LOGISTICS TREND RADAR 7.0

Insights. Shaping Tomorrow.

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Your guide to innovation in logistics.
AI & Sustainability in focus.

DHL TREND RESEARCH

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The DHL Logistics Trend Radar is an invaluable strategic resource for our customers and the logistics community. It consolidates key logistics trends, with artificial intelligence and sustainability taking the lead in this edition, driving the evolution of businesses, consumers, and technologies over the next decade.This empowers our customers and us to stay competitive in a demanding landscape.

KATJA BUSCH
CHIEF COMMERCIAL OFFICER AND HEAD OF DHL CUSTOMER SOLUTIONS & INNOVATION

Insights. Shaping Tomorrow.

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Today's professional climate is often called the "new normal," implying our world has changed significantly since the global pandemic. But this new state is not static. We are living in a period of constant transformation in society, business, and technology. Successful logistics organizations are responding powerfully to this by putting customers at the center of every action, aiming for supply chain excellence that is global, resilient and, above all, sustainable.

Over more than a decade, the DHL Logistics Trend Radar™ has become a recognized benchmark for strategy, innovation, and education, helping logistics professionals navigate ever-evolving landscapes and seize new opportunities. With this seventh edition, our commitment remains the same – to provide DHL customers, colleagues, and partners with valuable insights that reflect the direction of societies, businesses, and technologies, enabling the logistics community to shape tomorrow.

Shaping tomorrow requires innovation and collaboration. The DHL Logistics Trend Radar underscores the significance of both, enabling a deeper, shared understanding of emerging trends, anticipating future disruptions, and encouraging organizations to foster partnerships. Collaboration within and outside the industry is the most effective way to create and co-create groundbreaking solutions and proactively adapt strategies to stay ahead of the curve.

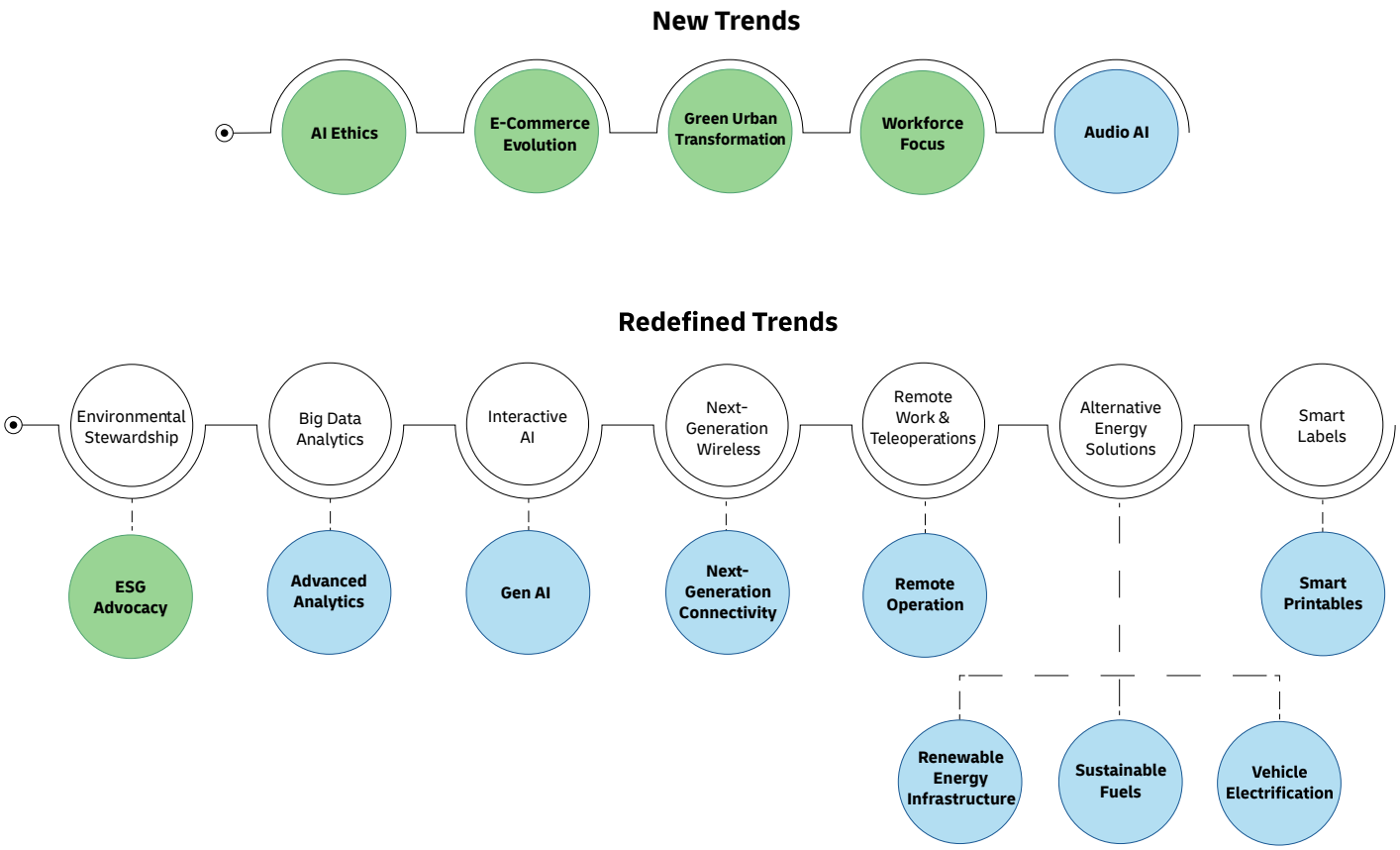
Please enjoy the discovery and inspiration of the latest trends influencing logistics. We welcome you to connect with the open DHL innovation ecosystem, and we look forward to shaping tomorrow together through true innovation – beyond potential.

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 publication of the previous edition of the Logistics Trend Radar in 2022, we have witnessed several relevant developments that influenced both trend adoption and trend impact. This has changed the position of some trends on the radar. Additionally, through countless engagements with customers, colleagues, and partners, we have identified new trends to drive enhanced discussions and accelerate collaboration on logistics innovation. Overall, this has altered the composition of this latest publication, the Logistics Trend Radar 7.0. There is more focus on trends identified with an adoption timescale of five years or less, as well as showcasing noteworthy developments in artificial intelligence (AI) and in sustainability.

The basis of the Logistics Trend Radar is DHL's customer-centric, integrated approach which 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.

LOGISTICS TREND RADAR 7.0
Overview of changes vs. 6.0



Graphic source: **DHL (2024)**

OUR INNOVATION APPROACH

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

We cultivate open conversations and engagement with our customers about business strategies, future needs, and challenges in order to validate ideas, develop use cases, and leverage technologies and expertise. We achieve success through strong customer buy-in and close collaboration across our innovation ecosystem.

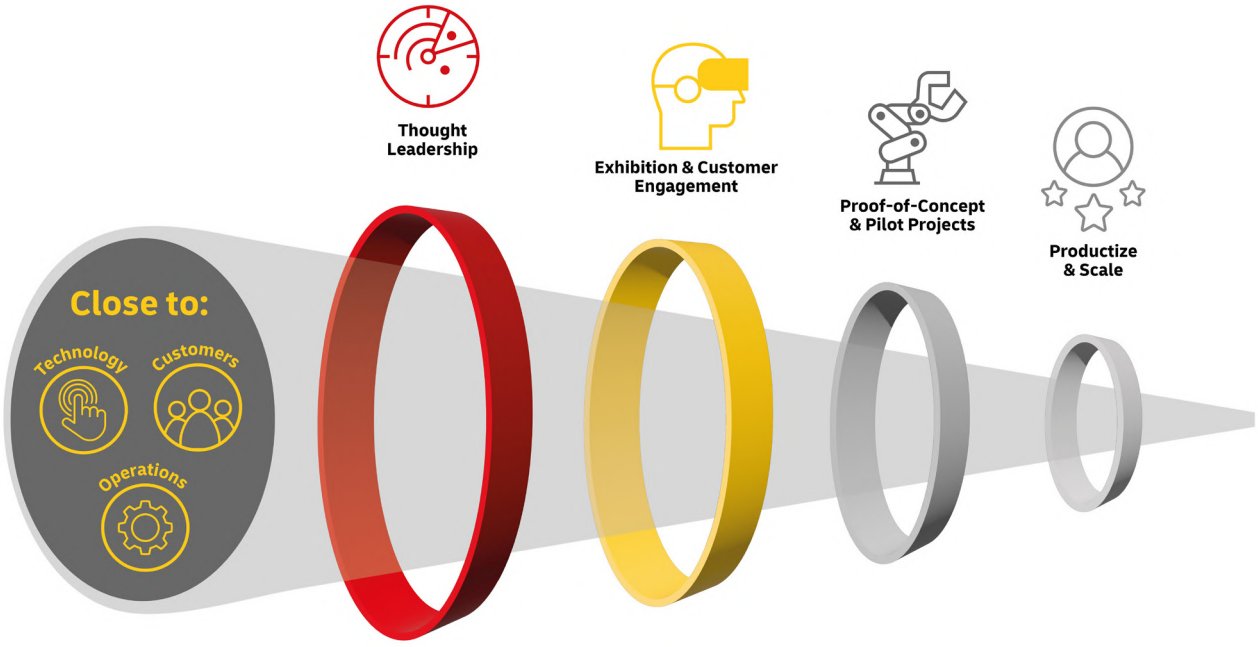
We are driving the transformation of logistics by tracking and engaging visionary developers and providers across industries and by staying at the forefront of emerging technology and supply chain innovation. This enables us to identify and co-create new solutions beneficial to our customers.

We leverage our own global DHL logistics operations to improve efficiency, quality, sustainability, and safety. Our commitment to spending substantial time on-site with facility managers and workers is testament to our dedication in visualizing and implementing solutions that yield benefits for both our valued customers and colleagues.

Our end-to-end innovation approach starts with thought leadership and continues through customer engagement, technology scouting, and research, all of which enables us to identify and understand technological breakthroughs.

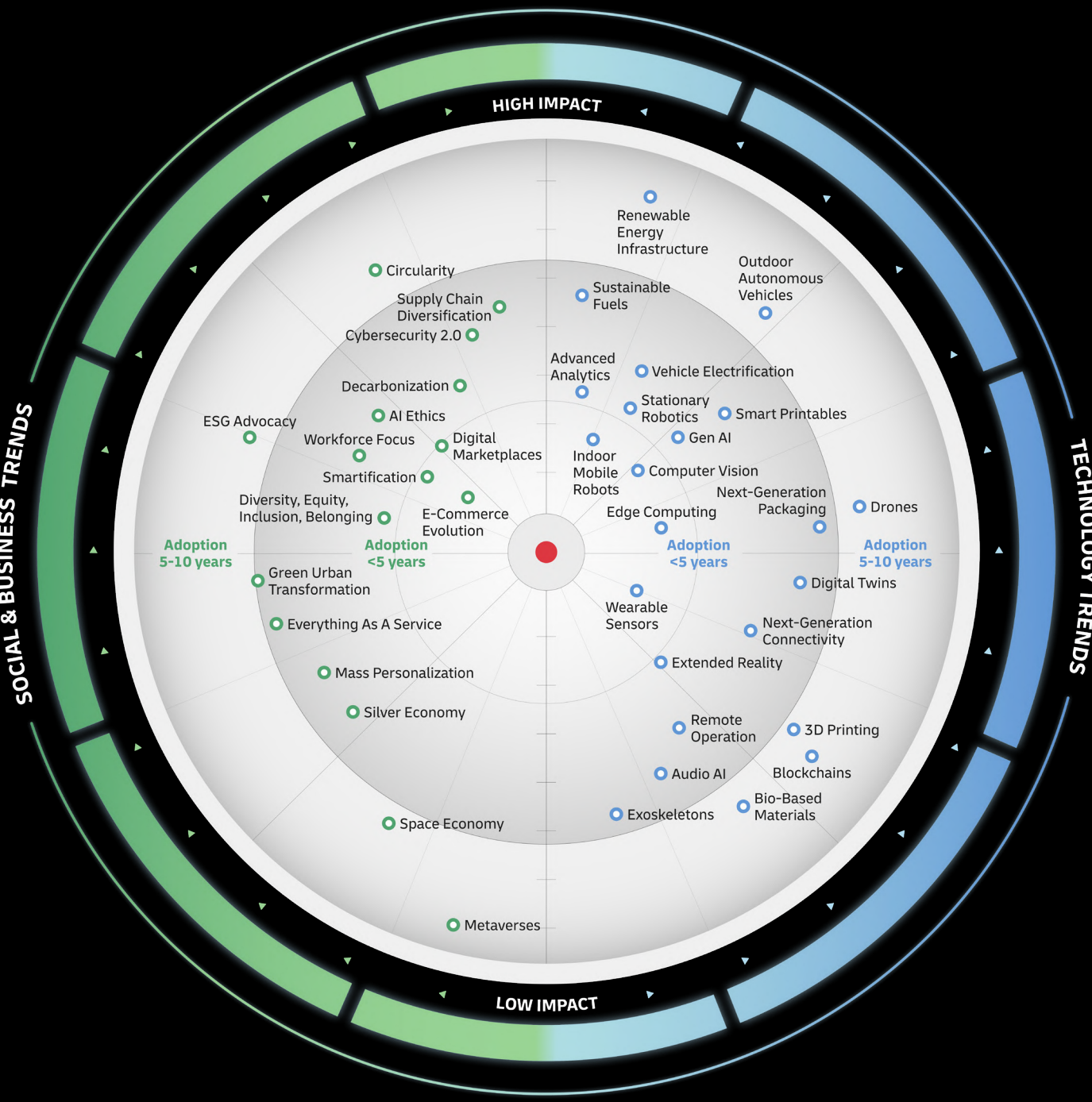
This is the foundation of the Logistics Trends Radar and of many other DHL thought leadership trend reports. With a finger on the pulse of relevant trends, we run proof-of-concept projects in real-world supply chain settings with our customers and within the DHL network of operations to fully understand application benefits and challenges. Successful projects open up opportunities for productization and scaling, so that these solutions are available internally across DHL operations and commercially to our customers.

DHL Trend Research Innovation Funnel



Graphic source: **DHL (2024)**

THE DHL LOGISTICS TREND RADAR 7.0



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

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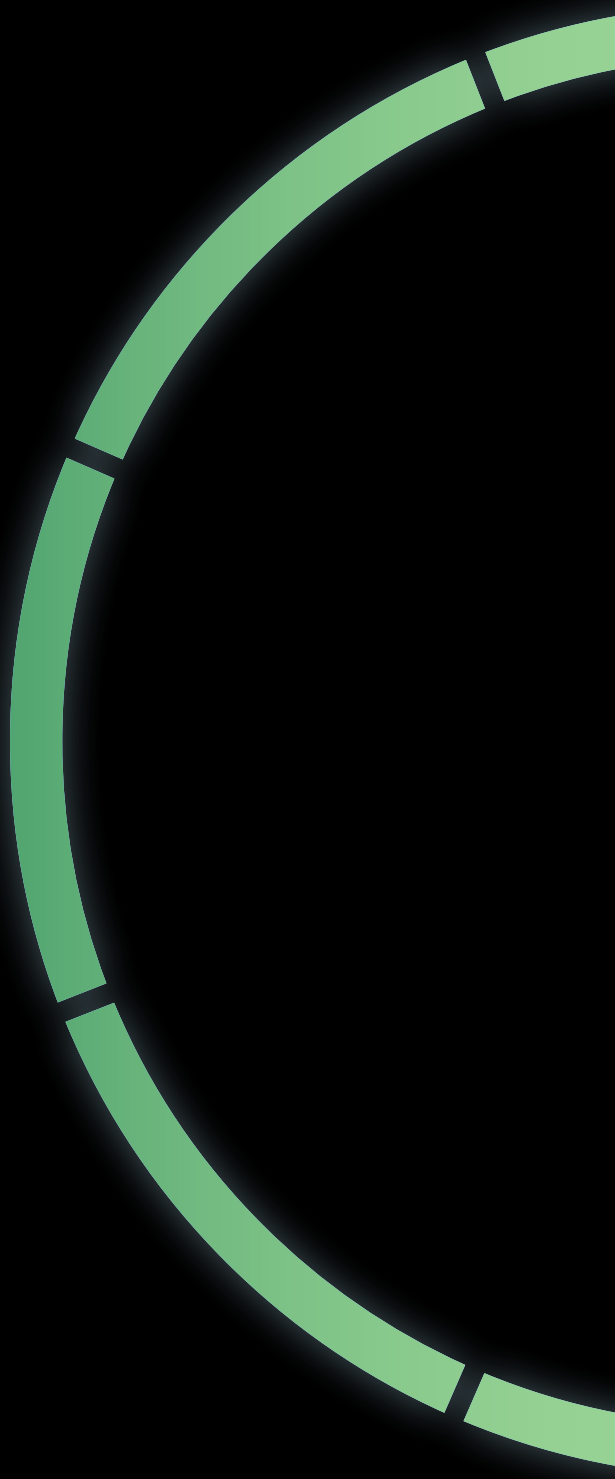
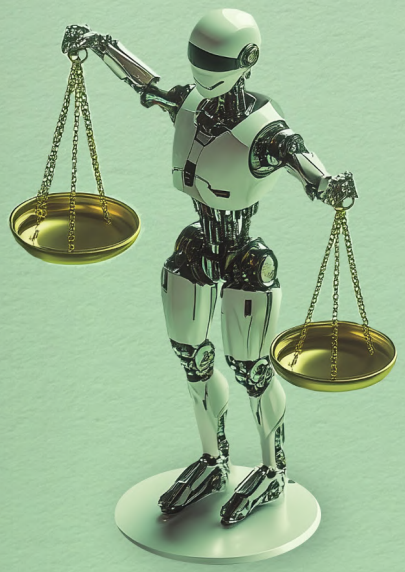




AI Ethics

The trend of Artificial Intelligence Ethics (AI Ethics) refers to the increasing focus on the ethical considerations and implications of AI technologies and ensuring their responsible development and deployment. Within this trend we also explore legislative developments of AI platforms, and the implications of data safety and algorithm security.

AI Ethics is an emerging field concerned with ensuring the responsible development, deployment, and use of AI technologies. Its development accelerated in response to growing public awareness of AI's ethical implications, fueled by high-profile incidents, debates around democratizing it, and developments in regulatory frameworks to address issues such as bias, privacy, explainability, and transparency in AI systems.

Topics to be addressed include explainability, trustworthiness, transparency, robustness, and interpretability. The trend plays a critical role in the logistics industry, especially around these topics, as the number of AI applications increases within logistics and the supply chain. In particular, data privacy concerns must be addressed and ethical use of AI platforms must be ensured.

As the topic of AI Ethics will impact most industries, this in turn will have significant impact on the logistics industry.

With increasing reliance on AI-powered systems for managing logistics operations, there's a growing need to address concerns regarding the privacy and security of sensitive data. AI ethics standards will emphasize the importance of robust data protection measures to safeguard customer information and proprietary data.

Company compliance regulations for employees have existed for decades. These must, however, be amended to also address compliant use of company data when AI is integrated with collaboration tools and with company portals. Here at DHL, we recognize company compliance regulations must align with national laws. This opens a new domain in the world of compliance and legal clauses/contractual obligations for employees.

Trustworthy & Explainable AI

Explainable AI is the ability to trace back an algorithm to the data that it is built on, and find the logical chain of association from secure and trustworthy data, and its traceable training, to build a deep learning algorithm. In this logic similar to a mathematical equation, we are able to determine and explain with high confidence the output of what AI has either generated or analyzed. Explainable AI can offer insights into the factors influencing demand forecasts, enabling better decision making and accountability. The explainability of those outputs is found in the processing of consumer data which, if tampered with, renders the output untrustworthy. Here we see an emphasis on the importance of data security and protection against cyberattack and hacking.

AI can be made explainable and trustworthy through understanding:

Intention: AI systems are constructed by humans to make decisions based on historical data or real-time information. Predetermined responses are embedded in the AI systems.

Intelligence: The ability to make intelligent decisions with AI systems is facilitated by combining machine learning and data analytics. AI isn't intelligent like a human being. Human intelligence is closest to what a machine can approximate.

Adaptivity: AI systems compile information to make decisions based on collecting and adapting to new information. AI systems can improve the outcome of decision making with information they learn from real-time data.

Ethical End User / Use

Consumer ethical behavior around the use of AI systems includes compliant and ethical content creation and not publishing deep fakes of any persons. Examples of this are the creation of deep fake videos of public figures posted with false messages about companies, governments, or other public entities. Such occurrences would involve hacking and accessing data which is "stolen" and not intended for use beyond approved groups of people, and using this data to generate untrustworthy outputs.

In logistics, employees have access to customer data, trade secrets, and other sensitive company information which can be used to build algorithms. Non-compliant behavior could stem from this. There is a growing need to implement robust measures to secure data processing and accessibility.

This can also be said for use cases such as AI-generated route optimization, or questioning outputs that appear biased or discriminatory. End users may report instances of bias to the relevant authorities or organizations encouraging the development of fairer algorithms and mitigating potential harm to marginalized groups. Some consumers actively engage in co-design processes or participate in feedback mechanisms to contribute to the development of more ethical AI systems. By sharing their perspectives, concerns, and values, all consumers can help shape AI technologies that align with ethical principles and better service diverse needs and interests.

AI Legislation & Democratization

General Data Protection Regulation (GDPR), applicable in the European Union (EU) and the European Economic Area (EEA), regulates the processing of data and imposes strict requirements on data controllers and processors. Logistics providers using AI systems must comply with GDPR principles, ensuring transparency, lawfulness, and fairness in the processing of all data.

> *The European Commission has published ethical guidelines for trustworthy AI, emphasizing principles such as fairness, transparency, accountability, and societal benefit.*

While not legally binding, these guidelines influence the development and deployment of AI systems in various sectors, including logistics. Other legislative implementations, such as the California Consumer Privacy Act (CCPA), underline the economic impact of AI and the need for regulatory measures to ensure ethical use. It is essential to keep pace. For example, in Singapore, government funding of $20 million Singapore dollars (US$15.3 million) now enables people aged above 40 to learn AI models.

Democratization of AI involves making AI technologies accessible, affordable, and easy to use for the widest range of individuals and organizations, irrespective of their technical expertise or financial resources. Key aspects of AI democratization include providing accessible tools and platforms, offering affordable pricing models, providing education and training opportunities, fostering community collaboration, and emphasizing ethical considerations in AI development and deployment.

The main branches of AI Ethics

Graphic source: **Based on DataCamp (2023): Explainable AI - Understanding and Trusting Machine Learning Models**

Challenges

- The logistics industry faces challenges related to algorithmic bias, which can lead to unfair treatment, inefficiencies, and discrimination in supply chain operations (sanctions and geopolitical events fuel public algorithms).
- Managing sensitive data within supply chains raises ethical dilemmas regarding data privacy, security, and ownership, particularly when AI systems are involved in data processing and analysis.
- Ensuring accountability and transparency in AI-driven decision-making processes within logistics requires clear mechanisms for understanding, auditing, and explaining the reasoning behind AI-generated recommendations and actions.

Outlook

Over the next five years, the logistics and supply chain industries are likely to face heightened regulatory scrutiny regarding AI Ethics, with governments and industry bodies introducing new laws, guidelines, and standards to address ethical concerns related to data privacy, algorithmic bias, and accountability in AI-driven logistics operations.

Companies operating in logistics and the supply chain are expected to increasingly adopt and implement ethical AI frameworks and best practices to mitigate risks, build trust with stakeholders, and ensure responsible AI deployment. This includes integrating principles such as fairness, transparency, accountability, and societal benefit into AI development, deployment, and use.

As awareness of AI Ethics grows, there will be a greater emphasis on ethical considerations throughout the supply chain, including sourcing, manufacturing, distribution, and customer engagement. Companies will leverage AI technologies to enhance supply chain visibility, traceability, and sustainability while addressing ethical concerns such as human rights violations, environmental impact, and employee welfare.

This trend should be carefully monitored with implementations available for many use cases today.

Related Trends

Sources:

YourStory (2024): Subsidy to Learn AI Models: Singapore Budget to Accommodate AI Learning for People Over 40

Circularity

The trend of Circularity aims to eliminate waste and pollution by considering the full product lifecycle in advance, designing and utilizing each item and its constituent parts to be returned in the supply chain. This trend seeks to reuse, repair, remanufacture, and recycle products as much as possible and, when these processes are no longer achievable, products are broken down into reusable components and raw materials and ultimately biodegraded.

There is gradual but unsteady progress towards a circular economy. Although 55% of large businesses have committed to circularity, more than half of their initiatives are narrowly confided to recycling or waste management. Many companies' strategies are not yet encompassing the full range of technologies and business models for a circular economy, for example, re-engineering products to last longer, embracing repairability, adopting leasing models, reducing virgin material use, and providing complementary services throughout the lifecycle of a product.

"The Circularity Gap Report reveals the vast majority of materials entering the economy over five years to 2023 were virgin, with the share of secondary materials declining from 9.1% to 7.2%."

However, new legislation is likely to strengthen progress. A good example of this is the European Commission's new rules on the 'right to repair' for consumers, which may incentivize companies to implement more sustainable solutions.

Circularity concepts require dramatic transformation of the processes of product design, production, and recycling, which is why the supply chain is a key enabler of this trend managing and moving flows of raw resources, goods, returns, and waste among a new network of users in a sustainable, circular manner. Circularity as a trend is therefore likely to significantly impact the logistics industry, with logistics players becoming essential sources of knowledge for the transfer of best practice across sectors. But current momentum to explore, invest in, and adopt circular products and solutions appears lacking. Hence, it will take considerable time for circularity to achieve maturity and widespread adoption along the supply chain.

The Rise of Recommerce

Industrial sectors, especially retail, are witnessing the rise of recommerce (also known as reverse commerce), in which previously owned products, new or used, are sold and shipped to buyers who then repair, reuse, recycle, and/or resell them, extending the lifespan of the product. This not only promotes sustainability but also reduces emissions associated with manufacturing new products.

This trend is evident in the smartphone sector, with the market for new smartphones falling by 3.2% in 2023. In contrast, International Data Corporation (IDC) estimated that global shipments of used smartphones, including officially refurbished and used smartphones, would reach 309.4 million units in 2023. This corresponds to an increase of 9.5% compared to the 282.6 million devices shipped in 2022.

This development is also evident in the e-retail and fashion sector; however, things are a bit more complex. While customer-to-customer (C2C) platforms like Vinted are growing, it remains uncertain whether large companies are committed to transitioning to a circular business model or if they view second-hand platforms as additional income sources only. In contrast to fast fashion giants, renowned for their mass production and affordability but often lacking a clear and dedicated recommerce strategy, the luxury sector has demonstrated notable advancements in this domain. Esteemed platforms like Vestiaire Collective, which is funded by luxury group Kering among others, are gaining increasing popularity by offering second-hand luxury goods such as bags and clothing. Furthermore, companies like Patagonia embrace recommerce as part of the business model, prioritizing circularity and sustainability. As the industry evolves, it is crucial for companies to consider the long-term environmental impact of their business models on the future of fashion.

Recommerce business models present challenges for all industries, especially in terms of goods inspection. Currently, this task is labor-intensive, although digital solutions, such as computer vision technology, may help in the future. However, used items typically have low profit margins, raising questions about the long-term viability of these business models.

The rise of recommerce impacts logistics in several ways. Instead of traditional return logistics, recommerce supply chains redirect return shipments to in-market repair, recycle, and/or resell channels, leading to more localized, yet complex supply chains.

Circular Packaging

In the context of circular packaging, plastic remains a significant concern. Over 90% of the 400.3 million tons of global plastics produced in 2022 was fossil-based. In the five preceding years, greener alternatives – mechanically recycled, chemically recycled, bio-based plastics, and carbon-captured plastics – increased only

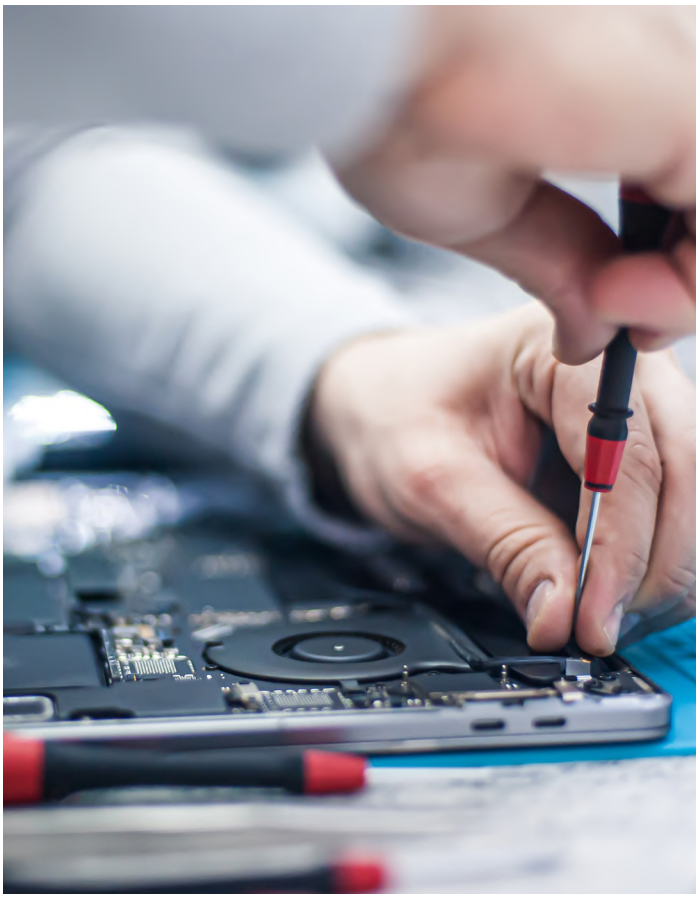
slightly from 8.4% to 9.4%. Targets for minimum recycled content in plastic packaging are under discussion – the Packaging and Packaging Waste Regulation (PPWR) of the European Union seeks 30% by 2030 and 50% by 2040 for contact-sensitive plastic packaging, excluding single-use plastic beverage bottles. Compostable plastic packaging and packaging with less than 5% plastic content are also included in the targets.

Existing solutions like refillable options for consumer goods and compostable, bio-based packaging in the e-retail and fashion sectors demonstrate the potential of circular packaging but are not widely implemented. What's needed are convenient and incentivized takeback processes that are as convenient as discarding the packaging.

In logistics, implementation of circular packaging requires comprehensive visibility of supply chain processes to ensure the appropriate distribution of packaging across warehouses and production facilities. Also, existing transportation capacity must be fully utilized, leveraging existing delivery routes to minimize carbon emissions and costs.

Forming win-win partnerships across the value chain helps de-risk circularity investments. Key challenges include significant upfront costs and the costs of returning and cleaning circular packaging, both of which limit solution scalability. Clearly, price points remain a crucial barrier to widespread adoption of circular packaging.

Reverse Logistics



As more companies around the world join the circular economy to reduce waste and save costs, they will be reexamining and redesigning their supply chains to conform to circularity principles. For organizations in logistics, from those handling storage to those delivering in the last mile, this can mean sizeable shifts in operations and a focus on so-called reverse logistics offerings. Next to running warehouses and moving goods, logistics providers may see increased demand for value-adding services for products and materials they currently do not carry.

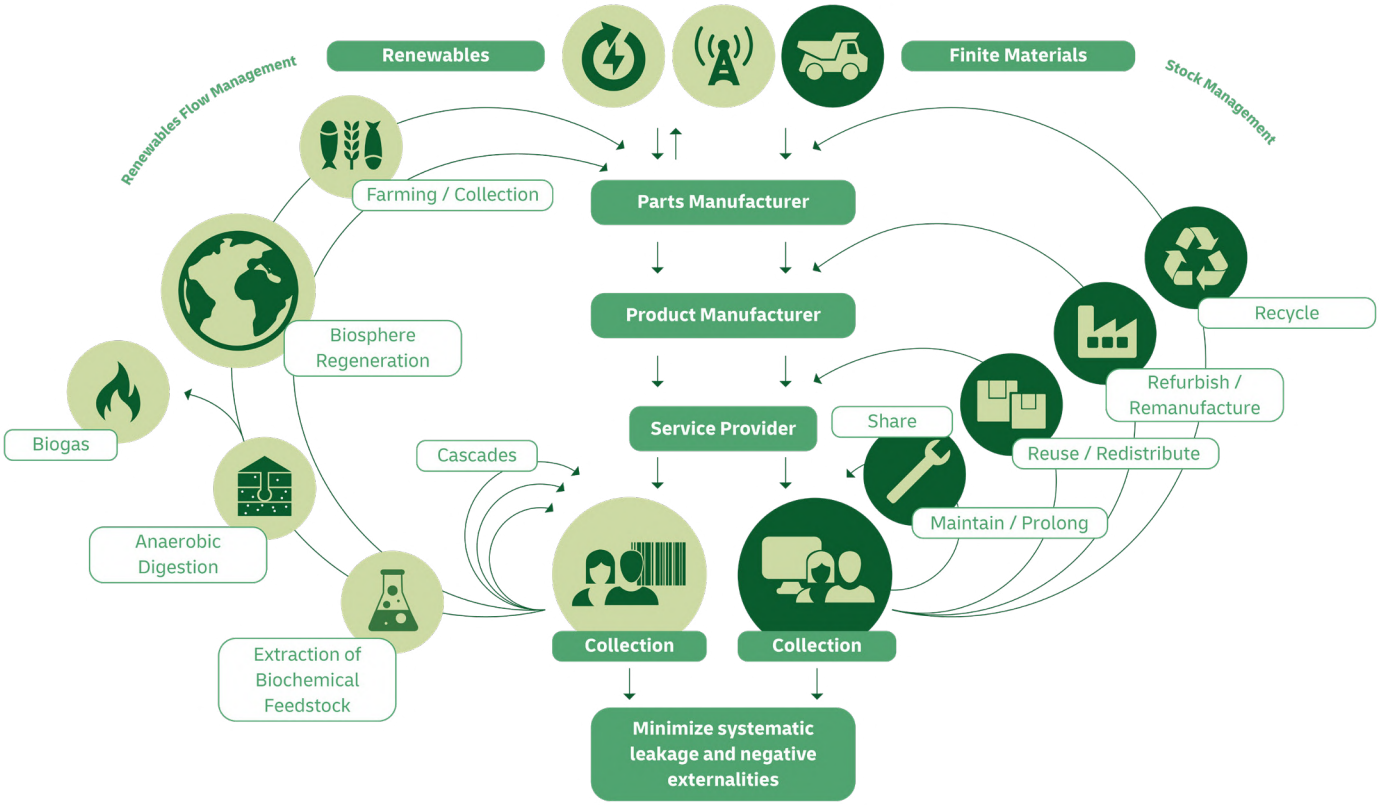
As mentioned above, circularity is boosted by the European Commission's legislation giving consumers the 'right to repair'. Consumers can save costs, as the law entitles them to repair during and after the legal guarantee period and are allowed to repair products themselves. For logistics and supply chain managers, this increases the need for accessible spare parts, repair manuals, and information on reparability, while

considering business concerns about intellectual property rights and professional repair services. Additionally, warehouses may see a greater throughput of secondary raw materials like fabric scrap or reprocessed lubricants and may need to reconfigure facility floorspace and operations to unload, store, and load more of these products.

Taking the complex example of damaged electric vehicle (EV) lithium batteries, logistics service providers must establish specialized expertise in reverse logistics to ensure compliance with local, regional, and global regulations on transportation. This entails comprehensive considerations for battery management, storage, and handling to guarantee adherence to regulatory requirements.

Overall, circularity and in particular the demand for reverse logistics solutions will bring changes and value-adding opportunities to local and global supply chains. The logistics industry needs to anticipate and prepare for this.

The Butterfly Diagram: Visualizing the Circular Economy system and material flows



Graphic source: **DHL Group (2024): Era of Sustainable Logistics Whitepaper**

SUMMARY & TREND OVERVIEW

Challenges

- Most products are not currently designed for reuse and recycling, limiting their ability to achieve circularity principles.
- The inhibition threshold for end customers to change their own lifestyle and actively participate in circularity is high.
- Coordinated visibility and transparency of products and their components is crucial for redirecting waste as raw materials, but data is currently severely limited, hampering attempts to close loops across supply chains.
- Changes in the supply chain set-up for companies to implement, such as circular packaging solutions, can be complex, very expensive, and take time.
- Smart, affordable, and convenient return solutions are not available everywhere, so recycling can be more expensive than using primary raw materials.

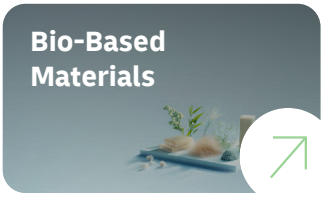
Outlook

As the right to repair becomes ratified by legislation, companies must prioritize repairable, sustainable product design, provide spare parts and repair information, and encourage consumer engagement in circular practices.

Supporting all this is the logistics industry as the backbone of circularity. Logistics service providers must adapt their capabilities, invest in technology, and collaborate to facilitate repair, refurbishment, and recycling. This also includes the development of new logistics service offerings.

This trend should be actively monitored with developments and use cases on the horizon.

Related Trends



DHL Resources

Return to Sender?
Reverse Logistics Explained

Whitepaper: Delivering on Circularity

Sources:

Bain & Company (2023): 55% of large businesses have made circularity commitments, but linear mindset is holding back progress;
Circle Economy Foundation (2024): The Circularity Gap Report;
International Data Corporation (2024): Worldwide Market for Used Smartphones Is Forecast to Surpass 430 Million Units with a Market Value of $109.7 Billion in 2027;
Plastics Europe (2024): Plastics – the *fast* Facts 2023

Cybersecurity 2.0

The trend of Cybersecurity 2.0 encompasses the next generation of solutions, processes, and standard operating rules and regulations that leverage artificial intelligence (AI) and other advanced technologies and ways of working against cyberthreats. It involves protection, detection, and response tools that not only prevent attacks but also actively predict and autonomously detect threats and respond to attacks.

Due to their critical role, logistics networks are a prime target for cyberattacks. Across the entire supply chain, technological advances in generative AI, quantum computing, and more represent an increasing challenge to traditional protection and encryption methods. Attackers seek to compromise the weakest link in supply chains, which could be a software supplier or hardware manufacturer whose products are used within the infrastructure. Meanwhile, increased usage of digital infrastructure, pervasive connectivity, and convergence expose previously isolated assets in operations (operational technology).

Not only cybersecurity teams but also every logistics professional must be vigilant. Major risks include ransomware, AI attacks, malware, denial of service, information manipulation and interference, and attempts to convince employees to share confidential information (known as social engineering). Moreover, increasingly sophisticated hacking makes it difficult to detect the launching of “dark” services such as FraudGPT and WormGPT.

Cyberattacks can significantly impact logistics organizations. Importantly, such an impact can reverberate throughout the entire supply chain, creating a ripple effect that can cause up to 26 times the loss for a company’s business ecosystem. For this reason, the trend of Cybersecurity 2.0 will undoubtedly play a pivotal role in ensuring the resilience and security of organizations in all sectors.

Here at DHL, we recognize the transportation sector is a prime target for ransomware due to its critical role in the supply chain. As logistics operations are heavily driven by digital applications and integration, enabling global reach within the supply chain ecosystem, any threat to these core tools could devastate the entire ecosystem and flow of goods.

Increases in vast data sets from the rise in Internet of Things (IoT) implementations provide attackers with a ready supply of data to sell or exploit. And just as AI and automation are helping logistics companies be more efficient, cybercriminals are using these capabilities in attacks which are increasingly hard to detect and manage.

As risks increase in the supply chain, the growing demand for skilled cybersecurity professionals outpaces the supply of qualified candidates.

RELEVANCE TO THE FUTURE OF LOGISTICS

Rise of Cybercrime in Logistics

The logistics industry is identified as being among the top 10 sectors impacted by cybercrime worldwide, as it is one of the most globally connected industries. While digitalization brings advantages, the dynamic transformation of systems can leave some security factors unconsidered. Outdated servers, unpatched systems, and knowledge gaps between employees equate to cracks in the IT infrastructure which provide loopholes for cyberattack. As this applies to all aspects of the industry, including maritime, rail, trucking, supply chain, and last-mile delivery, the potential expense of this risk is high and can disrupt global supplies, while also introducing additional liabilities like the theft of sensitive customer data during a cyberattack.

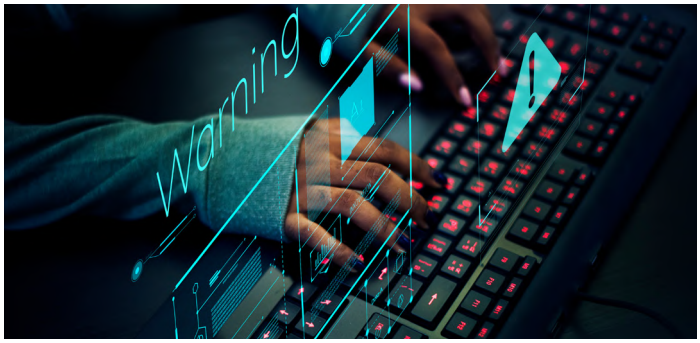
Massive losses are incurred by owners when ransomware cyberattacks compromise system access.

> *In 2023, the average cost of a security data breach was US$ 4.45 million. The cost for cybersecurity breaches across the board is expected to grow to almost $10.5 trillion by 2025.*

Cybersecurity 2.0 solutions, processes, rules, and regulations will help protect organizations from such losses, while also protecting brand reputation and customer loyalty.
Companies can use AI and machine learning (ML) to identify the unusual patterns and anomalies that indicate potential cyberattack. To mitigate damage, these technologies can quickly adapt to new threats and automate response actions.

Companies can also use behavioral analytics to monitor user and network behavior, detecting the deviations from normal activity that signal potential security breaches. And automated systems are available to rapidly disseminate threat intelligence, enabling a faster response to any emerging threat.

Anticipation & Resilience



While digitalization and new technologies create business efficiencies, the growth of (e-commerce) platforms and the masses of data being stored in the cloud increase the need for cybersecurity. Anticipating cyberattacks on these platforms not only secures suppliers but also the private data of their customers. Although logistics and the supply chain continue to operate in a very hands-on manner through the physical movement of products, this requires a significant volume of data processing and information sharing along the supply chain. The typically disparate network of parties involved in the supply chain creates more ways for would-be attackers to identify weak links in cybersecurity.

It is vitally important for logistics organizations to increase cybercrime resilience by implementing a strong digital backbone and by staying up to date with the cyberthreat landscape. The impact of IT system vulnerabilities on business processes, products, employees, and customers alike must be constantly monitored to preserve the value chain, keep the global supply chain moving, and ensure a position of cyber resilience.

