persistent driver shortages, rising labor costs, and inefficiencies in repetitive transport tasks. By automating predictable routes and standardized movements, logistics providers can increase safety, improve asset utilization, and reallocate human labor toward higher-value activities. Expanded government-backed trials and cross-sector pilots are also helping to validate performance, clarify regulatory expectations, and build stakeholder confidence, creating conditions for broader adoption.



Autonomous vehicles rely on a coordinated symphony of sensing, positioning, communication, and decision-making technologies to safely interpret and navigate the physical world.

University of Michigan (2024): Autonomous Vehicles Factsheet

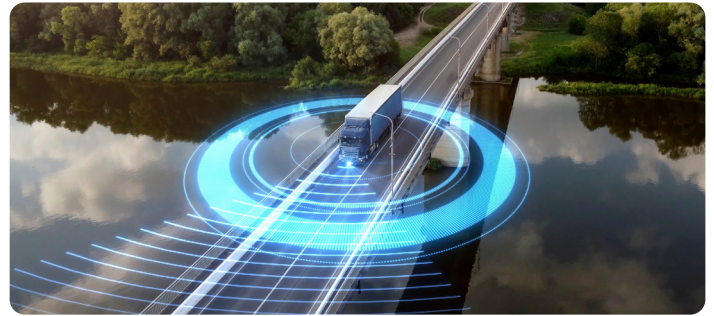
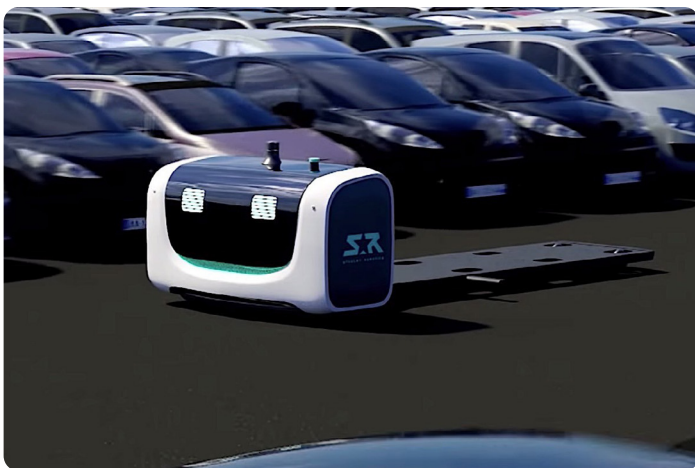
Relevance to the Future of Logistics

Automated Yard Operations

Logistics yards, ports, and airports represent some of the most suitable environments for early deployment of outdoor autonomous vehicles. Unlike open public roads, these locations operate within clearly defined boundaries, such as standardized routes, traffic flows, and operating procedures, which reduces both complexity and risk.

In these environments, AVs take over repetitive and labor-intensive tasks such as transporting containers, cargo, and baggage between fixed locations. For example, the standardized cargo units used in container terminals allow operators to preplan and continuously optimize vehicle routes. DHL Supply Chain worked with Oxa on a proof of concept at Heathrow Airport, exploring the use of autonomous baggage transport vehicles and how driverless operations can improve efficiency and sustainability within a high-traffic aviation hub. Hong Kong International Airport operates a fleet of 70 AVs to support baggage handling, air cargo movement, and patrol operations, demonstrating how autonomous systems can be scaled safely in complex but controlled environments.

Seaport operations also illustrate the maturity of this use case. At ports in Guangdong, Sinotrans has deployed a fleet of 10 autonomous electric container trucks, with full-area perception and centralized control, to support terminal operations. Looking ahead, large-scale projects such as Singapore's Tuas Port are designed to be fully automated, deploying electrified automated yard cranes and AVs to transport containers between yard and wharf, with a planned capacity of 65 million twenty-foot equivalent units (TEUs). Together, these examples show how automated yard operations are becoming a foundational layer of highly automated logistics hubs.



Autonomous Long-Haul Operations

Long-haul freight transport operations face mounting structural pressure from persistent driver shortages, an aging workforce, and demanding working conditions that make the job less attractive. While millions of truck drivers are expected to retire in the coming years, the pipeline of replacements is failing to keep up. AVs are seen as a potential complementary solution for highway routes that are long, predictable, and well suited to continuous operations.

Early deployments have focused on hub-to-hub corridors with lower traffic complexity and clearly defined regulatory oversight. For example, DHL Supply Chain is collaborating with Volvo and Aurora in the US to demonstrate feasibility, operating Volvo VNL Autonomous trucks powered by the Aurora Driver to move freight between major logistics hubs in Texas. Remote supervision allows autonomy to be introduced incrementally while maintaining safety and compliance.

Truck manufacturers and technology providers are also advancing dedicated platforms for autonomous freight. In China, SANY Group and Pony AI have announced mass-production readiness of autonomous heavy-duty electric trucks. These vehicles support "platooning" – one manned truck leads multiple unmanned trucks, improving efficiency while reducing operating costs and emissions. Aurora has expanded its commercial driverless operations to include nighttime autonomous driving on major highway corridors in the US.

Regulation remains a primary factor shaping adoption timelines, even as the underlying technology continues to mature. In the US, a growing number of states now permit autonomous trucking operations, with regulations for heavy-duty deployments becoming increasingly well defined. Europe is advancing through structured pilot programs underpinned by national legislation, and China continues to expand government-supported smart highway corridors. Together, these developments point toward early commercial deployment of long-haul autonomy on controlled routes and under supervised operations.

Autonomous Point-to-Point Transport

Point-to-point transport between logistics facilities is one of the most practical and near-term applications of outdoor autonomous vehicles. These deployments typically involve short, repetitive movements between warehouses, distribution centers, or production sites, often along access-controlled or low-traffic public roads, where predictable routes and controlled operating conditions make regulatory approval less complex than open-road urban or long-haul scenarios. AVs can support frequent cargo transfers between buildings, levels, or nearby facilities, improving efficiency while reducing labor dependency.

At DHL Supply Chain's Asia Pacific Advanced Regional Center in Singapore, we introduced two fully electric AVs to transport pallets between different floors, enabling driverless internal logistics flows. The deployment demonstrates the integration of point-to-point autonomy into live operations with minimal disruption and immediate productivity benefits.

We are seeing similar models in other regions. In Sweden, Einride has introduced fully autonomous heavy-duty commercial vehicles operating between adjacent warehouses for an e-commerce retailer. These driverless vehicles run along predefined routes with limited exposure to public roads under permit. In China, IKEA uses autonomous robovans from Neolix and other providers to shuttle goods between external warehouses and stores. By supporting in-store replenishment and customer pickup, these AVs significantly reduce transport costs.

These examples show that autonomous point-to-point transport is not only technically feasible but already delivering measurable operational and cost benefits. Each deployment also provides logistics companies with opportunities to build operational experience and strengthen stakeholder confidence. As regulatory frameworks mature, there will be more opportunities to scale AV adoption toward broader use cases.



New Last-Mile Models

In logistics, the “last mile” remains the most cost-intensive and operationally complex segment of the delivery journey. It accounts for roughly 53% of shipping costs in business-to-consumer supply chains. AVs have the potential to offer alternative models for last-mile delivery that reduce labor costs, address delivery density challenges, and extend service hours.

Autonomous last-mile solutions range from small delivery robots operating on sidewalks or within commercial buildings to larger robovans serving residential neighborhoods. In Singapore, logistics providers including DHL Express and FedEx have collaborated with local startup Quikbot to deploy autonomous delivery robots in selected commercial buildings. These robots operate in controlled indoor environments, enabling secure and contactless deliveries while reducing reliance on human couriers for short-distance handoffs.

Technology companies and retailers are also pushing into more advanced autonomous delivery concepts. Amazon has acquired Swiss robotics company Rivr to research and test robotic systems for doorstep delivery, including a four-legged robot on wheels capable of navigating uneven terrain and steps. This reflects broader efforts to extend autonomy beyond campus and building environments to more complex residential settings.

In China, autonomous robovans have already moved into scaled operations. Zelos and Neolix, for example, have deployed fleets of driverless delivery vehicles to support last-mile distribution in urban areas. These robovans transport parcels from distribution centers to pickup points, smart lockers, or retail locations, significantly reducing transportation costs and improving delivery efficiency. Growing consumer familiarity with autonomous deliveries is accelerating adoption, particularly in densely populated cities.

Many autonomous last-mile models are transitioning from pilots to early commercial use. While operating conditions remain controlled, these deployments demonstrate how logistics providers can improve efficiency, reduce costs, and develop scalable delivery alternatives as autonomy technologies and public acceptance continue to mature.

Summary & Trend Overview

Challenges



Regulatory restrictions and inconsistent legal frameworks across regions add complexity, particularly for vehicles operating across city or state boundaries.



Liability models for autonomous vehicles remain under development, raising questions around responsibility, insurance, and remote supervision requirements.



Cybersecurity and data privacy are ongoing concerns, as autonomous vehicles generate large volumes of sensor and video data while relying heavily on software systems.



Performance in extreme weather conditions and dependence on accurate, continuously updated digital maps require further validation.



Workforce readiness presents a barrier to adoption, as operational models built around driverless vehicles require significant upskilling and change management across affected roles.

Outlook

Outdoor autonomous vehicles are steadily progressing from pilots toward broader adoption across the logistics sector. Successful deployments in yard operations, point-to-point transport, and last-mile delivery demonstrate that the technology is already delivering operational and economic benefits in controlled environments. At the same time, continued advancements in vehicle connectivity, including emerging Vehicle-to-Everything (V2X) communication capabilities, are expected to further enhance safety, coordination, and scalability.

While fully autonomous long-haul freight transport may still take several years to achieve widespread adoption, the overall trajectory remains positive. As regulatory frameworks mature and confidence in autonomous systems increases, the trend of Outdoor Autonomous Vehicles is expected to play a central role in addressing labor shortages, improving efficiency, and enabling more sustainable logistics operations.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with use cases in some applications that can already be addressed today.

Related Trends

Computer Vision



Heavy Vehicle Electrification



Remote Operations



Next-Generation Connectivity



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Remote Operations

Trend Overview

Impact:

LOW

Adoption:

< 5 YEARS

Focus Areas:

Sustainability Health, Safety & Future of Work
Physical & Digital Security

Trend Clusters:

Bionic Enhancements Robotics

Sectors:

Engineering & Manufacturing Energy



The trend of Remote Operations refers to the control and management of machinery, vehicles, and other devices or systems by operators from a distance, without their physical presence at the asset. This capability relies on telecommunications infrastructure, sensor networks, and connectivity technologies that transmit real-time data between operator and machine.

Remote operations are expanding rapidly worldwide across multiple segments, driven by growing adoption of digital and automated industrial operations. The market for remote operation platforms reached approximately US\$8.5 billion in 2026 and is projected to grow to around US\$14 billion by 2030.

Key drivers of this trend include the expansion of industrial automation, rising demand for unmanned systems and drones, and continued investments in smart manufacturing and Industry 4.0 (the integration of digital technologies into industrial production).

Underpinning these drivers are advances across several enabling technologies. Artificial intelligence (AI) and machine learning (ML) are central to this shift, particularly their integration into systems that enable predictive analytics, autonomous decision-making, and adaptive control. Improvements in connectivity, especially through 5G and emerging low-latency communication technologies, are enabling reliable real-time remote operations. In addition, progress in computer vision and sensor technologies is expanding the range of applications, such as the precise remote control of robotic arms and mobile robots in dynamic environments.

The ability to operate systems or machines remotely is already proving valuable across a wide range of industries:

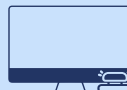
- Logistics: remote operation of forklifts, yard trucks, and warehouse robots.
- Healthcare: remote diagnostics, robot-assisted procedures, and patient monitoring.
- Manufacturing and mining: control of heavy machinery from safer, centralized locations, including sites located in hazardous or geographically remote environments.
- Automotive: vehicle testing, fleet management, and edge-case handling in autonomous driving systems.
- Agriculture: crop monitoring and automated spraying.
- Space operations: remote control technologies for exploration, maintenance, and experimentation in extreme environments – a frontier with emerging logistics implications as the space economy grows.

Adoption of the Remote Operations trend in logistics is expected to accelerate within the next five years. As unmanned vehicles and robots become more prevalent in warehouses and logistics operations, remote operations offer a cost-effective and safe way to monitor and manage these assets wherever it is practical and appropriate to do so.

The impact of remote operations on the structure of the logistics supply chain is expected to be low. While day-to-day working

practices will continue to evolve with growing requirements for remote setup and maintenance of robots, the underlying supply chain look and feel is not expected to change substantially.

However, remote operations hold appeal for workforce development: as more technology-oriented workers enter the industry and expectations around flexible working arrangements grow, the option to operate remotely broadens the available talent pool and may make certain roles more attractive.