Cybersecurity 2.0 brings various AI and ML tools to the table for threat monitoring and resilience within organizations. For example, continuous monitoring and real-time analytics enable security information and event management (SIEM) systems to aggregate and scrutinize activity from various resources across the IT infrastructure and analyze hardware and application security alerts. In addition, an intrusion detection and prevention system (IDPS) can monitor networks and systems for malicious activity or policy violation, taking action in real time to prevent intrusion.

Another valuable tool is vulnerability management. Regular vulnerability scanning of IT systems helps identify weaknesses that attackers could exploit. Also, automated patch management solutions keep systems up to date with the latest security patches, reducing the window of attack opportunity.

Incident response management is another effective method. Automated incident response solutions such as a security orchestration, automation, and response (SOAR) solution can automate responses to detect threats. This reduces response times and helps mitigate damage. A further tool is threat intelligence and analysis using a threat intelligence platform (TIP) to collect and analyze threat data from various sources. This provides insights into emerging threats and helps the organization proactively defend against potential attacks.

Cybersecurity in Operations

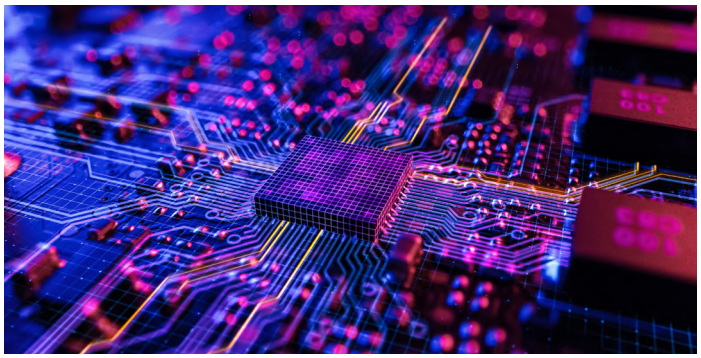
As intelligent security expands in operations through the adoption of technologies such as computer vision, IoT devices, and AI-powered autonomous surveillance systems, so too does the possibility of cyberattack. In addition, the level of risk increases when these technologies are deployed in cloud-based solutions which capture customer data and data generated by the logistics infrastructure, automated warehouses, transportation networks, and other logistics operations.

Many operational technology (OT) devices can be deployed in the supply chain to improve visibility and for process optimization. However, these technologies and automation systems may represent a back door through which cybercriminals can access the enterprise system. Cybersecurity within the software supply chain must be increased and constantly monitored up to second and third tier levels to protect the organization from attack through these OT devices.

There are several key areas where cybersecurity needs to ensure the integrity, reliability, and efficiency of devices and technologies. For example, a supervisory control and data acquisition (SCADA) system can control critical supply chain infrastructure including energy management and manufacturing processes. Robust authentication, encryption, and regulatory security updates are required to secure the SCADA system. Another example is separating or segmenting the IT network from the operational technology network to prevent a breach in one impacting the other. Companies can use firewalls, virtual local area networks (VLANs), and dedicated communications channels, actively monitoring these in real time.

Further examples include supply chain IoT devices such as sensors and smart trackers that need to be secured against cyberthreats. These require strong authentication and regular firmware updates. Mobile and edge devices are also being used in the supply chain and these need to be protected through encryption, secure authentication, and remote management capabilities. Another area is the security information and event management (SIEM) systems that can collect and analyze log data from various sources within the OT environment for real-time detection and response to security incidents.

Quantum Computing & Data Protection

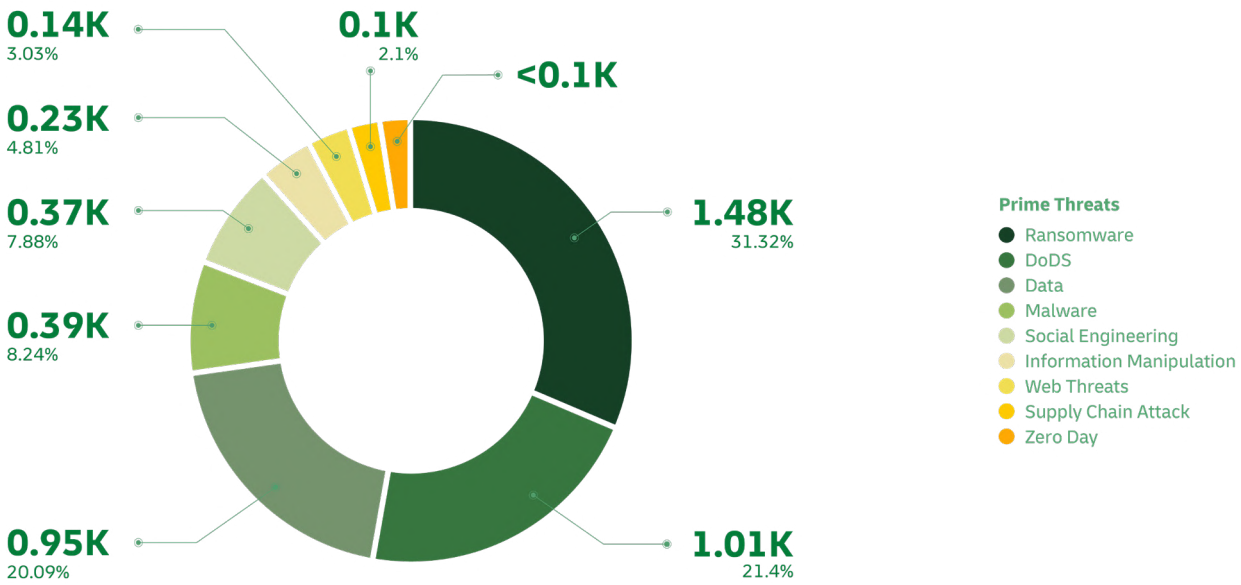


Quantum computing can provide an extra layer of digital privacy and security to counteract hacking. For example, quantum mechanics principles can be used to create almost unbreakable cryptographic keys and ensure secure communication channels resistant to quantum attacks. Quantum computing can accelerate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

However, quantum computers can also accelerate hacking, and this puts the enterprise and cybercriminals in a race for the upper hand. Quantum computing is therefore a double-edged sword, advancing opportunities for cybersecurity practitioners and raising risks in the cybersecurity environment at the same time. Although quantum computers are not yet commercially available, once they materialize and fully mature, attackers are likely to use them to break some current cryptographic systems.

Organizations are recommended to prepare for the quantum computing era by assessing their current cybersecurity position and developing transition plans. This should include evaluating the readiness of existing systems and infrastructure for quantum-safe solutions.

Number of incidents by threat type (July 2022-June 2023)



Graphic source: **ENISA (2023): ENISA Threat Landscape 2023**

SUMMARY & TREND OVERVIEW

Challenges

- Humans are the first line of cyberattack defense, so the organization must dedicate sufficient cybersecurity resources and provide ongoing employee training, reminding personnel how to remain alert to threats and, if necessary, conducting special exercises such as sporadically imitating phishing attempts.
- Responding to the increased availability of technology interfaces, fueled by AI, the organization needs a much larger pool of educated and knowledgeable cybersecurity personnel but these specialists may not be readily available.
- Companies must invest more because defense against cyberattack is becoming more costly, complex, and tech-heavy.

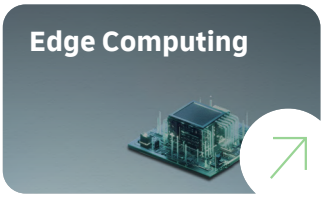
Outlook

The logistics cyberthreat landscape is increasing and becoming more complex with the arrival of new, improved technologies. For every company, cybersecurity and threat detection must be foundational to secure operations and protect all resources, with focus in the software value chain to more tiers, protecting the organization's suppliers and partners as well.

Cybersecurity 2.0 offers a comprehensive approach to navigate ever-evolving cyberthreat landscapes. By prioritizing prevention, detection, and response, the organization can safeguard its data, systems, and reputation in these challenging times.

This trend should be actively monitored with use cases in some applications that can already be addressed today.

Related Trends



Sources:
IBM (2023): Cost of a Data Breach Report 2023

Decarbonization

The trend of Decarbonization is the movement towards reducing the amount of carbon dioxide (CO_2) and carbon dioxide equivalents (CO_2e) in the atmosphere. Decarbonization involves burning less fuel for the same transportation operations and burning clean by increasing the share of clean, carbon-neutral transportation movements with the aim of reaching carbon neutrality and ultimately reaching carbon neutrality and to ultimately reach carbon negative operations.

With international concern about climate change and numerous new policy initiatives and regulatory obligations such as the European Council Green Deal and the European Union (EU) Sustainable Finance Disclosure Regulation (SFDR), the pressure is on organizations to decarbonize. This is particularly true for logistics – supply chains generate around 60% of all carbon emissions globally, about 80-90% of a product's emissions derive from its supply chain, and logistics accounts for ~10% of global greenhouse gas (GHG) emissions. Therefore, it is crucial for logistics organizations to decarbonize their operations and remain competitive.

The Decarbonization trend has high impact as practically all segments of the supply chain must change to eliminate CO_2e emissions from operations. However, while many business-to-business (B2B) and business-to-consumer (B2C) organizations and other companies have set zero emissions targets and are taking important steps, more progress is needed to decarbonize the supply chain. The development of this trend is expected to accelerate once regulations require disclosure of the carbon footprint of products and services, particularly as this will create an important point of comparison and competition between organizations.

Carbon Accounting & Tracking

Today, comprehensive accounting of Scope 1, 2, and 3 product emissions (direct, indirect, and upstream and downstream, respectively) remains a challenge. Many businesses, including logistics organizations, do not account for these emissions at all. The ones that do may rely on various secondary sources of carbon calculation with generalized values and assumptions, and often fail to factor in emissions by second-tier and third-tier players. This makes it difficult for B2B and B2C customers to accurately compare and choose suppliers and service providers that meet their environmental standards, especially when evaluating on a product-level basis.

However, steps are being taken to address this customer need. For organizations that currently struggle with carbon accounting, partners like DHL offer carbon calculators, estimates, and externally verified reports. This enables companies to account for Scope 3 emissions from a single shipment across all trade lanes, including data from third-party service providers.

Transparency holds the key as achieving visibility will likely stimulate compliance across all value chains and sectors. This in turn will ensure dependable comparisons between all players in the supply chain. Part of the World Business Council for Sustainable Development (WBCSD), the Partnership for Carbon Transparency (PACT) organization has developed a suitable framework which increases transparency, enables uniform calculation, and allows product-level emissions data to be shared across all value chains and sectors.

Besides that, more regulations and standards are being introduced, contributing to a future global framework for carbon accounting. These include the Greenhouse Gas (GHG) Protocol, ISO 14064 standard, and Carbon Disclosure Project (CDP) as well as recent regional examples include the EU SFDR and California Climate Corporate Data Accountability Act (CCDAA).

In future, more granular data will be obtained. Carbon accounting software platforms like Sage Earth can help companies maintain compliance and accuracy by translating financial data into a measurable carbon footprint. And the use of carbon calculators, estimates, and externally verified reports provides further transparency in carbon accounting and reporting. As sensor technology rapidly permeates the supply chain, it will be possible to accurately calculate and track this at shipment level and even product level. With this sensor data, logistics will not only provide companies with more accurate carbon footprint figures but also identify areas along the supply chain for decarbonization improvements.

Green Laws & Regulations

Greater awareness of climate change is pushing policy makers to do more, and citizens are increasingly supportive of this, although environmental protection measures may raise the cost of living. Logistics

organizations should anticipate new regulations, prepare for compliance, and recognize the opportunity for first-mover advantage.

Transportation is profoundly impacted by electrification legislation which is rapidly developing. It incentivizes the production and purchase of electric vehicles (EVs) and in some cases even bans the use of combustion engines. Examples include the US Inflation Reduction Act providing EV incentives, China's New Energy Vehicle (NEV) mandate ensuring automaker production levels, and the UK's Road to Zero Strategy cleaning up road transport by 2030.

Another crucial lever in the decarbonization of the supply chain is packaging, given its pollution potential, resource utilization, and carbon footprint. Many regulations aim to minimize harm from non-recycled material leaking into the environment, decrease greenhouse gas emissions associated with packaging functions, and improve the circularity of recycled materials throughout the supply chain.

The EU's Packaging Directive sets recovery and recycling targets for packaging waste and encourages minimization of packaging volume and weight, designing for reuse and recycling, and reducing hazardous substances in packaging materials. California's Rigid Plastic Packaging Container (RPPC) law mandates these containers have recycled post-consumer content, are reusable, or are sourced from recycling programs. In Japan, the Containers and Packaging Recycling Act requires businesses to sort and recycle containers and packaging. Manufacturers and importers of products are responsible for packaging recycling, which promotes the effective use of resources.

"Decarbonization is also supported by the rise of zero-emission zones (ZEZs), designated areas restricting or banning vehicles that emit pollutants. These zones help cut emissions, improve air quality, reduce noise, and encourage the use of clean transportation alternatives like electric vehicles, bicycles, and public transport."

Norway's capital city Oslo; as an example; has implemented a car-free zone with the intention of achieving a fully electric taxi system. The city also employs a combination of toll rings and differentiated parking fees based on vehicle emissions. Also, the Californian city of Santa Monica now has a Zero Emission Delivery Zone where electric delivery vehicles, cargo bikes, and walking deliveries are prioritized. In summary, rules and regulations are increasingly affecting all parts of the supply chain.

Optimizing Operations

As supply chains are responsible for around 60% of global CO_2 emissions, there is significant scope for improvement in logistics operations. Logistics organizations need to understand the carbon impact of each facet of their operations as the foundation to drive change and accurately track results.

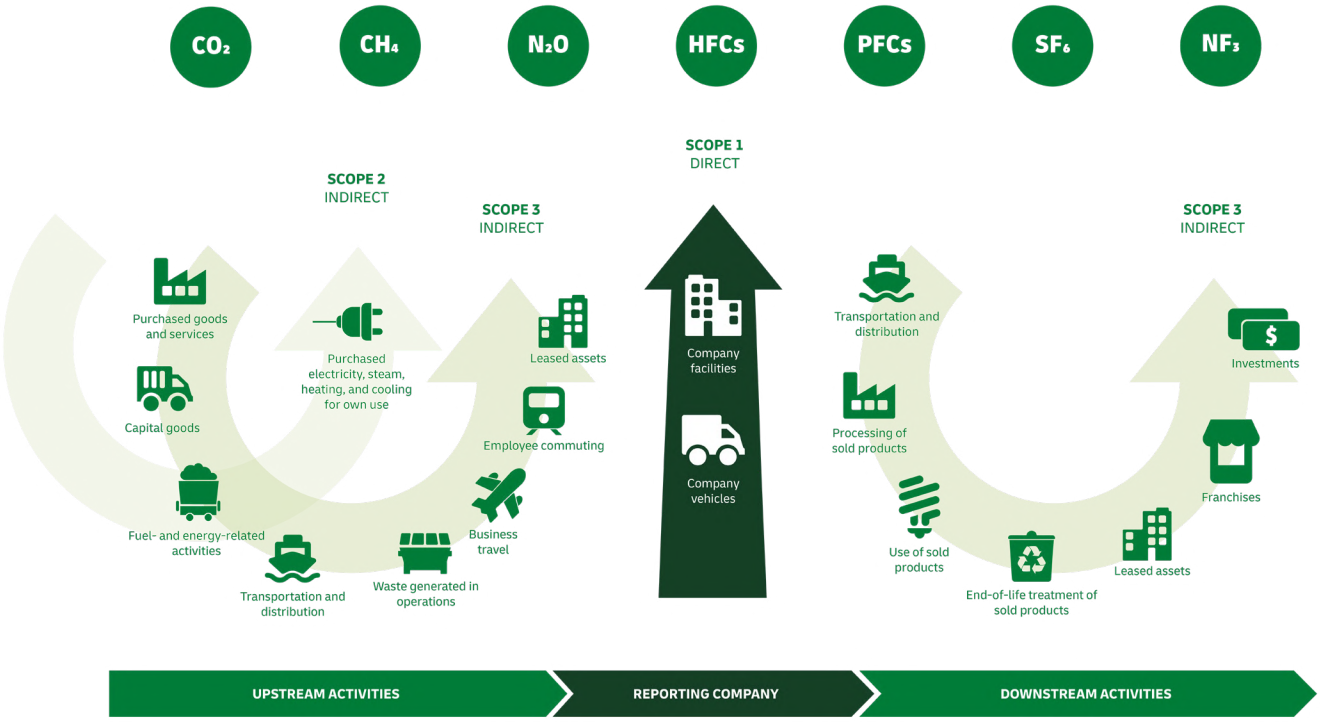
Available levers to achieve carbon reduction and eventually neutrality include electrification, carbon-neutral building design, and sustainable fuel sources such as liquified natural gas, sustainable aviation and maritime fuels and hydrogen power cells . Logistics organizations can also cut emissions by optimizing theand rail instead of air and truck is more carbonefficient, if time-to-delivery can be extended.

RELEVANCE TO THE FUTURE OF LOGISTICS

Measuring the total delivery time travelled and determining optimal routing for last-mile fleets is another way to shrink the carbon footprint. The German software developer Greenplan provides ways to track, measure, and evaluate the carbon impact of logistics activities. A further way to optimize operations is to ensure logistics facilities are carbon neutral. At DHL, we aim to leverage the latest green technologies to have carbon neutral buildings across our businesses worldwide. Back in 2021, DHL pledged to design all new buildings with a zero-carbon footprint, increase green electricity and heating, fuel e-vehicle fleets with local renewable sources, and implement smart facility management systems.

The initial costs of these and other environmentally friendly solutions may be higher than wasteful alternatives. But customers demand greater sustainability in the supply chain. As CO2e emissions become more identifiable, commoditized, and framed as operating costs, logistics players are finding ways to make the necessary investments while also reducing the financial and environmental cost of logistics operations.

Scope 1, 2, and 3 emissions, as according to the GHG Protocol corporate standards. They encompass all activities upstream and downstream of a reporting company.



Graphic source: **Greenhouse Gas Protocol (2013): Technical Guidance for Calculating Scope 3 Emissions**

SUMMARY & TREND OVERVIEW

Challenges

- Standardized carbon accounting practices are not yet global and legislation continues to develop around emissions and offsetting.
- As it is hard to predict the ramifications of policies and regulations, financial risk is involved in technology and new market selection.
- Inconsistent, generalized, decentralized, and opaque data may be used to calculate product carbon footprints (PCFs) and logistics emissions; this makes it difficult to assess and compare values.
- Decarbonization solutions often require heavy upfront investment and potential implementation downtime.
- Economies of scale in decarbonization solution investments are not yet available to logistics providers, so customers may have to pay more for products and services.

Outlook

The social and regulatory pressure to be carbon neutral or even negative pressure on logistics to be stronger today than ever before. More than 4,000 businesses around the world are already working with Science Based Targets initiative to achieve corporate climate pledges and reduce emissions in line with the Paris Agreement goals.

Given that supply chains lie at the heart of decarbonization conversations and agendas, it is imperative for logistics organizations to make the necessary moves early. Now is the time to adapt to decarbonization changes, ensuring the supply chain operates and delivers effectively in this era of sustainability.

This trend should be actively monitored with use cases in some applications that can already be addressed today.

Related Trends

DHL Resources

- Yellow goes green: DHL's 2050 sustainability commitment
- DHL Express' roadmap to decarbonization
- Decarbonization levers: the far-distant future is here
- Carbon Neutral Buildings

Sources:

Accenture (2023): How supply chain sustainability;
helps unlock resilience and growth;
DHL (2023): The Report – A retrospective on the Era of Sustainable Logistics

Diversity, Equity, Inclusion, Belonging

The trend of Diversity, Equity, Inclusion, Belonging (DEIB) refers to four concepts that work jointly to bolster the effectiveness, productivity, dynamics, and creativity of an organization while ensuring individuals have equal opportunities and feel valued. Guided by mutual respect, trust, openness, and honesty, this trend both encompasses and extends beyond the borders of gender, race, religion, age, different ability, sexual orientation, national origin, and other characteristics protected by law.

One of the most rapidly developing social and business trends in the last four years, DEIB has evolved from diversity and inclusion to now also recognize individuals as being a long-term, integral part of the organization. This is the frame in which employment seekers consider potential employers.

Companies cultivate DEIB as part of corporate culture as it helps attract and retain talent and boost employee performance. Here at DHL, we additionally see this trend developing from the individual level to the organizational level.

The imminent realization of this trend shows people and companies understand the importance of increasing DEIB.

Within logistics and the supply chain – previously predominantly male domains – there is growing recognition of the benefits of greater diversity at operational and leadership levels, especially as this alters the ways in which team members interact within the workplace. Employee engagement increases as inclusion is realized and, in turn, this increases the need to belong – which can be seen both as a "longing to be" and "being for long," an affective and sequential dimension that delivers psychological safety. Ultimately, inclusion and belonging lead to better corporate results.

When employees see their employer prioritizes DEIB, especially the belonging dimension, they are less likely to leave. Among a range of other benefits, research shows organizations that promote and support DEIB are 2.6 times more likely to increase employee engagement and improve retention.

In the US, the annual cost of workplace bias is projected at US$ 64 billion. This estimate is based on the expense of losing and replacing more than 2 million workers due to unfairness and discrimination – a key consideration for organizations seeking competitive advantage.

Supplier Diversity

In recent years, there has been a significant rise in companies preferring to trade and do business with diverse companies. Vendor selection and the process of auditing a potential supplier now focus more keenly on social responsibility and enabling minority-owned businesses to thrive.

Companies use supplier diversity programs to unlock new value; for example, to drive vendor competition, enhance brand perception, encourage innovation, positively impact the local economy, and improve the bottom line. In logistics, considerations are increasingly influencing vendor selection processes, with companies prioritizing partnerships with vendors that demonstrate a commitment to diversity and equity practices.

> *These programs also help promote diversity across each company's ecosystem. Research suggests industry-leading companies globally are aware of this, as they have committed more than $50 billion to partner with minority- and women-owned business enterprises (MWBEs) in the next decade. Further boosting the economy, MWBEs are 67% more likely to employ minority talent and develop these people into higher positions.*

According to McKinsey, if spending with certified MWBEs doubled, so $2 trillion rather than the current $1 trillion, this could generate $280 billion in additional income and 4 million jobs for minority populations and women. Corporations have the potential to add value and help boost the global economy by prioritizing MWBE vendor selection. According to Gitnux, compared to companies that don't have diverse suppliers, companies that do show a 133% greater return on procurement investments. This indicates the potential benefits of supplier diversity. Being more inclusive with its suppliers also allows the organization to reach a wider audience.

Clearly, vendor diversity benefits everyone. Companies gain new value and businesses run by minorities and by women gain new opportunities.

Diversity in Leadership

Diversity in leadership enables greater depth and breadth of experience, perspective, and knowledge; by sharing this, leaders are better able to relate to employees, partners, customers, and prospective customers. This, in turn, helps the business to grow. It also facilitates change and fosters innovation so the organization can retain and build market position.

Seeing diversity in the leadership team acts as a catalyst that empowers and enables the entire organization. For example, having women in leadership in predominantly male-dominant industries such as logistics positively changes the perspective of other female employees. The same applies when leadership roles are filled by people from minority groups – those of different races, religions, abilities, sexual orientation, national origin, and other previously underrepresented groups. Within these companies, everyone feels encouraged to bring their skills and talents to the workplace.

RELEVANCE TO THE FUTURE OF LOGISTICS

The leadership team must come together to make collective decisions during times of challenge and uncertainty. When this team is diverse – representing a rich kaleidoscope of perspectives, different vantage points, and wide-ranging experiences – conversations are more candid and decisions more innovative.

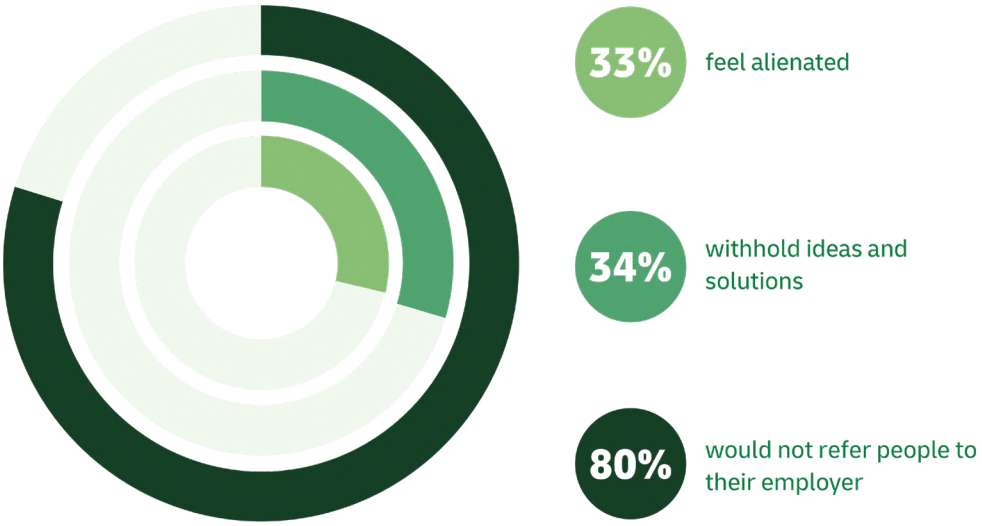
Talent Inclusion Through Technology

Traditionally, many industries are male dominated at all levels of seniority, including logistics. Today this is changing, often thanks to technology. For example, by using exoskeletons in a warehouse, people with less physical strength than the average man can now lift heavy objects with relative ease, broadening the pool of potential candidates for that warehouse role. Similarly, robotics that automate operations within a distribution hub can easily be supervised by differently abled people to ensure workflows run smoothly.

The talent pool expands exponentially when a company commits to DEIB – all can be included and all should belong – and technology-enabled innovations inspire positive change across the organization, encouraging more people to apply for work in logistics and the supply chain.

The downfall of workplace bias

Of those who reported experiencing workplace bias, here is what they revealed:



Graphic source: **Adobe (2023): 2023 B2B Commerce Growth Strategies Survey**

SUMMARY & TREND OVERVIEW

Challenges

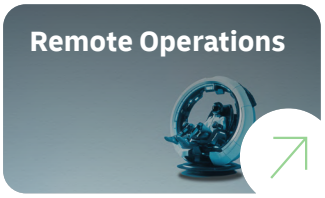
- Employee perception may not match organizational claims; for example, 97% of human resources (HR) leaders say their organizations have made changes that improved DEI but just 37% of employees strongly agree.
- To facilitate change and drive DEIB, organizations need to address underlying unconscious bias and enable open dialog during recruitment and career advancement conversations.
- Overcoming entrenched cultural norms and systemic barriers that hinder inclusivity and equality at all levels can be challenging, especially in large organizations.

Outlook

Diversity, equity, inclusion, and belonging go far beyond HR concepts. When successfully embedded in the organization's core values, they leverage the collective backgrounds and experiences of everyone in the organization and this inspires new ways of thinking and sparks fresh ideas. When DEIB is at the forefront of a job applicant's mind and is a priority item on the business agenda, this is pivotal to the company's future success.

This trend should be carefully monitored with use cases in some applications that can already be addressed today.

Related Trends



DHL Resources

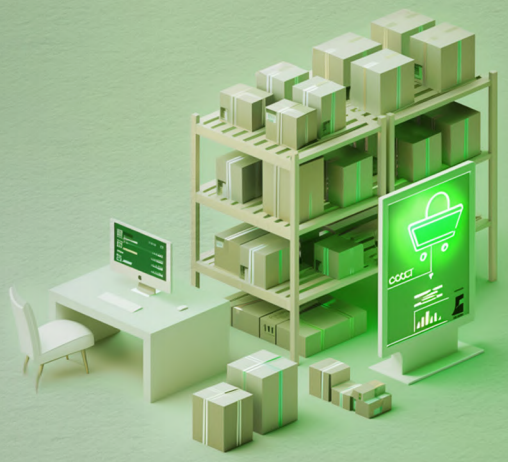
Diversity, Equity, Inclusion, Belonging (DEIB)

DHL Group receives awards for diversity, inclusion, and equal opportunity

Sources:

Business Leadership Today (2024): How Does DEI Affect Employee Retention?;
Procurement Tactics (2024): Supplier Diversity Statistics 2024- 35 Key Figures;
Harvard Business School (2023): Research: Where Employees Think Companies' DEIB Efforts Are Failing

Digital Marketplaces



The trend of Digital Marketplaces incorporates digital brokerage platforms that match demand for products and services with available supply. These platforms give suppliers and customers access to a greater market while also offering them comprehensive transparency and additional services.

Customers value the ease of comparing shipping options and pricing and the access to labor in a digital logistics marketplace. Due to this growing demand, logistics providers and others have expanded their offerings in recent years and new, specialized marketplaces have emerged. For example, companies can access available logistics labor during peak seasons and compare shipping alternatives on various platforms. Many of these platforms are becoming more versatile thanks to growing numbers of participants, deeper data analysis, increasing transparency, and the creation of a better customer experience.

Digital marketplaces are having a significant impact on logistics, especially because of increasingly complex supply chain networks and countless options of logistics services and providers. These marketplaces take transparency to a welcomed new level. However, there is a shortage of scalable solutions in some areas; for example, in matching available workforces and logistics providers. This means it will take another two to three years before logistics marketplaces achieve market maturity at scale.

RELEVANCE TO THE FUTURE OF LOGISTICS

Transparent Freight Forwarding

In today's highly competitive and fragmented freight forwarding market, it is difficult for shippers to get a comprehensive overview of the variety of logistics providers, their services, and related costs. The transparency of digital freight forwarding marketplaces is therefore a big attraction for companies.

Another important feature of digital freight marketplaces, which also distinguishes them from traditional freight exchanges, is that they are deeply rooted in all process steps of freight allocation, including booking, tracking, and invoicing. Digital freight marketplaces can access everything from the transport request through to invoicing data and can crunch this information using smart algorithms to obtain critical insights. For example, DHL's partner DigiHaul in the UK helps connect business-to-business (B2B) shippers with the country's largest carrier base and uses digital technology to optimize the operations of its platform users. This reduces operating costs, asset reliance, and carbon footprints.

The need to seamlessly connect freight networks in different markets and across national borders using digital freight platforms will become increasingly important for companies operating on a global scale.

On-Demand Warehousing

On the one hand, warehousing and storage providers are not fully utilizing space in facilities, with vacancy often reaching 25% while waiting for long-term, high-volume contracts. On the other hand, to meet customer demand it is increasingly important for manufacturers and retailers to be flexible and agile in times of market volatility, from predictable demand fluctuations to unexpected geopolitical events. On-demand warehousing, delivered via a digital marketplace, benefits both sides.

Companies like Warehouse Exchange in the US and Spacefill in France link retailers with warehouse providers under agreements more fluid in terms of timeframes and volumes than is normally expected with warehouse rentals. With these on-demand warehousing and fulfillment solutions, retailers and manufacturers can rapidly respond to disruptions and dynamic market demands, shifting goods quickly from one warehouse to another. Meanwhile, logistics companies can make more use of each facility, reach out to a much wider pool of potential customers, and realize higher margins from short-term or low-volume commitments.

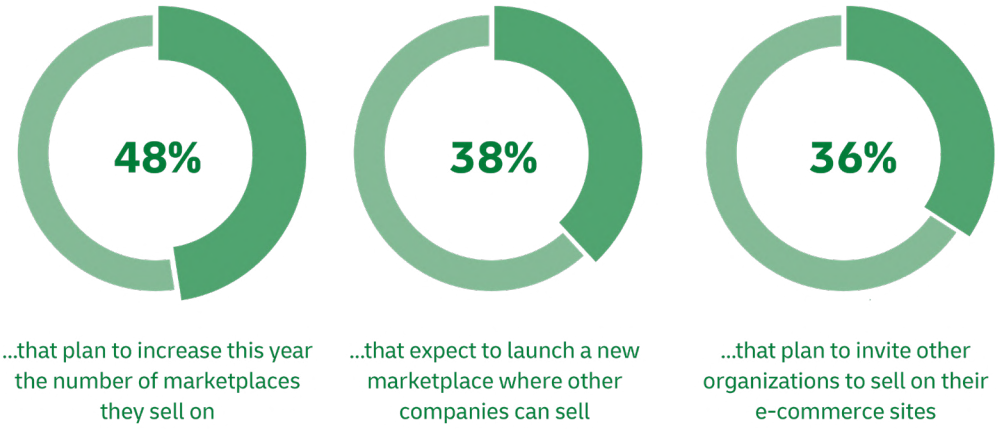
Labor-Gap Alleviation

As detailed in DHL's 2022 Future of Work in Logistics Trend Report, the aging workforce and greater labor shortages are having a major impact on the global logistics industry, especially in warehouse operations and truck driving.

> *The International Road Transport Union (IRU) estimated in 2023 that in 36 countries, representing 72% of the world's gross domestic product (GDP), 7% of (or more than 3 million) truck driver positions remain unfilled.*

Establishing workforce marketplaces that connect logistics providers with available workforces for a short period of time can help these organizations optimize personnel resources and address the volatility of workforce demands across regions and seasons. Czech company Grid, as one example, offers an emergency network of local drivers to help logistics companies meet acute delivery demands during peak seasons. With a labor shortage forecast over the next few years, these marketplaces for labor solutions can help logistics organizations avoid headcount deficiencies, better manage volatility, and keep up with customer demand.

Business-to-business organizations



Graphic source: **Adobe (2023): 2023 B2B Commerce Growth Strategies Survey**

SUMMARY & TREND OVERVIEW

Challenges

- In logistics, digital marketplaces must guarantee that sensitive customer data is kept confidential.
- Digital marketplaces require a minimum level of demand and supply to operate successfully and this can prove difficult to attain, especially in remote locations and for specialized logistics solutions.
- A strong application programming interface (API) is required to integrate every single supplier and customer on a platform and provide a seamless, transparent user experience.

Outlook

Digital marketplaces are already having a major impact on the logistics industry. In the future, platform providers will be able to use not only big data and smart algorithms but also artificial intelligence to even better forecast and match supply and demand as well as tailor the best possible solutions for customers.

This trend should be carefully monitored with use cases in some applications that can already be addressed today.

Related Trends

Sources:

Here (2020): Waste not want not: SpaceFill helps you turn warehouse space into profit;
Datex (2021): 2021 supply chain labor shortages and the role of technology;
Forbes (2022): Supply chain predictions for the coming year;
IRU (December 2023): Global driver shortages: 2023 year in review

E-Commerce Evolution

The E-Commerce Evolution trend encompasses a new wave of globalization in the e-commerce market, with successful players exhibiting both innovative and effective supply chain strategies and marketing techniques to engage with customers. Apart from offering inexpensive products, successful companies are leveraging discovery-based shopping and gamification to keep consumers glued to their platforms, while incorporating influencer marketing as well as mobile and social commerce. This especially appeals to the younger generation – Generation Z and Millennials who are more price sensitive and digitally confident.

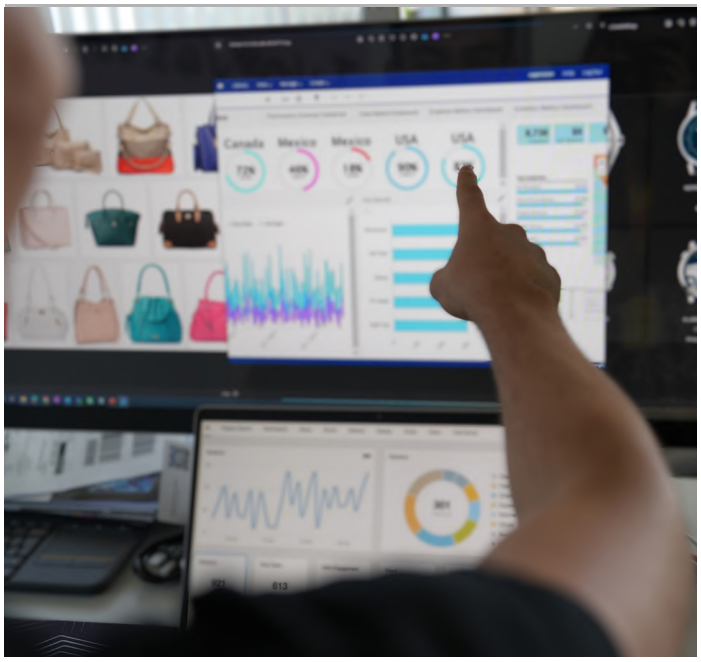
Many e-commerce and social commerce players are already aggressively expanding their presence and operations internationally; an example of this is current competition in the US between Shein, Temu, and TikTok Shop. This is why, here at DHL, we see the realization timeline for this trend within the next five years.

The success of e-commerce and social commerce companies joining this evolution will depend on not only their digital marketing strategies and social media integration (merging shopping and entertainment to engage website visitors with so-called shoppertainment) but also their data-driven management of the supply chain, specifically their network of suppliers and sellers. Also crucial to success will be the ability to sustainably offer products at low prices, taking into account the costs associated with international deliveries. The impact of this trend on logistics will be high, as it significantly impacts cross-border deliveries and global supply chains.

The COVID-19 pandemic supercharged the e-commerce sector, pushing regular online shoppers and traditional brick-and-mortar shoppers towards digital platforms due to lockdown and health concerns, and today we see a drastic shift in consumers' daily routines in the digital realm. By 2025, McKinsey estimates cross-border e-commerce in goods will expand to around US$ 500 billion and reach $1 trillion by 2030. The evolution of e-commerce is largely shaped by the behaviors and preference of Gen Z and Millennial consumers, the growth of data and artificial intelligence (AI), and the fact that Chinese e-commerce and tech companies are turning their attention overseas. Along with accelerated global trade, other phenomena driving this trend include social media integration and eventually data crawling (the automated process of systematically exploring the internet and indexing data sources).

RELEVANCE TO THE FUTURE OF LOGISTICS

Large-Scale Automated Test & Reorder (LATR) Model



The large-scale automated test and reorder (LATR) model is used by companies like Shein and Temu to enable identification of innovative and inexpensive items of merchandise and then commission just a small order from a partner factory. If that item proves popular, the model allows production volumes to be rapidly increased. Already, this “test-before-mass-production“ approach is directly matching consumer demand to dispersed production by a very large number of suppliers.

Relying heavily on the use of big data and data crawling, the model helps companies understand what products consumers respond to. Ultimately, it guides how companies manage their network of suppliers in producing these goods. With this model, companies can analyze data to create more successful products and, if design flaws are identified, quickly make changes and scale production. They can also use algorithms to guide consumers with purchases and match manufacturing capacity to consumer demand.

Deploying the LATR model gives companies significant competitive advantage in the e-commerce market, allowing them to respond to consumer preferences in an extremely agile manner, while keeping inventory lean and responsive. The success of these companies is reflected in an influx of products online, and these are often transported in smaller, faster, and more regular shipments. For example, the deployment of this model enabled Shein to generate 20 times as many new items as more traditional retailers H&M or Zara in 2021.

Social Commerce & Gamification

Continuous digital transformation and evolution, initiated by the advent of the internet and its subsequent transition to mobile internet on smartphones, plus the emergence of social networks, have together given rise to novel forms of online shopping. One in particular, shoppertainment, is highly popular with Gen Zers and Millennials. The aim is to give consumers a fun and immersive buying experience, as this helps build stronger connections, increase conversion and sales, and foster brand loyalty. Content is delivered through livestream selling, shoppable videos, contests and giveaways, gamification, and augmented reality (AR).

Platforms such as Facebook and Instagram with billions of users have inadvertently become sought-after apps through which to promote and sell goods. And e-commerce companies continue to integrate social commerce and gamification features on their websites to further fuel consumer purchases.

Examples include the Chinese online shopping platform Taobao which has huge followings and sells billions of dollars of products. TikTok Shop delivers shoppable short and live videos and gets creators to make captivating promotional videos, rewarding them with sales commission. The luxury brand Gucci partnered with Snapchat for the world's first AR shoe try-on campaign; it generated a positive return on advertising spending and achieved an 18.9 million unique reach. For now, these new forms of online shopping are fueling astounding growth in the e-commerce space. Supply chains must be agile and responsive to meet these increased demands.

Social Acceptance of Dupes & Counterfeits

Another shift in consumer behavior among the younger consumer base is a general social acceptance of dupes (products that mimic those of other companies without claiming to be the original nor including reproduced protected logos) and counterfeits (products that are copies of trademarked consumer goods and aim to appear as the original). Counterfeit goods account for $991 billion in international trade each year. Brands with the highest volumes of identified counterfeits include Celine, Dior, Goyard, Prada, and Saint Laurent.

Drivers behind the rise of dupes and counterfeits are cost-of-living concerns and inflation, resulting in consumers looking for cheaper alternatives to luxury brands. Also, online marketplaces, social media platforms, and mobile e-commerce applications have made it easier for consumers to browse and purchase these products. In addition, promotion of dupes and replicas by social media influencers can normalize and even glamorize these products, particularly with younger consumers. Perception plays a part too. Not everyone associates with a specific brand image or set of values, making them more likely to seek alternatives. And some dupes offer similar aesthetics or functionalities as brand-name products at a fraction of the cost, creating a perceived value proposition for consumers.

Examples of explicit copies include Dior's low-top sneakers which cost $1,050 on Dior websites – the counterfeit shoes cost $68 on the Chinese cross-border platform DHgate. Temu offers a wide range of goods at unmatchable prices such as an electric cooking pot for $2.14, a retractable storage rack for $6.58, and a swimsuit for $6.18 with free shipping. The social acceptance of dupes and counterfeits is impacting supply chains too. For example, logistics companies serving the e-commerce channels of multinational corporations may be liable to fines and penalties if caught storing, handling, and transporting counterfeit products, as these goods are illegal in many countries. As volumes continue to grow, logistics companies must navigate complexities and ensure regulatory compliance in all countries of operation.

Volume-Driven Supply Chain Implications

Due to the rapid rise of cross-border shipments, the e-commerce evolution has potential to disrupt the transportation industry. Traditionally, cross-border e-commerce products are consolidated and shipped

in bulk. However, to meet consumer demand for faster delivery, smaller orders of fast-moving products are now generally shipped via air freight. This means cross-border e-commerce retailers are increasingly competing for limited air cargo space to achieve quick shipping times.

> *Cargo Facts Consulting estimates Alibaba ships from China around 1,000 tons of packages daily, Shein 5,000 tons, Temu 4,000 tons, and TikTok Shop 800 tons – volumes equivalent to about 108 Boeing 777 freighters per day.*

The surge in demand for fast fashion and inexpensive products may have long-term implications for supply chains such as inflated air transportation prices, lack of air cargo capacity in the event of emergencies or crises, and e-commerce companies having to build logistics infrastructure globally to shorten transportation time. This puts further pressure on the supply chain to meet consumption and customer expectations.