	 Remote Driver			Tele-Assist 		
	T0	T1	T2	T3	T4	T5
Use case	Direct Drive	Low-level control	High-level control	Guide	Advise	Supervise
Pilot role	FULL control	Remote drive	Remote drive	Path planning	Respond	Monitor
Vehicle role	NONE	Validate / MRM	Control / MRM	Plan / MRM	Drive / MRM	Drive / MRM
Who's in charge of safety?	Driver	Vehicle	Vehicle	Vehicle	Vehicle	Vehicle
Input						
Sample latency	100msecs	100msecs	150msecs	200msecs	250msecs	300msecs
Sample use cases	Robots, Mining, Agri 	Low Speed, Robots 	Highway 	Urban 	Mature AI, Complex Cases 	Regulatory requirement 

Remote Driver and Tele-Assist use cases require different technologies, with low-latency solutions reserved for full piloting control to limit delays between the machinery and the operator.

EE Times (2023): Next Time You Hear 'Teleoperation,' You'll Know a Lot More

Relevance to the Future of Logistics



Remote-Controlled Operations Using Digital Twins

The efficiency of remote operations can be improved by using digital twins – virtual representations of the physical elements of machinery, facilities, or entire production systems. By replicating physical environments in real time, they eliminate the need for operators to be physically present at a site to diagnose, troubleshoot, or optimize operations. In logistics, digital twins can provide remote operators with a live view of warehouse activities, equipment status, inventory movements, and transportation flows, enabling faster decision making and intervention without requiring personnel on site. Digital twins also allow operators to test actions in a virtual environment before implementing them in physical operations, reducing risk and downtime.

For example, Shell has launched a digital twin initiative at its Singapore manufacturing site, enabling engineers to receive live information on operations via augmented reality (AR) and virtual reality (VR). They can remotely run troubleshooting processes on the digital twin before deciding on the best course of action at the actual site.

In another example, the Port of Corpus Christi launched its AI-powered OPTICS platform in late 2024 and expanded its capabilities through 2025. The system creates a real-time digital twin of port operations using live vessels, infrastructure, and environmental data. Operators can remotely monitor activities across the port, assess potential disruptions, and prepare responses to safety incidents and emergency situations using virtual representation before taking action in the physical environment.

Remote-Controlled Vehicles

The structural case for remote-controlled vehicles is rooted in automation, workforce economics, and connectivity. The COVID-19 pandemic sparked this shift, pressing technology providers to find ways to sustain operations while ensuring employee safety.

Examples of remote-controlled vehicles in logistics include material-handling forklifts, tuggers, and the like. Some current solutions, such as those from Phantom Auto and Teleo, allow one person to control multiple machines, with supervised autonomy, from the comfort of a command center.

A number of use cases demonstrate the potential of remotely controlled vehicles. In Germany, a Seafar solution has become the country's first remote-controlled inland waterway shipping center, enabling captains on dry land to remotely navigate vessels on inland waterways. In Hungary, Europe's first smart railway logistics terminal, the East-West Gate (EWG), leverages the 5G network and AI for remote crane operation. One worker can control four cranes at the same time from an office location, boosting efficiency by 20% and broadening the appeal of crane operator roles.

In the future, we see remote operations enabling truck drivers to steer vehicles from their desk, making the job more attractive by providing a safer workplace and better work-life balance.

Furthermore, as the space economy continues to grow, there will be growth opportunities for end-to-end logistic solutions. However, this will require significant investment and infrastructure to reduce the costs of transporting satellites and other equipment.



Human Oversight in Autonomous Operations

Remote operations provide a critical layer of human oversight for autonomous vehicles. While AI systems handle routine operations effectively, they cannot yet respond reliably in every scenario. When situations become complex or unpredictable, a remote human operator can intervene and take control. This human-in-the-loop model is being applied across autonomous road vehicles, maritime vessels, and robots.

A common scenario requiring human intervention is a stuck or blocked vehicle. For example, a delivery vehicle may encounter unexpected traffic congestion, a construction zone, or a stalled vehicle obstructing its path. Another scenario may involve emergency responders or traffic police, which would require a human to communicate with them and make decisions. Remote operators can also assist when vehicles encounter unfamiliar road layouts, infrastructure changes, or rare edge cases not yet fully incorporated into the autonomous driving system.

In the area of autonomous logistics vehicles, DHL operations supporting Infineon's automated warehouse environment demonstrate the model in practice. Using a system developed by ZelosTech, fully electric autonomous vehicles transport palletized goods between storage zones and floors within multi-story facilities. While operations are largely autonomous, remote operators can intervene if a vehicle becomes immobilized, encounters an accident or obstruction, or requires assistance navigating an unusual situation. Operators monitor fleets through remote-control platforms and can safely guide vehicles when human judgment is required.

Remote operations are also increasingly being integrated into autonomous trucking and delivery applications. Nissan has tested 5G-connected autonomous heavy-duty trucks to enable remote human operators to monitor and take remote control of the vehicles during abnormal driving situations.



In autonomous maritime operations, Norwegian chemical company Yara International and technology partner Kongsberg Maritime created the world's first fully electric and autonomous container ship, the Yara Birkeland. The vessel uses cloud-connected systems to provide operational visibility and enable remote human oversight and intervention whenever necessary.

In the area of autonomous robots, systems created by Sarcos Technology and Robotics Corporation augment humans to improve worker safety and efficiency. In a successful trial for the US Navy, remotely operated robots worked at height both onboard and alongside ships, performing inspections, removing rust and paint, and conducting maintenance. Meanwhile, autonomous sidewalk delivery robots continue to scale commercially through partnerships between Serve Robotics and Uber Eats in several US cities. Remote assistance platforms developed with companies such as Ottopia enable human operators to supervise fleets and intervene when robots encounter complex or unpredictable safety situations.

Summary & Trend Overview

Challenges



Remote operators rely exclusively on data feeds from cameras and sensors and cannot draw on the physical awareness that an on-site operator would have, limiting their ability to make informed decisions on behalf of an autonomous vehicle.



Even with high-quality sensor data, remote operators can experience gaps in situational awareness, spatial awareness, or depth perception, increasing the risk of misjudgment when managing autonomous vehicles or machinery.



When a malfunction cannot be diagnosed or resolved remotely, an agile on-site response becomes essential, otherwise these situations create operational risks, including potential cybersecurity and IT risks.



Maintaining sustained attention presents a significant challenge for remote operators as prolonged periods of low-activity monitoring can reduce alertness, and periods of high activity can overwhelm cognitive capacity.

Outlook

The trend of Remote Operations in logistics is expected to be more widely realized within the next five years, supported by growing deployment of autonomous vehicles and broader adoption of remote-controlled operations across the industry to improve efficiency and safety.

Furthermore, remote operations also have the potential to address the persistent labor shortages that the logistics industry faces (a well-documented challenge across warehouse, transport, and last-mile operations) by allowing a single remote operator to control multiple vehicles from one location.



Explore – This trend has the potential to deliver incremental improvements to logistics with use cases in some applications that can already be addressed today.

Related Trends

Next-Generation Connectivity



Outdoor Autonomous Vehicles



Indoor Mobile Robots



Humanoids



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Renewable Energy Infrastructure

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Sustainability Physical & Digital Security

Visibility & Resilience

Trend Clusters:

Internet of Things

Sectors:

Energy

The trend of Renewable Energy Infrastructure represents the movement toward developing sufficient and reliable networks for the efficient generation, transmission, distribution, and storage of energy from solar, wind, geothermal sources, hydro-power, ocean power, biomass, and hydrogen from renewable processes. Applications range from electric vehicles (EVs) and hydrogen charging stations to entire energy carrier grids.

Rising electricity demand, alongside climate commitments, is accelerating the global transition toward renewable energy. While the electrification of transport has driven demand over the past decade, the more recent rapid expansion of data centers and AI technologies has boosted global power demand significantly. Data centers consumed approximately 415 terawatt-hours (TWh) of electricity in 2024, roughly 1.5% of global electricity consumption, and their electricity demand is projected to more than double by 2030, highlighting the scale of infrastructure required to support the compute economy in an electrified world. To meet these growing electricity needs and pursue energy and emissions-reduction goals, additional generation from renewable sources will be required.

However, this rapidly growing demand is placing additional pressure on already stressed power systems. In many parts of the world, grid infrastructure is not keeping pace, creating bottlenecks in generation, transmission, and distribution. While technology such as AI-driven forecasting and grid optimization is helping improve efficiency, the underlying physical capacity constraints remain. Some regions are beginning to invest in large-scale upgrades, such as China's ultra-high-voltage transmission networks, to move renewable energy more efficiently across long distances. Still, widespread modernization will take time.

New deployment models are also reshaping how renewable infrastructure integrates into the landscape, reflecting a broader shift toward more space-efficient and lower land-use-conflict development. Brownfield renewable projects transform previously used industrial sites into energy generation hubs, such as Australia's 270-megawatt (MW) Kidston Renewable Energy Hub, which was developed on a 1,500-hectare former gold mine. Hybrid approaches such as forestry solar combine energy production with land restoration objectives, as seen from China's 13-gigawatt (GW) Ningxia Tengger Desert Renewable Energy Project.

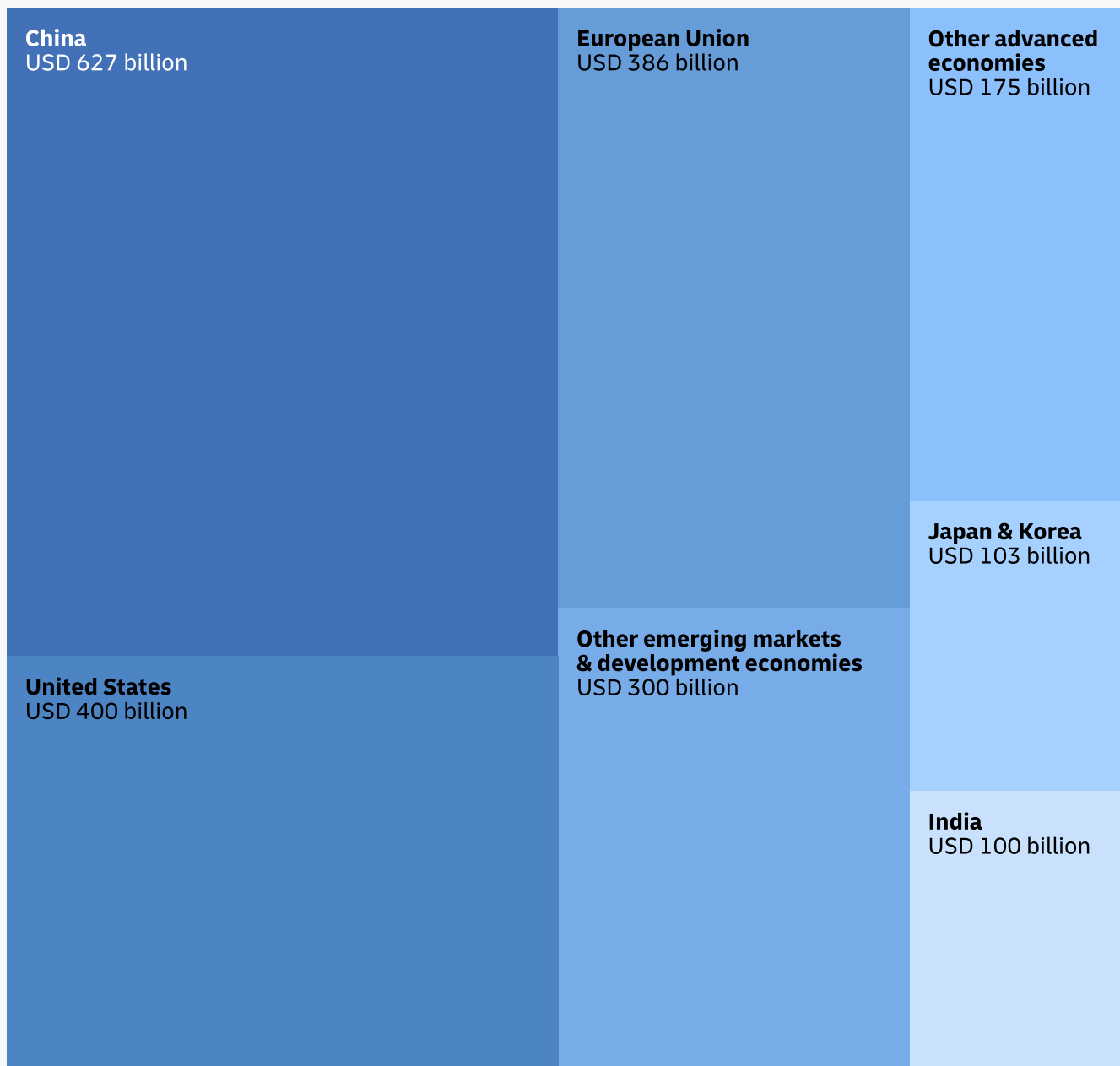
These developments are highly relevant for logistics, which is both an energy consumer and a participant in energy infrastructure supply chains. The electrification of energy-intensive logistics operations is increasing the need for reliable and scalable renewable power. Providers require both access to renewable electricity and integration with storage and charging solutions to align logistics facilities, fleets, and infrastructure with evolving energy systems. At the same time, building and maintaining renewable energy infrastructure requires reliable and scalable supply chains and logistics solutions.

Adoption of renewable energy infrastructure is advancing rapidly in some areas and more gradually in others. While we already see widespread deployment for light electric vehicle (EV) charging, infrastructure for heavy vehicles is only scaling gradually.

Overall, the increasing availability of renewable energy infrastructure could have a direct impact on logistics and supply chains, in some cases helping determine the pace and scale of electrification. It is likely to become a foundational layer of future logistics operations, supporting both emissions-reduction

efforts and operational resilience in an increasingly electrified world. In parallel, logistics is becoming essential to building and operating these systems – positioning renewable energy infrastructure as both a critical enabler of logistics operations and a growing business opportunity for logistics providers.

Clean energy



China and the United States account for almost 50% of global clean energy investment.

IEA (2025): World Energy Investment Executive Summary

Relevance to the Future of Logistics



Vehicle Charging Infrastructure

Vehicle electrification has advanced rapidly in recent years, driven by positive developments in heavy vehicle electrification.

On land, the introduction of megawatt charging systems (MCS) represents a major step forward, enabling high-capacity, fast charging for long-haul electric trucks. Early deployments across the US and Europe, including installations at major logistics hubs such as ports, signal growing momentum. However, scaling these systems will require significant upgrades to electrical grids, along with improved standardization across vehicles and charging interfaces.

In waterborne transportation, charging infrastructure is following a similar trajectory. Shore power and megawatt-level charging systems are proving effective for ferries and short-sea shipping, particularly in regions with strong regulatory backing such as Norway. These systems enable vessels to recharge during scheduled stops while also reducing emissions at berth, where the supplied electricity has lower associated emissions than onboard fossil-fuel generation. However, broader adoption is constrained by grid limitations at ports, high installation costs, and inconsistent regulatory incentives across regions.

Overall, vehicle charging infrastructure continues to be a critical enabler of electrified logistics networks. Its expansion will require coordinated planning between energy providers, infrastructure developers, and logistics operators. As networks mature, they could unlock greater flexibility, efficiency, and scalability for lower-emission transport solutions across land and sea.

Distributed Energy Resources

Distributed energy resources (DER) are small-scale generation and storage technologies – including solar panels, wind turbines, and batteries – on-site or close to where energy is consumed, rather than at centralized power plants.

Adoption of these localized renewable energy generation systems is accelerating rapidly, particularly in solar. Global solar photovoltaic installations grew by approximately 29% from 2023 to 2024, reaching 601 GW, and surged by a further 64% in the first half of 2025. This momentum is increasingly enabling logistics facilities such as warehouses, distribution centers, and ports to generate part of their own power, helping reduce dependence on centralized grids while improving resilience and cost efficiency.

Wind energy generation continues to improve in efficiency and incorporate innovative designs. The O-Wind Turbine, developed by O-Innovations, is a patented micro wind turbine designed with a city-first premise to harness chaotic winds from all directions in dense urban areas using the Venturi effect. Traditional turbines underperform or fail altogether under these conditions. While large-scale wind deployment remains more viable in rural settings, these innovations expand potential use cases.

Advancements in energy storage are making DERs more viable at scale. Costs for Battery Energy Storage Systems (BESS) have fallen significantly, with stationary storage dropping to around US\$70 per kWh in 2025, a 45% reduction compared to 2024. This is strengthening the business case for on-site storage, enabling peak shaving, backup power, and buffering for EV charging. However, BESS generally only provides two to four hours of discharge.

Long Duration Energy Storage (LDES) solutions (more than eight hours of discharge) are gaining traction, including Thermal Energy Storage (TES), Compressed Air Energy Storage (CAES), and emerging technologies such as hydrogen and gravity-based storage. These systems provide extended discharge capabilities, supporting more stable integration of renewable energy into operations. However, higher upfront capital costs and the absence of a clear market revenue mechanism continue to constrain the scaling of LDES.

Overall, DERs are enabling more energy-resilient and scalable logistics networks. By combining local generation with advanced storage, organizations can better manage demand, mitigate grid constraints, and support the electrification of transport and operations.



Microgrids

A microgrid combines local energy generation such as rooftop solar, battery storage, and an intelligent controller to operate as a coordinated system that can function with or independently from the main grid. Unlike standard distributed energy setups, microgrids include advanced control capabilities that enable intentional islanding, allowing operations to continue during grid disruptions.

This capability is increasingly important for logistics, with resilience as the primary driver. Microgrids provide a safeguard, ensuring that critical operations such as cold storage, warehouse management systems, conveyors, and security infrastructure remain operational during outages. As supply chains become more time sensitive and digitally integrated, even short disruptions can lead to significant downstream impacts.

Microgrids also play a key role in fleet electrification. By integrating battery storage and smart charging systems, they allow logistics operators to deploy EV charging infrastructure more quickly, often without waiting for lengthy grid upgrades. This helps manage peak loads and stabilize power demand at depots, which is essential as electric fleets scale. By enabling peak shaving, energy shifting, and greater use of on-site renewable energy, microgrids can help organizations optimize costs and support emissions-reduction efforts.

Advances in technology are accelerating adoption. Since 2024, the industry has increasingly focused on microgrid clusters with multiple interconnected microgrids coordinated through standardized control architectures. The International Electrotechnical Commission (IEC) published the IEC TS 62898-5 ED1, which provides the guidelines and technical requirements for clustering alternating current (AC) microgrids as well as operating and controlling microgrid clusters. These systems enable more efficient energy sharing, improved reliability, and advanced capabilities such as coordinated recovery following outages.

Overall, microgrids are becoming a strategic enabler for logistics operators seeking greater operational resilience, more flexible energy management, and readiness for large-scale electrification.



Renewable Energy Infrastructure Logistics

Renewable infrastructure logistics spans the full lifecycle of deployment – from coordinating equipment delivery and managing specialized components to sustaining operations once systems are running. Across each of these stages, logistics directly shapes the speed, scale, and reliability of deployment.

Specialized components represent a critical part of renewable infrastructure logistics, often requiring white-glove handling. For example, the expansion of EV charging networks depends on precise, end-to-end coordination to deliver equipment and components into diverse environments while aligning with grid connection timelines. Meanwhile, battery logistics adds significant complexity, requiring specialized handling of lithium-ion systems, strict compliance, and full lifecycle management, from deployment to recycling and repowering.

DERs and microgrids further increase the need for synchronized modular supply chains. These systems rely on kitting, staging, and plug-and-play delivery models, often in remote or offshore locations with a need for tailored transport solutions for oversized and sensitive components, particularly in wind energy.

Beyond deployment, maintaining uptime is critical. Agile spare parts and replacement logistics ensure continued operation of renewable assets, supported by responsive and resilient supply chains. In parallel, grid expansion and modernization require the movement of heavy, high-value equipment such as transformers and substations, demanding advanced engineering, permitting, and just-in-time delivery.

Across the renewable energy ecosystem, logistics is evolving from a supporting function into a strategic enabler of energy transformation. Through DHL New Energy Logistics, DHL supports the deployment, operation, and scaling of renewable infrastructure across the entire value chain, including wind and solar energy, EVs and batteries, battery energy storage systems (BESS), charging infrastructure, grid modernization, alternative fuels, and hydrogen. As energy systems become more decentralized, interconnected, and complex, logistics capabilities such as specialized transportation, installation support, lifecycle management, and supply chain orchestration will play an increasingly important role in accelerating the energy transition and enabling resilient, scalable, and sustainable energy networks worldwide.

Reverse Logistics for Renewable Components

As renewable energy infrastructure expands rapidly, a growing volume of assets (e.g., solar panels, wind turbines, and battery systems) is expected to reach end of life and require structured collection, transport, processing, and recycling. This creates new logistics flows that are complex, regulated, and often require specialized handling, particularly for hazardous or high-value materials such as lithium, cobalt, and nickel.

Large-scale deployment of solar panels, which typically have a lifespan of 25 to 30 years, began accelerating around 2005. This means a significant wave of decommissioning is expected from 2030 onward. Regulatory frameworks are beginning to emerge in response. The EU has introduced extended producer responsibility under the amended Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU, requiring manufacturers to fund collection and recycling. China has set targets to process up to 250,000 metric tons of retired modules by 2027. However, in many regions, solar panels are still treated as general waste, highlighting gaps in infrastructure and policy.

Wind energy faces similar challenges at scale. Of Europe's 290 GW of installed wind capacity, 80 GW will reach end of life by 2030. While about 90% of turbine materials are recyclable, blades remain difficult to process due to their composite structure. Furthermore, a self-imposed landfill ban on wind turbine blades by the European wind industry took effect on January 1, 2026. To overcome this, researchers have begun exploring recyclable blades, with Polyester Covalently Adaptable Network (PECAN) emerging as a promising solution. Still in early research, PECAN is a new type of plastic resin made from biomass-derived materials that is strong enough for industrial-scale wind turbine use and can be chemically broken down at the end of life.

Battery Energy Storage Systems (BESS) add another layer of complexity. With lifespans ranging from 10 to 20 years and decommissioning timelines of up to nine months, battery management is becoming one of the most regulated segments of the circular economy. The EU Batteries Regulation (EU 2023/1542) covers the full lifecycle and introduces a digital battery passport requirement from February 18, 2027, for electric vehicle batteries, light means of transport batteries, and industrial batteries with a capacity above 2 kWh. With the market projected to reach US\$100 billion by 2034, lithium-ion battery recycling rates are likely to rise from the current 5%.

Overall, reverse logistics for renewable components will be a critical enabler of circular energy infrastructure. Although it introduces new supply chain complexity and requires specialized logistics capabilities, it also offers significant opportunities for value recovery and regulatory compliance.



Summary & Trend Overview

Challenges



Developing renewable energy infrastructure often requires high initial investment, which is a major hurdle for project implementation and scaling.



The expansion and decommissioning of the renewable energy infrastructure involve multiple stakeholders and many regulatory frameworks, complicating coordination and planning.



Investment in the grid often lags investment in generation, increasing congestion and curtailment risk and, in turn, delaying or preventing fleet electrification.



Realizing large-scale infrastructure projects can take several years.

Outlook

Renewable energy infrastructure is advancing rapidly, supported by strong technological progress in charging systems, distributed energy resources, and microgrids, alongside growing adoption of stationary storage driven by volatile energy markets. However, this pace will need to accelerate further to keep up with even faster-growing energy demand from electrified transport and digital industries.

For logistics, this growth carries two distinct implications. Providers stand to benefit from more resilient and potentially cost-effective renewable energy access, while also taking on a growing strategic role in the deployment, maintenance, and decommissioning of this infrastructure. As a result, investing in renewable energy infrastructure is becoming a strategic priority for logistics providers seeking to enhance resilience, manage energy costs, and prepare operations for further electrification.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with use cases in some applications that can already be addressed today.

Related Trends

Light Vehicle Electrification



Heavy Vehicle Electrification



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Smart Printables

Trend Overview

Impact:

CONSIDERABLE

Adoption:

< 5 YEARS

Focus Areas:

Customer Experience Physical & Digital Security
Visibility & Resilience

Trend Clusters:

Internet of Things Packaging & Containers

Sectors:

eRetail & Fashion



The trend of Smart Printables reflects the emergence of a new generation of smart labels that can be attached to any product, shipment, or asset. Made of printed paper, plastic, or fabric, these labels include special intelligent inlay technology that digitally captures and communicates more information than is printed on the physical label.

Today's supply chains require real-time transparency, making item-level traceability increasingly critical. IoT-enabled smart printables act as a key bridge between physical products and their digital identities.

Embedded into standard label formats, the latest generation of smart printables are thin, flexible substrates that integrate sensing, connectivity, and lightweight computing effectively turning labelled items into connected IoT nodes. These printables incorporate printed electronics such as sensors, microchips, low-power connectivity (e.g., NB-IoT, LTE-M), and printed power sources to enable continuous data capture and communication.

Adoption is accelerating in line with the rapid expansion of IoT connected ecosystems and advances in underlying technologies, with the global installed base of connected devices expected to exceed 23 billion in 2026 and expand further toward roughly 39 billion by 2030. At the connectivity layer, cellular IoT is scaling steadily, with approximately 5.5 billion connections projected by 2030, driven mainly by LPWAN technologies such as NB-IoT and LTE-M, alongside growing adoption of 4G Cat-1 and emerging 5G RedCap.