Cross-border e-commerce will grow to a $1 trillion - 2 trillion market by 2030, depending on scenario

Graphic source: **McKinsey & Company (2022): Signed, sealed, and delivered: Unpacking the cross-border parcel market's promise**

SUMMARY & TREND OVERVIEW

Challenges

- There are growing concerns in some countries, particularly the US and Europe, about the data privacy practices of technology and e-commerce companies; this can potentially inhibit the global expansion of these organizations.
- Fast fashion and hyper-consumerism often raise concerns about environmental impact and labor practices.
- Companies accused of selling counterfeit products may be found guilty of infringing intellectual property rights.
- Maintaining consistent manufacturing standards and product quality can be difficult, especially when working with a large network of suppliers.
- The race to offer the lowest prices in the context of intense competition can erode profit margins and make it difficult for companies to invest in long-term growth strategies.
- Fast, reliable delivery is key to customer satisfaction, especially in e-commerce, but it may be impossible to deliver as quickly as a local competitor because of long distances between countries in different regions.

Outlook

Overall, e-commerce has become part of everyday life for consumers, notably Gen Zers and Millennials, and continues to evolve. The e-commerce market will continue to grow with established retailers jostling for market share and customers, with greater use of tools such as data crawling, LATR models, gamification, and shoppertainment. Additionally, expect to see Asian companies adopting supply chain diversification, setting up supply chain operations closer to markets in Europe and the Americas. This move, however, may trigger these regions to impose tighter import regulations in the form of custom duties on products.

E-commerce companies will need to consider and manage the complexities of international logistics, including transportation mode options and the availability of logistics infrastructure in each region and country, all while paying attention to ever-changing consumer behaviors.

This trend should be actively monitored with implementations available for many use cases today.

Related Trends

DHL Resources

Should you look to China to see the future of e-commerce?

Sources:

McKinsey & Company (2022); Signed, sealed, and delivered: Unpacking the cross-border parcel market's promise, Shopify (2023); What Are Virtual Fitting Rooms and How Do They Work? (2024); Frontier Economics (2017): The Economic Impacts of Counterfeiting and Piracy; Financial Times (2023); Why young shoppers are cool with counterfeits, Reuters (2024); Focus: Rise of fast-fashion Shein, Temu roils global air cargo industry

ESG Advocacy

The trend of Environmental, Social and Governance (ESG) Advocacy encompasses the growing awareness and acknowledgment of the significant and observable negative impact that human and business activities are having on a set of aspects, including environmental issues, social issues and corporate accountability and transparency across all stakeholder groups. This recognition extends beyond a narrow focus on decarbonization and emphasizes the importance of adopting a holistic perspective that considers the interconnectedness of the above areas. ESG advocacy aims to mitigate the negative sustainability and ethical impacts of human and business activities and promote a behavior of decision makers that prioritizes the well-being of employees, customers, the society, and the planet.

Climate change is negatively impacting the environment and the world we live in. Today, one million plants and animals are threatened with extinction, the annual deforestation rate is 10.2 million hectares (more than the size of Iceland) and 75% of the earth's surface has been altered. Additionally, global supply chains encounter challenges around social issues, including labor rights violations, unethical sourcing and unsafe working conditions in certain regions. Growing environmental and social challenges have prompted societal and business shifts. Initiatives such as the 'Fridays for Future' movement and the Science Based Targets network have exerted significant pressure on companies, compelling them to prioritize sustainability efforts. As a result, businesses are gradually developing and publishing clear ESG agendas; however, there is still progress to be made in embracing sustainability along all ESG dimensions comprehensively.

In addition to monitoring conventional key performance indicators (KPIs) associated with carbon accounting, such as carbon emissions tracking, a growing number of companies recognize the imperative of adopting a comprehensive, holistic approach to sustainability. This entails considering the direct and indirect environmental impacts and ramifications of all activities. In logistics, efforts to decarbonize transportation are currently underway. However it is imperative to acknowledge that certain aspects within the realm of sustainability are still not fully receiving the necessary level of attention they require. Comprehensive action is required on holistic monitoring and reporting of environmental data on biodiversity, animal welfare, ecosystem restauration, actively protecting natural habitats, and driving social and governance topics such as labor rights and ethical sourcing. This will require companies to disclose impact and promote sustainable practices. It will take over five years for industry-wide implementation of ESG advocacy, due to the complexity of the issues at stake, the overall regulatory landscape, the current lack of clear reporting standards, and the need for accountability and incentives. But right now, if progress is to be made, it is crucial to implement proactive measures as this will establish the foundation for this transformative mindset shift.

RELEVANCE TO THE FUTURE OF LOGISTICS

Sustainable Sourcing

Sustainable sourcing – the integration of social, ethical, and environmental performance factors in the supplier selection process – represents a critical pathway to addressing environmental and social challenges in supply chains and responding to the growing environmental consciousness of consumers and companies. It is essential for logistics to proactively engage in sustainable sourcing, fostering a more sustainable and resilient global economy. However, it may be difficult to fully adopt sustainable sourcing. Challenges include longstanding contracts with existing suppliers, limited transparency across the entire supply chain, and the often higher costs associated with sustainably sourced products. In this increasingly regulated business landscape, logistics managers have a key role in promoting environmentally conscious sourcing practices. They can prioritize transparency, risk management, and stakeholder engagement to enhance not only their own but also their customers' resilience and sustainability.

Biodiversity

Biodiversity refers to the array of life forms across ecosystems, species, and genetic compositions within the biosphere. In recent years, we have seen a concerning and unprecedented decline in biodiversity, and this is primarily attributed to human activity compounded by accelerated global warming. According to the United Nations Environment Programme (UNEP), approximately half the world's gross domestic product (GDP) is directly or moderately reliant on nature. Although vital to global trade, logistics operations can have a negative impact on biodiversity while simultaneously relying on diverse ecosystem resources to sustain activities.

> *Importantly, the industry is capable of positively influencing the biodiversity of local and regional ecosystems. For example, logistics can adopt advanced technologies and practices to mitigate air, noise, and soil pollution to improve public health, protect against climate change, and safeguard biodiversity.*

An effective measure for mitigating the risk of biodiversity loss involves the implementation of rigorous monitoring and control measures for traffic noise, coupled with proactive promotion of initiatives aimed at its reduction. Sustainable mobility plans can be implemented and hazardous materials can be handled safely to prevent environmental contamination. Similarly, logistics can help prevent the inadvertent spread of invasive species. This may necessitate finding ways to prevent the introduction of such species in imported goods. And it may mean adopting rigorous measures to stop proliferation of accelerants such as algae on ocean vessels. Stricter regulations are imminent, requiring logistics companies to integrate biodiversity conservation into their operations. For example, since September 2024, all ships must be fully compliant with the Ballast Water Management Convention. While it may appear biodiversity has no direct business implications, companies must preemptively integrate biodiversity conservation measures into their operations. Not only does this have future benefits, but it also strengthens the current strategic position.

Consumer Consciousness

The paradigm of conscious consumerism is reshaping the business-to-consumer (B2C) landscape, with customers now prioritizing sustainability and ethical practices in their purchasing decisions. They actively seek brands that align with their values and they demand genuine commitments to environmental and social responsibility. The influence of conscious consumers extends beyond individual transactions, compelling brands to enhance their sustainability and social credentials to stay competitive in the marketplace. Increasingly, consumers are seeking products and services from companies that align with their values and demonstrate social responsibility. B2C companies must adapt by integrating sustainability into their core strategies, offering eco-friendly products and logistics, as well as maintaining transparency regarding their sustainability efforts.

Concurrently, as conscious consumer behavior continues to evolve, it is crucial for business-to-business (B2B) enterprises to recognize and actively address these changes. The influence of end consumers is now extending to suppliers, leading to a growing demand from B2C companies for increased transparency regarding emissions and social aspects of supply chains. Consequently, B2B companies must conduct comprehensive assessments of their value chain. This entails evaluating scope 1, 2, and 3 emissions, as well as broader environmental impacts resulting from their own operations, their customers, partners, and downstream stakeholders.

A 2023 study by McKinsey shows products which claim ESG qualities exhibited an average cumulative growth of 28% over five years, while products without such claims achieved a 20% growth rate. The consumer's commitment to sustainability is reflected in purchasing behavior. At the same time, there is increased scrutiny of sustainability claims, with growing demand for substantiation of advertising claims and product descriptions. Similarly, findings from a 2023 study by Deloitte indicate a significant impact of ethical and sustainability-related concerns on consumer behavior. One in three consumers reported discontinuing purchases of certain brands or products due to such concerns, highlighting the critical importance for companies to address their sustainability agenda. Clearly, companies must focus both on the sustainability of their own supply chains – including decarbonization and mitigation of environmental impacts – and collaborating with upstream and downstream partners and stakeholders. Failure to do so risks ESG-related scandals that may adversely affect the organization.

Logistics is a pivotal component of global supply chains and can play a crucial role in driving sustainability efforts across value chains.

Regulatory Framework

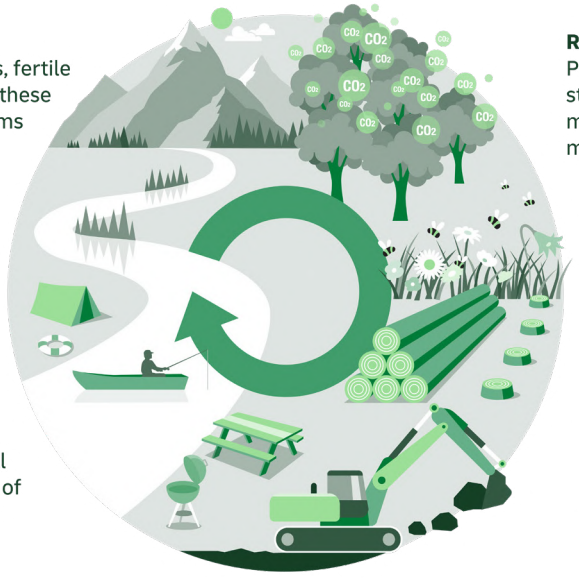
The regulatory landscape surrounding sustainability indicators and requirements has evolved significantly in recent years, with growing emphasis on carbon accounting, particularly focusing on greenhouse gas (GHG) emissions. This has become a priority for every medium-sized and large company. But in the 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 must acknowledge areas of business activity that impact local ecological systems, identifying where compensation is required and in which cases compensation represents only incomplete mitigation. Assessing this using standardized quantitative approaches is, of course, challenging as each location of business activity is likely to have unique characteristics. Companies should therefore make qualitative assessment of local ecological impacts, which introduces additional complexity.

Emerging initiatives address this issue; for example, The Taskforce on Nature-related Financial Disclosures framework seeks to empower organizations to report and respond to evolving nature-related risks. It offers a set of disclosure recommendations and guidance intended to encourage and facilitate businesses and financial institutions in evaluating, reporting, and addressing their dependencies on nature, along with associated impacts, risks, and opportunities. Governmental bodies 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) will be legally binding from 2029. It requires large companies in the region to conduct supply chain audits to address issues such as forced labor and environmental harm, adhere to human rights and environmental standards, implement preventative action plans, and ensure contractual compliance by direct business partners.

At DHL, we anticipate the implementation of regional and national biodiversity targets by governments, along with enforceable guidelines. As the regulatory landscape evolves, it will be imperative for companies to adhere to social topics as well. These measures will not only hold businesses responsible for detrimental environmental practices but also encourage initiatives that foster nature conservation and enhance human well-being. By embracing both environmental and social governance, companies can strive for a sustainable future that preserves biodiversity and promotes a thriving society.

There are various dependencies and services from the environment that businesses need and use for their core operations.



Supporting services
Services such as photosynthesis, fertile soil, and water cycling. Without these foundational services, ecosystems couldn't be sustained.

Regulation services
Pollination, flood control, carbon storage, and water purification help moderate natural processes and make ecosystems resilient to change.

Cultural services
Contribution to the cultural and spiritual development of communities via parkland and recreation.

Provisioning services.
These services -- trees used for lumber or mined natural resources used for fuel -- are extracted from nature and have a direct market value.

Graphic source: **PwC: (2023): Nature and biodiversity: Measuring your impact for a stronger business and better world**

SUMMARY & TREND OVERVIEW

Challenges

- Many companies are still not proactively shaping their approach to sustainability that goes beyond politically and regulatory mandated topics such as GHG reduction.
- The opaque framework for driving and measuring broader sustainability initiatives, which is still being defined, makes it difficult to compare key performance indicators (KPIs) across industries and use cases and limits standardized procedures.
- It is difficult to track, evaluate, and assess the integrity and environmental impact as well as social and governance impact of every party within complex supply chains; this prevents full transparency in the supply chain.
- Companies struggle to address sustainability risks if the ecosystem is diverse, there is insufficient site-specific information on biodiversity hotspots, and there are significant nature-related impacts in the upstream supply chain.
- Companies must proactively allocate budgetary resources towards ESG measures to ensure financial preparedness for future compliance regulations, while simultaneously driving ESG advocacy by investing in measures such as biodiversity conservation, SAF sourcing and ensuring fair working conditions.

Outlook

Companies must cultivate positive relationships based on actions with stakeholders as ESG expectations grow. Climate change is likely to exert more influence on business strategies in future, so the industry needs comprehensive guidelines on quantifiable metrics, such as emissions, and more nuanced, challenging-to-measure factors, such as impact on biodiversity.

For logistics organizations, it will become imperative to monitor operational impacts on regional ecosystems including forests, grasslands, and marine environments. Intact ecosystems are crucial to buffer against climate extremes, regulate hydrological cycles, protect soils, control urban temperatures, manage diseases and pests, reduce food insecurity, enable economic diversification, and more.

As regulatory frameworks tighten and consumer awareness regarding sustainability expands, companies will need to advance their sustainability agendas to encompass environmental considerations beyond emissions and develop institutional ESG advocacy. A proactive approach is essential to maintaining competitiveness in the market amid evolving sustainability expectations.

This trend should be carefully monitored with developments and use cases on the horizon.

Related Trends

DHL Resources

Sustainable Investment

Sources:

Food and Agriculture Organization of the United Nations (2020): Global Forest Resources Assessment 2020; IPBES (2019): Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services; McKinsey (2023): Consumers care about sustainability—and back it up with their wallets; Deloitte (2023): The Sustainable Consumer 2023

Everything As A Service

The trend of Everything as a Service, otherwise known as XaaS or Servitization, is the shift away from buying and selling products towards the vending of services to achieve an outcome. In this economic model, instead of committing to a one-off purchase of a product, the customer would consistently pay on a per-unit basis, like the amount of time utilized, the number of products produced, capacity provided, or the number of tasks fulfilled, for results that meet their needs.

XaaS business models bring a new way of doing business to both business-to-consumer (B2C) and business-to-business (B2B) relationships. For instance in the medical field, we here at DHL see change in how hospitals acquire medical capabilities. While in the past computed tomography (CT) scanning equipment had to be purchased, now many hospitals buy the service of that equipment and only pay per CT scan. Additionally, altering the patterns of consumer behavior and the way customers engage with products, individuals and companies alike can opt to pay for equipment usage for a specified period of time or output, and not pay when equipment sits idle or broken. For example, rather than buying air-conditioning (AC) units, XaaS allows the user to pay for the number of cooled hours. This shift in business model incentivizes a company to maximize the time its products are available to be used and minimize the cost of upkeep. Consequently, XaaS is often also seen as a tool when working towards sustainability goals, as equipment parts are made more durable and more easily replaceable with emphasis on products to be more repairable and reusable than disposable.

Increasingly, technology providers are offering as-a-service usage to logistics organizations for robotics, drones, warehouse management systems (WMSs), and more. This enables logistics professionals to redirect their focus from acquiring hardware and software to meeting demand, dealing with volatility, and reaching strategic customer engagement goals.

While the foreseen impact is not very strong on logistics and the supply chain, this adds an alternative to pure investment decisions for logistics professionals and greatly impacts end users of products, both consumers and businesses. Companies can keep customer experience at the core of their business by choosing everything as a service, reducing investments, enabling scalability, and building resilience to external disruption.

Logistics Services Diversification

Companies are broadening the lens of business potential to solutions that can be obtained as a service, and the providers of these services may choose to outsource operational processes to logistics organizations – introducing a new level of diversification. For example, many technology providers across industries offer automation solutions not as products but as services to their clients.

> *Whether it is for picking pieces on an assembly line or transporting assets around a factory, these solution providers charge on a per-piece-picked or per-mile/kilometer-traveled basis, thereby self-incentivizing robot upkeep and seamless continuous operations.*

This means that, when a robot does break down, the provider scrambles to get service back up running as soon as possible, shipping new spare parts or an entire replacement machine. As these companies look to expand their service market beyond their home region, they start to seek specialized logistics providers who can support timely and careful delivery of their solutions to their customers.

Another example is popular tire manufacturer Michelin's movement towards selling mileage and kilometers instead of tires. Previously, Michelin sold tires to logistics providers, such as road freight carriers, mining operators, and airlines, similar to how they would sell to a B2C customer for their private vehicle. Now, utilizing Internet of Things (IoT)-enabled sensor technology, Michelin offers tires-as-a-service to its B2B customers, measuring temperature and pressure in tires to prevent tire failure and unnecessary operational downtime. The company has since expanded its offering to a complete tire management system, coordinating tire replacement and other maintenance offerings with its customers, while simultaneously helping subscribers reduce fuel consumption through optimized driving and training.

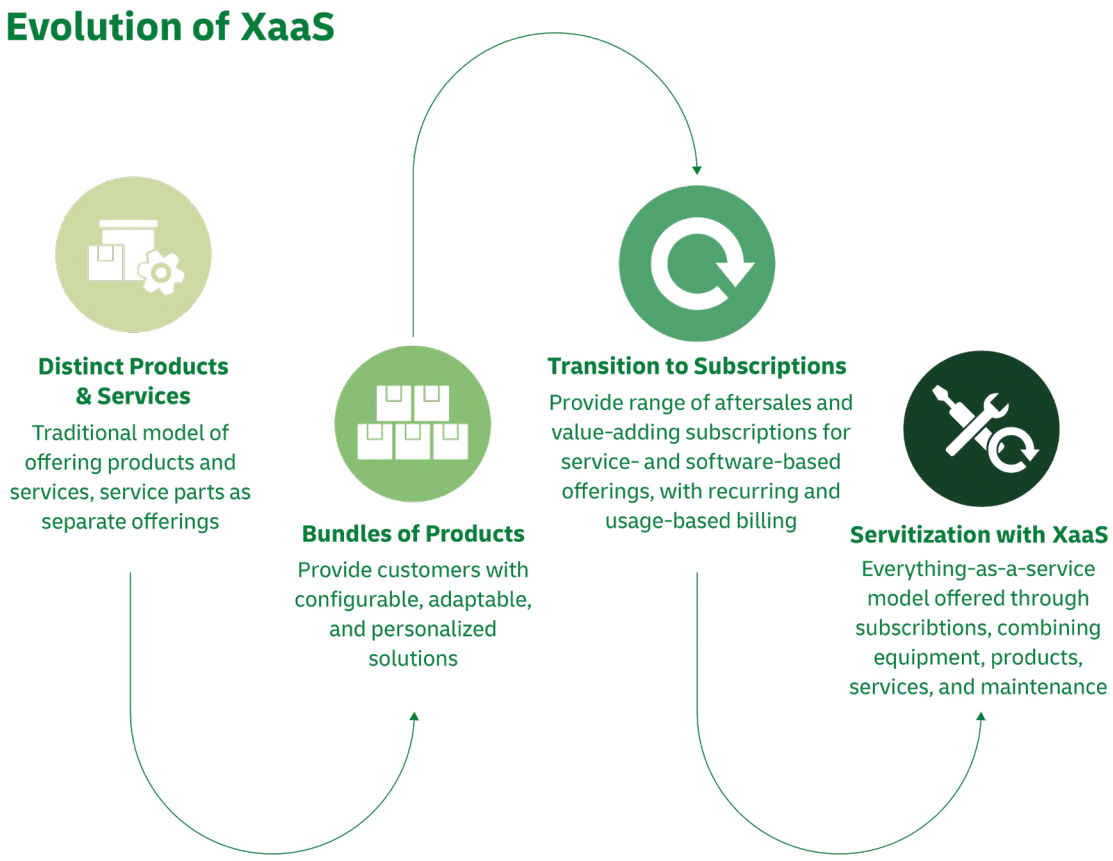
Co-Located & Distributed Service Logistics Facilities

As product ownership and responsibility for uptime remain with the XaaS provider rather than with the user, the response time for necessary predictive maintenance is a key differentiator. One solution to faster response times is co-located and distributed service logistics facilities of and for these service providers.

Co-located and distributed facilities and spare parts networks, including inventory positioning, must be a strategic building block in support of the business. As such, logistics plays a vital role in this new equation as the seamless supply and delivery of parts is critical to maintaining asset or fleet performance when provided as a service. The need for co-located inventory may be reduced, however, by onsite on-demand three-dimensional (3D) printing and there may be no need for a technician to visit if they can instead use augmented reality (AR) to provide remote repair and maintenance support.

Service Billing Models & Tools

As companies transition from selling products to providing them as a service, new service billing models and tools are required. Rather than managing inventory to record the products that have been sold, companies moving to XaaS must enable more complex usage-based invoicing. This is achieved with accounting tallies across multiple users on predetermined bases (per hour, per kilowatt, per mile/kilometer, per use, per pick, and more). Smart contracts using blockchain technology can automate complicated processes in a transparent way, performing steps when pre-agreed conditions are fulfilled.



Graphic source: **Siemens (2019): Everything as a service: a closer look at the business model for the future**

SUMMARY & TREND OVERVIEW

Challenges

- The shift from offering products to services requires a deep understanding of not only the needs of the customer, but also the many components and systems in the customer's domain that interact with the in-use product.
- XaaS increases the complexity of the billing model and therefore requires a strong IT infrastructure to ensure resilience.
- To integrate, deploy, and manage an XaaS platform in what is still an emerging field requires adequate yet scarce IT skills; development will therefore come with initial high costs.
- For the XaaS supplier, data analytics capabilities are crucial to business success, providing insights into customer behavior patterns as well as asset maintenance and inventory management.

Outlook

The global XaaS market expanded from US$ 436.82 billion in 2021 to $699.79 billion in 2023, with growth projection to $3,221.96 billion by 2030, based on a compound annual growth rate (CAGR) of 24.4%. This imminent market development means business models are changing B2C and B2B relationships from product-centric to user-centric and the same change can be seen in logistics.

This trend should be monitored to some extent with developments and use cases on the horizon.

Related Trends

DHL Resources

The power of XaaS in manufacturing: New business models boost productivity and generate recurring revenues

DHL White Paper: The Future of Services Supply Chain

Source:
Fortune Business Insights (2023): Global Everything as a Service (XaaS) Market

Green Urban Transformation

The trend of Green Urban Transformation refers to the development of urban spaces and cities towards smarter environments. By using digital solutions (smart cities) as well as regulatory actions, traditional networks, services, and infrastructure are utilized more efficiently, sustainably, and in business-friendly and/or citizen-friendly ways. The objective of this transformation is to support behavioral change and ensure urban areas are livable, sustainable, and vibrant places.

The population shift from rural to urban areas puts pressure on authorities to nurture cities, with particular focus on efficient use of space and infrastructure. Artificial intelligence (AI), Internet-of-Things (IoT) sensors, and other technologies are being integrated into core infrastructure and services (smart cities) to achieve green urban transformation. This is redefining how residents, businesses, and governments will live, exist, move, interact, and operate in the future.

By 2025, smart cities are expected to generate 60% of the world's gross domestic product (GDP). Green urban transformation is already underway in numerous big cities but is not yet so obvious in mid-sized cities. To reduce emissions in urban areas, the current focus is on mobility and transportation, especially last-mile delivery, and on enablers such as a smart, integrated infrastructure.

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 which are essential to every smartification project. The second layer comprises applications that translate raw data into alerts, insights, and actions. And the third is usage and adoption by members of the public, companies, and city authorities, resulting in behavioral changes. For example, people are encouraged to use public transit during off-peak hours or change their routes, use less energy and water and do so at different times of day, and use preventative self-care to reduce strain on the healthcare system.

Today entire new cities are planned from scratch using the same principles of green urban transformation. Saudi Arabia's NEOM initiative describes these as places where "People's health and wellbeing will be prioritized over transportation and infrastructure, unlike traditional cities."

Examples of traditional cities that have succeeded in turning smart include Singapore, which is planning entirely vehicle-free city zones and Finland's capital, Helsinki, which has created a three-dimensional (3D) representation of the city – a digital twin – to improve internal services and processes, provide data for further smart city development, and drive the city's green agenda of sustainable consumption and a healthy environment.

Logistics plays a significant role in the urban space, enabling the exchange of goods within cities. Logistics activities require space, infrastructure, contribute to 20% of all urban traffic, and generate 30% of all urban emissions. The impact of green urban transformation on logistics is somewhat indirect: logistics is both a "player" in the urban space and "contributor" to urban life. The rollout of this next evolution of urban logistics will not be uniform globally but varies from country to country and region to region. However, first initiatives are currently seen in China, Southeast Asia, North America, and northern Europe.

Zero-Emission Zones

Key issues in urban areas today include environmental impact and density of traffic. Governments are legislating to reduce the levels of traffic, ensure the use of cleaner urban (freight) vehicles, and achieve more efficient movement of goods and people. An example of this is setting up urban zero-emission zones.

To meet these new emissions rules, and given that public space may be scarce, it is essential to focus on more efficient planning, innovative consolidation solutions, and clean freight vehicles. Effective ways to reduce heavy- and light-duty traffic, energy consumption, and emissions include off-peak deliveries, leveraging micro-depots with cargo bikes, and using e-vehicles and cargo bikes at consolidation centers on city peripheries.

In addition, an increasing level of white-label logistics services (which effectively anonymize the logistics provider) can be used in zero-emission zones. This makes shipment consolidation independent of carriers and logistics providers, achieving a more efficient and eco-friendly approach to logistics operations.

At DHL, we recognize that a further, much discussed delivery method – urban air logistics – will not play an essential role in the near future. However, the potential for this should be assessed in each location, as it will become relevant for some niche use cases.

Underground Urban Freight

As urbanization brings more people to cities, transportation activity on urban roads around the world is projected to more than double by 2050. Freight trucks taking goods in and out of cities will contribute to this and impact the environment, and logistics organizations will feel the consequences – longer and less reliable delivery times for customers.

Foreseeing this issue, the Swiss government in 2022 gave the go-ahead to Cargo Sous Terrain to begin constructing its privately financed underground system with phase 1 operations starting in 2031. In this first phase, specially designed cargo pods, including refrigerated units, each loaded at a surface facility with up to two pallets of freight will be lowered to an underground freight-only highway that connects 10 destinations along 70 km (43 miles) between Zurich and a regional logistics center. Using electric motors, the pods will travel to the required destination, where they will be lifted to the surface and unloaded. In this way, freight can be delivered directly into urban centers without adding to or being affected by road congestion. If successful, by 2045, phase 2 will expand the system to include other major Swiss cities like Geneva, Bern, and Basel. However, concerns are being raised about this project by municipalities and citizens affected.

In March 2024, the European Hyperloop Test Center opened in the Netherlands, a significant step forward for this futuristic transport technology. The newly launched 420-meter (quarter-mile) white steel tube will be a proving ground for capsules floating on magnetic fields, with the potential to achieve speeds of around 700 kph (435 mph). This evolving technology could usher in a new era of passenger and freight transportation.

With urban roads around the world projected to suffer large increases in congestion in the coming decades, logistics organizations should monitor these and other underground system developments. In time, they may provide a valuable way to protect urban delivery times despite traffic delays.

Urban Fulfillment

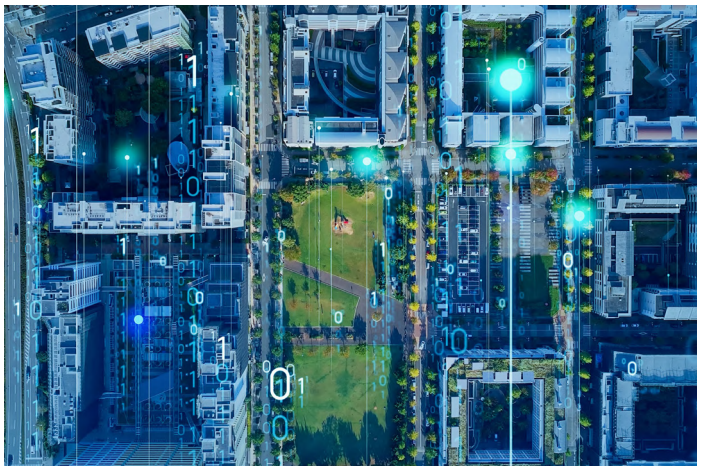
In the transformed urban environment, municipalities act as regulators of major logistics flows, with authorities typically taking over control tower functionality. In addition, authorities may seek to reduce inner-city vehicle numbers by creating white-label hubs – consolidation points managed by a third party.

> *Here, multiple logistics players arrange last-mile delivery (the most expensive segment of the fulfillment supply chain), effectively achieving parcel-load pooling. This represents a significant shift away from hubs traditionally located on the edges of a city, far from the primary customer base.*

Reacting to these changes, many quick commerce providers are opening and operating so-called dark stores (micro-fulfillment centers housed in what used to be retail space) in central neighborhoods or at the back of large suburban retail stores. These allow quick commerce providers to get closer to customers and ensure promised delivery times. As the dark store ecosystem grows, specialized services are appearing. For example, the American software company Mapbox offers mapping technology to help retailers pinpoint the perfect location for their next dark store.

Dark stores provide several benefits. They allow for faster picking and delivery. They can also achieve a lower cost per pick and delivery due to their more specialized product assortment and the fact they are closer to city consumers than traditional warehouses. While there may be higher fixed costs when renting these centrally located properties, dark stores offer savings that can make all the difference in last-mile delivery. At the same time, complaints are being raised about the presence of dark stores as critics claim they are a hazard to the public and too noisy.

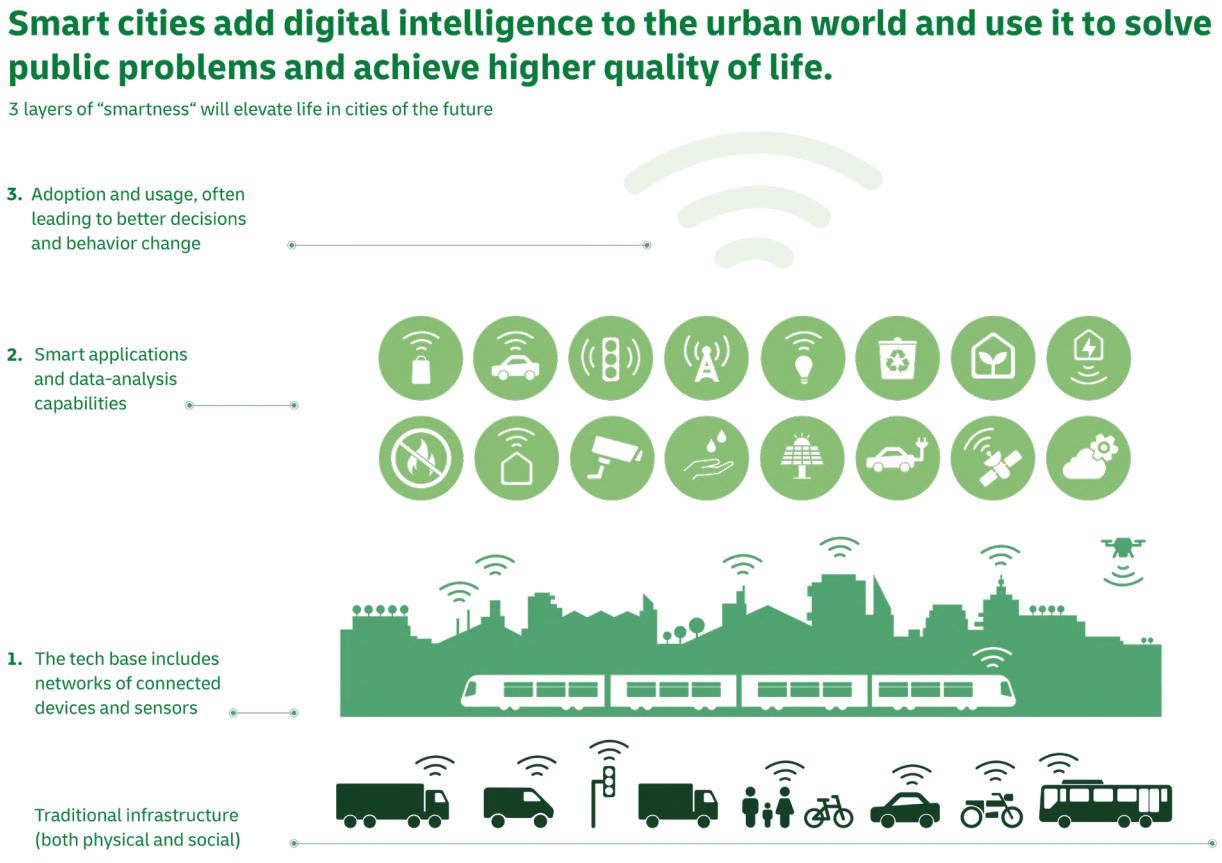
Smart Infrastructure



Many governments have made progress with their digital agendas, achieving widespread adoption of digital technology. Municipalities are promoting eco-friendly mobility, energy, heat, water, sewage, and waste concepts. And, to fully achieve a smart city, it is essential to integrate infrastructure and processes in energy, information, communication technologies, and transportation.

With smart city concepts for transportation, municipalities can provide real-time public transit information and road navigation data. They can also integrate multimodal information, deliver intelligent traffic control and smart parking management, introduce congestion pricing, and offer on-demand micro-transit services.

There are several benefits for logistics. For example, logistics providers can digitally interact with the infrastructure to plan logistics activities and adjust delivery windows according to real-time events. This is already possible for Helsinki, using its virtual rendering (digital twin) of the city's environment, operations, and changing circumstances.



Graphic source: **McKinsey & Company (2018): Smart cities: Digital solutions for a more livable future**

SUMMARY & TREND OVERVIEW

Challenges

- Not every region offers the necessary urban infrastructure to apply new technologies; for example, there may be insufficient grid-level charging infrastructure.
- It is difficult to use interactive smart technologies such as LoRa radio communication networks and private/public 5G networks in cities and areas with different communication layers.
- Managing space is a challenge; retailers and logistics companies are affected by new modes of transit, changing transportation policies, and the need to implement smart parcel lockers and urban consolidation centers.
- A critical mass of participating stakeholders – citizens, companies, and the public sector – is required to change behaviors; politics plays a crucial role in this, and incentives can be offered to encourage participation, but unpopular decisions will likely be challenged by voters.
- Public funding is required upfront; for example, investment in telecommunication networks, data spaces, and other infrastructure.

Outlook

Legislation will have a significant impact on green urban transformation, especially in the last mile of the supply chain. Cities will implement connectivity layers to enable increasing volumes of data collection about infrastructure, traffic, buildings, energy consumption, and more. Logistics players will therefore need to adjust, comply, and participate in the green urban ecosystem.

The biggest push will be towards more sustainable and emission-free mobility and transportation systems, and we expect significant investments in alternative energy technologies including electric vehicles (EVs) and the use of hydrogen fuel cells, which will in turn elevate the importance of connected technology trends.

This trend should be monitored to some extent with developments and use cases on the horizon.

Related Trends

DHL Resources

New DHL Group subsidiary launches open-supplier parcel terminals on the market

Sources:

IIoT World (2017): Smart City and Industrial IoT Applications
ESCP (2021): RETAILING 4.0 CHAIR Urban Logistics 4.0

Mass Personalization

The trend of Mass Personalization refers to the creation of highly personalized commercial experiences for individual customers that are designed to be applied on a mass scale. This trend utilizes advanced analytics of customer data, from geographic region to personal preferences and past customized purchases, to detect patterns at both the individual level and collective level and offer bespoke products and services.

Personalization differs from customization, which is when customers can choose from a set of attributes or amenities, like the color of their next sneakers or their seat position on a flight. Rather, personalization is when organizations proactively tailor the customer experience based on individual user and aggregated data such as demographic categories and past customization choices, in attempts to make the user feel more special and valued.

Looking across global e-commerce markets, Asia has become one of the earliest adopters in driving the majority of purchases through personalized recommendations. A few years ago in China, the majority of online purchases, approximately 80%, were initiated through search, while only 20% were influenced by product recommendations. However, the current landscape has witnessed a reversal, with product recommendations now driving 80% of online purchases.

Companies must elevate the accuracy and relevance of these recommendations in the near future. Already in 2022, a Salesforce survey revealed 73% of customers expected companies to have a comprehensive understanding of their distinct needs and expectations and more than 50% expressed the belief that companies should proactively anticipate these. Looking for deeper engagement with end customers, larger companies especially will adopt generative, analytics-based artificial intelligence (AI) models and deploy AI algorithms. This will drive 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 into how their organizations can better utilize data to improve the customer experience. Also, logistics players are the enablers of their business-to-business (B2B) customers' personalization strategies and must anticipate the shifting agendas of these customers to ensure high-quality service and cost-efficient offerings.

Mass personalization has relatively low impact on the logistics industry. While particularly relevant for B2C logistics engagement, the trend has only limited application to date in B2B logistics relationships. While supply chains should be capable of adapting to handle more customized products, it is not expected that overall operational changes for logistics will be disruptive. However, to stay relevant for certain customers, it will be crucial to offer the right logistics services to companies with more complex product portfolios. Looking for deeper engagement with end customers, larger companies especially will adopt generative, analytics-based artificial intelligence (AI) models and deploy AI algorithms. This will drive more relevant recommendations and offerings based on end customer needs.

Tailored Logistics Services

Logistics providers themselves can be adopters of mass personalization strategies for their own B2B and B2C customers to grow competitive advantages. By tailoring offerings based on each customer's needs and preferences, logistics professionals can increase customer retention while possibly also increasing revenue from value-added services. Research reveals that customer demands are a major force for transformation in the logistics sector, with 91% of companies recognizing that customers now prefer comprehensive logistics services from a single provider. Customers are seeking more than just conventional offerings like freight forwarding and customs brokerage; they expect logistics companies to provide added services including reverse logistics, e-commerce management, and analytics.

In ways, many logistics leaders already do this on a rudimentary level for B2B relationships, offering specific services to companies based on their industry and the products being handled.

> *As an example, logistics providers are already personalizing risk analysis of the supply chain for customers, helping to leverage customer-specific personalization of supply chains with predictive AI and application programming interfaces (APIs) as enabling technologies.*

By handling the end-to-end supply chain, the logistics provider gains visibility over all aspects of the end customer's journey and desires. This will allow the logistics provider to offer a more tailored program in the future.

There is a lot more opportunity for logistics organizations to offer B2C personalization, given the vast pool of customer data and varied preferences. Many logistics organizations already have websites where consumers can customize their shipments, like choosing delivery dates and types of packaging. However, logistics organizations can use more data and undertake deeper analyses to proactively create a more tailored customer experience. For instance, if a customer has a history of selecting greener options like recycled packaging, the logistics provider can also recommend other environmentally friendly options – like carbon-neutral shipping and delivery by cargo bikes – before the customer reaches the payment stage.

Overall, logistics providers can achieve competitive differentiation by providing more personalized services to B2B and B2C customers. By tailoring offerings based on each customer's needs and preferences, logistics professionals can increase customer retention while possibly also increasing revenue from value-added services.

Enabling B2B Customer Agendas

Many manufacturers and retailers are exploring and implementing mass personalization techniques to enhance the customer journey in different channels. Logistics organizations will be expected to collaboratively support these agendas, providing a newer, wider range of offerings to B2B customers.

For some logistics providers, this may mean holding an inventory of more products for quick fulfillment. To illustrate, personalized vitamin subscriptions – in which dozens of vitamins and supplements are combined in pre-dosed packets and delivered monthly or even daily to customers based on their health needs – are becoming popular and are offered by nutritional supplement giants GNC and Nature Made and startups like Perelel, Persona, and Ritual. Unlike typical purchases, when products may come from different fulfillment centers and be delivered individually, these subscription service purchases require the logistics organization to have the right stock available in larger volumes at a single fulfillment center.

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.

We here at DHL predict retailers will offer more delivery options to customers based on their needs and demographic data, as many digital marketplaces already do. This can be in the form of different delivery times, from free 5-day shipping to premium same-day shipping, as well as the ability to drop the shipment off at a neighbor's address or a nearby parcel locker. We recognize that, in order to provide these offerings, retailers will be pressuring logistics partners to develop such services; if the partner cannot do this, the retailer will turn to other logistics companies that can meet these requests.

Overall, in order to stay competitive and retain customers, logistics organizations will need to expand service capabilities, from enabling more inventory space to ensuring greener, faster last-mile delivery.

AI-Driven Customer Experience

As organizations get better at collecting and organizing granular customer data, we here at DHL expect the growing capabilities of AI to drive both internal and customer-facing recommendations, leading to an enhanced level of personalization in logistics services. There is a meteoric rise in the accessibility and capabilities of generative AI. A Klarna report on the

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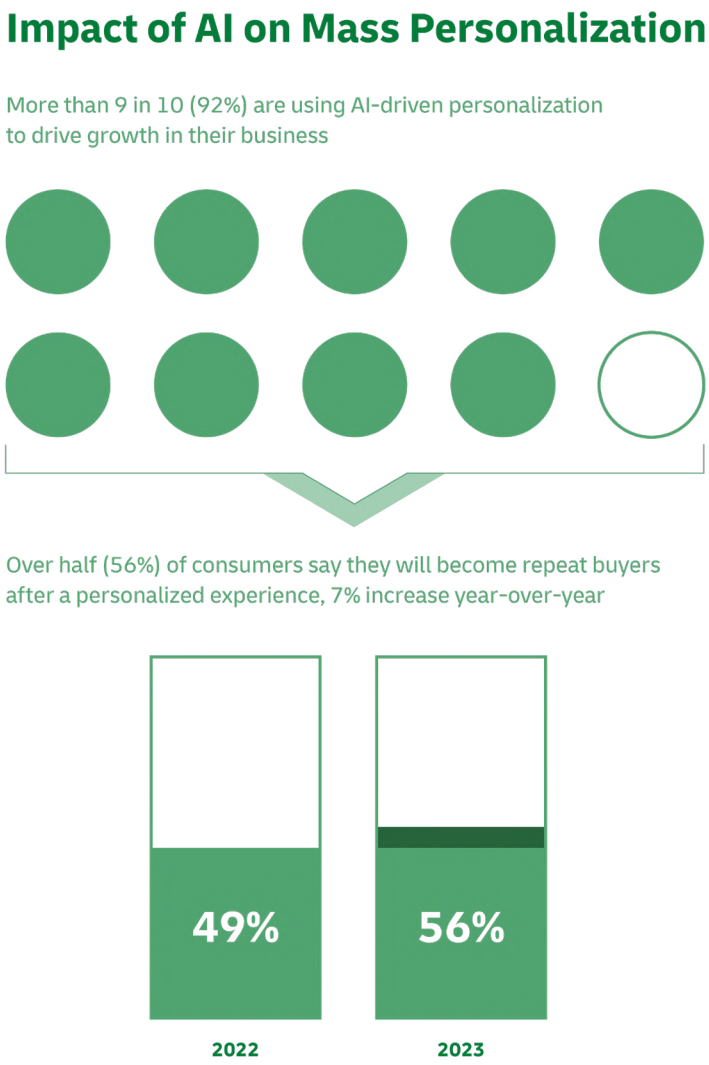
future of retail revealed 26% of US Gen Zers and Millennials imagine a future in which AI-driven customization in shopping becomes so advanced they will be able to completely avoid the need to shop if preferred.