In parallel, printed electronics, core to smart printables, are projected to grow from around \$20–25 billion in the mid-2020s to

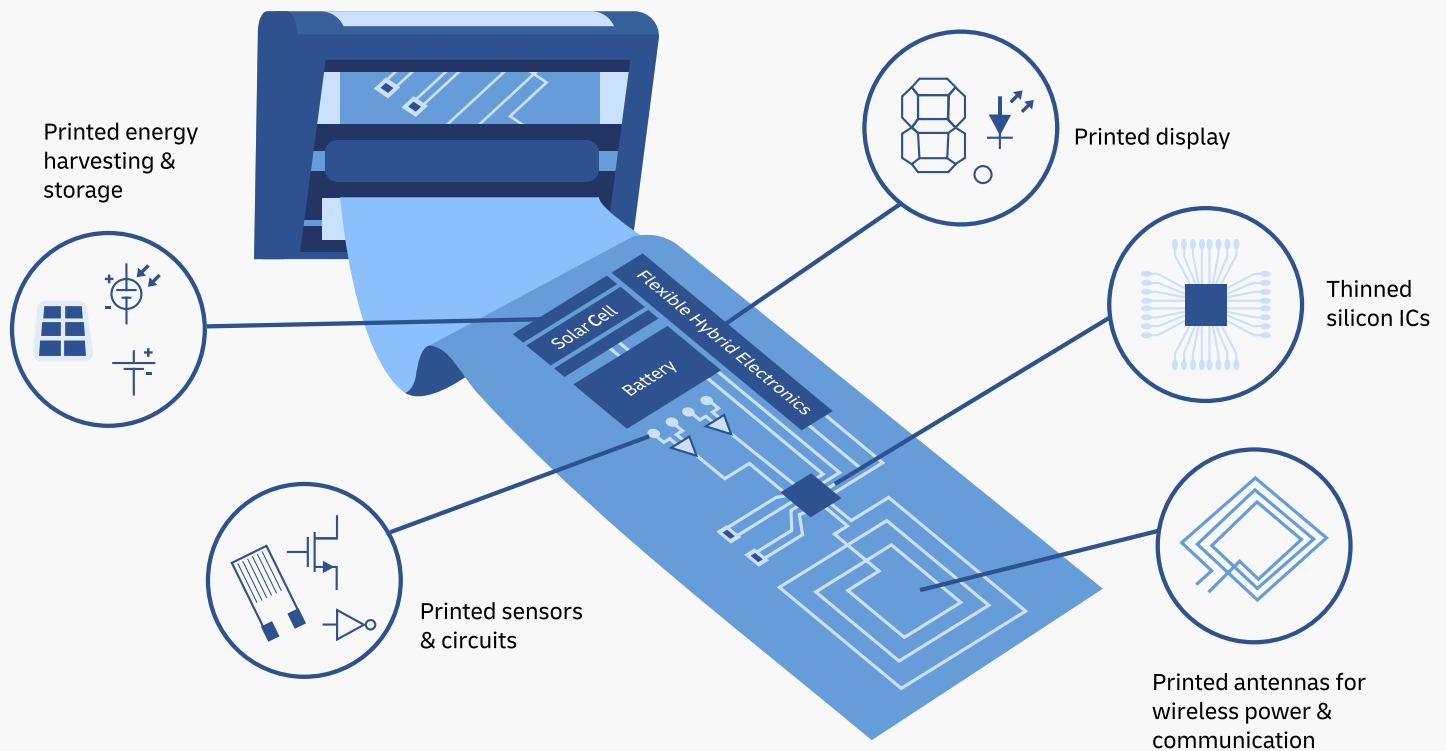
approximately \$40 billion by 2030, enabling low-cost, scalable, and flexible integration of intelligence directly into labels.

Together, these advances position smart printables as a scalable and efficient solution for real-time visibility, authentication, and condition monitoring at the individual item level across supply chains.

Despite these advances, a number of obstacles continue to constrain adoption, such as the stability of printed batteries, global connectivity coverage, and high per-unit costs. Progress is being made in all three areas: battery energy density and durability show strong gains, coverage is expanding through hybrid connectivity models, and manufacturing is beginning to scale. Even so, large-scale deployment will not be realized until per-unit costs drop further.

Regulations and compliance will likely also play a role. For example, widespread use of smart printables in airfreight requires airline approval.

Nonetheless, at DHL we believe smart printables will have a profound impact on logistics. As flexible and printed electronics (e.g., thin-film and flexible batteries) mature and manufacturing scales, smart labels will become low-cost, self-contained digital messengers – transforming labels from static identifiers into active, data-driven interfaces across the supply chain. This will reduce manual touchpoints and enable real-time end-to-end visibility, faster throughput and picking operations, and digital proof of delivery.



Smart Printables will enable scalable, real-time item-level visibility in logistics through intelligent, connected labels, contingent on advances in battery performance, connectivity, and cost viability.

Khan, Yasser et al. (2019): A New Frontier of Printed Electronics: Flexible Hybrid Electronics

Relevance to the Future of Logistics

End-to-End Visibility & Efficiency

As smart printables move from pilots to real-world deployment, they are delivering real-time, item-level shipment visibility across supply chains, from production through last-mile delivery. By supporting decentralized printing and seamless placement onto shipments, these next-generation labels integrate into existing workflows without requiring costly scanning infrastructure. This enables continuous data transfer, replacing manual scans or fixed scanning portals with automated tracking while driving end-to-end visibility and operational efficiency. In parallel, they support secure, event-driven Proof of Delivery by capturing time, location, and handover confirmation at the point of delivery, creating an auditable digital record linked to each item.

Several technologies illustrate the shift toward connected, data-enabled shipments. SmartTape, developed by Trackonomy, is a cellular-enabled tape that attaches to parcels and monitors

location and conditions in real time while enabling automated delivery confirmation through continuous data transmission. Printable 5G and Bluetooth Low Energy (BLE) labels developed by Reelables integrate real-time location system (RTLS) capabilities into standard barcode workflows, enabling seamless tracking and authenticated Proof of Delivery through scan or sensor-triggered events, including tamper detection and package opening logs.





Combating Counterfeit

Smart printables are significantly strengthening anti-counterfeiting efforts across supply chains, particularly in high-risk sectors such as pharmaceuticals, nutraceuticals, and cosmetics.

While traditional covert features such as UV, infrared, and taggant inks remain in use for authentication via specialized readers, newer smart printables integrate connected technologies directly into packaging. These include embedded NFC/RFID elements, printed sensors, and tamper-detection features that enable dynamic, real-time product verification.

These smart labels act as discreet, connected safeguards, allowing manufacturers to track authentic products throughout authorized distribution channels and quickly identify diversion or tampering. They also enhance transparency by providing verifiable proof of delivery, chain-of-custody tracking, and even confirmation of product interaction.

Additionally, linking each product's unique digital identity to secure cloud and blockchain platforms enables tamper-proof traceability, enhancing trust, strengthening authentication, and improving protection against counterfeit entry across global supply chains.



Perishable Goods Quality Control

Smart printables are evolving into intelligent, sensor-enabled labels that actively monitor freshness, quality, and temperature conditions in real time, using technologies such as color-changing indicators and IoT connectivity. This enables enhanced transparency across supply chains while strengthening perishable goods quality control and reducing waste.

Advances in battery-free, energy-harvesting labels and printed electronics are further enabling scalable and cost-efficient monitoring of both condition and location at the item level. These capabilities are extending beyond logistics into healthcare, where smart labels on prescription packaging support tracking, authentication, and patient adherence, contributing to improved safety and treatment outcomes.

Summary & Trend Overview

Challenges



Printable electronics and printed battery devices have yet to achieve technology stability, and connectivity remains unavailable in some areas.



Battery-powered, single-use labels generate electronic waste, creating a compliance challenge that requires environmentally responsible disposal.



Although per-unit costs are coming down, relatively high price points continue to hinder large-scale implementation.



Smart printables introduce a data security risk because they enable data transfer; mitigating this risk (e.g., by pairing with blockchain technology) may increase the cost and complexity of implementation.

Outlook

Smart printable technology has progressed significantly, but persistently high costs continue to limit usage to niche applications such as high-value shipments. Furthermore, the special intelligent inlay technology must mature before solutions can be scaled globally.

Here at DHL, we anticipate massive uptake once several constraining factors have aligned: printed battery technology advances (particularly more reliable battery life), per-unit printing prices drop, and security improves (e.g., sensor technology covering all sides of a parcel or box). Once these hurdles are overcome, smart printables will become a standard feature of product, shipment, and asset labels.



Strategize – This trend has the potential to bring substantial change across logistics with implementations available for many use cases today.

Related Trends

Smartification



Next-Generation Packaging



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Stationary Robotics

Trend Overview

Impact:

CONSIDERABLE

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Trend Clusters:

Robotics



The trend of Stationary Robotics encompasses all robots that perform value-adding tasks from a fixed location. Attached to the floor, ceiling, or other surfaces, these mechanized devices often take the form of robotic arms, automated storage and retrieval systems (ASRS), or packaging machinery.

The last 20 years of robotic arm development has shifted from fixed automation to flexible, sensor-driven systems. Today, we see widespread, cross-industry adoption for manufacturing and material handling. In logistics, recent advances in sensor technology and artificial intelligence (AI) have improved the performance and functionality of robotic arms across a broad range of use cases.

Stationary robots fall into two types of applications: collaborative and industrial. Collaborative applications require human interaction, as is common in many logistics settings, adding a layer of complexity to the risk assessment for each use case. Industrial applications require a high payload, long range, and high speed. They usually operate in a segregated area surrounded by security fencing.

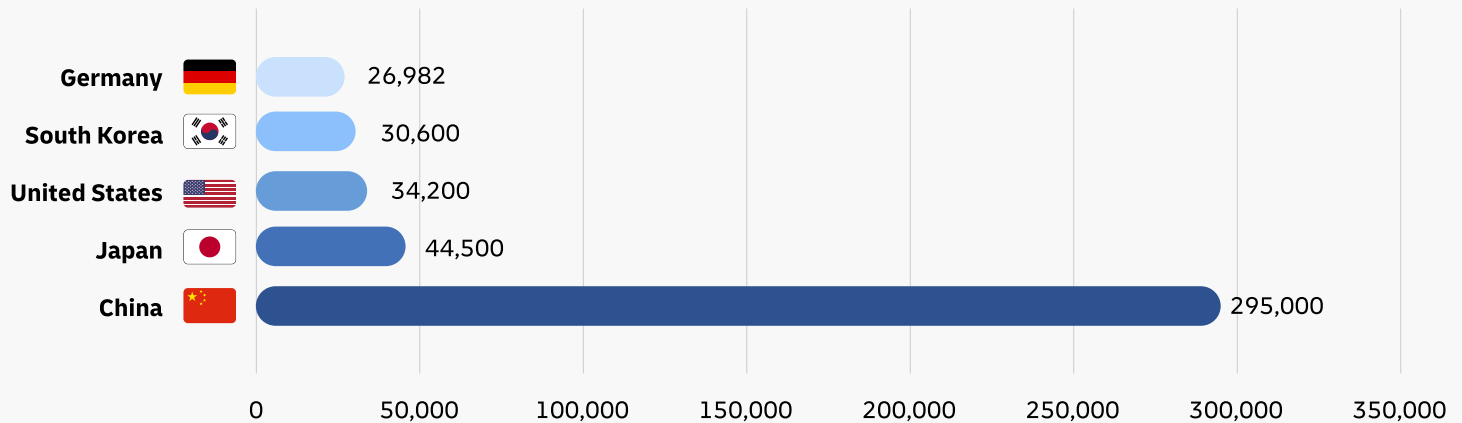
As machine learning and perception technology continue to develop in laboratory and real-world settings, at DHL we see more opportunities for interoperability between mobile and stationary robotic systems in logistics.

In light of labor shortages and demand volatility, many companies see economic potential in stationary robots for repetitive logistics processes. Several logistics organizations are now either implementing or actively testing stationary robotic systems in applications such as (de)palletization as well as induction, sorting, singulation, and inventory control.

Based on anticipated further development of stationary robotic hardware, software, and larger-scale production, we expect these solutions to scale extensively in the next two to four years. This will have a high impact on our industry.

Top 5 Markets by Annual Installations of Industrial Robots

number of industrial robots 2025



China overwhelmingly dominates global industrial robot installations, accounting for over 50% of annual deployments and far surpassing all other major markets.

International Federation of Robotics (2025): Global Robot Demand in Factories Doubles Over 10 Years

Relevance to the Future of Logistics

Automated Shipment Sorting

Manually sorting packages or goods is typically a highly repetitive and mentally fatiguing task, leading to loss of concentration, higher error rates, and increased rework costs. The dependence on manual processes, such as paperwork, scanning, and physical handling, often create throughput constraints, presenting an optimal business case for robotic support.

Conveyor-based sorting systems, often referred to as material handling automation, represent a mature technology that has long enabled logistics networks to efficiently process and sort growing parcel and order volumes. A wide range of automated material handling solutions exist to support varying throughput demands and facility layouts, with common examples including sliding shoe, cross-belt, and tilt-tray sorters. Advancements in enabling technologies are further enhancing performance, with AI-based vision improving induction accuracy and control systems enabling more dynamic routing and real-time flow balancing.



While conveyor-based sorting systems are often grouped with robotic sorting solutions, the two technologies differ meaningfully: Conveyor-based sorting systems are fixed and follow pre-defined paths, while robotic sorting solutions are mobile, more adaptable, and capable of operating with greater autonomy.

Some robotic sorting systems use a series of independently moving robots, often called a table-sorting (t-sort) system. Solutions like FlexBuffer, made by ABB Robotics, leverage robotic arms,

dynamic racking systems, and inbound and outbound conveyors to provide a comprehensive sorting system for uniform or mixed goods. They synchronize end-to-end parcel flow, offering high reliability and consistent performance at scale. As volume variability increases with global e-commerce growth, reliance on conveyor-based sorting systems and other fixed infrastructure is driving interest in more flexible and adaptive automation approaches.

Automated sorting solutions can help a facility meet its throughput requirements for order fulfillment amid rising consumer demand. At the same time, they guarantee proper handling of shipments to prevent sorting errors and protect against damage to outbound orders.