E-commerce and retail organizations have the best access to consumer data as it relates to purchase history and social media interaction with products, allowing these businesses to profile customers accurately. Added to this, they have a high product mix which allows them to drive greater diversity in personalized recommendations than service-based organizations.

Service providers can capitalize on advanced analytics by proactively recommending service offerings based on a customer profile. To unlock a new standard of personalization for customers, logistics organizations can leverage B2B customer account data. This will enable hyper-personalized supply chain offerings including mode of transportation, based on delivery needs and sustainability standards, and location of storage and fulfillment for short-term end customer orders.



Graphic source: **Twilio Segment (2023): State of Personalization Report**

SUMMARY & TREND OVERVIEW

Challenges

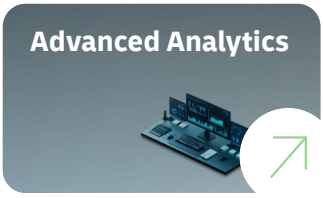
- Realizing a mass personalization approach requires comprehensive knowledge of customer preferences and a deep understanding of data analytics.
- Reacting to changing customer preferences consider necessi-tates flexible production lines and supply chains in order to fulfill customer needs on time.
- Logistics must be able to maintain the same cost-to-serve level for individualized goods and even partially customized goods as for standard products.
- In the pursuit of mass personalization, organizations often seek to collect more data than necessary, which can infringe on user rights to data privacy.

Outlook

The trend of Mass Personalization will continue to progress as the customer expectation and demand for tailored experiences grows. Logistics organizations can be the enablers of their B2B customers' mass personalization strategies but need to adapt service offerings to these customers and B2C customers in order to also fulfill demand for customized logistics services by using the ever-enhancing capabilities of AI-driven analytics.
As the B2B customers of logistics organizations seek to fulfill the increasingly personalized expectations of end consumers, this may – in practice – look like structuring the supply chain based on anticipated consumer demand or devising fully automated service triggers based on consumer purchases.

This trend should be monitored to some extent with developments and use cases on the horizon.

Related Trends



DHL Resources

- Customize delivery - On-demand delivery
- Improve customer relationship with customized logistics by MyDHL+
- Hyper-personalization explained: What you need to know
- Personalization in B2B e-commerce: Top tips to boost your conversions

Sources:
Forbes (2023): E-Commerce 3.0: The Future Of Retail Is Hyper-Personalized: Salesforce (2022): State of the Connected Customer Report: Accenture (2021): Logistics: Full service. Full stop.: Klarna (2023): Future of Retail

Metaverses

The Metaverses trend refers to a three-dimensional (3D) virtual environment that is open and interoperable, much like the internet. Users can enter in the form of avatars to gain knowledge, enjoy entertainment, interact with each other, work collaboratively, and consume assets and services in a virtual world that is linked to the real world.

First realized in online video games in the early 2000s, a metaverse is conceptualized as the next stage of social connection and engagement after the internet. A metaverse environment is typically but not exclusively built on extended reality (XR) technology.

Prior to the metaverse, XR applications occurred in contained digital environments with targeted functionalities; for example, solutions supporting employee training. Instead, the metaverse is a shared, and immersive world connected to the wider online ecosystem. It can be accessed with or without an XR headset, such as the Microsoft HoloLens, Meta Quest 3, or Apple Vision Pro.

Once the metaverse hype peaked in 2022, critical voices started to be heard, declaring the trend in decline because of continued losses at Meta's Reality Labs division, amounting to US$ 11.5 billion in 2023, and to the downturn of non-fungible tokens (NFTs). The trade and sale of blockchain-supported NFTs were core to the hype around metaverse economies. On the front end, NFTs can take many forms, like digital artwork and representations of real-world objects such as clothes and cars; on the back end, they are digital non-interchangeable receipts that act as proofs of ownership of digital or physical assets.

These doubts were reflected by Google search trends. The search term "metaverse" reached highest popularity in 2022 and subsequently declined. But, despite these indicators, the metaverse market is still predicted to grow. Between 2024 and 2030, an annual growth rate of over 35% is anticipated.

For all industries, including logistics, the metaverses vision remains relatively distant in terms of realization. Currently, different metaverse approaches exist, resulting in multiple "multiverses" that are fragmented, not interoperable, and unconnected. It is yet to be seen whether a single metaverse (or several large and connected metaverses) can form to the extent that the concept suggests. At DHL, we believe the possible impact of metaverses and its relevance to logistics and the supply chain are yet to be understood. Nevertheless, companies should be monitoring developments around this trend today as the course towards the infrastructure for a single metaverse is being set.

Industrial Metaverse

Metaverse experiences continue to develop from virtual gaming platforms, social networks, event spaces, and new sales channels, and in time will also impact more industries. It is easy to imagine the benefits of an industrial metaverse that connects the virtual and real worlds. Managers across all industries, including logistics, should consider ways of incorporating this trend into not just consumer-focused activities but also operations.

> *An industrial metaverse is the convergence of different technology trends, an all-encompassing digital twin that seamlessly integrates all sources of data and information relevant to the enterprise.*

Within this digital twin, employees can interact virtually; they can access and share information, collaborate, experience simulations, and receive training, making use of XR technology for a virtual interconnected experience. In 2022, Accenture coined the term "Metaverse Continuum," extending its offering to help enterprises lay the necessary groundwork to advance towards and build up an industrial metaverse in the future.

Evidencing progress, BMW already uses the NVIDIA Omniverse solution to connect all relevant data sources and create a collaborative virtual simulation environ-ment for better planning of new production facilities.

Meanwhile, in logistics there is strong progress towards greater visibility in a data-driven industry, particularly using the Internet of Things (IoT) and digital twins to connect physical assets. There are also well-established use cases in areas of collaboration, simulation, and training.

As more and more data sources are connected into a single all-encompassing data source, the vision of a single metaverse to consume and interact with available information starts to make sense. Within the logistics industry this could be of particular value in the design, simulation, and monitoring of complex supply chains and operations. The metaverse could act as a virtual control room, bringing together information from various data sources and enabling consumption of information in a very visual way, with the added advantage of easier virtual collaboration.

Having a vision of the metaverse in mind can help with setting up the required IT infrastructure from outset, enabling interoperability between different application spaces and allowing all spaces to connect, ultimately, in a single metaverse environment.

New Customer Channels

Retailers and marketeers are exploring metaverses as an opportunity for another channel to drive customer engagement and business. The immersive Roblox platform, for example, is growing steadily, with 70.2 million daily active users as of Q3, 2023.

Fashion brands such as Gucci, H&M, and Nike, to name a few, have been early adopters, launching digital showrooms and NFT-based fashion collections to position their brands in the metaverse, starting in 2022.

In April 2024, Nike released the second collection of its iconic Air Max sneakers to Fortnite, a popular metaverse gaming platform with over 220 million monthly users. Within the "Airphoria Vol. 2" experience, users can explore an Air Max Dn-themed virtual world and play mini games.

While brands experiment with new sales channels within still-forming metaverse environments, the question is unanswered: Will the metaverse become the next version of the internet or will it remain a niche environment for specific tasks – in this case, for brands to engage with specific target groups? Either way, the implications for logistics are expected to be rather limited.

Metaverses

Graphic source: **MeTech (2024): Metaverse (VR/AR/XR)**

SUMMARY & TREND OVERVIEW

Challenges

- Today's fragmented landscape of non-interoperable metaverse environments leaves uncertainty about whether a single metaverse or set of connected metaverses will ever materialize.
- The potential of metaverses as a retail channel is not yet clear, even though users can access several metaverse environments today and these are continually expanding.
- While the industrial metaverse is an aspirational concept calling for infrastructural groundwork today, its value for businesses remains unclear and the extent of realization uncertain.

Outlook

The Metaverse trend is exciting but the path towards a broader implementation is still not outlined; applications are rather isolated and limited.

Although metaverse environments now represent a growing channel with tens of millions of potential users, so far the foreseeable impact on logistics is limited. However, as more individuals and companies participate in metaverse economies, greater insight can be expected.

The vision of an industrial metaverse is important today when building infrastructural groundwork for XR use cases or digital twins, helping to enable interoperability from the start. However, the degree to which this vision will be realized in future is unclear, as this heavily depends on business value – something that is yet to be proven.

This trend should be passively monitored with developments still needed and use cases still being explored.

Related Trends

Sources:

Statista (2023): Meta's Money Pit: Metaverse Bet Bleeds Billions; Forbes (2024): The Rise And Fall Of NFTs: What Went Wrong?; Statista (2024): Metaverse – Worldwide; Backlinko (2024): Roblox User and Growth Stats You Need to Know; Demandsage (2024): Fortnite Statistics 2024 (Active Players, Revenue)

Supply Chain Diversification

The trend of Supply Chain Diversification refers to the proactive strategy that involves embedding one or more of these four dimensions into the supply chain network: multi-shoring, multi-sourcing, adding modes of transport, and diversifying logistics operations.It enables rapid adaption and reconfiguration of the supply chain to enhance customer centricity, resilience, sustainability, and agility which can improve competitive advantage. Supply chain diversification is facilitated by technology and proactive relationship management along the entire supply chain enabling multi-stakeholder collaboration.

Since 1980, global trade has increased more than tenfold, reaching a record high of over US$32 trillion in 2022. DHL's own analysis of global connectedness confirms that globalization hit a peak in 2022 and remained near that level in 2023. Hidden behind these figures is a complex network of globally interconnected supply chains with an ecosystem of countless customers, suppliers, service providers, and partners.

The recent accumulation of shockwaves caused by COVID-19, geopolitical crises, and natural disasters has led to considerable volatility, with disruption increasing by 183% since 2019 (33% in 2023 alone). The record highs also disguise the challenge of agility and resilience in supply chains, which prevent companies from responding effectively.

Understanding the complexities and dimensions of supply chain diversification and how they can be leveraged strategically beyond resilience can ultimately be a key to gaining a competitive advantage. Adopting a proactive approach to supply chain disruption is a strategic move for organizations, enabling them to increase sustainability, customer centricity, resilience, agility, and profitability in an uncertain business world.

In recent years, many companies have conducted strategic reviews of their supply chains to evaluate the need for diversification. For many organizations, these reviews have become a routine practice, and several have already implemented corresponding changes. These changes come in many forms, with the level of intensity depending on each company's markets, strategies, objectives, and risk-taking appetite.

Given the strategic importance of resilient and agile supply chains for global trade as well as for the sustainable long-term success of organizations, the impact of supply chain diversification is considered to be very significant.

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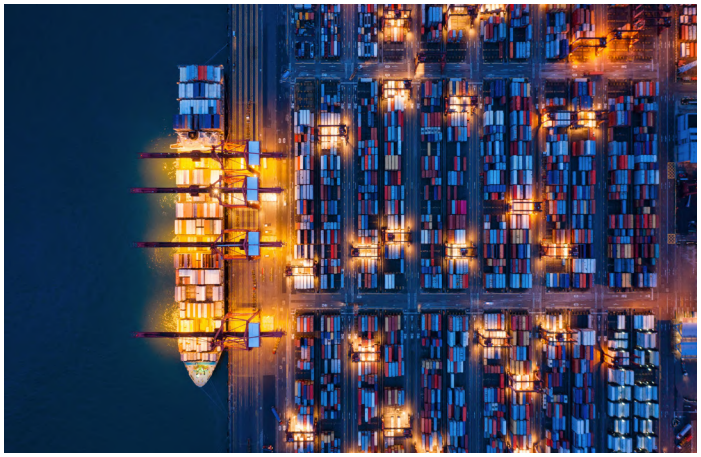
Multi-Shoring The Supply Network



The first dimension involves geographical diversification. Multi-shoring means introducing redundant manufacturing capacities or additional supplier locations in separate areas. This might include adding locations in other countries or even continents to mitigate operational, compliance, or reputational risks. Multi-shoring can involve the same supplier but from an additional location – for example, getting the same part from two different plants.

The spectrum of multi-shoring diversification ranges from a supply network built on one country (low) to one widely dispersed across multiple countries or even continents (high).

As an example, after years of manufacturing most of their products in China, many technology companies are now seeking to add manufacturing capabilities elsewhere, mainly in other Southeast Asian countries, often referred to as the "China+1" strategy.

For instance, HP is shifting its laptop production to Thailand, and Foxconn is moving a portion of its assembly capabilities from China to Vietnam3. Tech-giant Apple is also shifting production from China, where currently most iPhones, iPads, and other Apple products are produced, to India, Vietnam, and other Asian countries. Apple now builds around 14% of its iPhones in India, twice the amount it produced there the previous year4. Also in 2022, LEGO Group announced plans to invest more than $1 billion in a new factory in Chesterfield County, Virginia, its first in the United States and seventh factory globally.5 The company has served the North American market from its site in Mexico.

The group says it positions its factories close to its biggest markets to shorten the distance its products must travel, allowing the company to rapidly respond to changing consumer demand and better manage its carbon footprint.

Multi-Sourcing The Supply Network

Multi-sourcing focuses on quantity rather than geography. The most common approach involves adding redundant suppliers, although integrating additional manufacturing capacities is also standard practice. Diversification can take place within local or regional ecosystems, such as adding a new supplier located in the same city. Multi-sourcing is primarily used to mitigate financial or operational risks, such as a supplier's inability to deliver on time or at all.

> *The breadth of a company's supply network can range from having a single supplier for a specific part or product (low) to maintaining multiple suppliers on multiple tiers for each part or product (high).*

RELEVANCE TO THE FUTURE OF LOGISTICS

Although multi-sourcing is not a new concept, and companies across all sectors continually assess and adapt their supplier bases, there has been a noticeable increase in recent years driven by higher supply chain volatility. The 2022 EY Industrial Supply Chain Survey found that 62% of 6 industrial companies surveyed had made significant changes to their supplier base in the previous 24 months and 77% had or were planning to increase their total number of suppliers.

One of the world's largest fashion groups provides a prominent example of a business effectively leveraging multi-sourcing on a global scale. The company strategically spreads its supply chain across thousands of facilities and direct suppliers worldwide. This strategy allows the company to adapt swiftly to peak customer demand and leverage the unique strengths of each supplier. Multiple suppliers also mean it can respond quickly to disruption, redistributing production to ensure products are always in stock.

Parallel Modes Of Transportation

The third dimension centers on utilizing more modes of transportation for the trade lane of a particular product or part. Adding at least one mode to any part of the supply chain (first mile, long haul, last mile, etc.) makes a supply chain more diversified than it was before. Modes include air, ocean, rail, and road. Simultaneously, using various modes of transportation or multi-modal solutions for a part or product also typically diversifies shipping routes, which can reduce operational risk and buffer volatilities in demand.

It's important to note that adding modes of transportation is not a contingency plan but rather a parallel transportation method for the same point-to-point connection. Furthermore, different modes of transportation offer varying lead times, which must be considered and aligned with the business model.

Mode diversification spans from one mode for each part or product (low) to parallel modes for each part or product (high).

A retail market leader for example provides a best-practice example of this dimension of supply chain diversification. Aiming to respond rapidly to consumer preferences and trends within 10 to 14 days, the company utilizes all modes of transportation across all supply lines, opting, for instance, to ship goods via air freight between regions rather than using slower ocean freight. This allows swift and flexible stock reallocation between markets based on customer requirements and any disruptions.

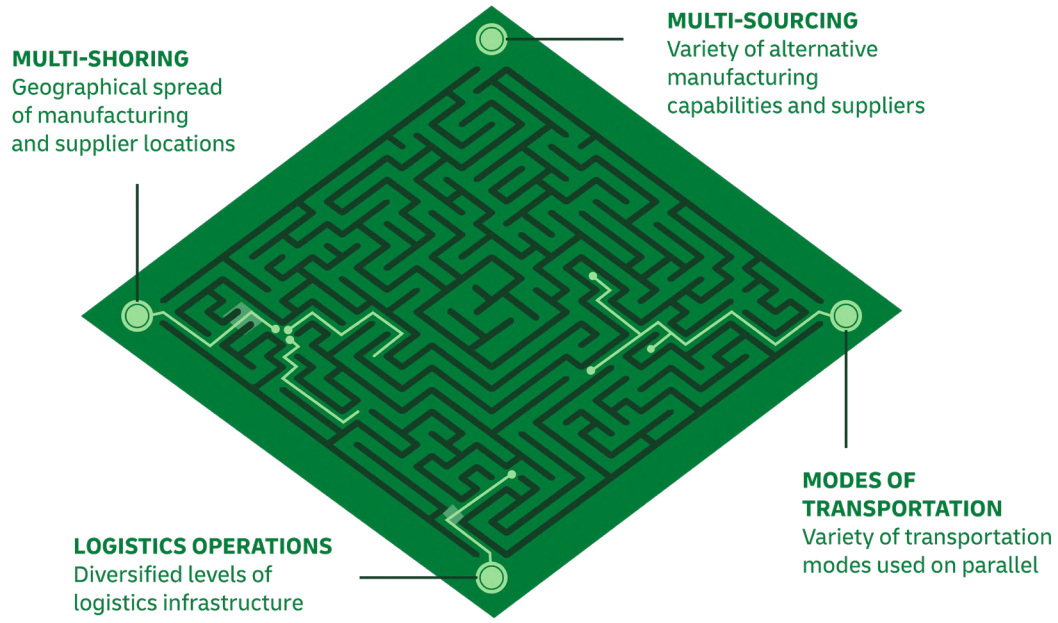
Diversifying Logistics Operations

The final dimension of supply chain diversification involves expanding logistics capabilities. This means augmenting the logistics infrastructure with additional capacities, such as hubs, warehouses, and distribution centers. Depending on the requirements, this could include redundant logistics capabilities in other locations both near and far. Diversifying logistics operations may also involve outsourcing certain logistics activities. Like multi-shoring and multi-sourcing, a diversified logistics operation provides alternative options that maintain continuity in the supply chain during disruptions.

The spectrum of logistics operations diversification ranges from a single logistics operation for a specific need (low) to multiple redundancies across diverse geographies (high).

A global sportswear and athletic equipment manufacturer provides an excellent example of a company transitioning from a centralized to a decentralized and diversified logistics network. While the company aims to optimize profitability, the goal of its supply chain strategy is also to improve resilience. It delivers products from production sites directly to regional and local warehouses, enhancing resilience and cost efficiency. The company has also increased its logistics footprint, establishing a presence in South America and India, opening a new hub in southern Europe, and expanding operations along the east and west coasts of the United States.

Supply Chain Diversification model



Graphic source: **DHL Group (2024): Supply Chain Diversification Trend Report**

SUMMARY & TREND OVERVIEW

Challenges

- It takes time and resources to source, pre-qualify, onboard, and manage many more suppliers, and supply chain complexity increases when also multi-shoring adding transportation modes, and diversifying logistics operations.
- Building a new supplier infrastructure in a different country or region for multi-shoring purposes presents challenges, as it necessitates acquiring new organizational knowledge and skills.
- While the risk of a comprehensive manufacturing stoppage or retail backlog is lowered by multi-sourcing, the risk of partial disruption is raised, since each source has its own risk factors.
- Multi-mode transportation may result in higher CO_2 emissions, adversely affecting suistanibility goals.
- Diversified supply chain setups can increase operational costs, reducing profitability.

Outlook

Supply chain diversification has already become a popular theme in supply chain management. It is an essential strategic lever for building resilience, enhancing customer centricity, driving profitability, improving sustainability, and gaining a competitive advantage.

With disruption accelerating, diversified supply chains are expected to become increasingly significant. Recent experience demonstrates that companies with strategically diversified supply chains are better positioned to navigate uncertainties and seize emerging opportunities. Today's new normal demands continuous assessment and more regular reconfigurations of supply chains to meet new requirements, enhance risk profiles and maintain or improve agility and resilience.

Transparency and visibility across the entire supply chain are imperative and the foundation for success, with state-of-the-art technology, supply chain management tools, and strong partnerships playing a decisive role.

This trend should be actively monitored with implementations available for many use cases today.

Related Trends & Downloads

DHL Resources

Trend Report Supply Chain Diversification

Sources:

DHL (2024): 2024 DHL Global Connectedness Report: Accenture (2023): Resiliency in the Making Report; Bloomberg (2024): Apple's India iPhone Output Hits $14 Billion in China Shift; Lego (2022): The LEGO Group to build US$1 billion, carbon-neutral run factory in Virginia, USA; EY (2022): Why global industrial supply chains are decoupling

Silver Economy

The trend of Silver Economy encapsulates the specialized demands and needs of the elderly, as populations around the world progressively age. This trend also includes support and services for older workers in supply chain operations.

By 2030, the number of people aged 60 years and above will grow globally to 1.4 billion, outnumbering the total of children aged under 10 years. While a significant proportion of this senior demographic category originally came from Europe and North America, it is projected that five times more people in this older segment will come from outside these two regions by 2050. Recognizing the changing face of the global population, industries around the world have begun distinguishing the needs of older people as employees and consumers from those of younger generations, creating a specialized but sizable market in its own right – the silver economy.

As waves of experienced supply chain leaders and operational staff retire, organizations risk a brain drain of time-acquired 'tribal knowledge' in an environment of growing labor shortages. Logistics organizations are beginning to act to retain elderly employees with valuable long-tenured experience. Meanwhile, retailers are increasingly targeting the older consumer, and supply chains are adapting to handle more bespoke products and services.

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Technology-Enabled Support in the Workplace

Employees in supply chain workplaces must always be mentally aware and often perform physically laborious tasks. This can be taxing on minds and bodies with the increasing average age of the workforce. New computer and robotic products and services can empower and encourage older workers to continue working in supply chains by improving health and safety while also reducing physical and mental stress.

Technologies such as exoskeletons and teleoperated driving can reduce the risk of physical injury, while other digital support systems like augmented reality (AR) smartglasses, and artificial intelligence (AI)-managed dashboards can reduce memory and cognitive demands. By supporting older employees in their tasks, supply chain organizations can retain long-tenured talent.

Age-Friendly Workplace Policies

Supply chain workers, especially those in operations, often have arduous shifts and contracts that may not be a good fit for those who are older and considering retirement. As much knowledge can be lost when an employee retires, organizations can stop this brain drain by reviewing and reforming work policies to accommodate older employees.

Senior worker support packages, such as flexible hours and part-time employment, can help retain retiring talent in an era of labor shortages. With these accommodating policies, time-experienced employees can still support their colleagues and, in particular, extensively share their valuable knowledge and skills. Furthermore, leadership can provide suitably ergonomic furniture and communicate to the entire team the value of its senior members in order to make the workspace more comfortable for older workers.

RELEVANCE TO THE FUTURE OF LOGISTICS

Elderly-Centric Customer Experience

With communities aging around the world and with more than six in 10 of today's seniors in some countries owning a smartphone (and this is likely to increase in the future), business-to-consumer (B2C) logistics and delivery businesses must consider senior needs as part of the overall customer experience, especially in the digital realm. Recently, retailers and digital marketplaces have released 'elderly-friendly' versions of their apps, with less crowded interfaces, bigger text, navigation shortcuts, and digital connections with family to share products and manage expenses.

Additionally, vendors should evaluate offering additional services like free advice and pre-purchase and post-purchase support with clear calls to action (CTAs) for its elderly consumers. While digital channels are growing and becoming more commonplace, support through phone, mail, and physical locations should not be overlooked. Overall, B2C logistics needs to adapt and incorporate changes to accommodate and meet the expectations of older customers along the entire supply chain – from order placement to last-mile delivery – or risk losing market share to age-friendly competitors.

Last-Mile Value-Added Services

The lockdown policies of the COVID-19 pandemic cultivated the diversification of traditional delivery services with the aim of supporting the older population. With many senior citizens unable to leave their homes and restricted in their daily activities, businesses and governments collaborated to ensure they still received essential goods at home.

To lower the risk of virus exposure, pharmacies, grocery stores, and other businesses started offering contactless home deliveries. While lockdowns and other restricting policies have been removed, last-mile services are anticipated to continue expanding beyond food and product delivery.

> *"In-home medical check-ups, home cleaning, transportation services, tech support, and auto-replenishment of goods such as medicines are speculated value-added last-mile services to be tested in the mid-term future."*

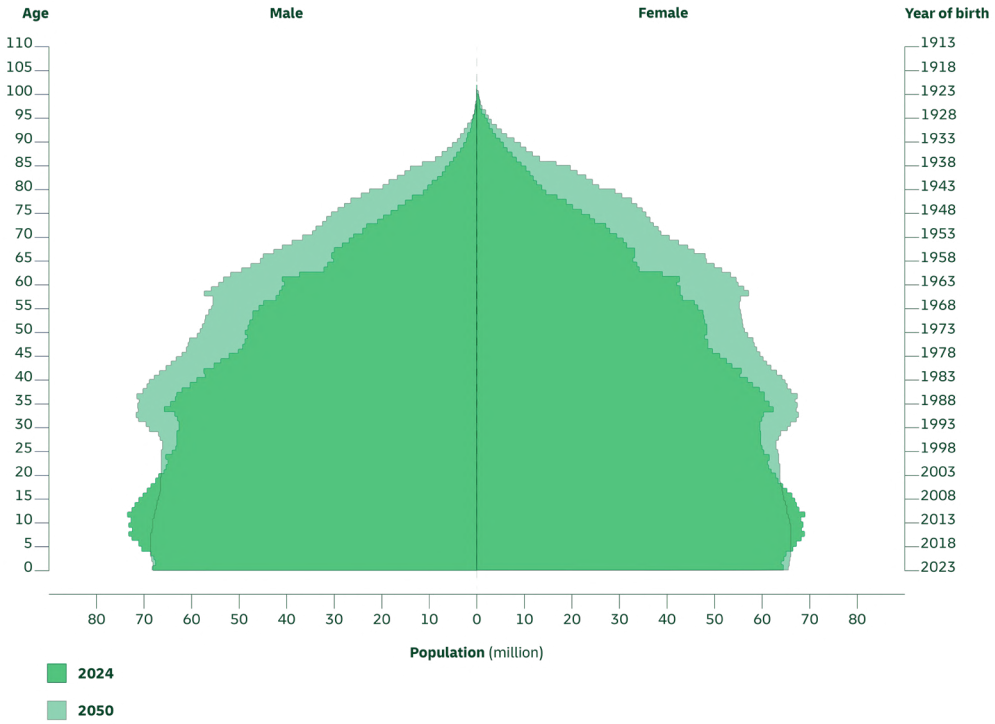
Senior Product Flow

The consumer market landscape is shifting towards the preferences of an older population. In many geographies, the aging community represents a demographic with substantial purchasing power demanding high quality, longevity, and even more individualized experiences, but it also represents a change in the kinds of products demanded.

For instance, according to Rothschild & Co Asset Management Europe, people aged over 50 have been increasing their spending on products in healthcare, food, leisure, communication, housing, and overall goods and services since 2011 and, simultaneously, decreasing spending on transportation, alcohol/tobacco, clothing, restaurants/hotels, and education. While fluxes are heavily dependent on the state of the economy, inflation, and other factors, overall demand for common medical and health products like medication, wheelchairs, prosthetics, and nutritional goods is almost certain to rise as more people age.

Logistics organizations need to adequately prepare operationally for the gradual increase of these products in the supply chain and the challenges this will present, especially as providers begin offering more personalized products and bespoke services to older customers.

World population by age and sex as predicted by United Nations



Graphic source: **United Nations Department of Economics and Social Affairs (2024): World Population Prospects 2024**

SUMMARY & TREND OVERVIEW

Challenges

- Technologies to handle or assist older workers with every physically and mentally taxing task may not yet exist or be ready for deployment at scale.
- Compared to younger employees, older employees may require a different set of resources, settings, and learning pathways to acquire fluency with new technology tools.
- Future personnel shortages, especially in seasonal peaks and line-haul transportation, will still likely occur despite elderly-friendly policies.
- Creating parallel services specifically for older customers like apps or last-mile delivery will require additional time and resources.
- Business models for new logistics value-added last-mile services are not yet fully validated.

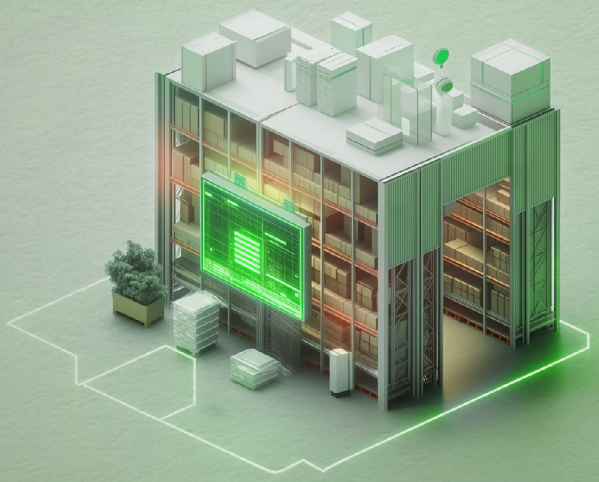
Outlook

The full impact of the Silver Economy trend in supply chain workplaces and marketplaces has yet to materialize. However, as global demographics continually move toward higher ages and as more people retire, we here at DHL see this trend maturing soon, with businesses taking active steps to retain older talent and attract senior customers.

This trend should be passively monitored with developments and use cases on the horizon.

Related Trends

Sources:
World Health Organization (2019): Decade of Healthy Ageing 2020-2030 (2019); UBS (2020): China's silver economy; Pew Research Center (2022): Share of those 65 and older who are tech users has grown in the past decade; European Commission (2018): The Silver Economy



Smartification

The trend of Smartification refers to the process of retrofitting or producing previously disconnected analog assets with sensor and wireless technologies, making them 'smart' and connected, bridging the analog-digital divide. Smartification enables users to collect a variety of sensor data for analysis, performance measurement, simulations, and data-based decisions. This involves the transformation of information into data, allowing for more efficient and effective operations.

Being connected has become a basic human need for large parts of the world's population and this is reflected in the average number of devices and connections per person globally, which is expected to grow from 2.9 in 2022 to 5.4 in 2028. By the end of 2024, there are projected to be more than 207 billion "things" connected to the worldwide network of tools, assets, devices, and appliances that make up the Internet of Things (IoT). However, many "things" remain unconnected and this is why it is increasingly important for companies to retrofit assets with sensors, achieving a comprehensive data-based view of operations.

Retrofitting will become more easily scalable as the cost of sensors falls and as they become smaller while improving accuracy and efficiency. And smartification will accelerate with developments in IoT, edge computing, and next-generation connectivity such as 5G. With these technologies, a powerful ecosystem emerges in which IoT devices can seamlessly communicate, process data at the edge, and utilize high-speed wireless networks for efficient and rapid transmission.

The Smartification trend will have moderate impact on the logistics industry as it drives visibility and transparency for optimization and enables data-driven decision making. However, it takes time to retrofit equipment and assets as well as integrate IT systems. Therefore, here at DHL we anticipate a few more years will pass before widespread adoption of smartification applications across industries.

Predictive Maintenance

Traditional asset maintenance methods, which rely on periodic inspections, may fail to identify abrasion and may overlook details that could lead to unforeseen expenses, reduced productivity, downtime, accidents, and equipment damage. Instead, data-collecting sensors can create insights about the condition and operations of all assets and software analytics can be employed to generate reports that highlight potential problems or risks of failure.

This explains why more and more companies are developing retrofit solutions to implement predictive maintenance, especially for older assets that are more susceptible to repair and failure. For example, DHL is using noise sensors for predictive maintenance of its sorters – these machines are the core component of successful automated sortation operations and, typically, maintenance is time intensive and not very effective.

> *Instead, the noise of individual cells can be used to identify at an early stage whether maintenance is required. DHL developed an algorithm to analyze this cell-noise data and provides visualization and alerts on a DHL IoT platform.*

This predictive maintenance solution is cost effective, helps avoid outages, reduces unnecessary maintenance activities and overall effort, and enables the switch from calendar-based to event- and/or alert-based maintenance.

Asset Tracking

Between 10% and 40% of supply chain assets are lost globally through misplacement, theft, and breakage every year. Smartification of assets such as pallets, forklifts, and containers enables localization and tracking. For example, since 2019, DHL has equipped more than 500,000 roller cages with smart long-lifetime trackers from manufacturer Alps Alpine, providing transparency on asset usage and improving distribution to ensure there are always enough cages at every location.

Another example is the partnership between shipping company Hapag-Lloyd and IoT-technology provider Nexxiot to create the world's largest connected fleet of smart containers. By the beginning of 2024, more than one million solar powered, cellular asset-tracking devices with a runtime of 6-10 years were installed in the shipper's dry container fleet.

Real-time location system (RTLS) manufacturer Sewio provides a forklift tracking solution to equip vehicles with a tag that transmits a signal to ceiling-mounted anchors. The anchors send any signal to the RTLS server so each vehicle's position can be calculated in real time, within 11.8" inches (30 cm) accuracy. The tag can be powered from the vehicle's battery or by its own battery. Collected data also provides insights into metrics such as distance traveled, run time versus stop time, and overall equipment effectiveness.

Facility Monitoring

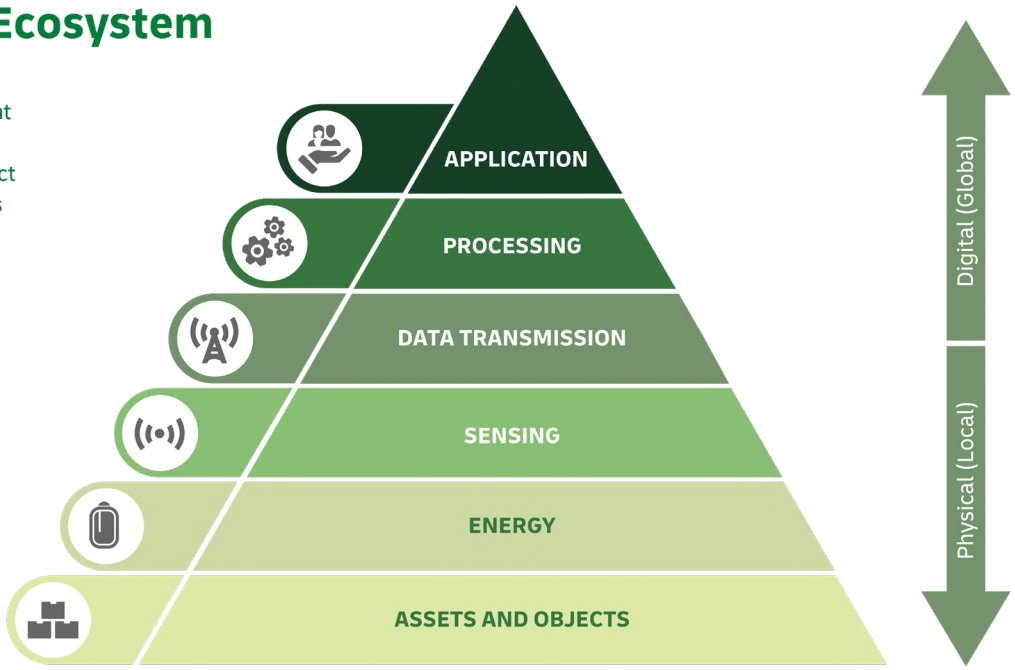
It is crucial to monitor environmental conditions within logistics facilities in order to prevent exposing goods to extremes of heat, cold, and excessive humidity – requirements that are especially relevant in the pharmaceutical, food, and technology industries.

Companies also need to monitor and understand facility energy consumption to identify and quantify potential energy savings, improving the carbon footprint and lowering energy costs. Retrofitting warehouses and production facilities with sensors can help with these tasks, providing data for analysis and informed decision making.

Companies like Singapore-based BeeBryte are able to measure, predict, and even independently adjust energy consumption-related functions (such as heating, ventilation, and air conditioning) in smart production facilities, warehouses, and commercial buildings. By analyzing data from different sources (for example, sensor-based, warehouse activity information and external sources like weather and traffic) the system can automatically adjust to optimum levels.

The IoT Ecosystem

A setup of different technical layers is required to connect assets and objects



Graphic source: **DHL (2024)**

SUMMARY & TREND OVERVIEW

Challenges

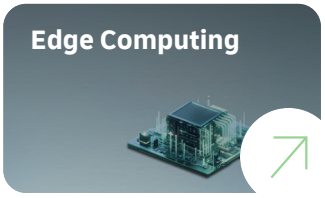
- The assimilation of formerly analog assets and systems into a corporate IT ecosystem and the increasing number of connected devices raise the risk of cyberattack.
- Integrating sensors from different suppliers requires a strong IT ecosystem and various application programming interfaces (APIs) to ensure all data is linked on one platform.
- The shift towards smart facilities, connected assets, and data-driven processes is expensive as well as time intensive.
- Growing data volumes due to the smartification of assets and systems means decision makers must learn to analyze this data and draw correct conclusions from it.
- Not every analog asset can be retrofitted with sensors and wireless technologies.

Outlook

As sensor technology advances and the cost and size of sensors shrink, more and more smartification use cases are emerging. This means newly produced assets are increasingly smart from the outset and there are more and more opportunities to digitize analog assets by retrofitting them with sensors. With the general trend towards more transparency and data harvesting, the relevance of the smartification trend will continue to increase in the future.

This trend should be carefully monitored with use cases in some applications that can already be addressed today.

Related Trends



DHL Resources

5 ways IoT trackers can save your ass(et)

The real value of IoT in supply chains

Sources:

Statista (2023): Number of connected devices worldwide in 2014 and 2028, by device; Worldometer (2022): World Population Projections; Forbes (2023): 2024 IoT And Smart Device Trends: What You Need To Know For The Future; Hapag Lloyd (2024): One million dry container monitoring devices installed!

Space Economy

The trend of Space Economy encompasses all activities of exploring, understanding, utilizing, and administering space for various reasons, including science, telecommunications, resource extraction, manufacturing, and tourism. This trend also covers the production, transportation, and storage of related materials and products on Earth, in space, and between the two.

According to The Space Report 2023 Q2 by the Space Foundation, the global space economy grew to US$ 546 billion in 2022, and is expected to near the $800 billion mark within five years. Global launch activity has reached new highs, with 223 launch attempts and 212 successful launches in 2023 – a record number of launches for the third year in a row, with 23% more satellites (2,800) deployed into orbit than in 2022 and commercial launch activity increasing 50% over the previous year.

There are several technological breakthroughs in the space economy industry that will accelerate its growth. These include reusable launch vehicles like SpaceX's Falcon 9 and Blue Origin's New Shepard tand the miniaturization of satellites which reduce costs of development and launches. Another technological breakthrough is in-space manufacturing with companies like Made in Space and Redwire Space pioneering 3D printing and other manufacturing technologies in space. There is also the growth of on-orbit servicing – provision of robotic technologies for refueling, repairing, and upgrading satellites in space. Lastly, other companies are advancing edge computing in space with technologies like Exo-Space's FeatherEdge platform to enable on-board processing of data from satellites.

The trend of Space Economy has a low impact and distant adoption for logistics. Currently it is an industry niche, representing a small percentage of the total throughput of today's supply chains.

Satellite-Powered Supply Chains

Global connectivity continues to be an ongoing issue for the supply chain. Many companies experience poor shipment visibility when their goods are transported across borders. However, the satellite internet is poised to revolutionize connectivity worldwide, providing access especially to underserved areas and remote regions. Satellite-powered supply chains feature real-time tracking and monitoring with GPS and other global navigation satellite systems providing precise location data for vehicles, containers, and other assets throughout the journey.

> *These supply chains benefit from improved inventory management – satellite imagery can monitor, for example, raw material sources, crops, and livestock health, enabling better 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.

Data-driven optimization can be achieved by combining satellite data with other sources like Internet of Things (IoT) sensors and enterprise resource planning (ERP) systems. These generate valuable insights and help companies make data-driven decisions on route optimization, fuel efficiency, carbon emission reduction, and more.

Examples include satellites in low-Earth orbit (LEO) constellations, such as Starlink, offering high-speed internet access to users around the globe. Already, Maersk teams are working with Starlink to use satellite data for tracking container ships, optimizing routes, and improving fuel efficiency.

Through data collection, satellites can help logistics providers optimize supply chains and provide better services to customers. And there is broad potential for satellites to provide network coverage across the globe, eliminating connectivity issues in so-called dead zones.

Supplying Cargo

As space activity expands, it will be necessary to transport more provisions, fuel, equipment, and materials into space to support this growth. There will also be demand for logistic players to move necessary space equipment and supplies between facilities.

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.

End-to-End Satellite Logistics

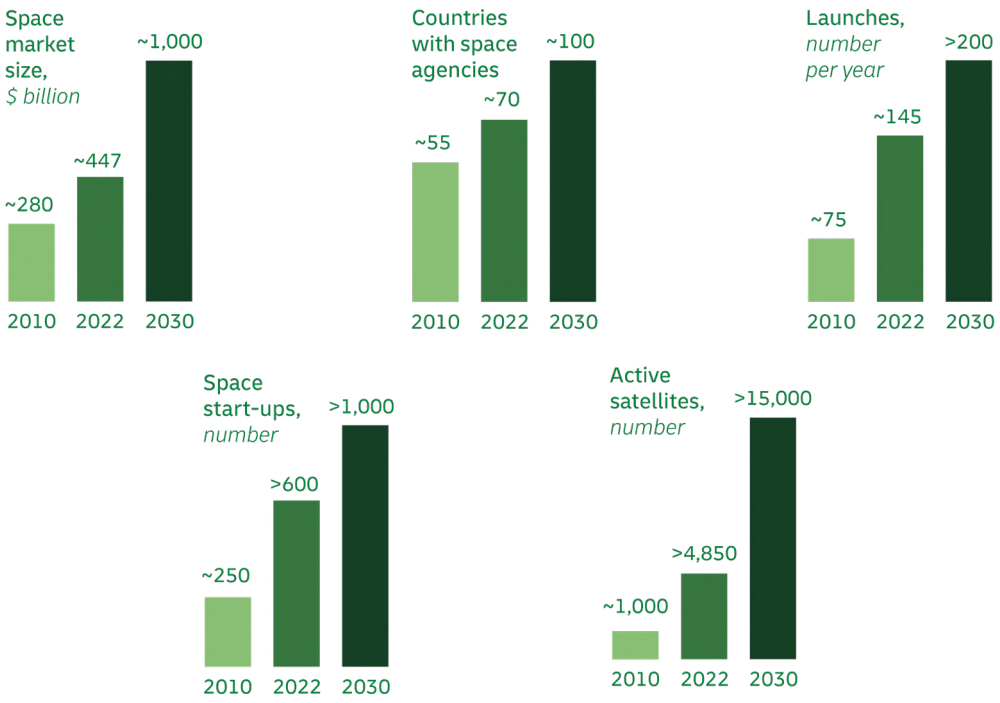
Tens of thousands of satellites are expected to be launched in the next decade. These satellites will require logistics services to reach their designated coordinates in space. This includes not only current logistics solutions focusing on aspects like launch and in-orbit services but also an end-to-end approach that demands significant logistics expertise.