Induction & Singulation

Induction means introducing items onto a conveyor or sorting system in a controlled and trackable manner. Similarly, singulation separates items so that they move individually through a system. In logistics, the two processes often happen in parallel to prepare parcels, letters, or cartons for automated conveyor transport downstream for sorting or value-add processes. Both induction and singulation are highly repetitious and monotonous tasks that present strong business cases for automation across supply chains. Combining advanced computer vision solutions with robotic arms for specialized package manipulation creates potential for consistent throughput and reduced reliance on a fluctuating labor market.

Technology providers such as Plus One Robotics, Körber, and Osaro continue to develop AI-based computer vision systems to meet the rising throughput requirements of logistics operations around the world. In Spain, DHL collaborated with Vanderlande & AWL to deliver a fully automated robotic induction cell. Robotic induction delivers more consistent throughput, reduces dependence on volatile labor markets, and shifts human roles toward higher value tasks.

Despite these successes, automation providers must continue improving performance in highly diverse package mixes.



Palletizing & Depalletizing

Stationary robotics have great potential for automating the palletizing and depalletizing process in inbound and outbound warehouse or hub operations. However, long-standing challenges around variability, scale, and deployment complexity have slowed the development of commercially viable solutions. New solutions are expanding the traditional boundaries of automation.

The complexity and handling requirements depend on whether the (de)palletizing is uniform or mixed. While uniform (de)palletizing involves moving same-shaped, unvarying goods from or onto pallets, mixed (de)palletizing involves handling pallets with items of various sizes and weights. In general, automating mixed (de)palletizing is more complex than uniform (de)palletizing as it requires much more powerful, sophisticated robotics technology and AI to stack a variety of packages securely and efficiently.

Jacobi Robotics has an AI-driven mixed-case palletizing solution that enables robots to dynamically perceive and interpret case dimensions, weight distributions, and arrival patterns in real time. This removes the need for upstream sequencing and allows systems to adapt to unstructured, high-variability flows. Red Cable Robotics has introduced a fundamentally different hardware approach, using cable-driven robots that suspend and move payloads across large workspaces with high speed and precision. This enables palletizing and depalletizing across wide areas with minimal infrastructure and reduced energy consumption. Together, these approaches highlight a shift toward more flexible, software-defined and spatially adaptive systems that extend automation beyond the constraints of traditional robotic cells.

In Jirny, Czech Republic, DHL Supply Chain operates a collaborative robotic arm by Universal Robots to palletize goods from two production lines. An industrial robotic arm made by Fanuc performs similar tasks at a DHL facility in Jažlovice.

We expect stationary robots to make pallet handling more efficient, with scalable mixed depalletizing solutions reaching maturity and commercially available mixed palletizing solutions gaining traction. This delivers greater consistency and reduces manual effort across logistics networks.

Automated Inventory Management

Storage racks have traditionally provided a cost-effective and scalable option for warehouses to increase inventory storage density. As facility density increases, however, inventory becomes less accessible, resulting in longer pick times and slower fulfillment. By introducing fixed automation to the inventory management process, operations can maintain a balance between high utilization and high accessibility to meet rising consumer demand.

One common example of fixed inventory automation is an automated storage and retrieval system (ASRS). These computer-controlled robotic storage systems autonomously handle, store, and retrieve bins or totes or shelves within a warehouse. ASRS solutions, such as the cube-based system by Norwegian company AutoStore, offer many advantages over traditional picking solutions. AutoStore's high-density grid design reduces the required footprint by up to a factor of four while increasing picking throughput by up to five times compared to conventional methods.

Although the initial investment for such solutions is relatively high, it can be economically viable, especially when handling large volumes of stock-keeping units (SKUs) of slow- and medium-velocity goods, which improves the efficiency of the system. DHL Supply Chain has worked with AutoStore to deploy ASRS solutions across operations in Singapore, the US, and Europe. The partnership has significantly boosted operational efficiency and throughput in DHL's fulfillment warehouses.

As inventory volumes and SKU complexity continue to rise, ASRS solutions are increasingly enabling high-density, high-performance fulfillment operations. While adoption is driven by clear efficiency gains at scale, ongoing advancements in flexibility, modularity, and system intelligence are expected to further expand their applicability across a broader range of warehouse environments.



Automated Packing & Labeling

In outbound logistics operations, several steps are often required to prepare shipments for transit, including selecting and erecting the right carton or container, consolidating multiple items into a single package, and applying labels to ensure accurate routing. Although these processes differ in their technical requirements and final output, they present similar operational challenges. Packing and labeling are both labor-intensive activities that can drive up costs, constrain throughput, and introduce quality variability across customer orders.

Stationary robotics are increasingly supporting these outbound preparation tasks, with solutions such as carton erectors, wrapping systems, and print-and-apply labelers helping to automate repetitive activities and standardize execution.

At a DHL facility in Spain, we use the Packsize X5 automated carton erector and the Locus Origin assisted picking bot to increase the efficiency of outbound fulfillment. By producing custom-fit cartons on demand and integrating them into a coordinated robotic picking workflow, the solution improves throughput, reduces packaging waste, strengthens labor productivity, and increases outbound execution consistency.

By automating packing and labeling activities, stationary robotic systems help staff perform outbound tasks more quickly, accurately, and ergonomically. It reduces waste and bottlenecks in fulfillment, improves consistency across orders, and enables logistics operations to scale more effectively in response to demand.

Summary & Trend Overview

Challenges



Stationary robots are typically designed to handle specific package shapes, limiting their ability to accommodate a wide variety of sizes and weights.



Under real-world conditions, many stationary robots fail to achieve the throughput rates reached in testing environments.



Brownfield facilities may lack the required technical infrastructure, requiring costly reconfigurations to implement stationary robots on a broad scale.



Even with progressive process automation, fully automated stationary robots without human supervision are unlikely in the near future.



When stationary robots are added, facilities require more safety infrastructure; with each new automation, this infrastructure needs reevaluation.

Outlook

The growing number of successful pilots and proofs of concept across diverse industries signals increased near-term adoption of stationary robotics in logistics. This technology has not yet fully matured, with capabilities expected to expand alongside innovations in 3D computer vision and deep learning algorithms.

This progression will ultimately pave the way for complex, multi-robot workflows, such as automated handoffs between stationary and mobile robots for end-to-end process orchestration.



Strategize – This trend has the potential to bring substantial change across logistics with implementations available for many use cases today.

Related Trends

Computer Vision



Indoor Mobile Robots



Outdoor Autonomous Vehicles



Humanoids



Sources

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Sustainable Fuels

Trend Overview

Impact:

HIGH

Adoption:

< 5 YEARS

Focus Areas:

Sustainability

Sectors:

Energy



The trend of Sustainable Fuels represents the trend toward using alternative fuels that may deliver lower lifecycle greenhouse gas emissions than conventional fossil fuels, depending on the feedstock, production pathway, energy source and end use. These fuels may be produced from renewable, waste-based, or synthetic feedstocks and include conventional biofuels such as ethanol and biodiesel, drop-in fuels such as hydrotreated vegetable oil (HVO), and synthetic fuels such as e-diesel and e-kerosene.

Demand for sustainable fuels is projected to grow as organizations worldwide strive to meet decarbonization targets. Particularly sustainable fuels are among the principal options for reducing lifecycle GHG emissions in aviation and maritime shipping, particularly for long-distance operations where direct electrification currently faces significant technical and economic constraints.

Many sustainable fuels are “drop in fuels,” meaning they can be used directly in existing engines and infrastructure without significant modification. One example is sustainable aviation fuel (SAF), which can be blended with conventional fuel (current standard is up to 50%) and deployed immediately across existing fleets and infrastructure, avoiding the need for new aircraft engine technologies. This is a major advantage over sustainable fuels like liquefied natural gas (LNG), hydrogen, or ammonia, which typically require new storage, handling systems, or engine adaptations.

Sustainable fuels can be broadly categorized into three main types: biofuels, synthetic fuels (e-fuels), and other alternative low carbon fuels such as hydrogen and ammonia. Their environmental impact varies depending on the feedstock, production pathway, and end use sector such as aviation, maritime, and road transport.

Biofuels are produced from organic feedstocks such as agricultural residues, waste oils, forestry byproducts, and energy crops. Biogenic feedstocks absorb CO₂ during growth, but biofuel lifecycle GHG emissions also depend on cultivation or collection, land-use effects, processing energy, transport, and combustion. Some waste- and residue-based pathways can deliver lower lifecycle GHG emissions than fossil fuels when assessed under an applicable methodology. Common examples include biodiesel, hydrotreated vegetable oil (HVO), and bio-based SAF.

E-fuels are produced by combining captured carbon dioxide with hydrogen. When hydrogen is produced using renewable electricity, synthetic fuels may achieve lower lifecycle GHG emissions than fossil equivalents; the result depends on the electricity source, origin of the captured CO₂, conversion efficiency, and the applicable lifecycle methodology. Examples include e-diesel, e-kerosene, and e-methanol.

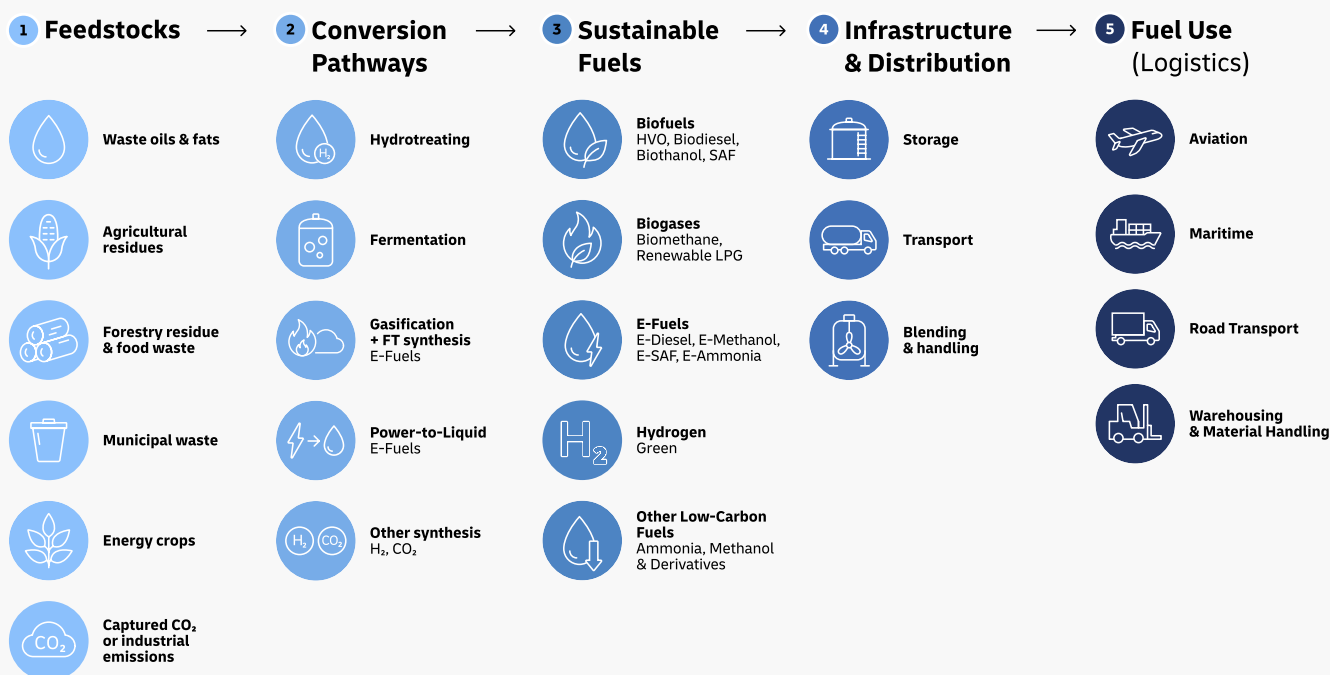
Emerging sustainable fuel options such as hydrogen, ammonia, and green methanol are gaining traction as well. Hydrogen is produced via water electrolysis powered by renewable electricity, while ammonia is synthesized by combining that hydrogen with atmospheric nitrogen. Because neither molecule contains carbon atoms, their ultimate combustion yields zero CO₂ emissions. However, unlike drop-in options, they require entirely new, specialized propulsion systems and fueling infrastructure.

For logistics operators, increasing the use of qualifying lower-GHG fuel pathways can support emissions-reduction targets and compliance obligations where direct electrification is not yet feasible.

Although e-fuels will only become available at scale as renewable energy capacity expands, sustainable fuels are rapidly transitioning from pilot projects to early commercial scale. In fact, drop-in fuels like HVO have even reached mature, large-scale deployment. As global production volumes increase, these fuels are being deployed immediately in existing fleets and infrastructure across the supply chain, including air, sea, and road transport as well as warehouse operations.

Drop-in biofuels may provide a near-term option for reducing lifecycle GHG emissions in existing fleets while electric and hydrogen technologies develop. Depending on fuel specifications and equipment approvals, some can be used with limited engine or infrastructure modification.

As production capacity, policy support, and infrastructures develop, qualifying fuel pathways may contribute to reductions reported in relevant Scope 1 or Scope 3 categories, depending on operational control, chain-of-custody arrangements, and the accounting methodology applied.



Sustainable fuels are the most scalable near-term solution to decarbonize logistics.