Various logistics activities are involved in the end-to-end movement of satellites, from reserving rocket freight space on behalf of customers and sending specialist teams to pick up satellites at manufacturing sites, to delivering these to launch sites. Additionally, logistics providers will be involved in transporting replacement parts and equipment for maintenance purposes and in satellite decommissioning at the end of a device's life.

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.

The space sector has come a long way and seems poised for future growth.

Projections for space activities



Graphic source: **McKinsey & Company (2023): A giant leap for the space industry**

SUMMARY & TREND OVERVIEW

Challenges

- Extreme conditions, such as zero gravity and frigid temperatures, impose limitations on permissible products and materials as well as transportation methods.
- Launch vehicle dimensions and weight constraints may not allow for economies of scale.
- Commercial cost-benefit propositions for logistics services are untested but developing and operating end-to-end logistics services for the space economy remain expensive; cutting costs will require significant investment and technological breakthroughs.
- The legal framework for logistics operations in space is not yet available and evolving space regulations might not fully adapt to new business models like end-to-end logistics, creating uncertainty and hurdles.

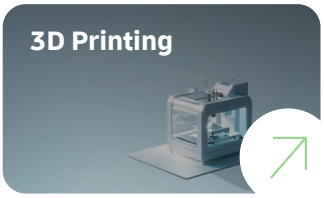
Outlook

Overall, the space economy is booming, with more nations and private investors pouring resources into space-related activities. The market for end-to-end satellite logistics continues to evolve, with significant uncertainties alongside promising opportunities.

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 full realization of the space economy is still distant.

This trend should be passively monitored with developments and use cases on the horizon.

Related Trends



DHL Resources

The space economy is booming

Sources:

Space Foundation (2023): Space Foundation Releases The Space Report 2023 Q2, Showing Annual Growth of Global Space Economy to $546B; Space Foundation (2023): The Space Report 2023 Q4 Shows Record Number of Launches for Third Year in a Row, Technological Firsts, and Heightened Focus on Policy

Workforce Focus

The trend of Workforce Focus refers to prioritizing employee needs, desires, and wellbeing as the foundation for organizational success. This involves crafting a work environment that puts employees' interests first, so their overall experience is enhanced, from the first touchpoint during the hiring process to the moment they leave a company.

Workforce focus across all industries, including logistics and the supply chain, will significantly alter future working conditions. Reasons for this trend are demographic change, changing employee expectations and needs, and technology developments such as artificial intelligence (AI), robotics, and digitalization. This global phenomenon will likely bring challenges for logistics leaders across the world.

Overall, there will be fewer available workers and over time the existing workforce will be replaced by younger generations with different aspirations; jobs they perceive as unattractive, such as delivering parcels and loading trucks, may not be filled appropriately.

Workforce Focus is driven by the younger generation's attitudes about work as, compared to former generations, these people have different employer and job expectations. Focus is much more on work-life balance, flexible working hours, new work models such as the four-day week, and opportunities to learn and follow a purpose. Younger employees expect personalized work experiences that fit their needs, comparable to the experiences they have as consumers, and compel employers take these topics seriously.

Technological developments are influencing and enabling employee centricity, too. New technologies offer the opportunity to tailor work to the individual, creating an automated and augmented workplace. First and foremost, employers must create an employee-centric strategy and work culture in order to attract and retain talent in the future.

As waves of experienced supply chain leaders and operational staff retire, organizations risk a brain drain of time-acquired 'tribal knowledge' in an environment of growing labor shortages. Logistics organizations are beginning to act to retain elderly employees with valuable long-tenured experience. Meanwhile, retailers are increasingly targeting the older consumer, and supply chains are adapting to handle more bespoke products and services. With an employee-centric strategy, logistics organizations can maintain a suitable workforce in terms of size and skills to match demand and succeed in navigating a challenging, changing, fast-paced environment.

In the next five years, organizations will increasingly feel the pressures of demographic change. While many are already taking proactive steps to attract and retain talent, it will take some time before shifts are widely

adopted and organizations fully implement employee-centric strategies. As companies realize an employee-centric culture is highly relevant in logistics and logistics is inherently a people-centered business, it is obvious that employee wellbeing and engagement are essential to successful operations.

Workforce focus has a significant impact on long-term success. Companies that invest heavily in the employee experience are 11.5 times more likely to be ranked among the best places to work on Glassdoor and 2.1 times more likely to be listed among the most innovative companies list by Forbes. Moreover, happiness at work, which can result from a good employee experience, is one of the most important factors in employee retention, as half of employees who enjoy their work are 49% less likely to say they would consider taking a new job than employees who do not enjoy their work.

Flexible Working Models

Very important in future to both employees and employers, flexible working models are sure to impact the logistics industry. But "flexible" can refer to working hours and location and/or to new working models such as new types of seasonal workers and gig workers (independent short-term contractors with work arrangements organized via online platforms).

Research shows 77% of workers perceive non-traditional working hours as a major advantage over a 9-5 schedule, apparently driven by the desire to integrate work and private life. Especially in Europe, there is strong demand for a four-day week, both in the office and in operations, and initial trials in office environments have yielded promising results. But implementing a new work model like this is challenging in logistics operations, where worker shortages are already high. This is further complicated by any need for night work and shift work. However, jobs must be made more attractive in an employee-centric company. Innovative solutions are needed, such as self-scheduling shift tools and shift-swapping platforms, as the status quo will inevitably lead to more workforce gaps.

When asked about flexibility in work locations, employees have strong opinions, raising significant challenges for logistics leaders. 81% of office workers do not want to work exclusively from the office and 11% want to only work from home. Meanwhile, 59% of operations employees want the opportunity to work from home some of the time. This is hugely challenging for managers, as many activities in operations require the physical presence of employees. In future, it may be possible to carry out some work processes remotely via remote operations; for example, driving warehouse vehicles. But areas of application are limited, meaning only specific tasks such as operations training and some administrative work can be done from home.

Seasonal workers have traditionally played a vital role in the logistics industry as a way of addressing pre-holiday and other seasonal fluctuations, but subjecting them to lay-offs during non-peak periods is not employee centric. This is why there is growing momentum to establish collaborative arrangements with companies in diverse sectors, enabling year-round employment and offering more enticing contracts accompanied by enhanced benefits. A strategic approach like this facilitates a smoother recruitment process to attract talent and allows implementation of innovative employment models. For example, individuals may engage in summer employment within the tourism industry and subsequently transition to support the logistics sector during a winter pre-holiday season.

Gig workers possess the greatest work flexibility – they are in charge of their working hours and location, what they do, and who they work for. Logistics managers can use the services of gig workers to meet fluctuating demand but this has its own challenges; managers may struggle to ensure consistency in the quality of work and gig worker availability.

RELEVANCE TO THE FUTURE OF LOGISTICS

Physical & Mental H&S

Minimizing incidents has been a key goal across the logistics industry for years, and today's employee-centric organizations also prioritize mental wellbeing as well as proactive, data-driven health and safety (H&S) management aligned closely with the needs of employees. Physical accidents are, unfortunately, still a continuing reality in logistics operations. Forklift drivers have accidents and employees are injured by pallets or incur musculoskeletal damage from excessive physical stress, resulting in serious challenges both in and outside the workplace, and high costs for employers. Measures to improve H&S are typically taken on the basis of past events.

Technology developments can help to prevent incidents proactively before they occur. For example, deploying exoskeletons and using data-based H&S management. Here at DHL, we are testing and piloting artificial intelligence (AI)-driven computer vision solutions such as Protex AI to proactively identify dangerous behavior and hot-spot areas within warehousing before any incident occurs.

Considered equally important as physical health, mental health is no longer a taboo subject and it is particularly important to the younger generation of employees.

> *Research shows 17% of sickness absences are caused by mental health issues and, regardless of whether the cause is work related, logistics managers must appreciate employee mental wellbeing contributes to a satisfied, productive workforce and affects an organization's ability to attract talent.*

Training courses, awareness days, and access to mental support services are all useful to logistics providers, along with a range of innovative solutions from startups, including app-based resilience training and comprehensive counseling services to supporting the mental wellbeing of employees.

Future-Forward Leadership

To foster an organizational culture and strategy that prioritizes employee wellbeing and engagement requires future-forward leadership. To complement existing leadership skills and qualities, logistics managers today must also further develop emotional intelligence, employee autonomy, and change management skills. Looking at these in turn, emotional intelligence (also known as emotional quotient, EQ) enables logistics leaders to effectively navigate complex and high-pressure situations, build strong relationships with team members, and inspire trust and collaboration. And as technology advances and automation is more prevalent, EQ will become even more important in the logistics industry. Leaders with emotional intelligence will be better equipped to deal with change, adapt to new technologies, and foster a

positive and resilient work culture as industry demands evolve. They will nurture a culture of psychological safety and although they may not always know how to do things, they will be able to integrate employee feelings and thoughts into their own actions.

Employee autonomy is a success factor to attract and retain talent, as almost half of employees would give up a 20% pay raise for greater control over how they work. Logistics leaders must adapt to this increasingly important development. Managers should provide individuals with the flexibility and freedom to make decisions and must trust their employees to manage their work in a way that suits their strengths and preferences. With the rise of remote work and the growing emphasis on work-life balance, employee autonomy becomes even more crucial. Logistics leaders will succeed by prioritizing and supporting employee autonomy and empowering their teams to achieve higher levels of productivity, engagement, and satisfaction. Together, this will contribute to the future growth and resilience of the organization.

In addition, constant change management will become an increasingly important attribute of logistics leaders. In a faster-paced world saturated with information, successful leaders will pierce through the noise and guide teams with minimal disruption through periods of great change and consider the individual employees and their needs and wishes. Digitization projects are a good example of this. Leaders need to be clear about the different digital personas (from all-digital/tech-savvy to traditionalist) and their characteristics in the team to successfully formulate a common way forward and created employee centricity.

Skill-Based Learning & Development

In the past, training and upskilling have played an important role in the logistics industry to attract and retain talent; in future, we expect these will become even more important. Employees in logistics operations and offices rate training and development among the top three incentives to stay with their current employer. In this context, more than 60% of employees see their employers as being (co-)responsible for organizing courses. And to remain competitive, logistics organizations must deliver continuous training and upskilling to keep everyone up to date with rapidly changing technical and regulatory conditions.

Companies can achieve employee-centric training and upskilling with a new skill-based learning and development approach. Appropriate in this era of artificial intelligence (AI), digitalization, and automation in which some tasks will be automated, this approach enables thinking beyond traditional job roles to categorize talent based on skills and experience (gained not just at work but also from other life events) and more effectively match individuals with evolving industry needs.

This enables organizations to proactively address the skills gap, foster continuous upskilling and reskilling, and ensure an agile workforce that is wellequipped to navigate the challenges and opportunities of the future. Employer-driven training and development is key to retaining and attracting talent and having a highly developed workforce. To provide employee-centric training and upskilling, all measures must be closely aligned with the needs and skills of employees, not with rigid plans or job positions. There is no one-size-fits-all model for training.

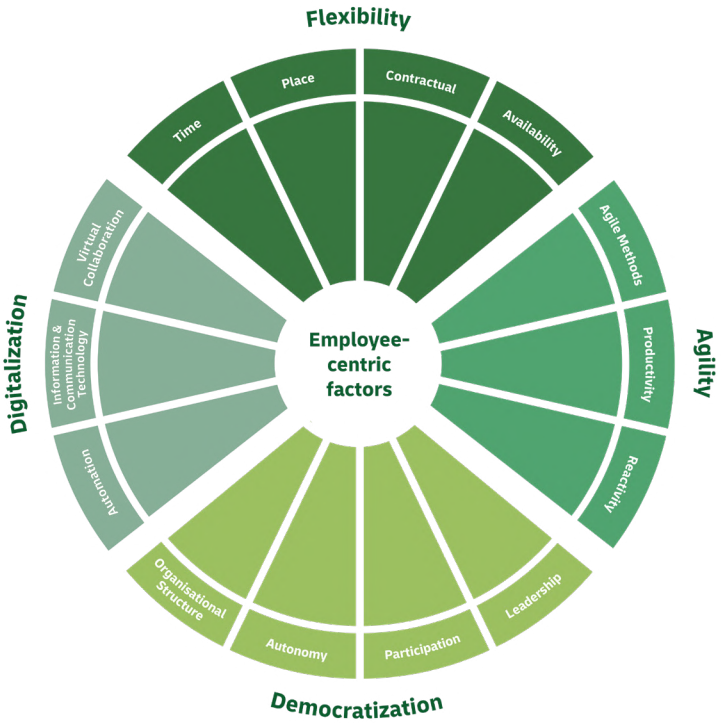
Workplace Values

Two organizational workplace values are key to an employee-centric strategy: a technology-forward mentality and a sustainable-forward attitude. These values underpin and support long-established values of leadership and teamwork.

One out of six young employees claim they left a job due to a lack of proper technology. In both the office and the warehouse environment, a technology-forward mentality helps attract and retain talent and has wider impact – a suitable working environment (which includes the right technology) contributes directly to increased productivity. Logistics leaders need to stay on top of technology developments, seeking out and deploying the best digital tools to enable their teams.

Research shows 71% of employment seekers are more likely to apply for and accept jobs with environmentally and socially responsible organizations – and nearly half would accept a lower salary to work for companies with a sustainable-forward attitude. Clearly this is central to attracting and retaining talent. Also, employees are increasingly wary of greenwashing so, to align with these employee expectations, logistics organizations must create tangible and transparent sustainability actions and policies, establishing a culture of trust.

Supply chain managers must customize employee-centric approaches to their unique workplace needs, as there is no one-size-fits-all solution



Graphic source: **Wawera et al. (2022): Arbeitsdefinition für New Work-Settings**

SUMMARY & TREND OVERVIEW

Challenges

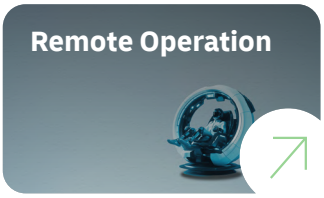
- Employee needs can vary greatly, which means it may be difficult to develop a common culture within the team.
- Balancing employee centricity with other values like effectiveness and productivity can be challenging, especially in operations.
- Workforce focus may be neglected during challenging market conditions but any short-term cost savings are outweighed by the high cost of subsequently attracting and hiring talent.
- Cultural transformation is needed to shift from a task-focused or management-centric culture to one that prioritizes employee needs and wellbeing, and may involve redefining leadership styles, communication methods, and performance metrics.

Outlook

Employee centricity will continue to grow in importance in the coming years, driven by societal and demographic changes, changing employee values and needs, and technological developments. In future, companies will be required to increasingly orientate the employee experience towards individual needs. Only by doing this will the organization remain an attractive employer and ultimately stay competitive.

This trend should be carefully monitored with implementations available for many use cases today.

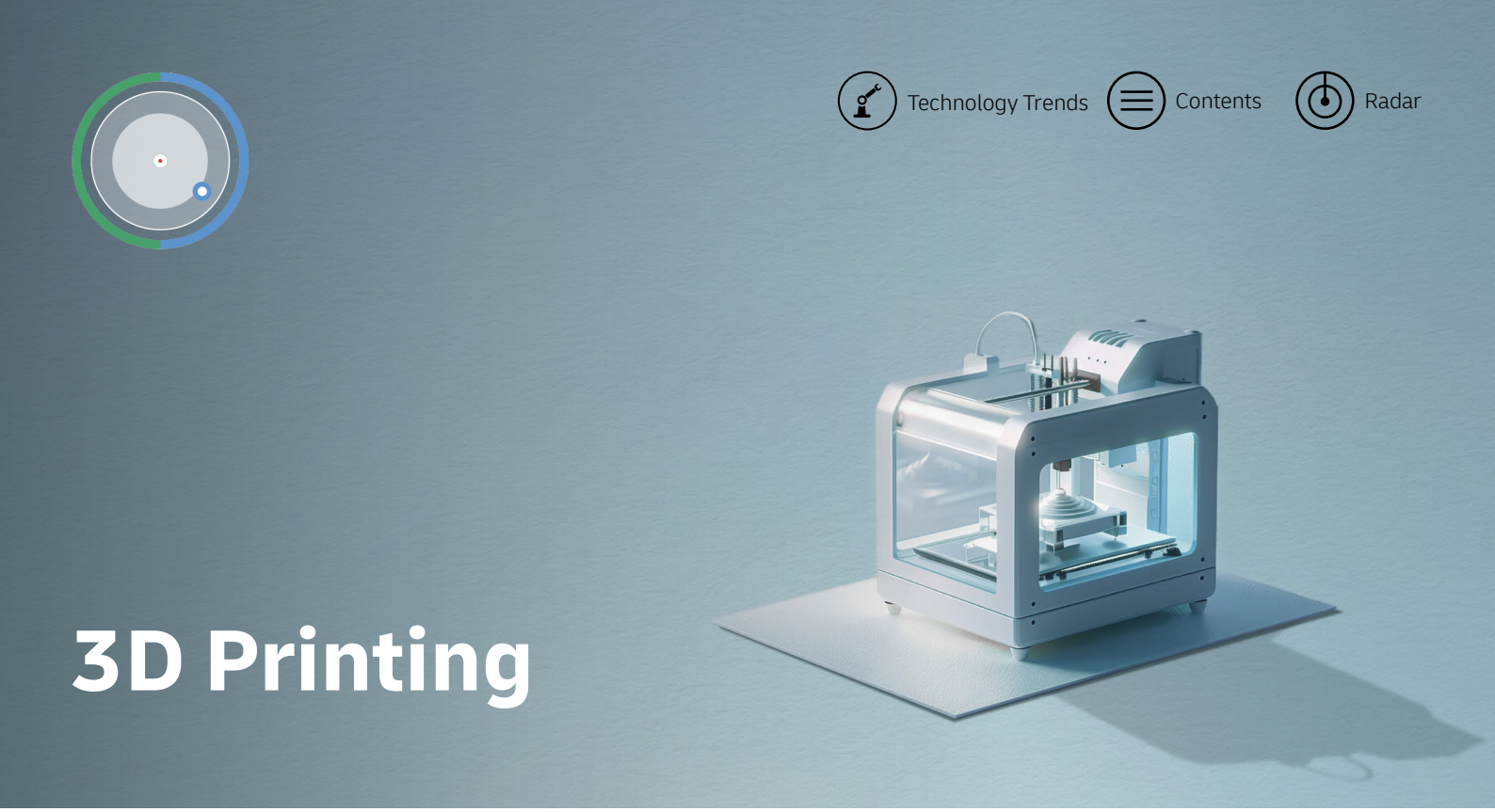
Related Trends



Sources:

BCG (2024): Enjoying Work Matters More Than You May Realize; DHL (2022): Global Workforce Survey; German Federal Ministry of Health (2022): Mental health in the workplace; PwC (2019): Provide autonomy. Create a competitive advantage through a more engaging people experience; IBM (2021): Sustainability at a turning point

Section Contents



3D Printing

The trend of Three-Dimensional (3D) Printing, otherwise known as additive manufacturing (AM), refers to the production process in which a 3D object is fabricated from a digital model file with physical materials typically being added together or etched layer by layer. 3D printing processes vary greatly, and they can involve a wide range of materials, such as plastics, metals, ceramics, and paper, to influence the strength, durability, accuracy, surface finish, and other attributes of the finished product.

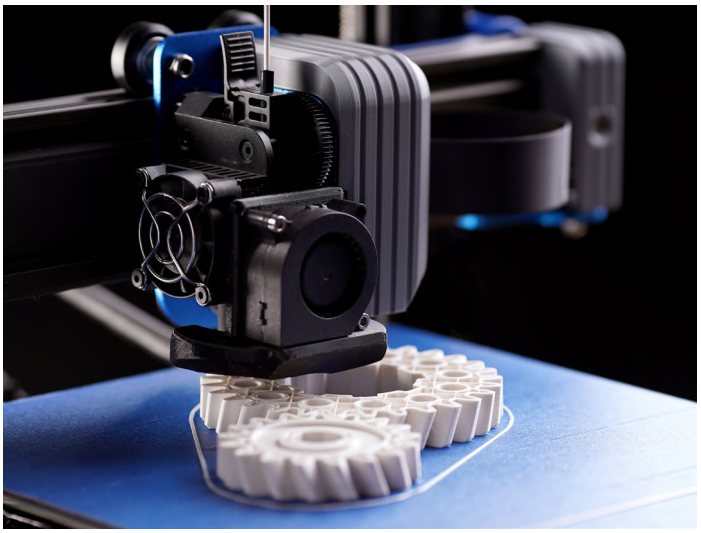
3D printing was initially used for rapid prototyping to accelerate product design processes. Today, with further technology development and maturation, it has been more widely adopted for larger batch size production across automotive, medical, aerospace, and other industries to create many different objects in a variety of materials. It offers the opportunity to reduce the weight of parts and to 3D print complex parts in one piece.

Products that can be 3D printed range from custom-made climbing shoes and printed dentures to fully 3D-printed wind turbines. GE Aviation, for example, began 3D-print production at scale of fuel nozzles for aircraft engines back in 2015 and, by 2021, made its 100,000th turbine shroud from ceramic matrix composite (CMC) using an additive manufacturing process – items which proved to be 25% lighter and 5 times more durable than traditionally produced parts.
The 3D printing landscape has grown in diversity and complexity, so the trend has evolved from niche to widely utilized applications. We here at DHL expect this production technology to achieve further adoption in the next few years.

Sales of 3D printers and 3D printing materials are estimated to increase at a compound annual growth rate (CAGR) of 11% between 2024 and 2034, when this market is expected to be worth US$49 billion.

To support this market increase in 3D print production, including business-to-business (B2B) printing services and delivery, logistics service providers are leveraging their regional networks in scale and complexity. They are also adapting their services to meet the increasing demand for the polymers and other raw materials used in 3D printing.

Mass Personalization & Customization

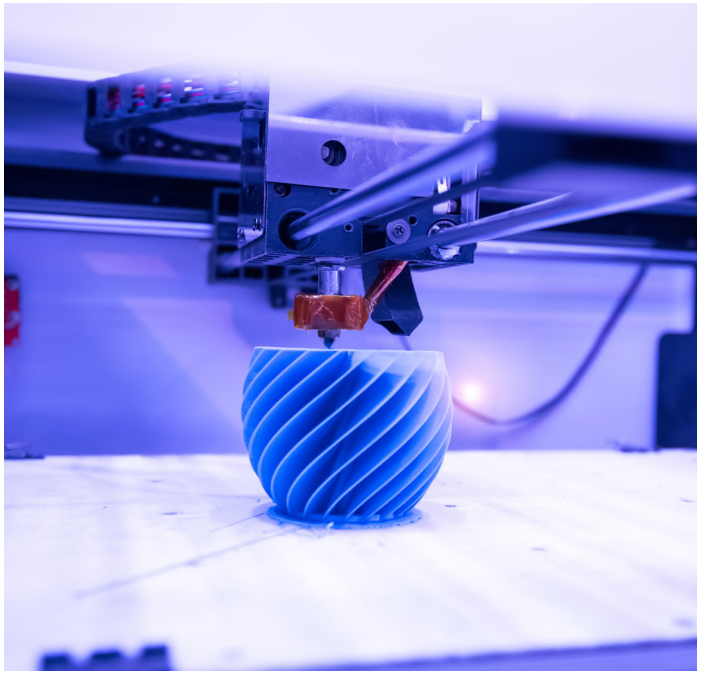


With 2.64 billion people around the world – one in three – already shopping online, there is vast potential for mass personalization and customization of products using 3D printing technology. Businesses need to rethink manufacturing and distribution to meet customer demand.

Not just consumers but also industries can benefit from mass customization of products. 3D printing brings value to many sectors, from automotive to aerospace and from semiconductor capital equipment manufacturing to healthcare provision. This technology can improve efficiency by simultaneously producing numerous customized end-user parts.

The increase in demand for mass personalized and customized products provides many new opportunities for businesses to leverage the capabilities of 3D printing technology. Examples include manufacturing lenses and eyeglass frames designed and positioned to fit unique facial features, prosthetic implants catering to individual patient requirements, customized hearing aids, and personalized footwear for users with special needs. Strong and agile local supply chain networks will be needed to accommodate efficient distribution of on-demand 3D-printed mass production items.

Decentralized Production

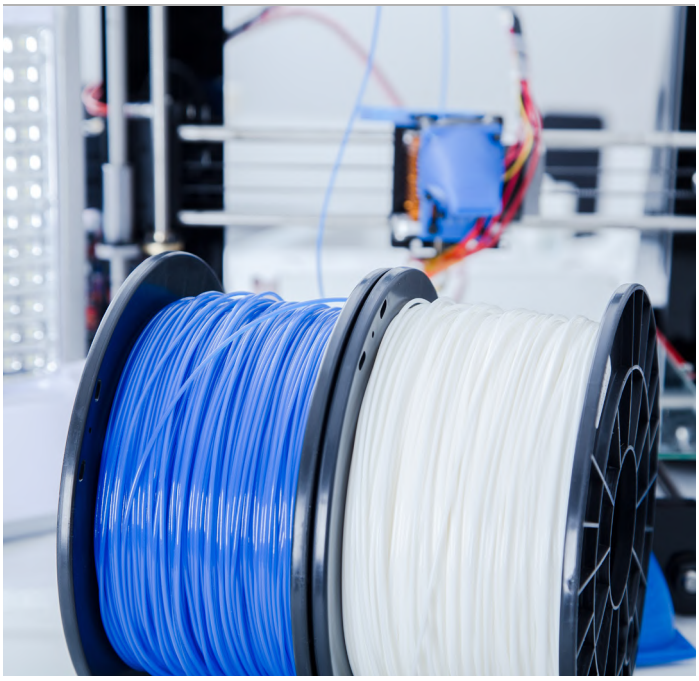


Effective spare parts management is crucial for maintaining product uptime, especially with the shift towards servitization (when customers pay for the use of equipment rather than buy it themselves), to avoid high costs and reduce the risk of lost sales if machines stand idle because spare parts are unavailable. The irregular and still hard to predict

demand for spare parts, coupled with the need to keep stock for the duration of a product's lifecycle (depending on the longevity of the product), present a challenge for aftermarket logistics.

Creating and storing digital part files on cloud and printing these items on demand gives companies flexibility in managing the supply chain, reducing inventory, optimizing warehouse storage space, and achieving shorter lead times. This can be attained by setting up decentralized local 3D printing facilities. A logistics company can take advantage of this opportunity and build servicing capability by, for example, partnering with local 3D printing services or producing spare parts in-house, and can use its supply chain network to deliver parts on time.

Environmental Sustainability



3D printing can play an important role in enabling companies to reach their sustainability strategy targets, as it reduces waste through the process of building a product layer by layer rather than subtracting and discarding materials, which is common in conventional production processes. 3D printing is also an enabler for decentralized production, reducing transportatation distances. And it offers ways to optimize product design by eliminating the design constraints of traditional manufacturing, which in turn reduces material use.

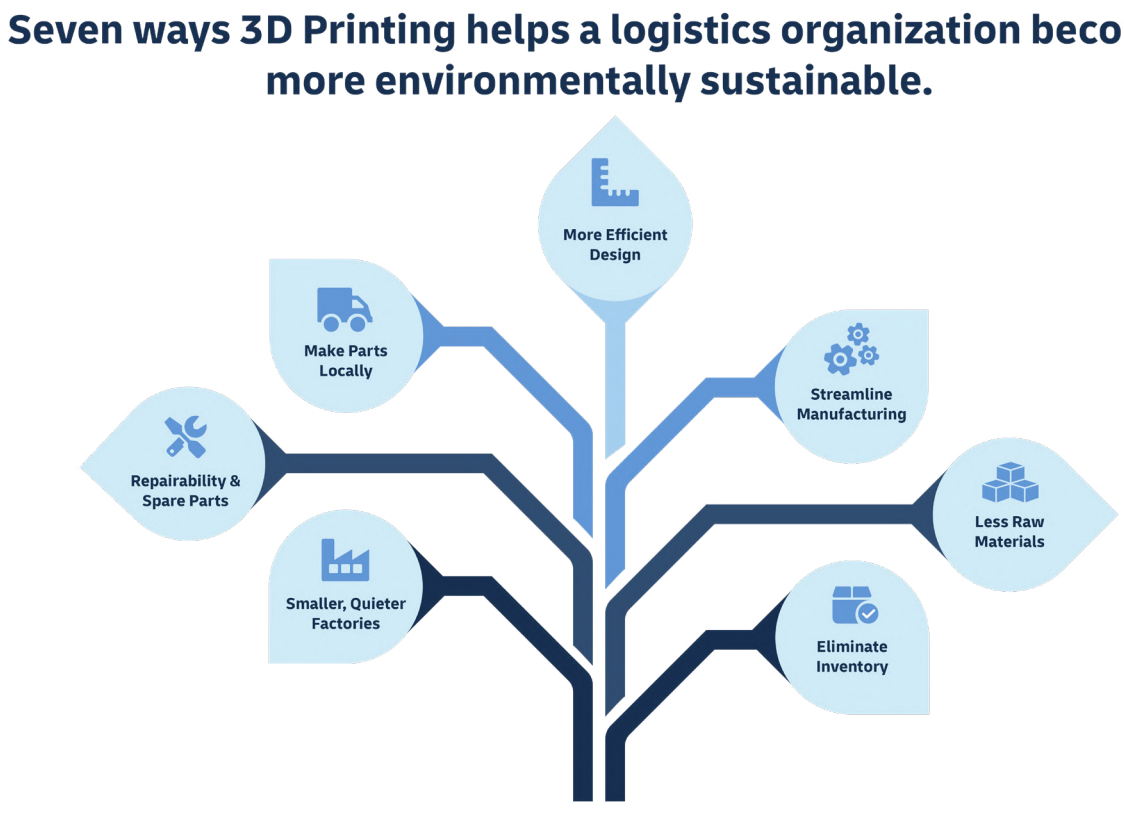
Increased investment in material research and development has resulted in the creation of environmentally friendly materials such as ABS and bio-based materials which help reduce the carbon footprint. Leveraging 3D printing therefore results in less need for waste logistics and reduces overall carbon emissions during the printing process. Within logistics and the supply chain, the benefits of advances in the field of materials science (such as using more lightweight materials to build airplane parts and sustainable packaging material) also bring more opportunities to reduce the carbon footprint.

3D Printing in the Supply Chain

In logistics, 3D printing enables rapid prototyping, too. A good example of this is the creation of parts for automation trials, when it is better for new concepts to 'fail fast' rather than incur long lead times before a result is achieved.

At DHL, one of our in-house technology teams has used 3D printing to develop a grabber for robotic arms deployed in supply chains. Creating sample products for logistics operations could take weeks from design to prototype but, with 3D printing, this can be reduced to days, allowing logistics planners to minimize the optimization window. For logistics applications requiring high levels of design customization or flexibility, on-site printed automation parts are likely to accelerate project turnover and optimize goods flow. Obtaining bespoke parts is not just much faster; it can also be much more cost effective and sustainable.

To use 3D printing as an alternative to conventional production methods in the supply chain requires more documentation, along with new quality standards and product testing methods suited to this new type of manufacturing.



Graphic source: **All3DP (2023): 7 Ways 3D Printing Helps You Become Sustainable**

SUMMARY & TREND OVERVIEW

Challenges

- A small-batch production size compared to conventional manufacturing makes 3D printing more costly and slower than mass production; this restricts widespread adoption across industries.
- Another barrier to adoption is the limited range of materials that can be used in their raw state for 3D printing; in some cases it continues to be difficult to achieve the same material properties as in conventional manufacturing.
- The size of the printable object is restricted by the dimensions of the 3D printer chamber; larger items must be built in parts and then combined manually.
- 3D printing risks intellectual property rights (IPR) infringement as, in the wrong hands, a printer can make lower-quality counterfeit products; original designers and manufacturers incur loss if fake goods find a way into the supply chain.

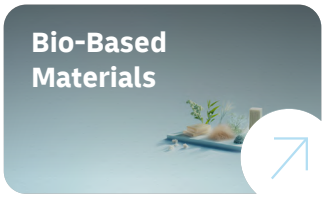
Outlook

3D printing will remain a good fit for low- to medium-volume production. With the right level of planning, engineering, and materials development, it can be seamlessly integrated into production. As this technology moves towards integration into all stages of new product development from conceptualization to production, in future we can even expect being able to print objects embedded with electronic chips and sensors at reasonable cost. This will help reduce reliance on third-party suppliers, meaning companies gain more control of their production processes, mitigating risk in the supply chain.

For the most part, logistics will play a supporting and enabling role within this trend. There is significant market opportunity. The global 3D printing market size is projected to achieve a CAGR of 24.3% between 2023 and 2030, reaching a value of $105 billion.

This trend should be monitored to some extent with developments and use cases on the horizon.

Related Trends



DHL Resources

3D printing: A new dimension

Sources:

IDTechEx (2024): 3D Printing and Additive Manufacturing 2024-2034: Technology and Market Outlook;
Meetanshi (2024): 45 Online Shopping Statistics to Take Note Of in 2024

Advanced Analytics

The trend of Advanced Analytics refers to sophisticated techniques and tools used to analyze and interpret data, aiming to extract insights and foresights and provide actionable intelligence beyond what is offered by traditional business intelligence methods today. This trend encompasses a range of methodologies including statistical analysis, predictive modeling, artificial intelligence (AI), machine learning, and data mining, enabling organizations to leverage data for strategic decision making and competitive advantage.

The ascendancy of advanced analytics in logistics and supply chain organizations signifies a notable shift in the paradigm of data utilization within the industry. From the early days of accumulating vast datasets and undertaking basic analysis, the industry now employs complex analytical methods to unearth insights and enable data-driven decisions along and across segments of supply chains. Rather than merely having access to large volumes of data (data quantity), logistics professionals can intelligently use and analyze this data for strategic advantage (data quality, which is essential to answer the increasingly complex and specific questions asked by businesses today.

At the heart of leveraging advanced analytics lies the paramount importance of clean, high-quality data. The accuracy of insights and the efficacy of predictive models are directly contingent on the integrity of the underlying data. Understanding this, organizations in various industries have invested in robust data management practices, emphasizing the cleaning, integration, and governance of data.

To achieve strategic agility and operational resilience, companies are increasingly aiming for data-driven decisions and the trend of advanced analytics helps logistics and supply chain managers navigate the way ahead.

In terms of impact, the importance of advanced analytics in logistics cannot be overstated, especially when considering the critical need for data-driven decisions in various departments, like operations and sales, to significantly enhance operational efficiency, customer satisfaction, sustainability, and overall competitiveness. In terms of adoption, this trend is in the mid-future. While much of the supporting technologies, like low-code / no-code platforms and data mesh architecture, already exist and are being currently used by some supply chain organizations, business data collection and analysis initiatives still require more years to be prioritized and implemented before they can be considered as mainstream in the logistics industry.

Forecasting

Forecasting in logistics and supply chain management is essential for operational efficiency, customer satisfaction, sustainability, and strategic planning. Advanced analytics, including the latest AI-driven techniques, greatly enhance forecasting capabilities.

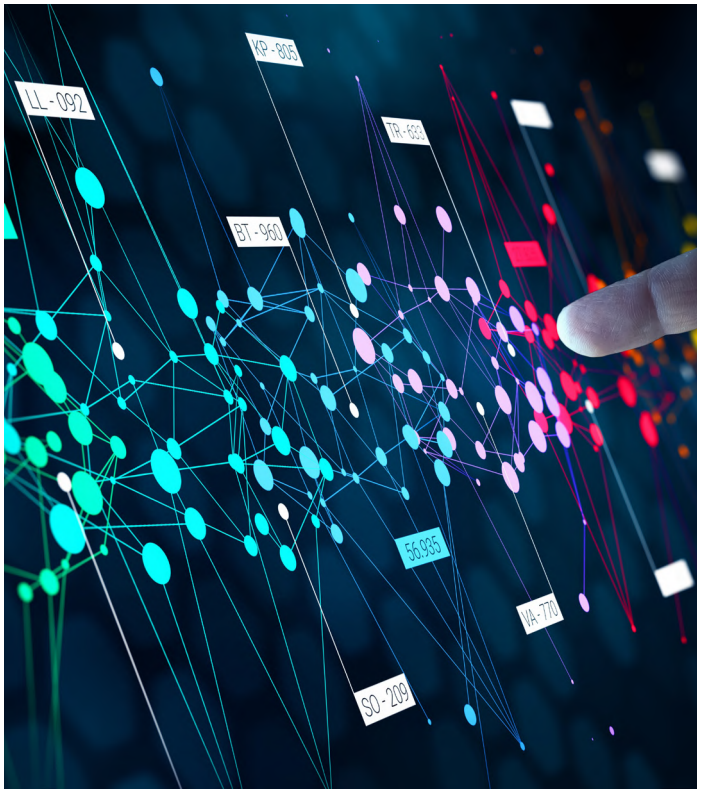
For financial forecasting and predicting consumer behavior, advanced analytics enable businesses to anticipate market demands, adjust pricing dynamically, efficiently plan resourcing, and optimize inventory levels. With a trade barometer, for example, which uses AI and big data to analyze import and export data, companies can get early indications of future trade and economic performance – a predictive capability enabling informed decisions about inventory management, production planning, and resource allocation, directly influencing operations and the bottom line. Predictive models can forecast consumer demand spikes on particular days or weeks, enabling retailers to stock up on trending products. And recent advances in AI, such as machine learning models that can analyze complex datasets and identify patterns beyond human capacity, have significantly enhanced forecast accuracy and timeliness.

Tech providers like IBM and its watsonx platform further refine demand forecasting, enabling models to be trained, tuned, and distributed with generative AI and machine learning capabilities. Forecasting also helps build supply chain resilience.

> *By predicting weather patterns and climate change impacts, businesses can mitigate risks related to natural disasters. They can adjust logistics strategies, reroute shipments, and secure alternative suppliers in advance.*

Moreover, AI-enhanced analytics extend to geopolitical and social factors, such as anticipating strikes or political instability that could disrupt supply chains. Predictive models might analyze social media senti-ment and political news to forecast disruptions, enabling proactive measures. Companies like Everstream, for instance, use AI-driven analytics to monitor scores of data sources globally, providing clients with real-time insights into potential disruptions and alternative routing options to ensure continuity.

Low-Code / No-Code



The surge in low-code / no-code platforms represented a significant tech shift, enabling users across various sectors, including logistics and supply chain management, to engage in advanced analytics without extensive coding knowledge. Platforms like Microsoft Power BI and Google Data Studio democratized data analysis, allowing logistics professionals to visualize and monitor key metrics such as inventory levels, shipment tracking, and supplier performance through user-friendly interfaces. These tools facilitate rapid, informed decision making critical to managing complex logistics operations efficiently.

Many startups are at the forefront of integrating low-code / no-code technologies into their logistics solutions. Locus, a logistics API-based platform company based in India, is an example of such innovation, offering advanced supply chain optimization and analytics solutions that utilize AI and machine learning to automate decision making in logistics operations. Its platform enables businesses to plan deliveries more efficiently, predict transportation volumes, and optimize routes without requiring users to have any coding expertise. By integrating these advanced analytics capabilities, Locus helps logistics companies in Asia and beyond reduce costs, improve delivery times, and enhance customer satisfaction through data-driven strategies, showcasing the potential of low-code / no-code platforms to transform logistics and supply chain management on a global scale.

Data Mesh

Data mesh represents a novel architectural paradigm designed to address the complexities and scalability challenges of managing data in large, distributed organizations, including those in logistics and supply chains. At its core, data mesh shifts the perspective from centralized data management to a decentralized approach, where data is treated as a product, with domain-specific teams responsible for its quality, governance, and accessibility. This methodology encourages a more collaborative and efficient data ecosystem, enabling various departments – such as procurement, warehousing, and distribution – to manage and share their data autonomously yet cohesively. For supply chain managers, this means

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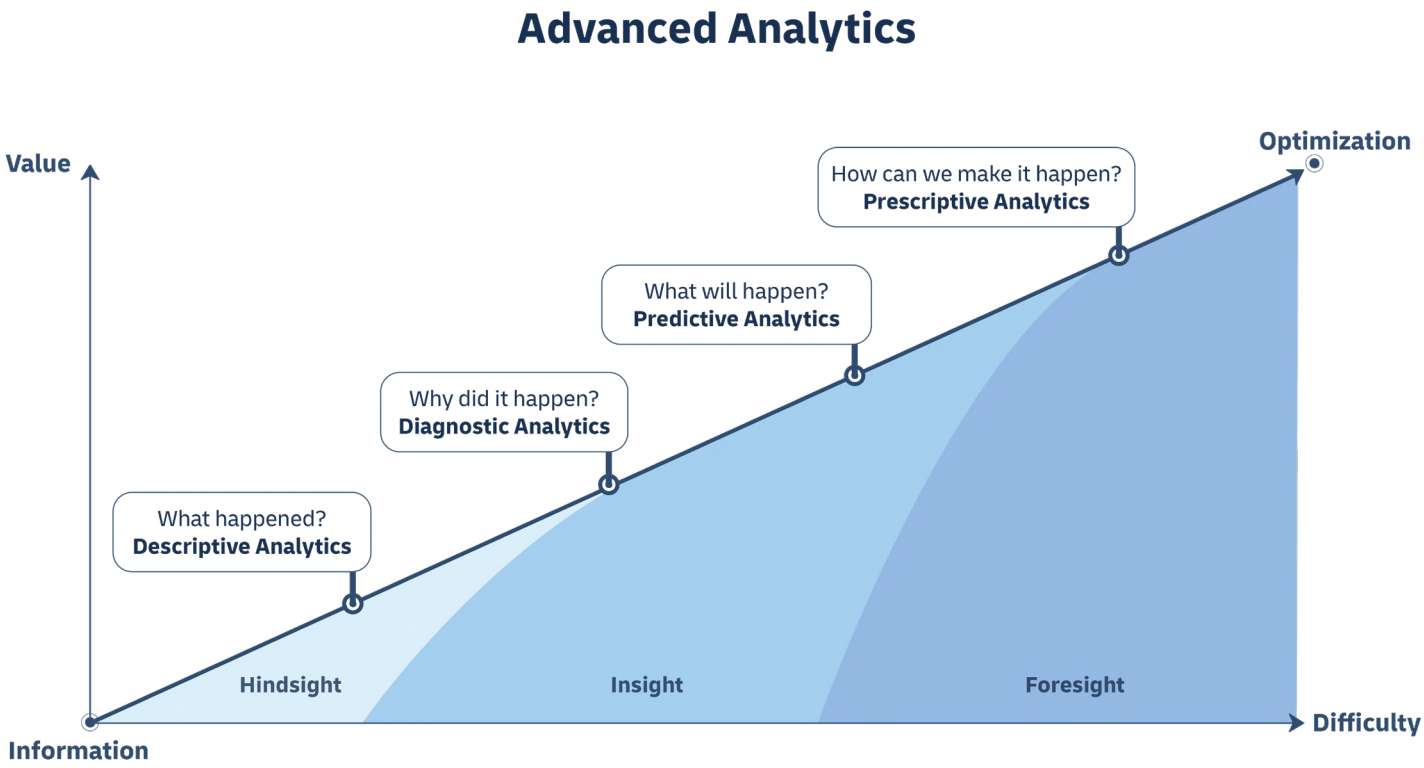
having direct access to high-quality, actionable data across different touchpoints of the supply chain, facilitating better decision making and operational efficiency.