DHL (2026)

Relevance to the Future of Logistics



Sustainable Aviation Fuels

SAF is currently the principal drop-in alternative to conventional jet fuel for reducing lifecycle GHG emissions from long-distance air freight without replacing existing aircraft and fuel infrastructure.

Hydrogen and battery solutions remain in early stages, making full electrification not yet viable. As a result, SAF serves as the key commercial pathway for decarbonizing aviation.

Certain SAF pathways can deliver lifecycle GHG-emissions reductions of around 80% compared with conventional aviation fuel, although actual performance varies by feedstock, production pathway, and accounting methodology. Despite this potential, supply remains extremely limited, accounting for only a small share of global aviation fuel, highlighting the urgent need to scale production through greater investment and demand.

In 2025, SAF output reached approximately 2.4 billion liters (1.9 million metric tons), nearly double the 1 million metric tons produced in 2024 – yet it still accounts for only around 0.6% of total jet fuel consumption. SAF production growth is expected to decelerate in 2026 due to high price premiums, policy gaps as well as limited market maturity, underscoring the continued gap between supply and demand.

Availability and high cost remain barriers to widespread adoption. SAFs are derived from renewable sources such as biomass, animal fats, oils, and alcohol, which can be blended with conventional kerosene. Industry initiatives have brought together aviation stakeholders to support SAF market development and the reduction of lifecycle GHG emissions from aviation.

At DHL, we have expanded our Sustainable Aviation Fuel (SAF) supply network globally. By 2025, we used approximately 185

metric kilotons of SAF, achieving a SAF blend of roughly 10% across our air operations. This represents one of the highest SAF utilization shares among global airlines, reflecting DHL's commitment to accelerating the transition toward more sustainable air transport. In May 2026, we added the first SAF production facility in the Middle East to our global network, signing an agreement with SAF One to secure 25,000 metric tons annually for 10 years from the company's Bahrain plant.

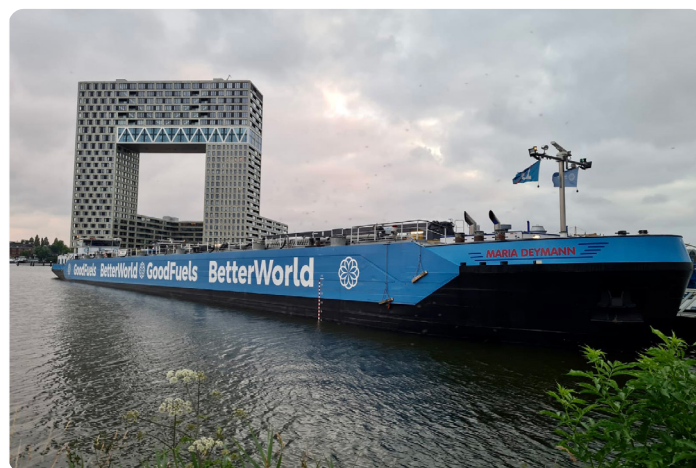
Looking further ahead, hydrogen-derived e-fuels and other synthetic aviation fuels remain promising long-term solutions. Startups like H2FLY and ZeroAvia are working on promising concepts, but experts do not expect commercial application of sub-regional and regional hydrogen fuel cell aircraft before 2030. However, DHL experts view the scaling of SAF from advanced feedstocks such as novel vegetable oils, agricultural residues, and municipal solid waste as the more immediate priority.

Sustainable Marine Fuels

International maritime transportation, including vessels ranging from small recreational boats to massive, ocean-going container ships, accounts for roughly 2 to 3% of global greenhouse gas (GHG) emissions, with total emissions estimated at 900 to 1,000 million metric tons of CO₂e annually.

More than 80% of global traded goods are transported by cargo ships, 95% of which rely on heavy fuel oil (HFO) for propulsion, a residual fuel produced from petroleum refining, which emits relatively large amounts of GHG when combusted.

Alternative marine fuels may lower well-to-wake GHG emissions relative to petroleum-based marine fuels, depending on the



production pathway and engine technology. Some alternatives can also reduce sulfur oxides and certain local air pollutants at the point of use, although pollutant profiles vary by fuel and combustion system.

A wide range of SMFs are being explored, each with distinct characteristics:

- Fossil LNG is currently the most widely adopted alternative marine fuel, but its well-to-wake GHG performance relative to fuel oil depends on upstream methane emissions and methane slip from the engine; it therefore remains a fossil-based option.
- LPG provides reduced emissions and benefits from established infrastructure, making it a practical near-term option, however its long-term viability is challenged by its fossil origins and strict safety hazards.
- Methanol is a versatile and scalable fuel with simpler handling and growing adoption potential, although supply and cost remain challenges.
- Biofuels provide a near-term, drop-in solution compatible with existing engines, though scalability is constrained by feedstock availability and sustainability considerations.
- Ammonia contains no carbon and therefore produces no CO₂ at the point of use, but its well-to-wake GHG performance depends on how it is produced and managed; storage, toxicity, nitrous oxide emissions, safety, and infrastructure remain challenges.
- Electric propulsion enables highly efficient, low-emission operations for short-range vessels but is limited by battery energy density and operational range.
- Hydrogen fuel cells produce no CO₂ at the point of use, although lifecycle GHG emissions depend on hydrogen production and supply. Storage volume, infrastructure, safety, and technology maturity remain barriers to maritime deployment.
- Nuclear propulsion offers high energy density and produces no direct combustion-related GHG emissions during operation, but lifecycle impacts, radioactive waste, security, regulatory, safety, and public-acceptance issues remain significant.

Taken together, these tradeoffs indicate that the maritime sector will likely follow a multi-fuel transition pathway depending on vessel types, routes, and infrastructure readiness.

Despite low fuel penetration, fleet transition is accelerating rapidly, reflecting a growing readiness to adopt sustainable fuels. In 2025,



ship owners increasingly ordered alternative-fuel-capable vessels across leisure and merchant ships. Vessel fuel capabilities are diversified across LNG, methanol, ammonia, and hydrogen-based fuel. LNG dominates this transition, followed by methanol, with ammonia and hydrogen fuels still at an early stage of adoption.

The GHG intensity of maritime transport varies by vessel efficiency, utilization, route, fuel pathway, and the lifecycle boundary applied.

The future of marine fuels is not a single-fuel shift but a gradual transition to a diversified fuel mix, with retrofitting of existing fleets and scaling of alternative fuel supply as the key enablers of decarbonization.

Sustainable Fuels in Road Transportation

Although electric vehicles (EVs) are rapidly becoming mainstream for short to medium distance transport, especially in light-duty and urban use, electrification remains challenging for long-haul, heavy-duty transport due to limited range, long charging times, and a shortage of suitable high-capacity truck models. This means the industry continues to rely on combustion engines running on fossil fuels.

Sustainable fuels represent a key near-term solution for decarbonization in road transportation, playing a complementary role to electrification, particularly for segments that are difficult to electrify. Biofuels are currently the most practical option because they can be blended with conventional diesel. The IEA forecasts that the share of biofuels in road transportation will rise from 5% in 2022 to 10% in 2030.

This momentum is reinforced by policy and a strong shift by traditional fuel producers toward biofuels and synthetic fuels. Governments are actively supporting the growth of sustainable fuels through blending mandates, incentives, and regulatory

frameworks and major energy companies such as Neste are accelerating investments in low-carbon fuels. The company's capacity is expected to reach roughly 6.8 million metric tons annually by 2027.

The two primary truck biofuels in use are biodiesel (FAME) and hydrotreated vegetable oil (HVO). Biodiesel is derived from vegetable oils or waste fats (for example, recycled fats from the catering industry) and can be blended with conventional diesel (typically up to 7% in many regions such as the EU). HVO is vegetable oil that has been treated with hydrogen, offering similar properties to fossil diesel that allow higher blend levels or even 100% substitution.

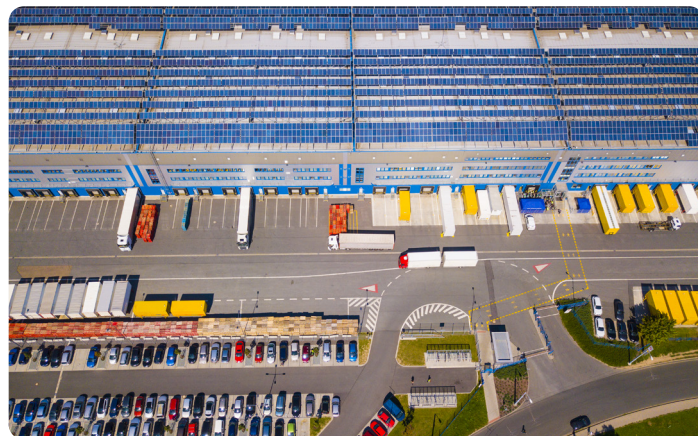
E-fuels are another emerging class of sustainable fuels, produced using captured CO₂ and green hydrogen from water split by low-carbon electricity sources including wind and solar. These fuels can reduce lifecycle emissions by up to roughly 75% compared to fossil fuels. Adoption remains limited due to high production costs and early-stage commercialization, with large-scale deployment dependent on further technological and policy support.

Sustainable Fuels for Warehouse Operations

Warehouses are among the most energy-intensive building types, with material handling, heating, and hot water accounting for a considerable share of total energy demand. Electrification is the default decarbonization pathway, but it has real limits. Alternative fuels may address some warehouse energy uses that are not readily electrified and may reduce relevant Scope 1 emissions, depending on the fuel pathway. Renewable electricity is an energy source rather than a fuel and primarily affects market- or location-based Scope 2 reporting.

Today, a significant share of material handling equipment (MHE) in modern warehouses, such as forklifts and pallet movers, is already electrified and powered by batteries. Electrified material-handling equipment produces no direct exhaust emissions at the point of use; associated Scope 2 and lifecycle GHG emissions depend on the electricity supply and accounting method. However, battery-powered systems still present operational challenges in high-throughput environments, including charging downtime, battery swapping requirements, and space constraints for charging infrastructure.

Hydrogen fuel cell technology is gaining traction for MHE, particularly in large-scale, high-intensity warehouse operations. Fuel cell-powered forklifts offer continuous operation without battery degradation, significantly reducing downtime. Refueling takes approximately 2 to 3 minutes, compared to several hours



required for battery charging, while fuel-cell operation produces no direct CO₂ or combustion-related air-pollutant emissions at the point of use, while lifecycle GHG emissions depend on hydrogen production and supply. This makes hydrogen particularly suitable for multi-shift, high-utilization environments where operational efficiency and uptime are critical. Leading companies such as Amazon and BMW have already deployed hydrogen fuel cell forklifts at scale in their distribution and manufacturing facilities.

Beyond material handling, building heating and hot water present a different decarbonization hurdle. Electrification of these thermal loads can be challenging at scale, particularly in colder climates or large industrial facilities. In this context, Biomethane upgraded to the applicable gas-grid specification can be used in many existing natural-gas boilers and CHP systems. Its lifecycle GHG performance depends on feedstock, methane leakage, processing, transport, avoided-emissions assumptions, and the accounting method applied. RNG is chemically identical to fossil natural gas and can be used directly in existing infrastructure, including boilers and combined heat and power (CHP) systems, without requiring major retrofits. Produced from organic waste streams such as agricultural residues, landfill gas, and wastewater, RNG supports circular economy principles while enabling immediate emissions reduction in heating applications.

Sustainable fuels for warehouse operations allow logistics providers to take a more holistic approach to decarbonizing supply chains – extending efforts beyond transport. This supports compliance with emerging regulatory frameworks and aligns with growing customer demand for end-to-end low-carbon logistics solutions.

Summary & Trend Overview

Challenges



Sustainable fuel production is constrained by resource availability: feedstock scarcity limits biofuel output, while e-fuel volumes depend on the expansion of renewable electricity capacity.



Production of sustainable fuels from agricultural crops can create competition for land and resources, potentially driving deforestation, habitat loss, and biodiversity decline, all of which have a negative climate impact as well as impacting food security.



Lack of consistent standards and definitions makes it difficult to verify sustainability claims and navigate complex certification processes.



Demand for sustainable fuels exceeds current supply by far, while production processes remain expensive and require further technological advances to reduce costs.



Governments, suppliers, and shippers struggle to understand the opportunities and challenges of sustainable fuels given the range of fuel types, technology pathways, and materials involved.



Many regions lack the essential infrastructure such as fuel handling, blending facilities, hydrogen pipelines and CO₂ transport network, as well as port readiness needed to scale new fuels.

Outlook

Alternative fuels are expected to contribute to reducing lifecycle GHG emissions in selected aviation, maritime, road, and facility applications, with their role varying by pathway, infrastructure, cost, policy, and technology maturity. We anticipate markets for sustainable fuels and technologies will grow and become more robust, and we expect this will drive development and scalability, increasing competitiveness against traditional fossil fuels.



Strategize – This trend has the potential to fundamentally transform or disrupt logistics with use cases in some applications that can already be addressed today.