The adoption of a data mesh architecture solves several pressing issues in logistics, including data silos, inconsistent data quality, and the cumbersome process of integrating data from diverse sources for analytics. By promoting a self-serve data infrastructure, it enables non-technical users to easily access and analyze data relevant to their specific domain, thus democratizing data analytics across the organization.

International startups like Paris-based Dataiku, as well as Ververica, headquartered in Berlin, are at the forefront of offering data mesh services that are reshaping how logistics and supply chains manage data. Dataiku provides a platform that supports the democratization of data access and analytics, facilitating the creation of self-serve data products that can empower domain experts within logistics to analyze effectively data relevant to their areas. Meanwhile, Ververica offers real-time data processing and analytics capabilities, which may be essential for implementing a data mesh in dynamic logistics environments. Its technologies enable logistics companies to build and manage data pipelines that process data in real time, allowing for immediate insights and responses to supply chain challenges.

By incorporating these innovative solutions, logistics and supply chain organizations can harness advanced analytics for more informed decision making, significantly enhancing operational efficiency and resilience.



Graphic source: **Gartner (2012): 2012 Gartner Magic Quadrant Report**

SUMMARY & TREND OVERVIEW

Challenges

- Ensuring data privacy and security becomes increasingly complex with advanced analytics, as data from various sources must be protected against breaches and unauthorized access.
- Implementing advanced analytics requires a well-built data governance framework in an organization to ensure data quality and compliance across all departments and functions.
- The integration of advanced analytics into an existing IT infrastructure can present significant technical challenges, requiring careful planning and possibly substantial investment in technology upgrades.
- Navigating the fast-evolving landscape of advanced analytics tools and technologies can be challenging, making it difficult for organizations to choose the most appropriate and future-proof solutions.

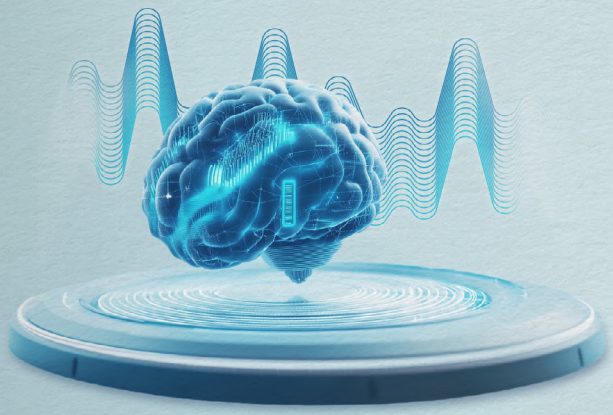
Outlook

The trajectory of the Advanced Analytics trend in logistics is continued innovation and expansion, driven by development of sophisticated analytical techniques and the proliferation of data across the global supply chain ecosystem. As organizations embrace data mesh architectures, low-code / no-code platforms, and advanced forecasting models, we anticipate a deeper integration of AI and machine learning technologies, further enhancing the precision and efficiency of logistical operations.

This evolving landscape not only promises to refine the capabilities of supply chain managers in making data-driven decisions but also sets the stage to explore new frontiers in predictive analytics, potentially revolutionizing how logistics and supply chains operate in an increasingly complex and dynamic global market.

This trend should be actively monitored with implementations available for many use cases today.

Related Trends



Audio AI

The Audio AI trend refers to the branch of artificial intelligence (AI) focused on the analysis, synthesis, and understanding of audio signals, enabling machines to perceive, process, and interpret sound in a manner similar to human auditory systems. It encompasses techniques such as speech recognition, sound classification, and environmental noise detection to enhance human-computer interaction.

Audio AI, a subset of artificial intelligence, is a specialized field which deals with the pattern recognition, comprehension, and analysis of auditory data. This applies to audio data from humans (voice recognition), machines (manufacturing equipment and more), and the environment. Analyzing this information provides insights across several use cases relevant to logistics.

Recent progress in audio AI include breakthroughs in speech recognition accuracy, stylized music generation quality, and environmental sound classification and analysis, driven by deep learning algorithms and improved computational resources. This is due to advances in deep learning techniques, particularly in neural network architectures such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs). Built on different architectures, these either use filters and pooling methods to feed information forward (CNNs) or feed results back into the network (RNNs).

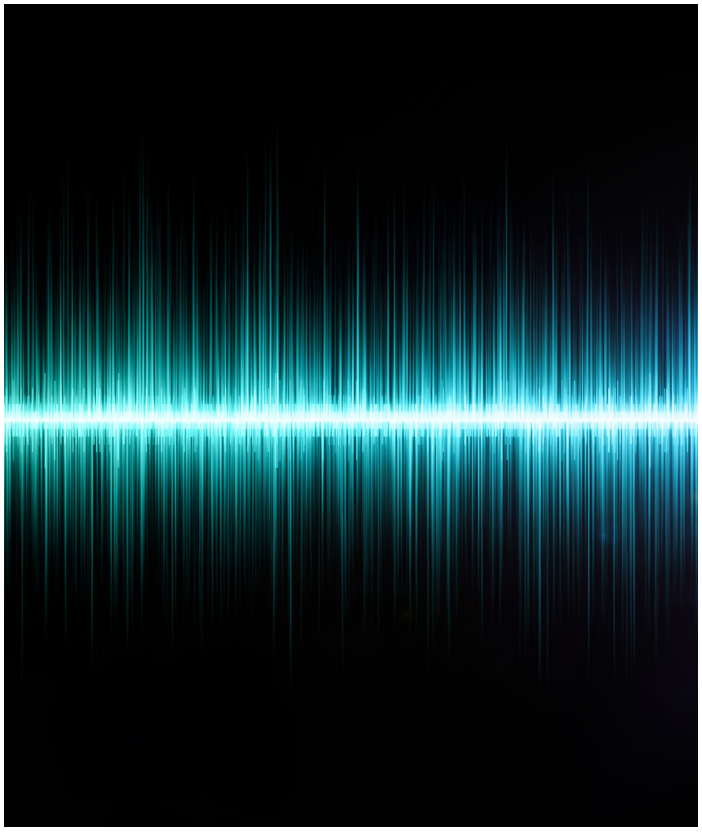
The market size for sound recognition alone was valued at US$ 1.2 billion in 2022, and this industry is projected to grow from $1.38 billion in 2023 to $4.29 billion by 2032 with a compound annual growth rate (CAGR) of 15.2%.

Here at DHL, we do not foresee this trend having a very high impact on logistics, but we have identified several audio AI use cases likely to change the way desk-based workers engage in their daily professional lives. Also, certain operational workflows can be enhanced with audio AI – examples include predictive maintenance, the use of virtual assistants, and, for operations employees, language translation.

Other trends and technologies are likely to command the spotlight due to their disruptive impact on supply chains, changing the ways goods flow through a warehouse. However audio AI can act as a supporting trend for many technologies, ensuring they operate optimally.

RELEVANCE TO THE FUTURE OF LOGISTICS

Predictive Maintenance



In manufacturing facilities, warehouse operations, hubs, or any loud environment where heavy machinery is used, it is challenging for the human ear to pick up sound anomalies that would help identify early-stage defects in machinery and equipment. With audio AI, granular sounds which are even out of the ordinary (and therefore out of the trained algorithm) can be picked up, enabling predictive maintenance before equipment breaks down and causes backlogs and delays.

In logistics operations involving vehicle fleets, audio AI can analyze the vibrations and sounds produced by trucks, vans, and delivery vehicles while in operation. By identifying patterns associated with mechanical issues or component degradation, predictive maintenance systems can also forecast maintenance needs, including engine tune-ups , tire replacements, and brake repairs, optimizing vehicle reliability, reducing unexpected breakdowns, and ensuring timely servicing to uphold customer delivery schedules. Audio AI can be used to continuously monitor the sounds produced by conveyor systems used in logistics warehouses and distribution centers. By detecting irregularities in conveyor belt sounds, such as excessive friction, misalignment, or component wear, predictive maintenance systems can anticipate potential failures and proactively schedule maintenance tasks, ensuring uninterrupted material flow, minimizing downtime, and optimizing productivity.

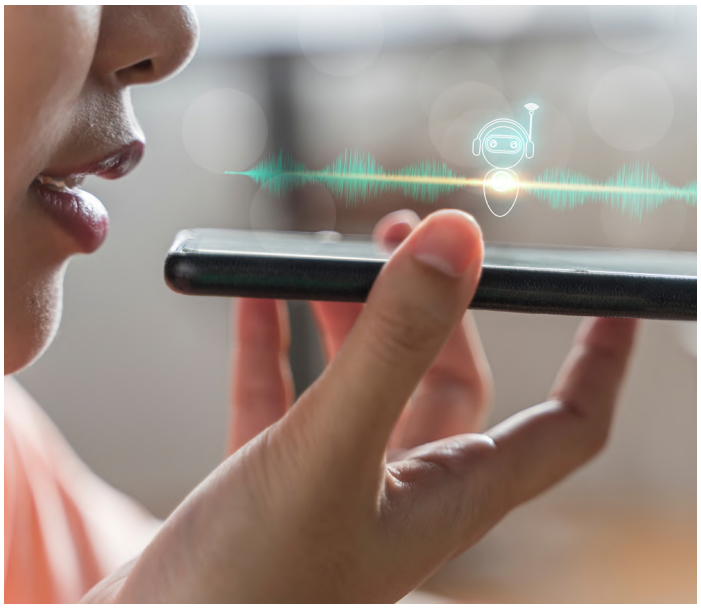
Predictive Fatigue Detection

Audio AI can analyze the speech patterns and vocal cues of drivers operating vehicles in logistics transportation fleets. By detecting changes in speech cadence, tone, and articulation which indicate tiredness or drowsiness, predictive fatigue detection systems can alert both the driver and the management team that a break is needed or when it will be needed. An example of this can be found in Wombatt, an as-a-service solution which trains its algorithm on the individual user's voice prior to starting a long-haul driving shift so later it can detect any fatigue. Initially designed for use in space engineering, we recognize its useful application in logistics, too.

With this type of solution, through personally trained algorithms based on individual user voice inputs,

an audio AI system can provide recommendations to manage fatigue. It can also look ath the number of hours slept the preceding night and at other possible contributing factors such as food consumption, medicine intake, and more.

Voice Sentiment Classification & Access Control



Companies can use large language models (LLMs) in conjunction with classical AI to transform service-related call center experiences. Example applications for audio AI include predicting customer intent and creating a tailored tone of voice – especially important when handling complaints.

LLMs can also be used to summarize calls, generate action points, and draft customer responses, freeing up employees to focus on bringing human creativity and empathy to customer actions where they can add most value. Furthermore, each new customer interaction serves as additional context and data input for AI models, improving the relevance and quality of outputs which then increases customer retention.

Here at DHL, we also see opportunities to enhance security by implementing access control using voice pattern recognition. This can be leveraged to identify individuals and to detect emotions in a voice, giving the potential to block access if this person has negative intent.

Language Translation

In logistics operations, we see applications for audio AI in process and workflow training. This can be within the warehouse for guidance in workflows and on the road assisting drivers with audio in their preferred

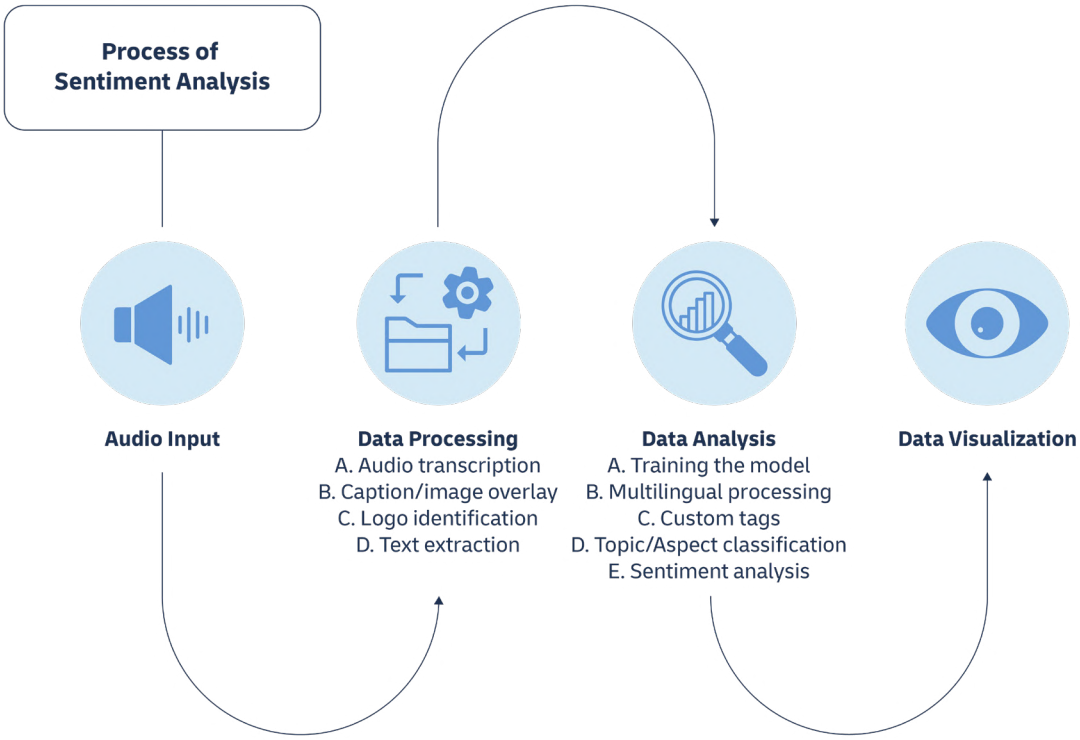
language, translating real-time navigation instructions, traffic updates, route optimizations, and more. This audio AI system could also monitor driver behavior and provide alerts in the driver's first language about potential safety risks, enhancing driver safety and reducing accidents.

Applications in language translation can also positively impact the customer experience. Automated voice-to-voice translation during customer service calls (delivered either by a human or through a chatbot) can facilitate and enhance customer communication.

> *In cross-border freight operations, audio AI language translation can assist truck drivers, customs officials, and warehouse personnel to understand and comply with regulations and instructions provided in different languages.*

This streamlines customs clearance processes and promotes smooth movement of goods across borders.

What is the process of sentiment analysis?



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

SUMMARY & TREND OVERVIEW

Challenges

- Audio AI systems can struggle to accurately distinguish relevant signals from background noise; machinery sounds, vehicle traffic, and the hubbub of human activity in logistics environments could be challenging.
- Audio data collected in logistics operations may vary in quality, format, and labeling standards, complicating the training and deployment of audio AI models across different locations or systems.
- For privacy reasons, companies must comply with laws and regulations such as the EU's General Data Protection Regulation (GDPR) and corporate policies on data collection, storage, and usage.

Outlook

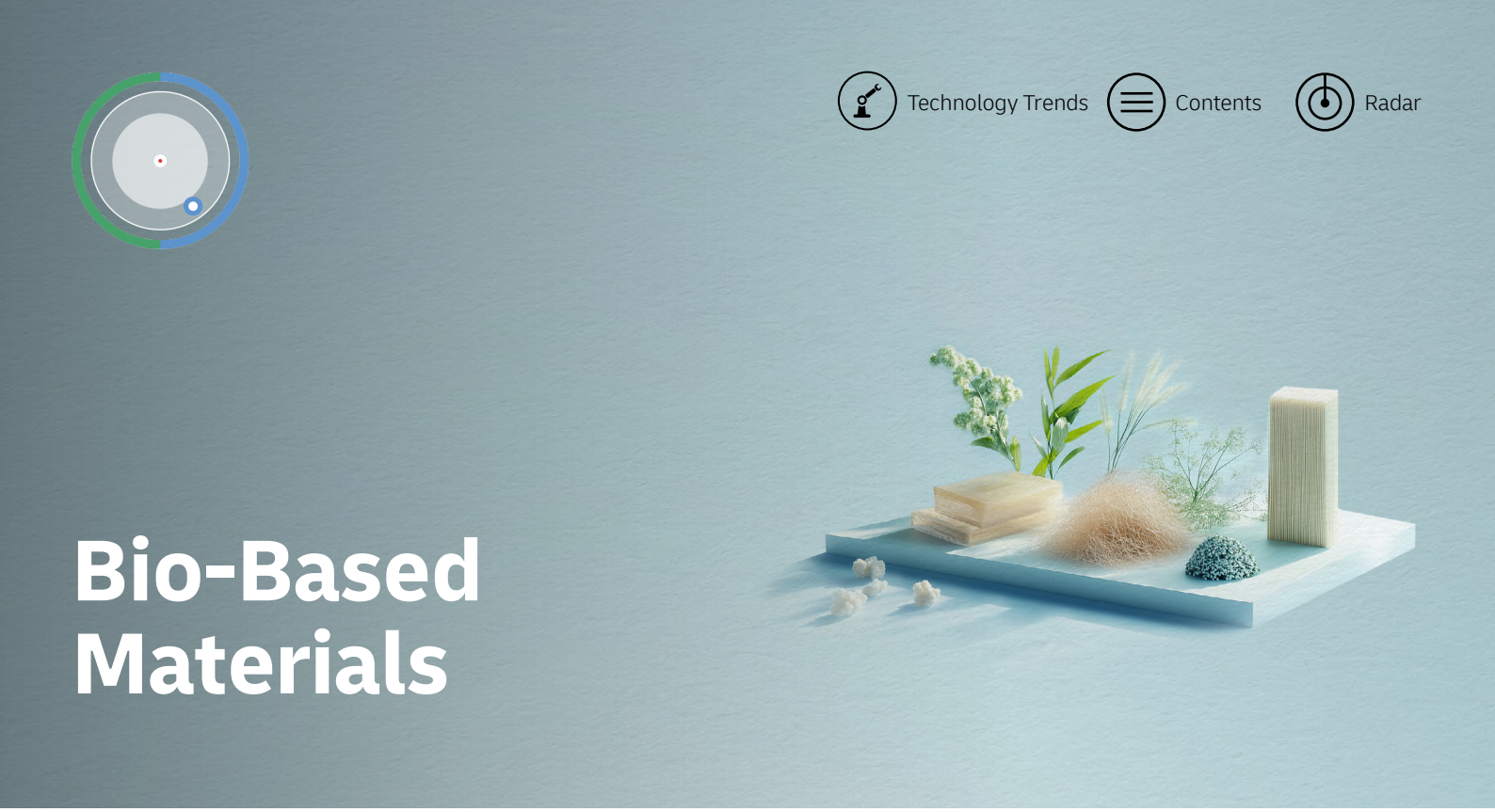
By leveraging audio AI for predictive maintenance, fatigue detection, process optimization, and more, logistics companies can streamline operations, minimize downtime, improve health and safety, and maximize equipment utilization, leading to increased productivity, faster order fulfillment, and a better customer experience.

Integration of audio AI with existing logistics systems enables intelligent automation and decision support capabilities, facilitating tasks such as inventory management, route optimization, and demand forecasting, empowering logistics professionals with actionable insights to make informed decisions and adapt to dynamic market conditions.

This trend should be passively monitored with developments and use cases on the horizon.

Related Trends

Source:
Market Research Future (2024): Global Sound Recognition Market Overview



Bio-Based Materials

The trend of Bio-Based Materials encompasses all materials produced exclusively from substances derived from traditional sustainable biomass, as well as modern bio-synthetic processes. This trend focuses on the beginning rather than the end of the product lifecycle and so it includes both biodegradable and non-biodegradable materials.

With consumers and corporations paying increased attention to sustainability in recent years, and as expectations rise and demands increase, logistics organizations are seeking to eliminate from daily operations materials seen as unsustainable and to reduce waste.

Bio-based materials are identified as carbon- and waste-reducing resources that can be integrated into more sustainable solutions. A wide range of potential applications for bio-based materials exists in various supply chain segments, from building construction to packaging. A survey conducted by McKinsey highlights the importance of bio-based solutions in the packaging industry. It reveals compostable packaging and plant-based packaging receive the highest rankings among end consumers, with 69% and 68% respectively, showing a generally positive correlation between the use of bio-based materials and consumer satisfaction. These high levels of consumer demand could push the application of bio-based solutions further in future.

Some bio-based materials have been used in logistics for many years already, especially those derived from conventional biomass. The best example of such a valuable and long-standing bio-based solution is the wooden pallet. More recently, additional bio-based materials have been introduced and tested, including bamboo, rice husk, palm fiber, mushroom, and solutions made of algae.

While the development of bio-based materials with comparable properties to conventional industrialized solutions is progressing, the industry is yet to witness a transformative development. Therefore, it is anticipated that it will take a minimum of five to seven years before bio-based alternative solutions are widely adopted as standard practice. Despite some potential impact on the sustainability and circularity of a supply chain, bio-based materials are not anticipated to have a profound effect on day-to-day logistics operations.

RELEVANCE TO THE FUTURE OF LOGISTICS

Building & Construction Material

The building and construction sector is the largest contributor to greenhouse gas emissions, responsible for an astonishing 37% of energy-related carbon emissions. This substantial carbon footprint is primarily attributed to the production and utilization of materials such as cement, steel, and aluminum, which have significant environmental impact.

Since logistics organizations use hundreds of thousands of facilities, warehouses, and offices made from these materials, this represents a great opportunity to reduce the environmental footprint of the supply chain.

Switching to bio-based building materials wherever feasible can help meet sustainability goals, and already many tech providers recognize this potential. Mycelium, derived from fungi, presents a compelling opportunity as a sustainable construction material. A good example of its application in construction is Ecovative's MycoComposite™ hemp blend. This innovative solution boasts strength, water resistance, mold resistance, fire resistance, and other qualities. The material's inherent flame-retardant properties ensure heightened safety, while its insulation and noise-dampening benefits enhance environmental comfort. Solutions like these can help lower the carbon footprint of the building and construction industry, offering logistics providers alternatives when planning the construction of greenfield projects. When DHL decided to build a European Innovation Center, sustainability was a high priority. Aiming for climate neutrality, we used locally sourced timber along with many green technologies.

Logistics Operations Assets

As the megatrends of global trade and e-commerce expand in future, the number of warehouses will grow exponentially along with associated assets such as pallets, racks, and picking bins. Today, the vast majority of pallets are wooden and mostly bio-based, but they break relatively easily compared with fully metal or plastic counterparts. Instead of replacing them with these less sustainable alternatives or with increasingly expensive wood and nails, logistics organizations are steadily searching for more durable and reusable bio-based materials.

Companies like Origo in Malaysia are developing bio-based alternatives for logistics assets and packaging. Origo utilizes agricultural waste from palm fibers or rice husks to produce pallets that are fully recyclable and compostable. The challenge lies in ensuring these bio-based solutions have comparable longevity to traditional wooden pallets and can be a sustainable and viable alternative. Further testing and scaling are needed to determine the resilience of these alternative solutions.

By using bio-based materials for assets in logistics facilities, organizations can achieve greater sustainability while also reducing replacement costs.

Packaging & Packing Materials

The most visible waste outputs from supply chains are packaging and packing materials - mostly plastic - with less than 9% of plastic products recycled globally in 2022. Bags, wraps, cardboard, and styrofoam are contaminating natural environments around the world and pressure is growing to address this, compelling the logistics industry to seek biodegradable alternatives.

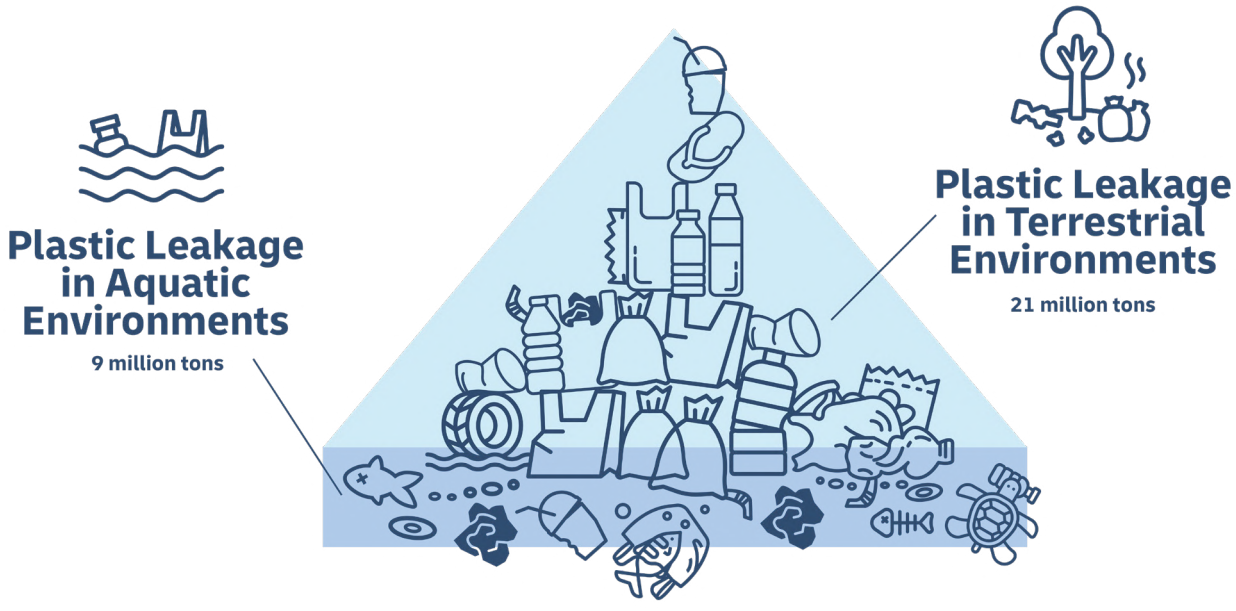
However, not all biodegradable products come from renewable sources, and several companies, around the world are seeking to bridge this gap.

Due to the demand for completely bio-based solutions, a growing number of startups are developing solutions in a wide variety of areas. The Australian company Planet Protector produces insulated wool-based packaging solutions as an alternative to polystyrene packaging materials.

> *Furthermore, materials like algae, mushrooms, and bamboo are also gaining popularity as viable options for sustainable packaging.*

These bio-based materials offer promising alternatives to traditional plastic packaging and contribute to a more environmentally friendly approach in the industry. By adopting packaging and packing material that are both biodegradable and bio-based, logistics and supply chain organizations can better ensure they are tackling the sustainability challenge for the entire product lifespan, not just downstream.

Unsustainable growth: Projected increase in plastics and plastic leakage by 2040



Graphic source: **Organization for Economic Co-operation and Development (OECD) (2023): Towards Eliminating Plastic Pollution by 2040 A Policy Scenario Analysis**

SUMMARY & TREND OVERVIEW

Challenges

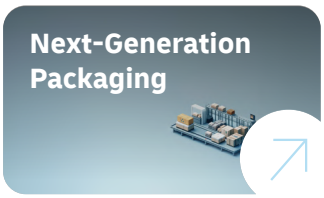
- Bio-based material production is still relatively small and there may be supply challenges if such materials are adopted on a large scale.
- Most bio-based solutions are pricier than less sustainable alternatives, limiting adoption.
- While still a worthy step towards achieving sustainability goals, bio-based materials are not always biodegradable and may still contribute to waste.
- Bio-based alternatives to logistics assets and packaging are more sustainable but often have limitations in terms of durability or stability compared to plastic-based alternatives.

Outlook

Bio-based materials continue to provide valuable alternative solutions for logistics and supply chain operations. However, it is important to note that many of these solutions are still in the developmental phase, and finding completely bio-degradable and environmentally friendly alternatives with properties comparable to conventional solutions remains a rarity.

This trend should be monitored to some extent with developments and use cases on the horizon.

Related Trends

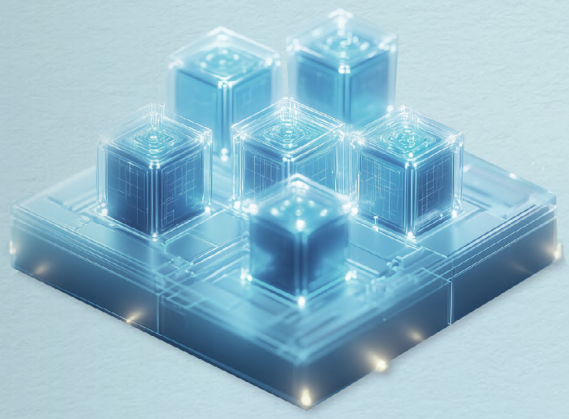


DHL Resources

The European Innovation Center in Germany prioritizes holistic sustainability

Sources:

McKinsey (2023): Sustainability in packaging 2023: Inside the minds of global consumers; United Nations Environment Programme (2023): Building Materials and the Climate: Constructing a New Future; Plastics Europe (2023): Plastic – the *fast* Facts 2023



Blockchains

The trend of Blockchains includes the development, implementation, use, and management of decentralized, digitally recorded ledgers that are distributed across networks. By incorporating immutable and serialized recording, blockchain technology acts as a single source of truth for its users.

A blockchain in simple terms is a distributed database that maintains a continuously growing list of records, called blocks. These blocks are connected using a method where each block has a cryptographic hash (an equation used to verify the validity of data) of the previous block, a timestamp, and an item of transaction data. These details cannot be altered retroactively without the alteration of all subsequent blocks as well as the consensus of the entire network. This ensures integrity of the data and enables this information to be considered a single source of truth for its users.

In recent years, logistics leaders in several industries have sought applicable use cases for this technology in their supply chains. Some logistics service providers, including DHL and Maersk in partnership with IBM and others, launched their own blockchains. However, in Q1 2023 Maersk and IBM decided to discontinue their blockchain-enabled shipping solution as it “has not reached the level of commercial viability necessary to continue work and meet the financial expectations as an independent business.”

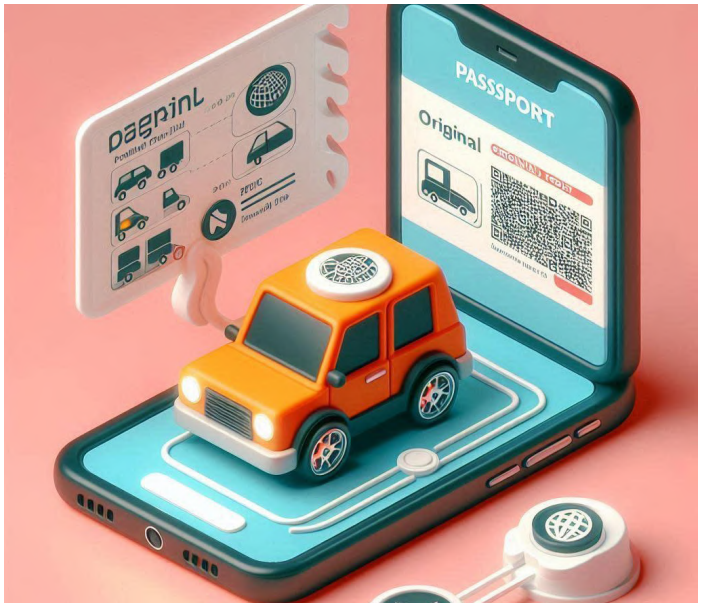
There are different perspectives on market growth within this trend. The global blockchain funding market, worth US$9.2 billion in Q1 2022, dropped to $6.5 billion by Q2 2022 – a quarter-on-quarter decrease of 29%. But market intelligence company Fortune Business Insights projects blockchain industry growth from $17.57 billion in 2023 to $469.49 billion in 2030, a compound annual growth rate (CAGR) of 59.9%.

Blockchain technology exists today and is applicable to many segments along a supply chain, although not necessarily to the same degree. To maximize the benefit and utility of blockchain, however, companies need the right data and thus various methods of data collection. This requires coordination and collaboration among many players in the typically highly diverse supply chain ecosystem. Therefore, the small number of blockchain implementations of today are likely to need several more years before they mature to meaningful, comprehensive integration within the end-to-end supply chain.

Although there are many players in the market offering blockchain-based solutions, the technology has not yet been widely accepted across supply chains and it will take more than 5 years for this to happen at scale. Also, different levels of acceptance and thus adoption of the technology by country differs, determined by several factors including government legislation and funding.

RELEVANCE TO THE FUTURE OF LOGISTICS

Digital Product Passports



Blockchain can track products across their lifetime, all the way from production to end of life and including lifecycle circularity. Building a product passport on blockchain technology is likely to increase the item's credibility, acceptance, and sustainability across borders, wherever this technology benefit has been accepted.

All parties involved at any point with the product's lifecycle, including logistics service providers, would be identifiable in the digital product passport so this, in turn, would boost product visibility, traceability, and accountability. For example, EU rules could soon require UK toys sold on the continent to come with a digital product passport.

> *A digital product passport would show whether virgin materials have been used in a product and whether the entire product or some part of it was used for a previous purpose. It would also show where the product and its constituent parts have been – their physical location, monitored and recorded using Internet of Things (IoT) technology.*

Together, this increases the credibility of any claims to circularity. This lets the end user take informed decisions before making a purchase. Everyone can see from the blockchain record when a product is new, recycled, remanufactured, upcycled, or partly sourced from recycling. This increased visibility and traceability achieved using blockchain is likely to significantly boost materials circulation.

Crypto Stamps

There is growing interest among collectors in crypto stamps. Companies like DHL are responding to this demand by creating these items. Each physical stamp includes a digital image which, in the blockchain, is clearly assigned a non-fungible token (NFT). As this data is stored in the blockchain, the collector is assured exclusive ownership of the NFT; they can include it in their personal digital wallet and it proves their possession of a uniquely numbered crypto stamp or a digital piece of art.

Traceability & Transparency

Today, companies have limited visibility of products as they move through production processes and supply chains. Manufacturers, retailers, and end customers are all demanding better and more reliable track-and-trace capabilities for products, raw materials, and waste. Blockchains, paired with logged records from sensors, can provide this visibility as a trusted, immutable ledger.

Supply chain professionals and customers can access a blockchain ledger with an interface from which they can see each product's shipment status and accurately confirm product attributes, such as whether it was locally produced, organically grown, or received certifications. Additionally, using blockchain technology, companies can quickly identify points of unauthorized removal or the insertion of products, helping to investigate theft, fraud, and counterfeiting. Finally, with hundreds of international trade laws and regulations, a blockchain-supported level of transparency enables supply chain organizations to ensure supplier and distributor compliance. By acting as a single source of truth, blockchains can bring a sense of fidelity to all partners along the supply chain.

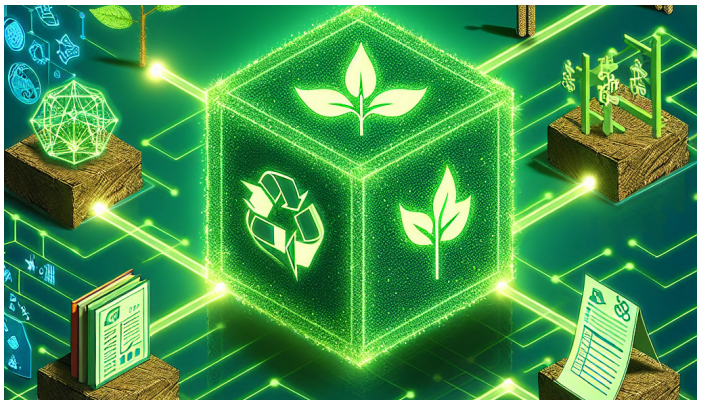
Smart Contracts

During its supply chain journey, each product can be subjected to multiple back-office processes, from manufacturing invoices and customs forms to retail agreements and delivery payments. These processes can take weeks or even months of human activity, involving many different parties. Instead, blockchain-based smart contracts effectively eliminate delays and shorten the critical-path timeline.

The smart contract is essentially an elaborate digital 'if-then' statement which self-executes procedures once pre-determined and agreed criteria are met. For example, if a product and all its components have been properly recorded, tracked, and traced in a customs agency's smart contract, the product meeting all requirements may automatically clear customs without any forms. Smart contracts can also perform more advanced functions like splitting payments among parties based on the distance each has travelled or subtracting varying degrees of penalties from payments depending on how late or damaged a package is when it arrives at its destination.

By implementing blockchain-based smart contracts, logistics organizations can streamline processes, reduce clerical errors, and bring transparency to an automated system.

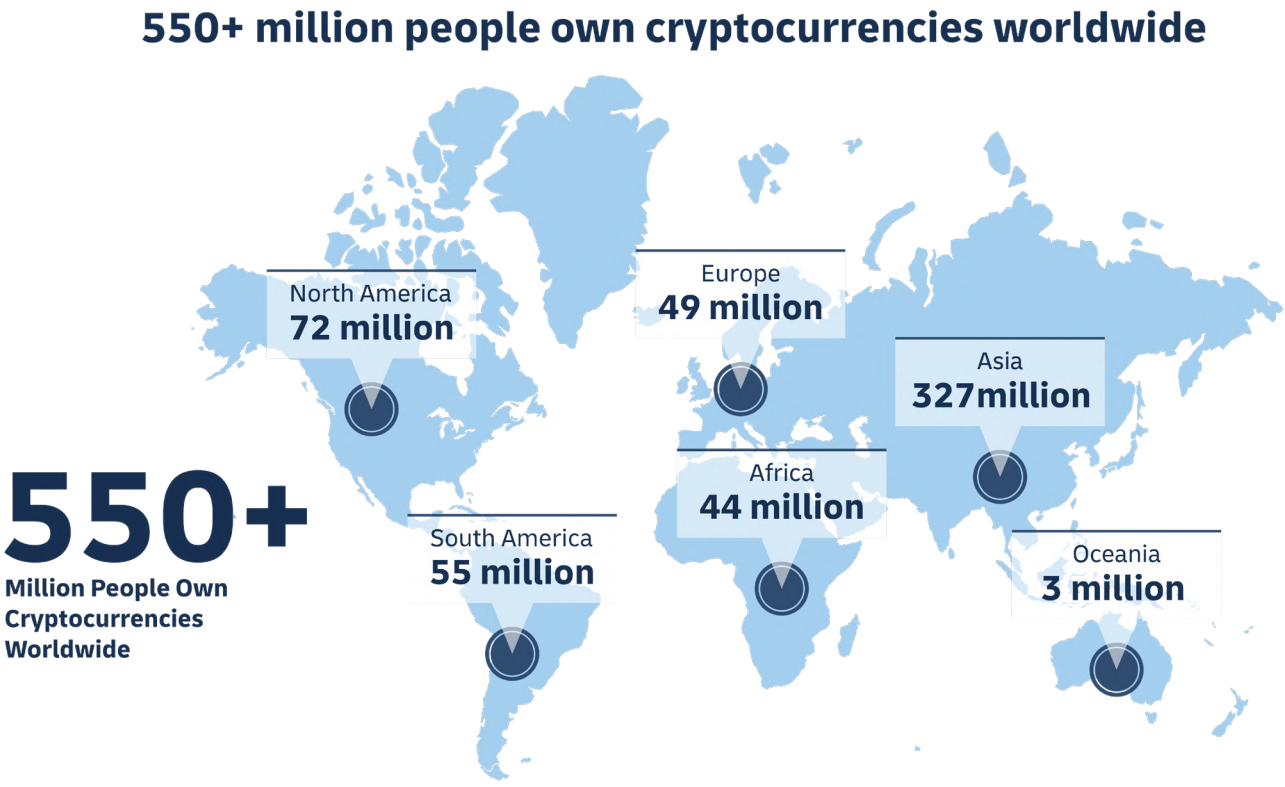
Blockchain & ESG



Blockchain technology can increase transparency and accountability around environmental, social, and governance (ESG) reporting for corporates. ESG metrics are normally self-reported so, by using blockchain to securely record carbon emissions, social impacts, and governance practices, all parties can track this data, and with greater granularity than before. While achieving more visibility, this helps build trust in the organization's compliance and reporting standards.

There are numerous application examples. For a more sustainable neighborhood in smart cities, blockchain facilitates smart grid mapping and management to improve utility usage and control. And for companies using carbon trading to deliver on net-zero targets, blockchain ensures accountability and verifiability.

Innovation and alignment are required not only with blockchain but also with other initiatives to effectively tackle ESG challenges. The most significant of blockchain technology are to introduce much-needed trust in the ecosystem and evidence the strategic actions taken. Organizations using blockchain can be held accountable for their practices and can showcase their progress with transparent and verified ESG metrics.



Graphic source: **Triple A (2024): The State of Global Cryptocurrency Ownership in 2024**

SUMMARY & TREND OVERVIEW

Challenges

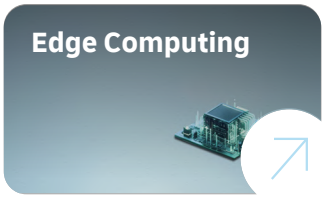
- Technical limitations such as scalability and high power consumption must be overcome to enable sustainable, large-scale deployment.
- Industry-wide adoption along and across supply chains is difficult given industry fragmentation and competition.
- Governance, standards bodies, and industry consortia are required to ensure conformity to regulations and interoperability between carriers, operators, customers, and customs authorities.
- Cryptocurrencies are mostly unregulated, increasing the risk of scams and lowering levels of trust; this is a barrier to the acceptance of crypto as payment and assets.