Related Trends

Decarbonization



Renewable Energy Infrastructure



Heavy Vehicle Electrification



Light Vehicle Electrification



ESG Advocacy



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Unmanned Aerial Systems

Trend Overview

Impact:

CONSIDERABLE

Adoption:

5 – 10 YEARS

Focus Areas:

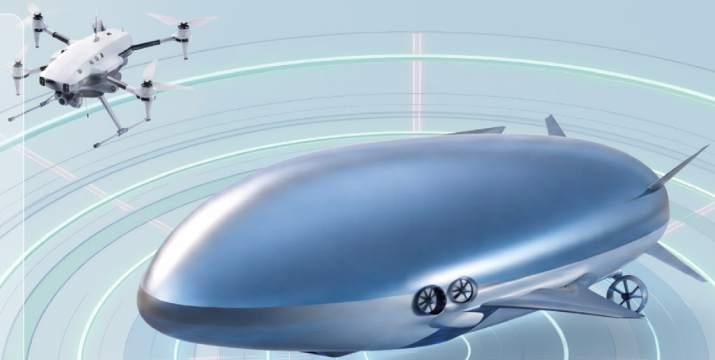
Automation & Efficiency

Customer Experience

Physical and Digital Security

Trend Clusters:

Robotics



The trend of Unmanned Aerial Systems (UAS) encompasses drones, airships, helicopters, and other aircraft without a human pilot or crew on board. While most existing UAS are remotely controlled by a human pilot, advanced autonomous versions use sophisticated sensing technologies and software-controlled flight plans to fly beyond visual line of sight (BVLOS).

UAS have evolved rapidly from simply remote-controlled aircraft into a diverse and increasingly capable category of aviation technology. They now come in a variety of sizes and configurations, including single-rotor helicopters, multi-rotor platforms, fixed-wing aircraft, and (hybrid) vertical take-off and landing (VTOL) systems. Advances in energy technologies, including next-generation solid-state batteries and hydrogen fuel cells, are extending flight endurance and enabling longer-range commercial operations. And rapid progress in artificial intelligence (AI), machine learning (ML), computer vision, and sensor fusion technologies is increasing UAS autonomy and operational reliability.

Modern systems can combine Global Positioning System (GPS), Light Detection and Ranging (LiDAR), radar, and onboard vision systems to navigate complex environments, avoid obstacles in real time, and operate effectively even in areas with signal interference. Swarm intelligence is also emerging, enabling coordinated fleets of autonomous UAS to perform tasks such as large-area inventory scanning, infrastructure monitoring, and search-and-rescue operations.

As these capabilities develop, UAS are increasingly being deployed across logistics and supply chain operations for a wide range of applications, including parcel delivery, inventory

counting, infrastructure inspection, site security, and emergency response.

In 2026, the market has begun to transition from isolated pilot projects toward more scalable commercial deployment. Several developments are accelerating adoption across logistics networks: expanding BVLOS approvals, the development of Uncrewed Traffic Management (UTM) and U-Space frameworks as well as tighter integration with warehouse management, enterprise resource planning (ERP), and transportation management systems. Furthermore, proposed regulatory frameworks, such as the US Federal Aviation Administration's (FAA) Part 108, are designed to authorize and standardize routine BVLOS operations and highly automated drone operations at scale.

As regulation matures, UAS deployment in logistics is expected to expand across areas such as mid-mile transport, healthcare logistics, rural delivery, and industrial supply chain operations over the coming years. At DHL, we expect UAS to complement traditional transport modes and enable faster, more resilient, and increasingly autonomous logistics operations. They will likely have the greatest impact on time-critical, remote, and regional delivery networks where conventional transportation faces cost, infrastructure, or capacity constraints.

Drone Industry Insights

Advanced Air Mobility (AAM) Components, Regulation and Operation



Small Delivery Drones



Big Delivery Drones

Technology	Propulsion	Electric, Hybrid-Electric	
	Control	Remote Controlled / Fully Automated Flight	
	Takeoff & Landing	Vertical Takeoff & Landing Capability	
	Ground Infrastructure	Base Station	Vertiport / Airfield
Design & Operation	Certification	Risk-Based	Type Certificate
	Operation Focus	Cargo Transport	Passenger Transport
	Takeoff Clearance	Approval	
	Operational Limitations	BVLOS*, Operation Over People, 1:N Operation	BVLOS, Operation Over People, Piloted / Remotely Piloted
	Traffic Management	Unmanned Aircraft System Traffic Management (UTM)	

*Beyond Visual Line of Sight

Advanced Air Mobility (AAM) is evolving into an integrated logistics ecosystem, combining cargo drones, enabling infrastructure, automation, and airspace management to support scalable commercial operations.

Drone Industry Insights (2023): Advanced Air Mobility (AAM) Components, Regulation and Operation Infographic

Relevance to the Future of Logistics



Mid-Mile & Last-Mile UAS Delivery Corridors

Delivery networks around the world face increasing logistics volumes, rising demand for rapid fulfillment, and persistent labor shortages. In response, the logistics industry is increasingly exploring UAS beyond last-mile delivery to mid-mile transport between logistics nodes such as warehouses, micro-fulfillment centers, hospitals, factories, retail locations, and distribution hubs.

Mid-mile routes are often more operationally predictable, easier to regulate, and better suited for BVLOS operations than dense urban last-mile operations. As a result, logistics organizations are now piloting scheduled drone corridors for time-critical and high-value shipments, particularly across distances of 20 to 120 km.

For example, several healthcare logistics networks in Europe and the US are testing autonomous drone routes between hospitals and regional laboratories, where blood samples, diagnostic materials, and urgent medical supplies are transported on fixed, repeatable schedules. Similarly, pilot programs test UAS delivery corridors for moving high-priority spare parts from distribution hubs to industrial sites such as energy or manufacturing facilities, where consistent mid-mile distances and controlled airspace make BVLOS operations feasible.

For last-mile delivery, UAS adoption continues to progress, albeit selectively. The most viable applications remain rural and semi-urban deliveries, particularly where road infrastructure is limited or delivery density is low. Hybrid truck-and-drone delivery models are also emerging, where drones operate alongside conventional delivery vehicles to optimize route efficiency, reduce emissions, and improve delivery speed for selected stops.

Autonomous UAS Facility Patrolling

Security and surveillance in large facilities is a challenging but essential function. Human security patrols and surveillance teams

have limitations, and hidden intruders can easily go undetected. UAS equipped with cameras offer a solution to mitigate the risk of overlooking intrusion. The captured visual data can accelerate patrolling tasks and increase the number of daily patrols at randomized intervals. AI-based systems help identify threats more accurately, capture and process more information, provide a bird's-eye view of a facility, and reduce the chance of missing suspicious activity.

UAS are also becoming more autonomous, leveraging 5G for real-time data transfer and processing. Many can now operate with increased speed, reduced latency, and improved reliability – and some are equipped for fully autonomous operation. For example, modern UAS-in-a-box security solutions no longer need to be manually launched and retrieved, nor do batteries need to be swapped or changed. Tethered solutions can keep UAS airborne indefinitely.

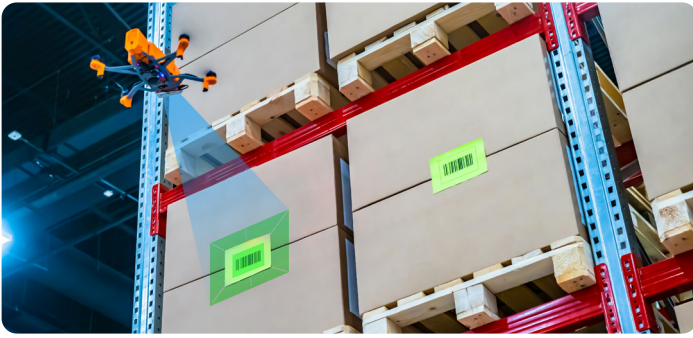


UAS-based Inventory Counting

Many logistics organizations currently rely on human resources to manage inventory, particularly warehouses full of palletized goods on shelves. As shipments enter, rotate, and leave the warehouse, workers must confirm stock counts and vacancy rates on shelves. This makes real-time inventory management difficult.

Another common challenge is height: warehouse racking systems are high enough to pose a safety hazard. While ground-based warehouse automation technologies aim to solve this problem, drones offer a viable solution for this expensive, time-consuming, and risky activity.

Instead of dozens of workers scanning codes and recording placements, drones equipped with cameras can be deployed to quickly scan and count inventory. This is more efficient and eliminates the need for aerial work platforms and other special equipment to reach high shelves. A future system could theoretically deploy fleets of autonomous drones, with a single human operator overseeing operations and handling flagged exceptions.



UAS-based inventory counting could lead to more frequent stock counts and fewer personnel, which would benefit supply chains by increasing data accuracy, reducing risk, and optimizing warehouse operations.

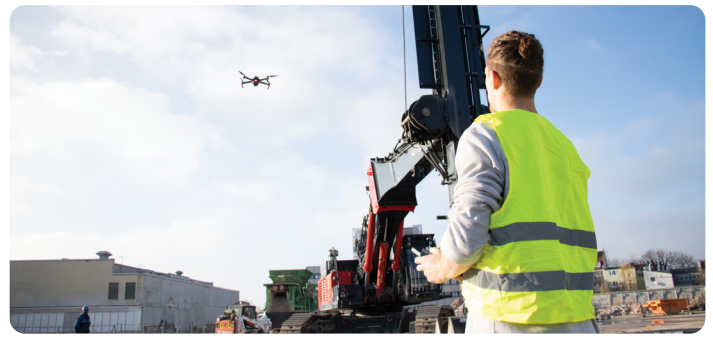
At DHL, we have tested and deployed drone cycle counting solutions globally, including the Eyesee solution from Hardis, and we are collaborating with many technology companies around the world to develop and pilot similar UAS solutions.

Dimensioning & Inspecting Large Assets

Manual processes for dimensioning and inspecting large assets are time-consuming. Inspectors must be meticulous because even a small error – such as mismeasuring or missing an equipment fracture – can have costly consequences. These tasks present a workplace safety risk, especially when personnel must climb to heights or walk on uneven surfaces.

UAS are poised to improve the efficiency of this process. For example, AI-enabled drones with advanced sensors can measure large-area stockpiles with below-centimeter precision in a matter of hours. The manual process can take days. These drones leverage several technologies, such as a global navigation satellite system (GNSS) receiver to connect to more satellites for improved precision. Real-time kinematic (RTK) positioning and ground control points (GCPs) achieve consistent data alignment over time, which is vital for monitoring ever-changing stockpiles. Without RTK or GCPs, maps may shift several meters, resulting in inaccurate stockpile measurements – especially when comparing data captured on different dates. A photogrammetry engine and software such as DJI Terra are used to process the captured images.

Airplanes are a good example of large assets requiring inspection. Inspectors have always done this manually, physically walking around an airplane to assess its overall condition and compliance with safety regulations. They carry out general visual inspections (GVIs) to inspect, locate, and evaluate any visually obvious damage, failures, or anomalies. They often rely on ladders, scaffolding, and cherry pickers to reach areas that are not visible from the ground.



New UAS solutions offer a compelling alternative for airplane inspections. For example, automated aircraft inspection drones made by Dutch startup Mainblades can autonomously inspect all sides of an airplane, capturing data for inspectors to review.

In this use case, drones eliminate safety risks, free up staff, and reduce time, which enables faster turnaround and more missions. These efficiencies are also likely to lower operational costs.

Heavy Lifting

Heavy-lift and long-range UAS are advancing rapidly, expanding logistics applications beyond small-package drone delivery. New cargo drone platforms can transport larger payloads over regional distances, enabling use cases such as inter-facility replenishment, offshore delivery, medical logistics, and urgent spare-parts transport. MightyFly, Dronamics, Elroy Air, and ST Engineering are among the companies developing autonomous cargo aircraft optimized for mid-mile logistics operations.

At the same time, the technology is expanding into other autonomous aerial cargo platforms such as airships and hybrid VTOL aircraft. Hybrid Air Vehicles and Flying Whales are two companies developing heavy-lift airships designed to transport oversized or high-volume cargo to remote or infrastructure-constrained regions. These platforms are particularly relevant for industrial supply chains, energy and mining operations, disaster relief, and remote-area logistics where road or airport access is limited.

Together, these developments are broadening the role of autonomous aerial transport from niche parcel delivery to larger-scale regional and heavy-cargo logistics applications.



Summary & Trend Overview

Challenges



The absence of a global and country-specific regulatory framework prevents drone operators from scaling operations in ways that protect public and manned airspaces.



The negative image of drone technology, which has been deployed in warfare, organized crime, and other irresponsible uses, is an obstacle to regulatory and public acceptance.



Drone noise, along with privacy and safety concerns, hinders social acceptance.



Specialized drones designed for industrial and commercial use carry a high price tag, driven by the advanced technologies (e.g., chips and sensors) they require.

Outlook

UAS technology is developing rapidly, enabling many use cases in logistics and supply chains. However, regulations, social acceptance, and cost remain key challenges impeding commercial deployment.

At DHL, we anticipate that UAS uptake in logistics will vary by application. Adoption in public spaces will likely be slow, especially for last-mile deliveries in dense urban areas. By contrast, use cases in remote areas will expand in the next few years. We also expect increased use of UAS inside logistics facilities like inventory counting.

The convergence of autonomous flight, digital airspace management, and advanced cargo drones is enabling UAS to become an integrated component of future logistics networks, improving speed, flexibility, and operational resilience.