Outlook

Many pertinent and impactful use cases have been identified in the supply chain for existing blockchain technology. It is only a matter of time before multiple players along and across supply chains coordinate and collaborate to create comprehensive blockchain ecosystems, accelerating the full capabilities of this technology.

This trend should be monitored to some extent with developments still needed and use cases still being explored.

Related Trends



DHL Resources

Exclusive and colorful.
Our new crypto stamp

Source:
Krusche & Company GmbH (2024): The blockchain and blockchain development sector – statistics and facts

Computer Vision

The trend of Computer Vision utilizes cameras to capture photos or videos and applies artificial intelligence (AI) algorithms to analyze data extracted from this digital imagery. Rudimentary visual AI systems are trained to simply differentiate objects from each other, while more advanced – increasingly AI-enabled – versions can track objects across viewpoints and learn on their own and, in recent developments, enable prediction through pattern recognition.

Enabled by AI, the trend of Computer Vision has developed in conjunction with advances in deep machine learning (ML), leveraging the rising quality and decreasing cost of camera devices.

Several things are driving the adoption of computer vision technology, including the growing need for workflow automation and optimization across many industries, from auto-mobility to healthcare and banking, financial services, and insurance to retail.

In 2023, the global computer vision market was valued at around US$ 17.7 billion and – with continual improvements in AI, vision systems, and computer processing – is expected to grow at a compound annual growth rate (CAGR) of 19.6% by 2026.

Today, advanced computer vision technology is perfecting depth perception, 3D reconstruction, and dark and blurred image interpretation, all of which will unlock more opportunities in supply chains. Future deployment will be driven by further implementation of AI, automated ML, edge computing, the Internet of Things (IoT), and more.

Computer vision will become commonly utilized in logistics operations within the next five years, and many new use cases are likely to emerge. This technology will underpin and drive future logistics success by enabling more automated and efficient processes as well as sustainable and safe operations. However, to be fully realized, this trend will require additional investment. As experienced in the early days of sensor adoption, computer vision applications must be scalable for logistics organizations to maximize benefits.

RELEVANCE TO THE FUTURE OF LOGISTICS

People: Operations, Health & Safety

Computer vision and AI technologies offer effective solutions for enhancing workplace safety in logistics facilities by monitoring and analyzing movements of people and vehicles in real time. They enable proactive safety decisions, workflow improvements, and prompt corrective actions to mitigate risk and ensure a safer working environment.

In addition, computer vision used in human pose estimation (HPE) enables assessment of ergonomics in the workplace. TuMeke, a tech company, has developed an AI ergonomic risk assessment platform using computer vision that enables users to record and analyze smartphone videos of tasks like lifting boxes in warehouses to identify unsafe postures and enhance workplace safety.

The workforce should not only use appropriate personal protective equipment (PPE) but also wear it correctly. Using computer vision technology, AI systems can track and ensure compliance with PPE safety-at-work protocols, reducing incident risk.

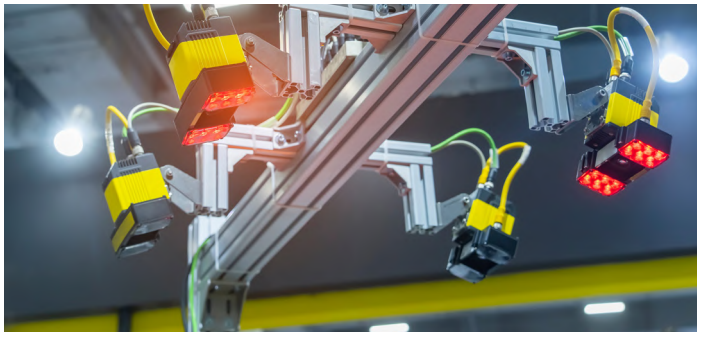
> *Bottlenecks, inefficiencies, and activity hotspots can be revealed by computer vision-based heatmaps in warehouses and yards, informed by surveillance camera feeds.*

With this information, managers can optimize inventory placement and increase operational efficiency.

Computer vision systems also offer a solution for efficiently counting people and vehicles in logistics facilities, helping managers optimize staffing levels and ensure compliance with safe occupancy requirements. Startups like AIVID provide automated detection and counting capabilities along with demographic insights.

To optimize the pick path, computer vision can be used alongside ML algorithms. Managers can analyze camera feeds to identify patterns, trends, and potential workflow adjustments to increase efficiency, save costs, and enhance overall warehouse operations. Additionally, intelligent surveillance systems equipped with computer vision technology can analyze real-time video footage using advanced algorithms to enhance safety and security. They can detect unauthorized entry or suspicious behavior, generate alerts for prompt response and proactive intervention, and ultimately reduce theft and increasing overall safety.

Shipments: Measurement, Identification & Inspection



Accurate measurement and efficient processing of packages are essential to storing, handling, and transporting goods. The task of dimensioning can be automated using computer vision technology – examples include solutions from MetriXFreight and Qboid.

Computer vision systems can also make valuable contributions to quality inspection, especially as early detection of damage during shipment protects brand image and ensures consumer satisfaction. Items must be correctly and legibly labeled, and computer vision technology helps ensure label accuracy and integrity, identifying errors and anomalies to facilitate efficient resolution and compliance with legal requirements. Startups like Visionify offer solutions for label checking in various shipping scenarios. To further streamline product identification, companies like Banner and Zetes offer innovative solutions for decoding challenging barcodes and ensuring shipping and loading accuracy.

In addition, automated sorting systems utilizing AI and neural networks streamline the visual classification of shipments, enhancing efficiency and accuracy. Good examples are Photoneo singulation and sorting solutions which can recognize parcels with 95% accuracy and high throughput rates using 3D scanners and AI algorithms.

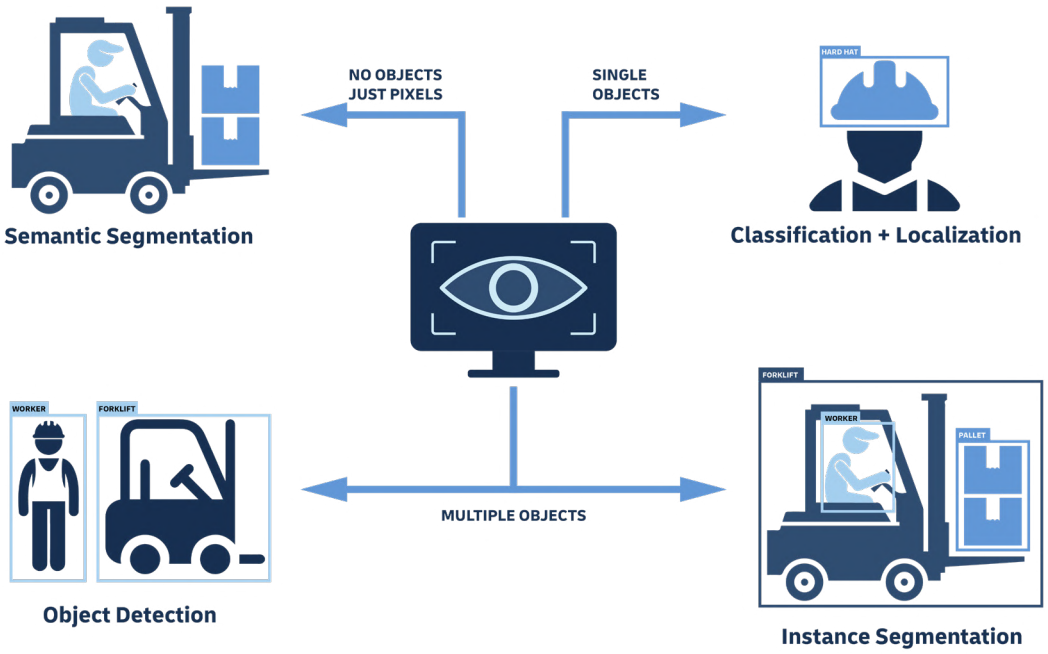
Assets

To protect logistics assets, computer vision technology can be used for predictive maintenance, issuing alerts so that the maintenance team can intervene before any issue arises. This also allows managers to schedule repairs and upkeep to prolong asset life and prevent failure.

Combining computer vision with human observation helps capture the full picture, as asset performance may be impacted by qualitative factors, such as the way a worker interacts with a device. When planning capacity to optimize asset utilization, computer vision can be implemented in asset management to deliver quicker insights than the human eye and those from human experience. For example, this AI-based technology can assess the overall space inside trucks and containers to calculate available volume prior to loading – information that helps determine the optimal arrangement of items to maximize loads and minimize wasted space.

In the warehouse, computer vision can be used to analyze the dimensions and orientation of pallets and roller cages, helping ensure these assets are positioned for optimal load distribution and peak efficiency. Meanwhile, assets outside the warehouse can be monitored 24/7 by an integrated system combining computer vision with surveillance. To restrict yard access to registered vehicles only, cameras can identify each truck and log its entry time, exit time, and number of daily trips. The system can also measure asset usage patterns, including idle time, and use this data to help optimize fleet operations.

Classification & Segmentation of Computer Vision



Graphic source: **Packt Publishing (2021): Computer Vision**

SUMMARY & TREND OVERVIEW

Challenges

- If workplace surveillance methods are perceived as invasive, this 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.

Outlook

Computer vision technology has matured significantly in the last two years, leading to remarkable growth in implementation and expanding applications in logistics operations. Increased investment in AI is anticipated to further advance computer vision solutions, with AI serving as the backbone for image recognition.

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.

This trend should be actively monitored with developments and use cases on the horizon.

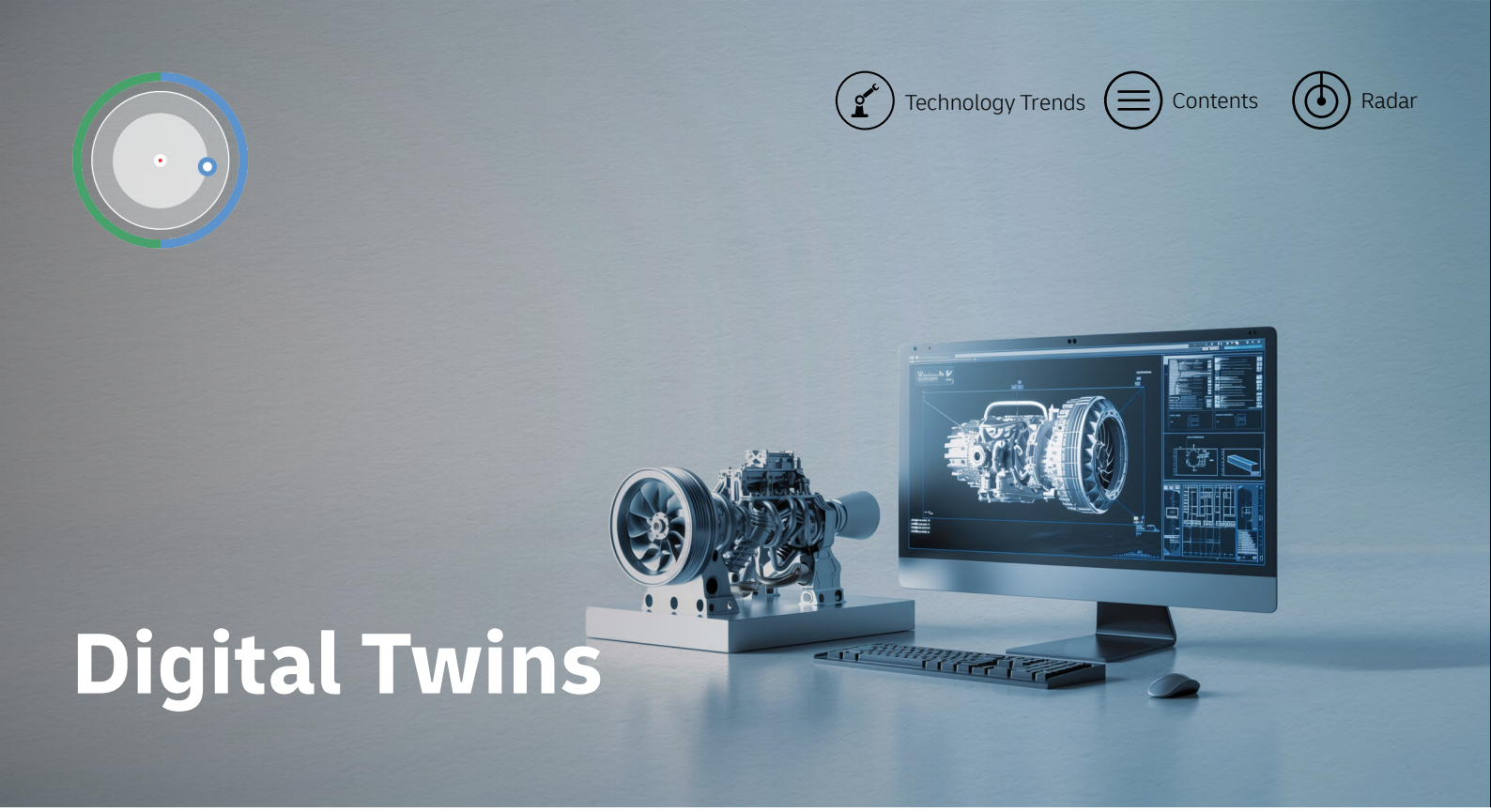
Related Trends

DHL Resources

AI-Driven Computer Vision Trend Report

Computer Vision AI | Health & Safety Proof-of-Concept with Protex AI

Sources:
DHL (2003): DHL - Computer Vision Health & Safety Proof-of-Concept with Protex AI; Global Data (2023): Computer Vision Market Size, Share, Trends and Analysis by Region, Industry Vertical and Segment Forecasts to 2026



Digital Twins

The trend of Digital Twins encompasses virtual models that accurately mirror the real-time conditions and behaviors of physical objects or processes they represent. A digital twin provides value through visualization, diagnosis, analysis, prediction, simulation, and optimization without the need for someone to interact with its physical twin.

The rapid advancement of sensor technology, cloud computing, and artificial intelligence (AI) over the past few years has significantly enhanced the accuracy and capabilities of digital twins. These virtual replicas now include a wide range of objects and systems, from individual machines to entire cities, providing unprecedented insights and control.

This technological evolution has caught the attention of numerous industries, including logistics, where the potential to revolutionize supply chain operations is immense. The digital twin market, valued at US$ 12.8 billion in 2024, is expected to continue to grow, driven by innovations and increasing adoption rates, with projections showing a compound annual growth rate (CAGR) exceeding 40% from 2023 to 2035 ($240.3 billion).

Adoption of digital twins in logistics has accelerated due to recent technological developments, and yet full integration into supply chains remains quite a few years away. Digital twins are moving from single-use applications to utilization in more comprehensive systems, integrating all aspects of logistics operations. Larger logistics companies like DHL are leveraging digital twins to enhance efficiency, resilience, and sustainability across their operations. As the technology matures, its impact is expected to grow, eventually but not yet transitioning from moderate to significant as organizations build more interconnected digital ecosystems.

RELEVANCE TO THE FUTURE OF LOGISTICS

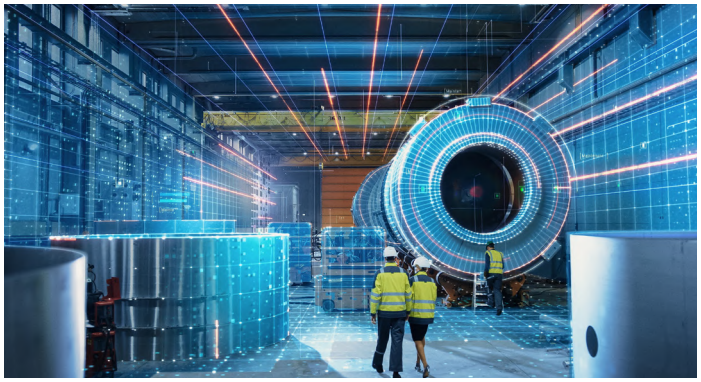
Stress-Testing Resilience

Global supply chains are performing under extreme pressure, navigating disruptions to meet increasing demand and handle ongoing volatility. Recent events such as the Covid-19 pandemic and geopolitical tensions have underscored the need for resilient supply chains. Stress testing an entire supply chain with a digital twin can help build resilience.

Logistics and supply chain organizations can leverage digital twins to simulate disruptions across global networks, including natural disasters, cyberattacks, and sudden market changes. These simulations provide a comprehensive view of potential impacts on service levels, the cost to serve, and supply chain integrity without affecting real-world operations. By applying these scenarios, logistics planners can identify vulnerabilities and optimize their response strategies in real time. Additionally, digital twin technology enables the modification and rerunning of scenarios to test various strategic adjustments, helping to enhance overall supply chain resilience.

With this proactive approach, more informed decisions can be taken, strengthening logistics operations in the event of unexpected disruptions. This new level of robustness ensures continuity, reliability, and sustainability in service delivery.

Optimizing Logistics Processes



Practically all processes within supply chains can benefit from the use of digital twins. From appropriately allocating workloads to efficiently managing inbound and outbound flows, a digital twin can facilitate logistics optimization through visibility.

German drugstore retailer dm-drogerie markt, for instance, has used digital twins to optimize inventory operations, including replenishing products on shelves. The retailer created digital twins of each of its 2,000+ stores, including the shelf layout and all product stock-keeping unit (SKU) locations in every branch. By having real-time visibility of product availability across all its locations, dm-drogerie markt has been able to optimally combine goods on incoming mixed pallets from distribution centers to ensure shelves are properly stocked with the fewest pallets needed. Furthermore, as the retailer knows where exactly in each branch every product belongs, this helps minimize employee in-store walking distances. On a smartphone display, personnel can see the optimal restocking path for each item.

In implementing digital twins for specific supply chain processes, logistics organizations can potentially reduce the cost, time, resources, and waste previously incurred when completing tasks.

Predictive Maintenance

Unplanned downtime is disruptive and expensive, costing industrial manufacturers lost time of over 15 hours a week and over $50 billion a year.

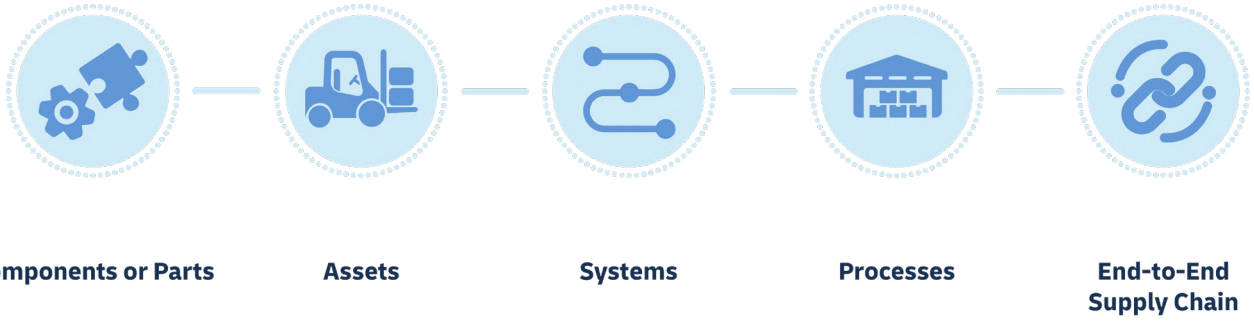
With equipment failure cited as the cause of almost half of all downtime, predictive maintenance (anticipating and repairing assets before they break or fail) is seen as a worthy strategy to effectively cut costs and increase productivity for manufacturers and logistics providers alike.

Able to provide real-time visibility of the condition of physical objects, digital twins are often seen as the ideal solution for predictive maintenance. Kraft Heinz partnered with Microsoft to create digital twins of all its 34 manufacturing sites in North America, with one of the goals being to reduce mechanical downtime at each facility.

Digital twins can additionally be applied to smaller, individual assets, not just whole warehouses. The most advanced logistics players and equipment service providers are creating digital twins of assets like individual robots, forklifts, trucks, and other assets, tracking the condition of each one and detecting any wear and tear that should be addressed to avoid breakdowns.

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

Five Types of Digital Twins



Graphic source: **Vidya Technology (2022): The 3 Levels of the Digital Twin Technology – 2023**

SUMMARY & TREND OVERVIEW

Challenges

- Real-time, high-quality data is the basis for any digital twin solution but demanding or prohibitive field conditions can limit data access and degrade the accuracy of a digital twin.
- Digital twins require considerable investment in sensor technology, platforms, model development, and high-touch maintenance.
- Some qualities of a complex asset like its chemical, electrical, and thermal state can be extremely costly and challenging to accurately replicate, often forcing users to make generalized, less accurate assumptions and simplifications in digital twin models.
- With direct connection to physical objects, digital twins potentially pose a security risk, giving cybercriminals a possible new point of entry to disrupt an organization's operations.

Outlook

While digital twin technology has existed since the start of the 21st century, it is now approaching a tipping point where widespread adoption is likely within the next 5-10 years.

Initially, the primary application areas focused on singular assets and contained systems. However, the future will see digital twins encompassing entire supply chains, integrating thousands of assets across various players. The continuous development and integration of AI, machine learning, and Internet of Things (IoT) will further expand the capabilities of digital twins, making them indispensable tools for modern supply chain management.

This trend should be monitored to some extent with use cases in some applications that can already be addressed today.

Related Trends

DHL Resources

DHL Supply Chain partners Tetra Pak to implement its first digital twin warehouse in Asia Pacific

Source:

Roots Analysis (2023): Digital Twin Market Size; Forbes (2022): Unplanned downtime costs more than you think

Drones

The trend of Drones, otherwise known as unmanned aerial vehicles (UAVs), refers to the development and utilization of variously shaped aircraft without a human pilot or crew on board. Enabled by embedded sensors and transceivers to navigate, drones are often controlled remotely by a human pilot, but advanced versions can fly autonomously beyond visual line of sight (BVLOS) using software-controlled flight plans. Drones come in a variety of sizes and form factors; examples include single-rotor helicopters and multi-rotor, fixed-wing, and fixed-wing hybrid vertical take-off and landing (VTOL) drones. Drones can carry out a variety of tasks, ranging from delivering packages to supporting operations, enhancing security, and enabling inventory counting.

Today's drones are equipped with the latest technological advances, including new energy technology to increase drone endurance. Panasonic developments indicate next-generation solid-state batteries will provide significantly longer range and faster charging than traditional lithium-ion batteries. And companies like Hylium are using hydrogen fuel cells to achieve flight times of five hours. Enhanced navigation systems are another example of technology advances; sensor fusion by Teledyne Geospatial combines GPS with LiDAR, radar, and other sensors to enable drones to navigate reliably even where there's signal interference.

In addition, computer vision algorithms now enable drones to "see" and understand their surroundings, identifying and avoiding obstacles in real time.

Drones equipped with artificial intelligence (AI) and machine learning (ML) algorithms can autonomously navigate complex environments, avoid obstacles, and even make on-the-fly decisions. In fact, an AI-powered drone has beaten human champion pilots.

Arguably the biggest development within the Drones trend is swarm technology. A subfield of AI, swarm intelligence (SI) is based on the study of decentralized, self-organized systems; these systems typically comprise many simple agents that interact to accomplish a common goal. Mostly seen today in entertainment drone displays, SI can be usefully applied elsewhere; for example, in disaster relief, where drone swarms cover large areas to accurately locate targets during search and rescue operations.

Over the past eight years and still today, regulations continue to suppress the realization of this trend. A 2023 survey found almost 75% of survey responses listed "regulators" as a barrier to widespread adoption of drone operations. Despite this, much technological progress has been made. Today, drones are capable of supporting delivery applications, both in urban and remote locations; importantly, this can help alleviate pressure on the scarce delivery workforce.

Drone Deliveries

Logistics volumes continue to grow while available delivery labor shrinks. Many cities are urgently attempting to tackle traffic congestion and companies want to deliver to customers everywhere. A solution that answers these needs could be drone delivery, covering the first, middle, and last mile. However, for the foreseeable future last-mile delivery will be focused on rural areas. While drones do the work, existing labor can be upskilled or assigned to value-adding tasks, fewer vehicles are needed, safety is increased, and rural delivery costs are reduced. Examples of progress in the area of heavy-lift cargo drones include Sabrewing's pre-production drone capable of lifting a record-breaking 376 kg (829 lb) payload, Dronamics' cargo drone technology, and Elroy Air's first vertical takeoff and landing drones.

Recently, the US Federal Aviation Administration (FAA) granted numerous drone companies approval for BVLOS flights. Other countries are likely to follow this lead. Even so, DHL anticipates limited growth in commercial drone deliveries within the next five years, for the same reason that growth has been limited since 2013: aviation regulations. At DHL, we believe there will be growth in niche use cases, such as deliveries within large private compounds and deliveries of critical or medical goods to rural areas, but growth is less likely for deliveries in urban and other built-up areas.

Security & Surveillance

It is challenging to patrol and secure large facilities, and human vision is limited; if an intruder is hiding, detection may not be easy. Rather than risk overlooking intrusion, drones with cameras can be deployed. This visual data can help accelerate patrol tasks, potentially increasing the daily number of patrols at randomized intervals. Enabled by AI-based systems, companies can expect increased accuracy of threat identification, less chance of missing suspicious activity, and more information captured with a bird's eye view of the facility.

Drones are also getting smarter, leveraging 5G for real-time data transfer and processing. They can now operate with increased speed, reduced latency, and improved reliability. Some even allow for fully autonomous operations. For example, security staff do not need to manually launch and retrieve drone-in-a-box security solutions, nor swap and change their batteries, and tethered solutions even allow drones to stay airborne indefinitely.

There is a disadvantage to consider. As this technology has developed, malicious use has also increased. Such activity is today being tackled with counter uncrewed aerial systems (C-UAS), particularly focused on removing the menace of rogue drones disrupting flights and having a negative financial impact at commercial and cargo airports. "Soft-kill" methods can also be deployed, such as jamming or cutting off the drone's communication with its pilot or source, and "hard-kill" methods, such as physically taking down a drone, using nets, ammunition, and even eagles.

RELEVANCE TO THE FUTURE OF LOGISTICS

Dimensioning & Inspecting Large Assets

Dimensioning and inspecting large assets manually can take many hours as, for example, mismeasuring or missing an equipment fracture can have costly consequences. Also these tasks may risk worker safety, especially if personnel are required to climb heights or walk on uneven surfaces to dimension and inspect large assets. Drone technology can make such activities more efficient.

> *Taking the example of stockpile dimensioning, drones with improved AI and sensor technology can measure amassed stock volumes with below-centimeter precision in a matter of hours instead of days.*

Several technologies can be deployed in this application. Drones may use a global navigation satellite system (GNSS) receiver to connect to more satellites for improved precision. They can use real-time kinematic (RTK) positioning and ground control points (GCPs) to achieve consistent data alignment over time. This is vital for monitoring ever-changing stockpiles – a significant advantage as, without RTK or GCPs, maps may shift several meters, resulting in inaccurate stockpile measurements, especially if comparing data from different dates. And to process the captured images, a photogrammetry engine and software can be used, such as the DJI Terra solution.

A good example of a large asset to be inspected is an airplane. This has always been done manually with inspectors walking around an airplane to assess its overall condition and compliance with safety standards. General visual inspections (GVIs) are then carried out to inspect, locate, and evaluate any visually obvious damage, failure, or anomaly. Many times, ladders, scaffolding, and cherry pickers are involved when something is out of reach and viewed from the ground. New solutions, such as the solution from Dutch startup Mainblades, provide a great alternative. Drones can be used to autonomously inspect all sides of an airplane without the need for additional equipment and without putting inspectors at risk. The captured data can be reviewed later by the inspector.

Using drones eliminates safety risks and significantly reduces time and staffing requirements. Spending less time on currently manual tasks allows for faster turnaround and more missions. Warehouses also can minimize personnel numbers for inventory tracking while also getting updated inventory data more regularly, thus increasing inventory visibility. As well as lowering operational costs, these efficiencies are likely to have a positive effect on the company's brand and reputation.

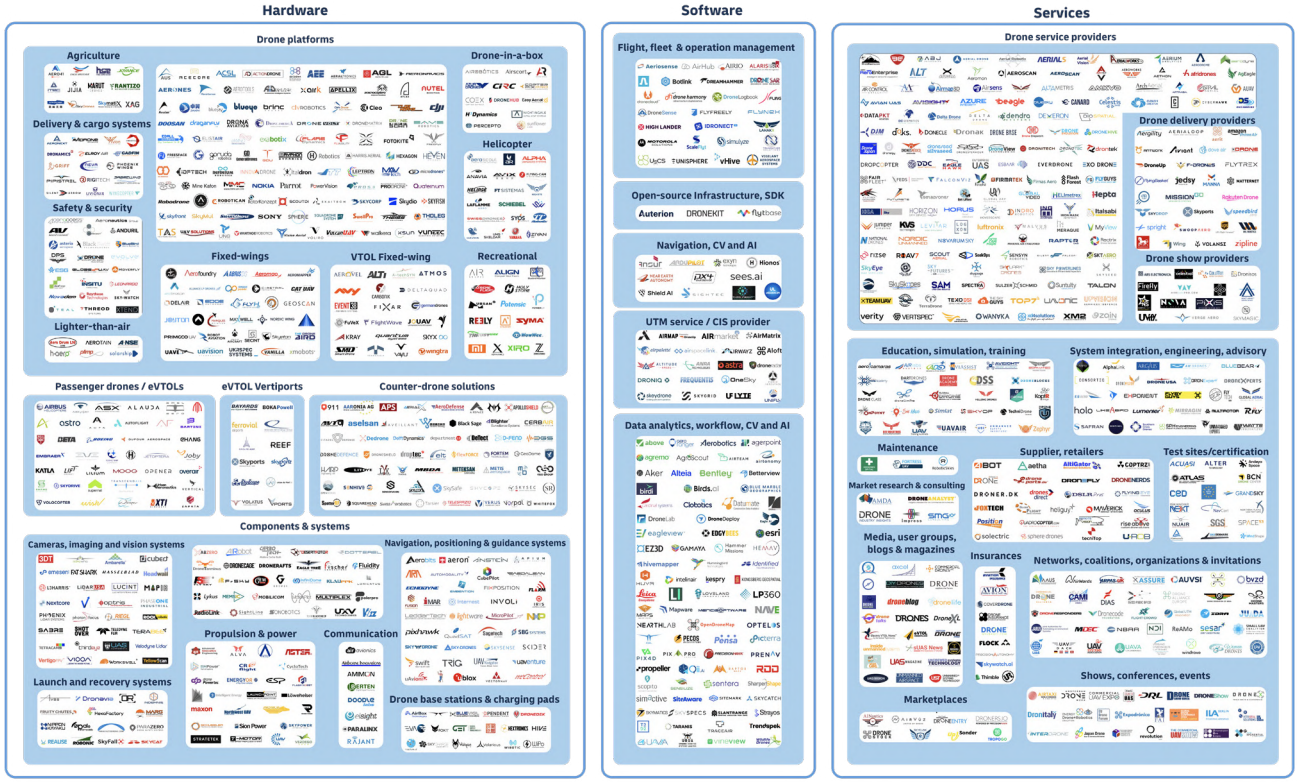
Inventory Management

Currently, many logistics organizations rely on human personnel to check inventory in facilities, particularly shelves for pallets. As shipments enter, rotate, and leave the warehouse, workers must assess and confirm stock counts and vacancy rates on shelves. This manual approach makes it difficult to obtain a real-time view of inventory data. Another typical challenge is that counting inventory in warehouse racking systems may involve heights, a danger for the workforce. While several technologies aim to automate this process, drones are seen as a viable solution for what can be an expensive, time-consuming, and risky activity.

Instead of deploying dozens of workers to scan codes and record placements, companies can use drones equipped with cameras to scan and count inventory quickly. This removes the need for specialized equipment like aerial work platforms to examine the higher shelves. A possible future state would involve fleets of drones operating autonomously, with only one worker needed to manage and assess flagged circumstances.

As completing inventory counts would no longer require a large workforce, supply chains could benefit from more frequent stock counts. This would lead to increased inventory data accuracy, enable warehouse optimization, and eliminate risk for staff. DHL has already tested and deployed drone cycle counting solutions globally, including the Eyesee solution from Hardis for customers such as Dyson, and continues to collaborate with technology companies in Malaysia, Spain, and other countries around the world.

The drone market environment



Graphic source: **Drone Industry Insights (2022): The Drone Market Environment Map 2022**

SUMMARY & TREND OVERVIEW

Challenges

- Global and country-specific aviation authorities have some ways to go in creating a framework that allows drone operators to thrive while protecting public and manned airspaces.
- Consumer drones have been used in warfare as unconventional weapons, in organized crime, and in irresponsible ways, creating a negative image of this technology – an obstacle to regulator and public acceptance.
- Social acceptance is jeopardized by drone noise levels, as well as privacy and safety fears.
- There is a high price tag for specialized drones designed for industrial and commercial use; these models require advance chips, technologies, and sensors.

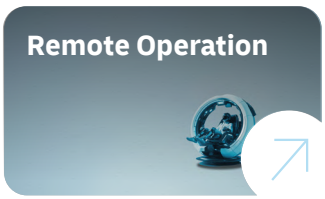
Outlook

Even though drone technology is developing rapidly, enabling many use cases in logistics and supply chains, regulations, social acceptance, and cost remain key challenges in deploying commercial drones.

For this reason, we here at DHL anticipate drone uptake occurring in logistics at different paces. There is likely to be very slow adoption in the public space, especially for last-mile deliveries in dense areas. However, we expect the number of applications in remote areas to increase in the next few years. And we see greater adoption of this trend in the near future for applications such as inventory counting within logistics facilities and on private property.

This trend should be monitored to some extent with use cases in some applications that can already be addressed today.

Related Trends

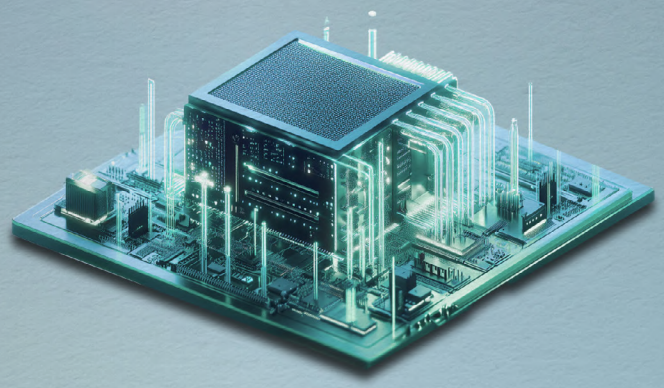


DHL Resources

DHL introduces use of autonomous drones for inventory management

Sources:

Dronelife (2023): The Top 3 Challenges Facing the Drone Industry: Elsight and P3Tech's 2023 Drone Market Survey



Edge Computing

The trend of Edge Computing refers to the decentralization of IT architecture, bringing computer processing closer to sensors and other data sources – at the edge of a network – and away from remote cloud servers and data centers. Deploying computing and storage resources at the location where data is produced, edge computing minimizes the need for continuous, long-distance communication between clients and servers. It improves processing time, data security, and the speed of response to surrounding changes.

The increasing use of technologies such as artificial intelligence (AI) and Internet of Things (IoT) in enterprises continues to multiply data volumes with unprecedented scale. At the same time, as data strategy shifts to the edge, AI is being trained on edge data to look for patterns in real time.

A 2023 Accenture survey of 2,100 C-level executives in 18 industries across 16 countries found that 83% believe that edge computing will be essential to remaining competitive in the future. Still, only 65% of companies are using edge to some degree today. Of these, only half have deeply integrated edge with their digital core.

Decentralization with edge computing adds an extra layer of speed and information security as data is processed and stored near its source rather than sent from the logistics facility to centralized or cloud servers.

The global edge computing market size was valued at US$ 16.45 billion in 2023 and is expected to grow at a compound annual growth rate (CAGR) of 37.9% from 2023 to 2030.

As edge computing is still in its relative infancy, it is far from realizing maximum potential. However, already today it is accelerating digital transformation across many industries, including logistics.

Efficiency in the supply chain can be boosted by edge computing as it frees up resources and lessens reliance on human management. It also significantly increases bandwidth and reduces latency for time-sensitive activities. Furthermore, it is helping businesses predict, manage, prepare, adapt, and achieve resilience.

Camera Vision for Operational Efficiency & Security

A traditional closed-circuit television (CCTV) setup can overload the warehouse internet infrastructure, constantly streaming high-bandwidth raw video signals to a cloud server for analysis. Instead, edge computing offers a viable alternative.

By applying camera vision technology in the warehouse, computation of context-rich visual data occurs locally, at the network edge. Each camera uses its own internal computer to run a motion detection application, and only this footage is sent to cloud, greatly reducing bandwidth use and increasing data security. This achieves real-time monitoring and analysis for operational efficiency and security; for example, accurate stock counting, location tracking, identification of misplaced items, detection of unauthorized access, monitoring of high-risk areas, and quality control.

In a collaboration project with DHL Global Forwarding in Denmark, a proof of concept was run with Protex AI, a solution which uses computer vision and AI to analyze data and generate proactive safety events and dashboards. Edge devices connect to the local CCTV setup and network, processing and storing visual data on site. Only selected clips are sent to the management system in the cloud server.

Data Privacy

Data privacy and protecting individual worker identity are essential in logistics and the supply chain. With its decentralized approach, edge computing helps companies comply with stringent data regulations such as the European Union's General Data Protection Regulation (GDPR).

Processing data where it is collected at the edge reduces the need to transmit sensitive information from logistics operations to centralized or cloud servers. After processing data locally, it may still be necessary to transmit some of this information to central servers or the cloud. By using encryption at the edge, the data is unreadable without the required decryption key, keeping information secure even if intercepted during transmission or storage.

As an additional layer of security, established techniques such as tokenization can be used, replacing personally identifiable information (PII) with unique tokens. This way, visual data can be used to enhance operational efficiency but worker anonymity is also assured in the warehouse or yard.

RELEVANCE TO THE FUTURE OF LOGISTICS

Fleet Management Telematics

Telematics plays a significant role in fleet management by providing real-time data and insights about vehicles and drivers. With edge computing, relevant data can be captured, processed, and used for rapid analysis and decision making. Examples include tracking the location, speed, and movement of vehicles in real time, monitoring engine performance and fuel consumption, diagnosing vehicles and receiving real-time maintenance alerts, and analyzing driver behavior.

American IoT company Samsara uses edge computing in an integrated platform solution to improve fleet safety, efficiency, and sustainability. This covers dash cams, telematics, compliance, trip management, driver vehicle inspection reporting (DVIR), trailer tracking, and speed monitoring. For example, the highly effective dash cam uses sensors, computer vision, and AI to analyze both the road and the driver at the edge. Through video analysis, edge computing identifies and documents safety-related events such as instances of high-risk driver behavior or driver fatigue. Edge computing then selects recordings of only relevant events to automatically upload to cloud for fleet managers to access.

Supply Chain Resilience

Edge computing offers several specific applications in strengthening supply chain resilience. To meet growing demands for visibility and enable increasing levels of e-commerce, better stock transparency is required in logistics. This transparency is essential at all times and all stages of the supply chain, ideally with granularity to individual product level.

Responding to this need, companies are using IoT devices to monitor temperature, track real-time location, and watch stock levels. This information enables data-driven business decisions.

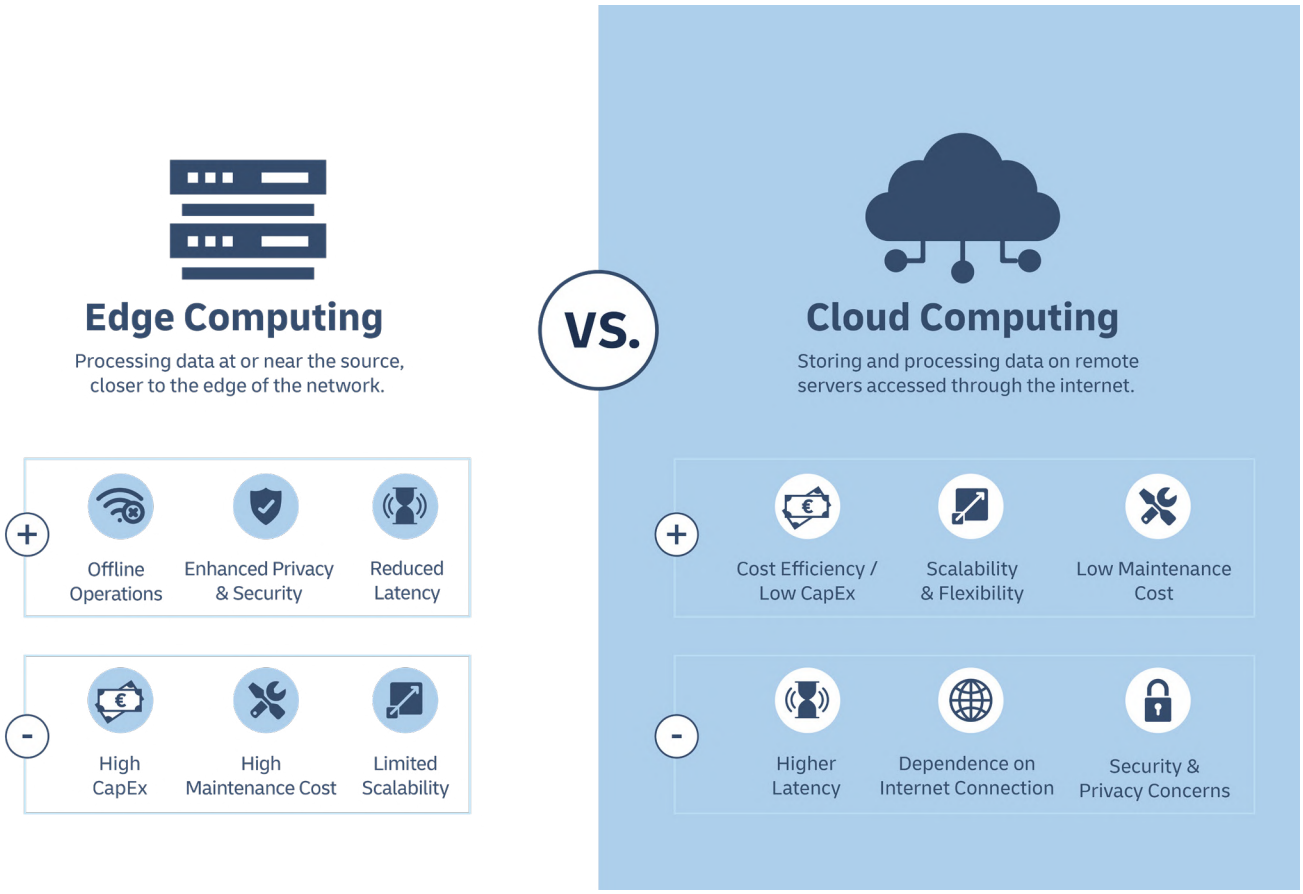
There are numerous opportunities to increase resilience by leveraging edge computing in supply chain processes. For example, this technology would be effective during autonomous vehicle transportation (trucking and last mile delivery), as the truck is vulnerable to an increasing number of cyberattacks. Also if vehicle control is compromised, there is a danger to other road users and to the shipment itself.