Prepare – This trend has the potential to bring substantial change across logistics with developments and use cases on the horizon.

Related Trends

Augmented Workplaces



Wearable Sensors



Smartification



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Wearable Sensors

Trend Overview

Impact:

LOW

Adoption:

< 5 YEARS

Focus Areas:

Automation & Efficiency

Safety & Future of Work

Physical & Digital Security

Trend Clusters:

Bionic Enhancement

Internet of Things

The trend of Wearable Sensors describes sensor-equipped devices worn on the body to capture movement, behavior, and work-related conditions. These smart wristbands, connected badges, smart glasses, integrated textiles, and other devices are designed to improve operational efficiency, safety, and worker well-being.

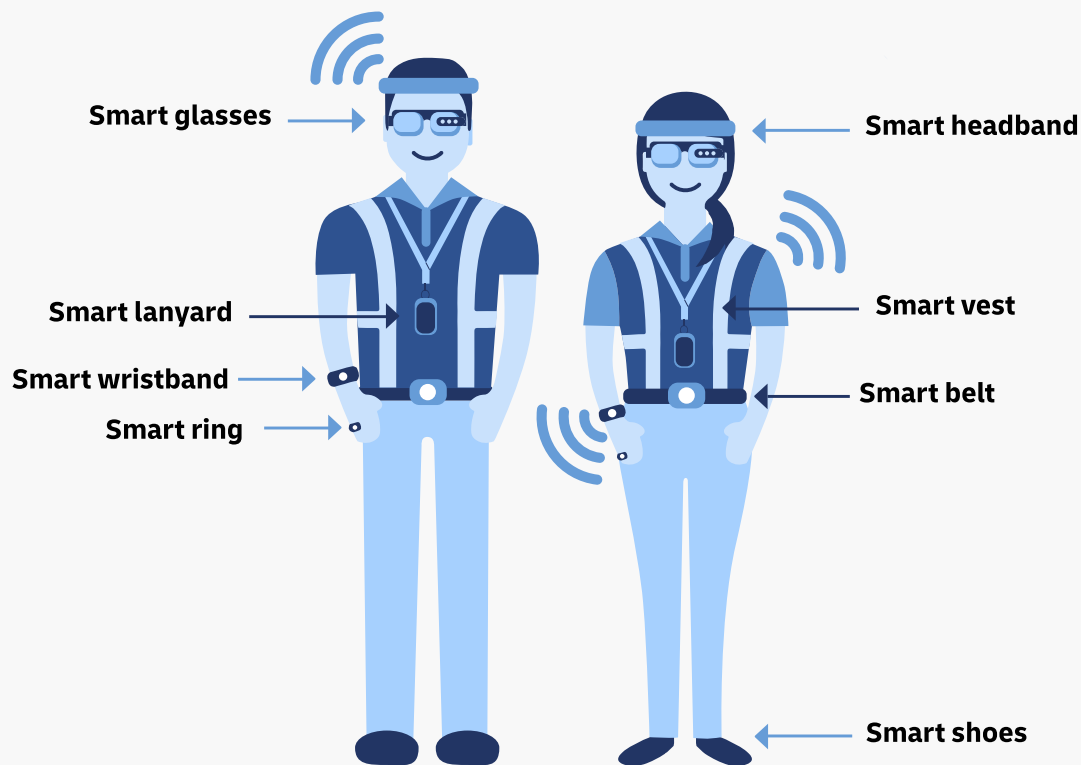
Wearable sensors continue to shrink in size and open new possibilities, such as integration into clothing (smart textiles). Recent innovations are moving beyond single-parameter tracking toward continuous, multi-analyte biosensing. For example, Adaptic Biosciences raised US\$14 million in 2025 to develop a wearable patch capable of monitoring a wide range of molecular biomarkers in real time.

Industrial applications already represent a significant share of demand, accounting for nearly 28% of wearable sensor adoption in the US market. As such, many logistics organizations have begun implementing various smart wearable devices and equipping facilities with wireless communication infrastructure.

Wearable sensors support ergonomic risk detection, fatigue monitoring, and heat-stress prevention. Early deployments of AI-enabled wearables have demonstrated significant safety benefits, including case-study reductions of up to 86% in ergonomic injuries and 91% in strains and sprains. Overall, wearable sensors provide a critical data source for safety, health, and process-related analytics within connected logistics operations.

While the impact of this trend on logistics is expected to be moderate, wearable sensors represent building blocks for data-driven logistics networks. These devices are already active in modern logistics operations, providing targeted operational insights while improving workplace safety and efficiency.

At DHL, we expect wearable sensors to become largely commonplace in the near term. However, while many applications are technically feasible today, navigating worker anonymity and strict data privacy regulations remain limiting factors.



Wearable sensors are embedded across different types of body-worn devices, enabling real-time data collection.

Kong, Xiang (2019): Industrial wearable system: the human-centric empowering technology in industry 4.0

Relevance to the Future of Logistics



Motion Monitoring for Process Intelligence

Operational optimization is a continuous and essential business process, but many workflows are difficult to track digitally. Wearable sensors offer a solution to that challenge, providing clear value for logistics operations. Data is collected as workers move through daily tasks and then analyzed using algorithms to generate detailed insights and identify improvement opportunities.

For example, DHL Supply Chain used the GDPR-compliant Motion Mining platform, developed by German startup MotionMiners, to collect data from purpose-built wearable devices. The goal was to identify process waste and improvement potential. The automated process produced a large, detailed dataset free from observation bias.

As wearable devices such as smart glasses and wearable scanners become more widely implemented in logistics operations,

organizations increasingly reuse the sensors already embedded in these devices to generate continuous process insights, rather than introducing additional purpose built hardware. For example, ProGlove offers the ProGlove Insights platform alongside its wearable scanners to convert raw operational data into actionable shop-floor intelligence.



Wearable-based Ergonomic Risk Monitoring

Ergonomic workplace hazards are one of the main causes of musculoskeletal disorders (MSDs), which are the most common work-related health issues in the EU. MSDs are costly for business, increasing sick leave and early retirements. Wearable sensors can lower the MSD risk in two ways: by providing real-time feedback that helps train users to adopt more ergonomically friendly movements or by leveraging data-driven insights to evaluate and mitigate ergonomic risk in processes or work areas on a continuous, preventive basis.

For training, wearable solutions monitor worker movements and detect high-risk postures such as bending, overreaching, or twisting. These devices provide real-time haptic feedback, such as vibration alerts, prompting users to correct unsafe movements immediately. Soter Analytics, Kinetic, and StrongArm Technologies are among the companies offering wearable devices for training.

Many of these solutions also connect to analytics platforms that aggregate movement data across individuals, shifts, and processes to identify systemic ergonomic risks and enable targeted interventions and workflow optimization.

Beyond movement-based ergonomics, wearable sensors increasingly capture physiological data to enable fatigue and heat-stress monitoring. These devices continuously track specific parameters, such as heart rate, skin temperature, and activity levels to detect early signs of fatigue, overexertion, or heat strain in real time. They trigger alerts when certain stress levels are reached, enabling rapid intervention before health incidents occur.

In addition, the aggregated data from across the workforce can be analyzed to identify patterns in workload, shift structure, or

environmental conditions. This allows preventative operational adjustments (e.g., break schedules, staffing, workplace conditions) to reduce risk exposure and improve overall worker well-being.

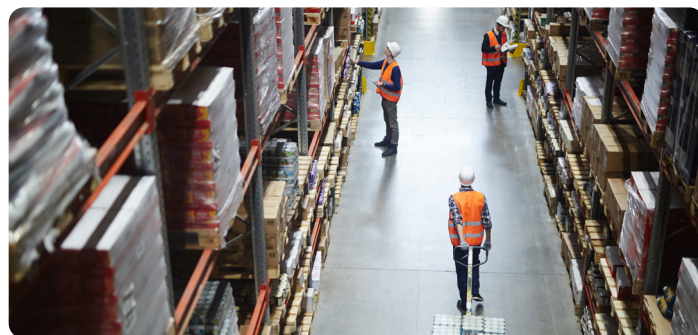
All in all, wearable-based ergonomic risk monitoring is evolving from a reactive alert solution toward data-driven preventative health and safety management. However, individual health data is considered highly sensitive and therefore an obstacle to user acceptance. This requires strict anonymization of user data.

Real-Time Indoor Worker Localization

Wearable sensors introduce the ability to track worker location, which opens an array of potential use cases that could improve occupational safety and health (OSH). For example, an injured worker can be located faster after a person-down alert has been triggered. Also, real-time indoor localization systems can prevent accidents between pedestrians and forklifts by issuing collision warnings to both the worker and the driver so they can take preventive action. These systems work best in environments with sufficient localization accuracy and low latency data transmission.

Wearable sensors are also being used for automated reporting and billing. In multi-customer logistics facilities, for example, billable work hours per customer can be captured by collecting data on time spent by employees in each customer's specific areas. In addition, wearable sensors can be used to automate access control, restricting access to specific areas, vehicles, and tools to those individuals with the required training or experience.

The costs of worker localization systems typically depend on the level of accuracy and the data transmission speed. Ultra-wide-band-based solutions provide high-accuracy tracking in real time but require a substantial investment in devices and infrastructure, preventing scaling beyond safety critical or high value use cases. Bluetooth Low Energy (BLE) costs less to deploy and is less accurate but is often sufficient and therefore the preferred choice. For example, the Norwegian startup Sonitor uses BLE and ultrasound technology for real-time indoor localization that supports automated labor reporting, geo-fencing, or indoor navigation.



Summary & Trend Overview

Challenges



Data privacy concerns can limit acceptance and hinder adoption; addressing this requires strict, transparent, and GDPR compliant anonymization and governance of collected data alongside clear communication regarding purpose, data usage, and retention.



The growing number of applications for wearable sensors risks becoming a burden for workers; user acceptance increasingly depends on perceived personal benefit, ease of use, and trust in data handling, as well as prioritizing multi-functional devices that integrate seamlessly into existing workflows.



High-precision localization systems require significant infrastructure investment, leading many organizations to deploy them only for safety critical or high value use cases.

Outlook

As more wearable sensors are introduced into logistics operations, the market is moving away from devices purpose-built for each use case toward solutions that leverage data from built-in sensors. Cost continues to limit scaling of highly accurate localization systems, but we expect the democratization of devices and support infrastructure to reduce the price per use case. Generic gateways will lower the entry barrier for these kinds of applications and enable broader reuse of shared infrastructure across multiple applications. Advances in electronic miniaturization, flexible printed circuit boards (PCBs), and battery life will accelerate the use of smart textiles.



Explore – This trend has the potential to deliver incremental improvements to logistics with implementations available for many use cases today.

Related Trends

Indoor Mobile Robots



Computer Vision



Remote Operations



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The DHL Team



Dr. Klaus Dohrmann

Vice President, Head of Innovation & Trend Research
Project Director & Co-Author



Emily Pitcher

Director PMO, Technology Sector Global
Editor-in-Chief & Co-Author



Jordan Toy

Innovation Manager
Research Lead & Co-Author



Susanne Lauer

Marketing Director Innovation & Content
Marketing Lead

Special Thanks & Contributions

Core DHL Research Team

Till Buettner, Benjamin Dippolito, Livia Fabrin Pereira, Abdulla Fayis, Sarah Funderburg, Christopher Fuss, Obie George, Cedric Grosch, Inga Lena Hemmert, YingChuan Huang, Pradeep Koppal, Jordan Racek, Simran Rohra, Akihiro Tan

DHL Innovation Marketing Team

Zineb Darkouch, Fnan Berhe, Philip Jensen, Susanne Lauer

Other Contributors

Hayley Absolom, Markus Doehn, Inka Goethe, Hendrik Guhlich, Emily Jaworski, Peer Labonte, Michael Lohmeier, Dr. Christina Pakusch, Lars Pappe, Niklas Ring, Teuta Saka, Maheen Saleh, Dr. Paul Schlinkert, Florian Schneider, Florian Schwarz, Gagandeep Seth, Daniel Siebeck, Bastiaan Snaterse, Tim Tetzlaff, Noah Tombs, Dr. Jessica Voss

Steering Committee

Irina Albanese

*Vice President Global Head CSI Innovation Centers,
DHL Customer Solutions & Innovation*

Thomas Dammann

*Vice President Sector Development,
DHL Customer Solutions & Innovation*

Dr. Klaus Dohrmann

*Vice President, Head of Innovation & Trend Research,
DHL Customer Solutions & Innovation*

Stefan Fuehner

*Vice President Strategy & Commercial Development,
DHL Customer Solutions & Innovation*

Homeira Kohlert

*Vice President Marketing,
DHL Customer Solutions & Innovation*

Special Thanks

Special thanks go to all our colleagues from the various DHL teams and divisions – Supply Chain, Express, Global Forwarding, Freight, eCommerce Solutions, and Post & Parcel Germany – who supported us with invaluable input and expertise. We additionally would like to thank our external partners, including consultancies and academia, for providing further valuable insights that shaped this edition of the Logistics Trend Radar. Furthermore, we would like to express our sincere thanks to all our customers, partners, and colleagues who visit our DHL Innovation Centers every year and share their knowledge in workshops, tours, events, and trend insights sessions.

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