RELEVANCE TO THE FUTURE OF LOGISTICS

When a self-driving vehicle is connected to the edge, however, it is able to react to situations in real time, rectifying any malfunction and correctly responding to cyberattack without requiring human intervention.

Within a warehouse, edge-enabled devices share and process data in real time. This improves the speed and accuracy of warehouse operations. For example, edge-enabled cameras can scan barcodes on individual pallets to monitor stock per micro-location in the facility. The cameras can read barcode metadata and indicate if a box has been placed in the correct location. Crunching metadata in real time, the analytics platform can trigger an alert of fraudulent barcodes and incorrect placements. This data can then be streamed, connecting the edge-enable devices to the warehouse management system and enterprise resource planning system via cloud, so that employees are actioned to rectify the situation.

Edge Computing vs. Cloud Computing



Graphic source: **Xenonstack (2023): Edge Computing vs Cloud Computing | 8 Key Differences; Muvi (2020): Cloud Video Encoding vs On-Premise : Pros, Cons and Beyond; 2gig (2021): Edge vs Cloud Computing**

SUMMARY & TREND OVERVIEW

Challenges

- The distributed nature of edge computing creates a broader attack surface for cyberthreats; each individual edge device is vulnerable and could render the entire network vulnerable.
- Managing disparate networks and storage systems to edge compute is complex and requires specialized IT expertise and talent at multiple geographical locations simultaneously.
- The physical isolation of devices powered by edge computing, and therefore the data being exchanged by multiple devices, makes it difficult to monitor, authenticate, and authorize data access.
- Edge computing requires time and investment which can be challenging while running hundreds of container clusters simultaneously with different microservices provided at different edge locations at different times.

Outlook

The proportion of supply chain decisions based on data from the edge ecosystem is expected to continue to grow. Organizations are shifting away from centralized systems towards more distributed networks enabled by developments in Wi-Fi, Bluetooth, and 5G/6G data communication.

With edge processing of real-time data, we here at DHL anticipate logistics operations becoming more dynamic while covering larger networks, with data and decisions originating from the edge. This will improve warehouse operations, asset utilization, fleet management, the overall workforce efficiency and safety.

This trend should be carefully monitored with implementations available for many use cases today.

Related Trends

DHL Resources

Innovation at the edge of the network

Sources:

Accenture (2023): Edge Computing to Enable New Business Models in the Next Three Years, According to New Accenture Report; Grand View Research (2023): Edge Computing Market Size, Share & Trends Analysis Report

Exoskeletons

The trend of Exoskeletons involves wearable devices built to support or enhance human physical capabilities. While passive exoskeletons absorb energy from movements and relinquish power when support is needed, active devices are externally powered and can sense and react to specific movements of the human body.

With over 1.7 billion people affected worldwide, musculoskeletal disorders (MSDs) are one of the most common work-related health issues. Originating from the healthcare and military industries, exoskeletons appeared on the market for industrial use in logistics more than a decade ago, aiming to reduce the occurrence of MSDs in the workplace.

Since then, performance, usability, and comfort of wear have improved in both active and passive industrial exoskeletons. Also, within the last two years, cost has further decreased, with providers standardizing their products and scaling up production.

The exoskeleton market is expected to continue growing; industrial exoskeleton shipments are projected to reach 181 million units in 2030, resulting in US$ 2.2 billion revenue. A 2023 study shows more than half of these products are deployed in the manufacturing sector, and others in construction, the energy sector, agriculture, and mining.

While the trend of Exoskeletons will likely have only minor impact on efficiency gains within supply chain operations, the technology is widely understood to positively impact employee health and safety, leading to higher employee satisfaction and retention rates.

Facing an aging workforce and growing labor shortages, exoskeletons that can reduce physical strain on the human body have become a topic of interest for logistics organizations seeking to limit the particularly high sick leave rates per full-time equivalent (FTE) affecting the industry. In addition, the implementation of exoskeletons in operations could provide differentiation to attract and retain labor.

However, large-scale deployments have yet to be seen. This is mostly because currently available devices typically offer support only for specific sets of movement, limiting their application to niche use cases. Also, proof of efficacy is lacking; there are no long-term studies of large-scale deployments to provide evidence of the expected health and safety-related benefits as well as talent attraction and retention benefits.

Tasks with Frequent Bending & Lifting

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

Manual handling activities are among the main risk factors for lower back pain, and employees involved in this type of work, frequently lifting items, can benefit from using exoskeletons specifically designed for lower back support. Key for the technology to be able to provide support is that a bending movement is involved.

Products currently on the market are diverse. They include passive devices using spring systems such as the IX BACK from SUITX by Ottobock and fully textile solutions that make use of rubber bands such as the Apex 2 from HeroWear. There are also actively powered systems such as the Apogee from German Bionic. They all serve a similar purpose, helping supply chain organizations improve employee health and safety in the workplace and reduce costs arising from preventable injuries.

Overhead Work

Neck and shoulders have both been identified as body areas widely affected by MSDs and associated symptoms. Activities involving either static overhead work, such as inspecting and repairing the underside of delivery vehicles, or continually handling weight above shoulder height, like when loading or unloading the top spaces of containers, are considered major risk factors for injury.

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

Due to the very task-specific design of these devices, here at DHL we see limited applicability within logistics as there are few or no use cases which consist of overhead handling only.

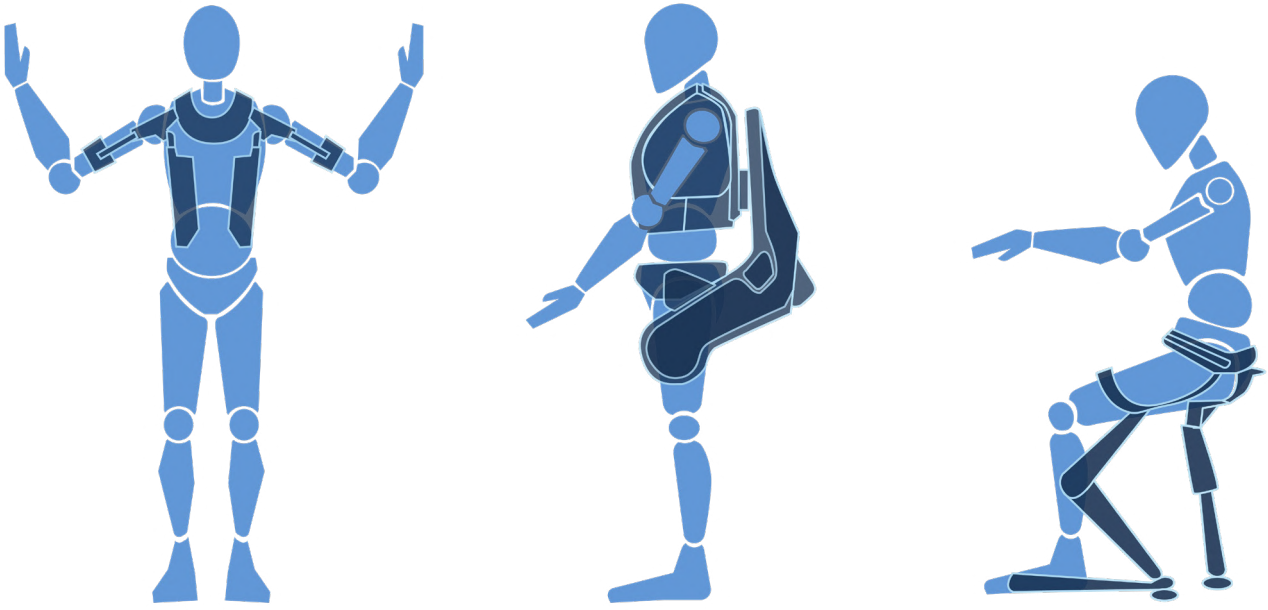
Workspaces Without Seating

Many facilities in supply chains do not accommodate seating in workspaces because of space constraints or for operational safety reasons. As a result, workers must always stay on their feet when working – a requirement that can also further restrict the industry's talent pool.

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

Although the cumulative impact of these chairless chairs in logistics has yet to be fully understood, like other types of exoskeletons, they have potential in attracting prospective workers who otherwise would not qualify or not want such physically demanding jobs.

Different Types of Industrial Exoskeletons



1. Overhead work
2. Tasks with heavy bending & lifting
3. Workspaces without seating

Graphic source: **DHL (2024)**

SUMMARY & TREND OVERVIEW

Challenges

- Productivity impacts, cost savings from reduced sick leave, and other quantifiable data is missing but is essential to prove the business case and eliminate doubts about medical efficacy.
- User acceptance of exoskeletons requires well-organized onboarding and personalization; initial implementation is similar to a change management project rather than a new hardware installation.
- Most available exoskeletons are not entirely effortless to wear and still add a significant amount of weight; this creates a trade-off between benefit in certain movements and perhaps a burden to other movements.
- A lack of long-term studies of large-scale deployments to provide evidence of the expected health benefits leaves room for skepticism and remains an entry hurdle for those who do not want to take the risk of a first mover.

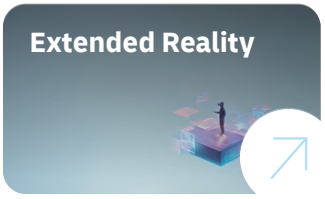
Outlook

Industrial exoskeletons have yet to find their place for large-scale adoption within logistics operations. Here at DHL, we recognize further product improvements in terms of performance and usability but we acknowledge today's available products still tend to serve only very specific subsets of movements.

While both the business case and medical effectiveness are not yet fully proven, due to lack of long-term studies, we see a rise in interest in the topic. With worker health and safety being a top priority and logistics organizations coming under increasing pressure to find and retain their operational workforce, the potential value of exoskeletons increases. These products have a role to play in improving worker health and safety, expanding the pool of candidates who qualify for physically strenuous tasks, and overall making the workplace more attractive.
It is likely that the recent drop in cost for many devices could pave the way for further testing and adoption.

This trend should be monitored to some extent with use cases in some applications that can already be addressed today.

Related Trends



DHL Resources

The rise of exoskeletons in logistics

Sources:
World Health Organization (2022): Musculoskeletal health; ABI Research (2023): Exoskeletons

Extended Reality

The trend of Extended Reality, otherwise known as XR, encompasses the different experiential technology genres of augmented reality (AR), virtual reality (VR), and mixed reality (MR). AR enriches the physical world with purely visual digital screens or overlays in the right place at the right time; VR is a fully immersive digital experience requiring special headsets; and MR is at the intersection of both, infusing interactive virtual content within the physical world.

As the most basic form of extended reality (XR), AR has been around for over a decade allowing two-dimensional information to be displayed on top of real-world images. While mass market popularity of AR reached its peak in 2016 with the launch of interactive smartphone and tablet apps like Pokémon GO, it first appeared in enterprise applications as early as 2013 with the launch of Google Glass. DHL was an early adopter of the technology using wearable smart glasses for workflow guidance and seamless, hands-free remote support, completing first pilot projects in 2014.

With the development of VR, a fully immersive virtual experience could be achieved through headsets. The gaming market was an early adopter but, over time, many enterprises, including those in logistics, recognized the potential of 360° virtual content for training, especially for scenarios which are difficult or maybe even dangerous to replicate in reality.

Following this, the most groundbreaking XR developments in recent years have included MR. One example is the Microsoft HoloLens, a holographic device for business use.

> *Another example, launched in early 2024, is the Apple Vision Pro, which introduced the term 'spatial computing.' With these devices, users experience a unified perceptual reality in which virtual three-dimensional (3D) content is spatially aligned with the real world.*

This creates a combined reality in which users can naturally interact with both virtual and real objects or content. While these capabilities open up new possibilities to achieve truly interactive training content and simulations that allow for enhanced remote collaboration, further use cases where MR can offer real differentiation have yet to be implemented. In time, these capabilities will achieve much more than just enhancing the user experience.

Unit sales of XR headsets dropped significantly in 2022 and 2023, following a massive increase during the pandemic. More recently, announcements about new devices have helped renew the hype, especially the 2024 launch of the Apple Vision Pro, and analysts predict unit sales in 2024 will bounce back by more than 40% over 2023. It remains to be seen whether mainstream adoption will follow.

In logistics , some XR use cases are now well-established, mature solutions; for example, workflow guidance during the warehouse picking process. However, available XR

technology has not yet been used to full potential. While the wider application of XR within logistics will not revolutionize how businesses are run, it will most likely deliver many benefits. It will enhance the employee experience, increase safety, improve the effectiveness of training and onboarding, boost productivity by reducing error rates, and enable information sharing with employees wherever and whenever needed.

Workflow Guidance

Making operational processes more efficient and less prone to human error as well as quickly onboarding new employees are crucial to success in the logistics industry. 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 a first mover in using smart glasses for workflow guidance in the picking process, with pilot projects completed as early as 2014 and a productized solution scaled to more than 25 sites globally today.

What has worked for the picking process can easily be replicated in other processes – for example, upskilling labor so workers can provide more complex value-added services to customers and accelerating new employee onboarding time. With the increasing availability of quick-to-build no-code applications, it is now very easy to digitalize workflows and run them on smartphones, tablets, and smart glasses.

Using MR to guide employees through a workflow, via the Microsoft HoloLens for example, provides an enhanced user experience. But it is not always necessary to spatially relate 3D virtual objects to the real world to achieve what is needed.

Although there is some applicability for MR in logistics – for example, offering step-by-step instructions for maintenance of complex machinery – other suitable use cases are yet to be explored.

Remote Support & Collaboration

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 which is not always available locally. For example, the global energy company TotalEnergies uses RealWear smart glasses for faster equipment diagnosis and repair of refinery equipment. This solution makes specialist knowledge available via remote support calls, reducing travel time and therefore lowering the risk of production stoppages.

In addition to providing immediate access to expert knowledge, some software solutions are specifically designed for remote collaboration with a smart glasses user, and even allow for automated report generation for documentation purposes.

If higher levels of collaboration are required, it is interesting to consider using VR and MR headsets. With an MR solution, people in multiple locations can, for example, meet in a single virtual collaboration space and use 3D holograms to design products, solutions, and processes. Another example application is holding conferences and events in a fully virtual way, with delegates using VR headsets to meet as avatars in a virtual space.

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. Participants in a fully immersive VR training session learn four times faster than in a classroom setting, possibly because participants show a significantly higher emotional connection to virtual content and are far less distracted.

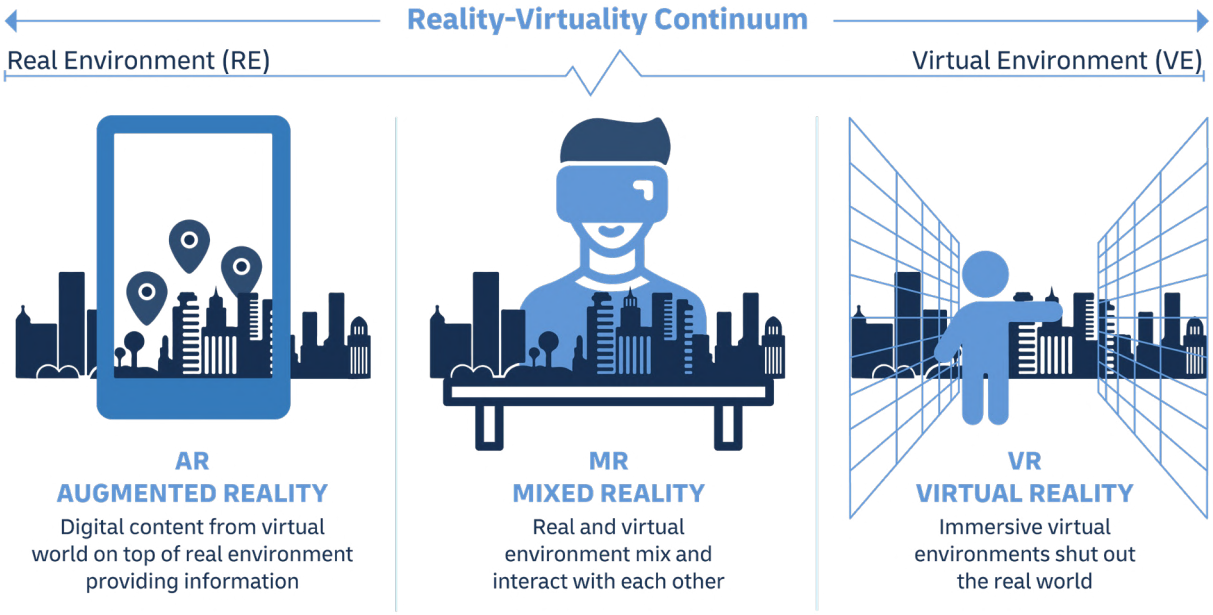
For years, DHL Express has been using VR as a training and engagement tool for employees and external audiences. In a gamified approach, people can learn how to load pallets and containers with shipments. Leveraging gamification, participants are awarded more points if they use space optimally and pay attention to special-handling labels.

Using VR for training is ideal to simulate a real-world situation, allowing people to learn and take 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 , due to the global scalability of training content across operations globally. A few start-ups, 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.

With ongoing improvements in MR and spatial computing capabilities, virtual content is integrating into the real-world environment so successfully that the human brain perceives the two as a single, unified reality. This has significant potential for more hands-on training experiences to occur within the real world instead of a fully immersive space.

The reality-virtuality continuum offers users a wide range of experiences



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

SUMMARY & TREND OVERVIEW

Challenges

- Most XR use cases involve specific hardware; used at scale this requires significant investments and may require onboarding if employees are not yet familiar with these devices.
- Time, effort, and often significant investment are needed to create fully immersive content and workflow content; however, this barrier decreases as more and more platforms support no-code app building.
- Mobile networks may not offer the coverage or bandwidth that applications need for live connectivity; this limits the ability to pull data from a system via live video call connectivity and to live stream fully immersive 3D content.

Outlook

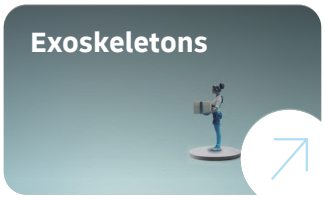
Here at DLH, we expect new XR applications to emerge in the near future. Following the launch of Apple's Vision Pro, developers are already working on Apple's new platform. It will be interesting to see if Apple can generate sufficient hype around XR to enable mass adoption of MR and spatial computing by consumers and by users in the industrial context.

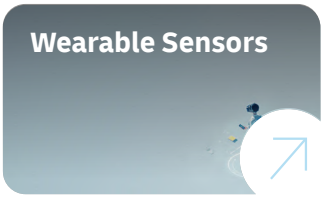
With more and more software companies offering no-code solutions and ready-to-customize library content, we already see one of the entry hurdles to creating XR experiences disappearing.

Further development towards improved remote collaboration by making use of spatial computing technology is likely to take global collaboration among team members within an organization to the next level.

This trend should be passively monitored with use cases in some applications that can already be addressed today.

Related Trends





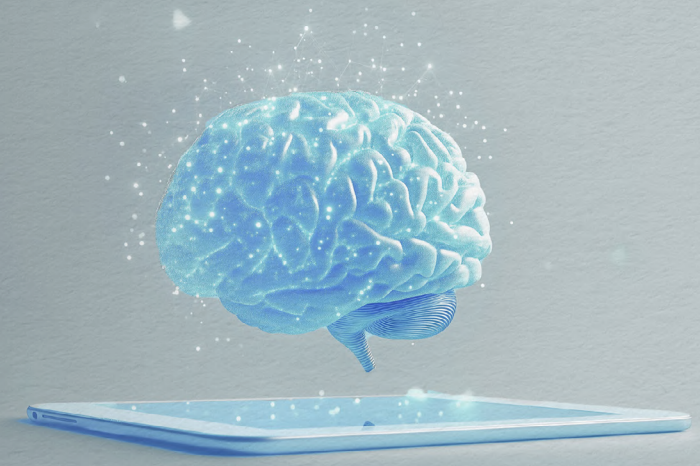
DHL Resources

DHL makes augmented reality a standard in logistics

Leveraging technology to get airports ready for disaster during a pandemic

Sources:

CNBC (2023): VR market shrinking as Meta pours billions of dollars into metaverse; Circana (2023): New Devices Increase the Appeal of Extended Reality; Computerworld (2024): 2024 will be a big year for AR/VR, but mainstream adoption will lag



Gen AI

The trend of Generative Artificial Intelligence (Gen AI) refers to techniques that can autonomously produce new content, such as images, text, audio or videos, based on patterns learned from existing data. It utilizes algorithms and neural networks to generate original outputs that mimic the style or characteristics of the input data.

Gen AI grew from advances in machine learning (ML), particularly in the development of currently the two most widely used generative AI models. One type is generative adversarial network (GAN) models, which enable technologies to create visual and multimedia artifacts from both imagery and text input data; the other type is transformer-based models including technologies such as generative pre-trained (GPT) language models that can use information gathered on the internet to create text content.

These models have introduced new methods for training neural networks to generate realistic and novel data by learning underlying patterns from large datasets. The field has since expanded to encompass various techniques and applications, leading to widespread use in creative tasks, data augmentation, and more.

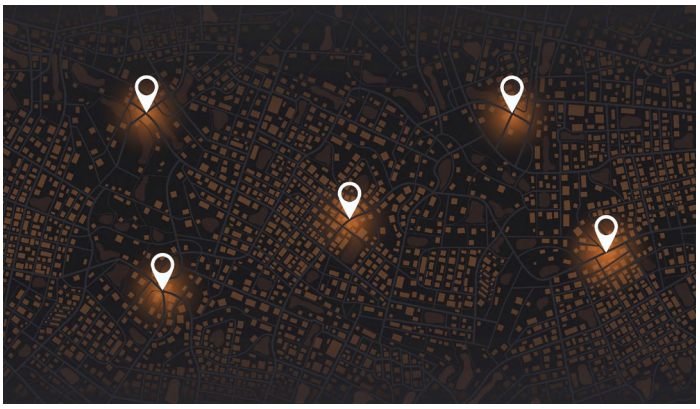
The gen AI market size was valued at US$ 29.00 billion in 2022 and is projected to grow from $43.87 billion in 2023 to $667.96 billion by 2030, with a compound annual growth rate (CAGR) of 47.5% during the forecast period (2023-2030). North America accounted for a market value of $14.49 billion in 2022, representing approximately 49.93% of the global market.

The trend of Gen AI is set to have a relatively high impact on logistics, with widespread adoption in logistics anticipated within the next three to five years. Here at DHL, we mostly expect gen AI developments to impact use cases involving image, video, or text generation. We also anticipate use cases within logistics that will impact both white-collar and blue-collar employees. Applications that will automate certain back-office processes will continue to expand, as well as supporting operational processes. These can range from streamlining IT helpdesk requests and automating simple HR enquiries to generating translations, to name a few.

In addition, we believe there will be a steep increase in adopting sandboxed environments in which companies can use gen AI tools to try new ideas and initiatives. For example, within DHL we have developed our own GenAI Hub to test out automating certain processes, developing content, and generating information.

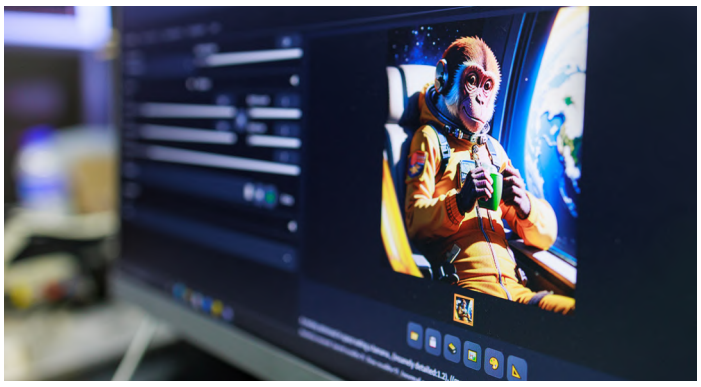
RELEVANCE TO THE FUTURE OF LOGISTICS

Optimized Route Planning



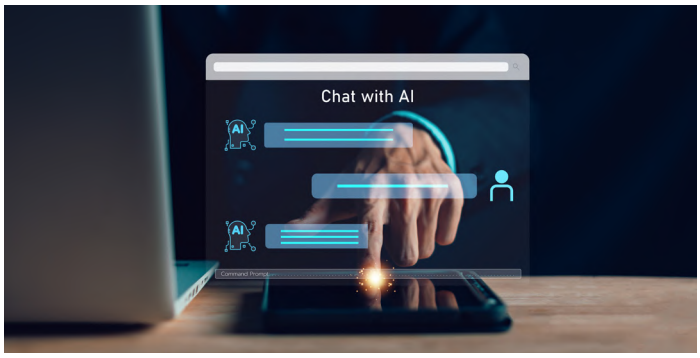
AI algorithms can be used in logistics to optimize route planning for deliveries. By considering various factors such as traffic patterns, weather conditions, and delivery priorities, AI-powered systems can generate efficient routes while providing transparent explanations for the decisions made. This ensures logistics providers can trust the accuracy of the suggested routes and understand the rationale behind them. In logistics, which relies heavily on location services, gen AI may also be used to accurately convert satellite imagery to map views, enabling the exploration of yet uninvestigated locations.

Content Creation



Gen AI offers the creation of text, images, and even coding. For logistics, this means the potential for acceleration across a number of functions. The technology can for example automate the creation of text for product descriptions, inventory reports, and customer service responses, streamlining communication within logistics operations and improving efficiency. It can also generate visual representations of inventory items or warehouse layouts to help with inventory management. Other image generation applications include creating designs for packaging that maximize space efficiency and protection of goods. These AI generated images can help in prototyping new packaging solutions quickly. Gen AI can also automate the creation of scripts for data analysis, optimize algorithms for route planning, and build predictive models for demand forecasting. This enhances data-driven decision-making processes and operational planning in logistics companies.

Customer Experience Automation



Chatbot interfaces offered by gen AI can be used in many ways to enhance customer-centric supply chain networks. This technology can also help customers get immediate and satisfactory responses to their enquiries, with their input processed through commonly used communication channels. For example, each customer can receive a prompt and customized email response or automated phone call or text message.

Gen AI can also swiftly analyze various unstructured customer feedback sources such as online reviews and social media sentiment. So, for example, when multiple customers make comments about a particular product, gen AI can help rapidly integrate these insights into product development workflows. In e-commerce, gen AI helps to improve the shopping experience and increase customer satisfaction. A good example of this is personalized product recommendations generated by AI-driven algorithms based on customer preferences and past purchase history.

AI Assistants

Currently, several different types of AI assistants are being developed at scale but not all are suitable for deployment in the logistics industry. Here at DHL, we see logistics operations making use of AI-based predictive analytics assistants, which can forecast demand, optimize inventory levels, and anticipate potential supply chain disruptions, enabling proactive decision making and resource allocation. We also expect the industry to make use of warehouse management assistants, which can optimize inventory placement, automate picking and packing processes, monitor equipment maintenance schedules, and enhance overall operational efficiency within warehouses and distribution centers.

> *Another useful type of AI assistant in logistics is a supply chain visibility assistant. These provide real-time visibility of the entire supply chain, tracking the movement of goods from suppliers to end customers, helpfully identifying bottlenecks, mitigating risks, and optimizing logistics processes for enhanced transparency and responsiveness.*

In the logistics back office, administration, legal documentation, finance, or HR department, we see AI assistants providing support such as screening lengthy texts and summarizing the key points. This could accelerate tasks, ensuring faster turnaround times for non-disclosure agreement (NDA) processing, contract processing, candidate curriculum vitae (CV) screenings, and financial report summarizing and forecasting.

Gen AI Models: Types & Use Cases

Generative adversarial networks (GANs)	Realistic images and videos
Transformers	Predictive text and speech recognition
Variational autoencoders (VAEs)	Images and text
Flow-based models	Images, audio and video
Recurrent neural networks (RNNs)	Speech recognition and natural language processing

Graphic source: **Zendesk (2024): A beginner's guide to generative AI for business**

SUMMARY & TREND OVERVIEW

Challenges

- Implementing and integrating gen AI into existing logistics systems and workflows is likely to be resource intensive and requires specialist AI and data science expertise not commonly available in the industry today.
- Logistics companies may face challenges in adapting their infrastructure, training personnel, and ensuring seamless integration with existing software platforms.
- It can be difficult for stakeholders to assess the relib-ility of output from generative AI models (which typically operate as"black boxes"); this lack of interpretability can lower trust in a solution, even preventing acceptance.
- Trust in AI is a challenge that can be addressed through AI ethics.

Outlook

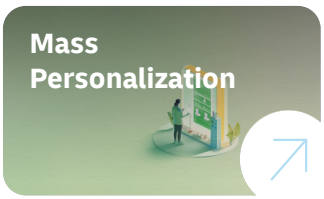
Here at DHL, we have witnessed developmental leaps in AI over recent years. This explains why AI continues to generate interest and investment and is predicted to grow in the long term, with an ever-expanding range of gen AI applications capable of driving significant business value.

The three key building blocks of more data, continuous advancements in algorithms, and stronger computing power indicate these use cases are likely to materialize and scale.

Logistics and the supply chain are integral to soaring AI adoption levels every year. By adopting gen AI, the logistics industry will be able to better respond effectively to the operational challenges of growing business-to-business (B2B) and business-to-consumer (*B2C) demand, and more recently emerging consumer-to-consumer (C2C) demand.

This trend should be actively monitored with implementations available for many use cases today.

Related Trends



DHL Resources

Generative AI: Answers to frequently asked questions

Source:
Fortune Business Insights (2024): Generative AI Market Size, Share and Industry Analysis, By Model

Indoor Mobile Robots

The trend of Indoor Mobile Robots encompasses the various types of movable robots that fulfill tasks primarily inside facilities without direct input from human operators in a collaborative way. Automated guided vehicles (AGVs) follow predetermined visible or invisible paths, while their next-generation successors, autonomous mobile robots (AMRs), use real-time path planning and can more freely move around obstacles.

Mobile automation has progressed through two-dimensional (2D) lidar autonomy to three-dimensional (3D) visual autonomy, which has developed since the last edition of the Logistics Trend Radar with an increase in accuracy, capabilities, and offerings across the robotics component market. This has significantly advanced AMRs in various applications and boosted uptake.

The logistics robotics market (including indoor mobile robots) is projected to grow from US$ 7.11 billion in 2022 to $21.01 billion by 2029, driven by factors such as the rising demand for automation in e-commerce and the healthcare, retail, food and beverage, and automotive industries. DHL expects that up to 30% of its global material-handling equipment will use some form of robotic process automation by 2030.

In markets with high labor costs, rising consumer expectations for rapid order fulfillment has driven the adoption of robotics to higher levels. The deployment of mobile robotic solutions plays a crucial role in the area of driving automation within warehouses. In fulfillment operations, it also helps in driving real-time insights for inventory management to provide accurate estimates on delivery time.

There has been significant interest in early-stage market offerings following recent developments in mobile robotic solutions that specialize in case manipulation. However, cost remains a barrier to widespread introduction in logistics. As soon as indoor mobile robots can be deployed at scale, they have enormous potential to increase efficiency and resilience within operations. Therefore this trend is considered highly impactful for the logistics industry.

RELEVANCE TO THE FUTURE OF LOGISTICS

Point-to-Point Transportation

Moving goods between predefined locations within a warehouse is an essential yet highly repetitive process that takes up a lot of warehouse staff time. Using indoor mobile robots is an effective way to save resources, with just a few employees overseeing a fleet of indoor mobile transportation robots while the rest of the workforce is free to perform more value-adding tasks. When select-ing the appropriate autonomous solution for point-to-point transportation, there is a distinction between device types – either 3D (such as an autonomous forklift) or 2D (such as an autonomous jack lift, pallet jack, or tugging robot).

Within DHL Group, we are accelerating the commercial deployment of autonomous forklifts and pallet movers in more than 1,500 warehouses worldwide, focusing on sites in labor-tight markets across Europe, the United Kingdom, Ireland and North America.

Fleets of autonomous high-reach robots take over pallet-picking and put-away tasks, lifting goods to a height of up to 11 m (36 feet) while also performing double-deep storage activities. In addition, there are solutions such as the EffiBOT, a fully autonomous handling robot from the French company Effidence, which also has a follow-me mode to follow humans and carry loads of up to 300 kg (660 lb). This allows the system to be utilized in environments that continue to be too complex or dynamic for most AMR technology today. It is clear from these examples that many solutions are available for point-to-point transportation. They are capable of significantly reducing repetitive workloads and walking distances, saving time for logistics staff.

Container (Un)loading

Loading and unloading containers and loose-load trucks can involve some of the most physically demanding activities in logistics. Workers are exposed to harsh climate conditions and must repeatedly move heavy goods in confined spaces as quickly as possible to ensure downstream operations can continue uninterrupted.

More and more companies are exploring ways to automate these tasks. To unload pallets from a trailer, Fox Robotics has developed the Automated Trailer Unloading solution which allows one operator to control several robots simultaneously via a tablet.

Boston Dynamics has developed the Stretch robot for a range of different warehouse tasks, but initially this indoor mobile robot will enable autonomous unloading of 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 the perception arm that includes depth sensors and 2D cameras to help the robot identify cartons of different shapes and sizes and provide insights that help Stretch perceive its operational environment. Future models may be capable of loading, building up pallets, and depalletization. In January 2023, DHL Supply Chain became the first company to achieve commercial application of Boston Dynamics' Stretch robot developed for carton unloading of trucks. Today's deployed solutions are typically for unloading uniform cartons or pallets. Loading and unloading of mixed cases are complex tasks and it will take further research and development before scalable fully autonomous solutions come to market. However, with advances in robotic software and computer vision capabilities, indoor mobile robots will soon achieve additional autonomous tasks in mobile piece manipulation.

Order Fulfillment & Assisted Picking

In the unautomated warehouse environment, workers can sometimes be required to walk up to an average of 14.5 km (9 miles) each day. This puts an enormous physical burden on workers and at the same time presents an opportunity and a strong argument for the introduction of indoor mobile robots. Assisted picking robots can drive efficiency in the overall order fulfillment process by shortening the distance walked by humans and reducing the time between picks.

There are different types of order fulfillment applications including goods-to person solutions, and solutions that fall into a zone picking category. A classic goods-to-person AMR solution comes from Geek+ with robots able to pick up inventory shelves and transport them to the required picking or pack station where an employee prepares the order for fulfillment without having to walk anywhere.

In zone-picking applications, workers are assigned to operate in a specific predefined warehouse area. Locus Origin is a prime example of a direct zone-picking solution, where totes are placed on robots that travel to pickers in various work zones and then visually indicate the closest pick option for each tote via a screen. At DHL, we have recently expanded on our partnership with Locus to encompass a total deployment of 5,000 Origin bots across warehouses and distribution centers globally and we have celebrated our 500 millionth pick by Origin bots globally.

Using AMRs to support order fulfillment allows workers to focus on the accuracy of their picking and significantly diminishes the distance they must cover each day and the required travel time.

Facility Support

Significant progress in the development of perception technology and AMR capabilities has encouraged further investment in automated solutions to support facility functions like cleaning, security, and maintenance and repair operations (MRO).

Since 2020, the global warehousing market has seen significant growth, driven largely by the surge in e-commerce and increasing demand for more sophisticated logistics.

Such growth in the footprint of warehousing operations has driven additional investment in and deployment of intelligent cleaning robots. Solutions like the Karcher KIRA bot have enabled smartification of the cleaning process by deploying cloud-based artificial intelligence (AI); KIRA can learn and improve its cleaning performance over time. Additionally, smart detection systems allow for safe navigation of the bots around the people and obstacles that are present in the warehousing environment.

With increasing sprawl and the resulting higher requirements for security infrastructure, today's warehouses are also at risk of theft. Companies can integrate autonomous security robots (ASRs) to better monitor and control these facilities. Use cases range from automatic license plate recognition to the detection of blacklisted mobile devices or suspicious devices and video surveillance.

The four-legged mobile robot Spot, from Boston Dynamics, can be used as an ASR, equipped with additional cameras and night-vision technology. Designed to walk stairs and uneven terrain, this robot can live monitor different levels in a warehouse or operations facility and can be operated remotely via a tablet or follow pre-mapped routes.

The use of cleaning bots and ASRs in warehouse cleaning and security functions remains limited but, in future, it is likely that indoor mobile robots will play a significant role in intelligent facility support infrastructure.

Inventory Management Automation

Warehouse space utilization is becoming increasingly important. For example, the overall cost of warehousing properties across 52 international markets rose by an average of 8.4% (12 months to June 2022), largely due to heightened demand for warehouse space, a consequence of the pandemic, and e-commerce expansion.

One way of boosting storage density is to introduce an automated storage and retrieval system (ASRS). These computer-controlled robotic storage systems can be used for autonomous handling, storage, and retrieval of totes or shelves in warehouse. ASRS solutions, such as the cube-based system from Norwegian company AutoStore, have many advantages over traditional picking solutions. AutoStore's solution offers a high-density system reducing the required space by a factor of up to 4 and can speed up manual picking by up to 5 times compared to conventional picking.

Although the initial investment for such solutions is relatively high, this can be economically viable, especially when handling large volumes of stock-keeping units (SKUs) of slow- and medium-velocity goods, optimizing the throughput and operational efficiencies of the system.

DHL Supply Chain is currently involved in nine AutoStore deployments across Singapore, the US, and Germany, with four more in planning. Through this partnership, a fleet of over 1,000 robots has significantly boosted operational efficiency and throughput in DHL's fulfillment warehouses.

Humanoid Robots

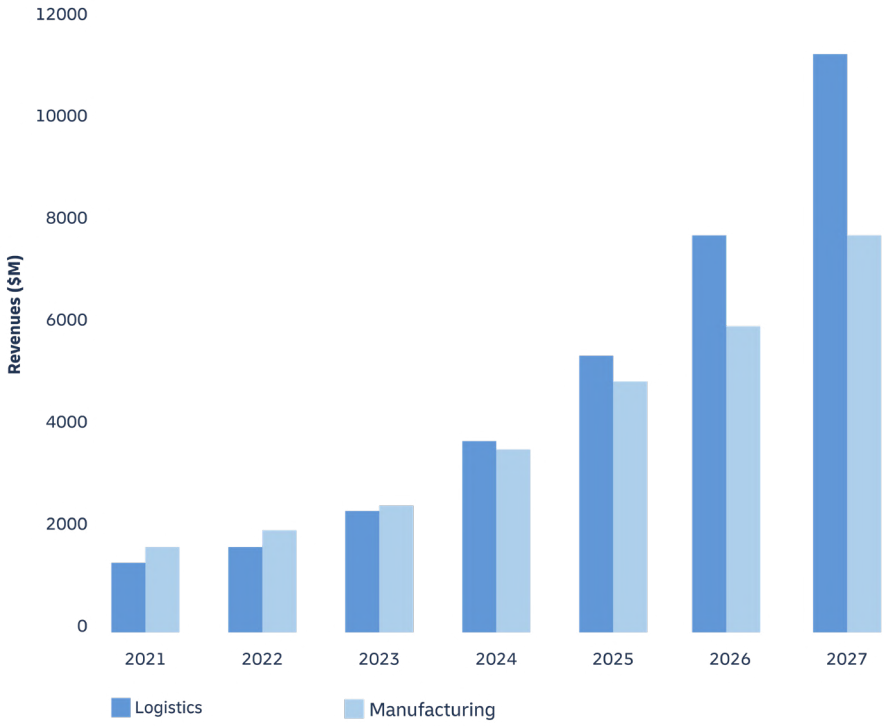
In recent years, there's been steady development and commercialization of humanoid robots – machines designed to resemble humans and perform similar tasks using human-like movements and interactions. In logistics operations, these robots could relieve personnel from monotonous tasks that cannot be performed by conventional stationary robotics, such as loading and unloading pallets and containers.

While humanoid robots may appear to provide an ideal solution, it may not make sense to construct legs if wheels are the swifter option for moving around the warehouse. Similarly, there may be no need to equip the machine with two arms if one is sufficient to do the job.

> *Rather than recreating the human body, it may be better to design robots according to their tasks and for optimal interoperability.*

There is significant development potential for humanoid robots, particularly in achieving a completely autonomous and non-externally controlled flow of activities. Companies like Boston Dynamics with its Atlas robot, the humanoid-specialized company Figure AI, and the Chinese company Unitree, which offers its G1 at a relatively low price point, are making significant progress in this technology field. Nevertheless, in future, even the most advanced robots will not completely replace humans in logistics.

Forecast for Mobile Robot Revenues: Logistics vs. Manufacturing Applications



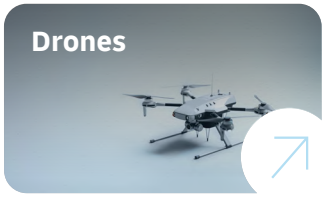
Graphic source: **Interact Analysis (2022): Mobile robot shipments grow by 53% in 2022**

SUMMARY & TREND OVERVIEW

Challenges

- Adequate Wi-Fi or cellular network coverage is required throughout the facility for frictionless integration of a large-area AMR solution, which must also meet IT security requirements.
- Deploying a fleet of numerous automated robot solutions from different manufacturers requires a very robust software platform enabling efficient route planning and mission dispatching.
- In crowded facilities where many people are working and numerous obstacles block the way, an indoor mobile robot may encounter so many obstacles that this interferes with its ability to integrate seamlessly into operations.
- Indoor mobile robot system integration can be challenging given the wide variety of warehouse management platforms in use.
- In an environment where indoor mobile robots operate alongside personnel, a comprehensive safety and risk analysis must be performed due to the added complexity of navigating in close proximity to humans.

Related Trends



Outlook

There are already many different indoor mobile robot use cases and applications currently being scaled in logistics. However, it is not yet feasible to implement the entire indoor mobile robot technology suite in every warehouse.

Before further solutions can be scaled and used in a variety of applications, the technology must further mature. In addition, decision makers must gain confidence in this technology before they are to willingly deploy indoor mobile robot solutions in mission-critical tasks.

More steps are being taken towards full warehouse orchestration so, in the not-so- distant future, indoor mobile robot solutions together with stationary robotics will start to automate and support a large part of warehouse work.

This trend should be actively monitored with implementations available for many use cases today.

DHL Resources

DHL Supply Chain and robotics technology company AutoStore announce partnership expansion to further automate global warehousing

DHL Supply Chain Passes Unprecedented 500 Million Picks Milestone Using Locus Robotics Autonomous Mobile Robots

DHL Supply Chain Further accelerates commercial deployment of its fleet of autonomous forklifts and pallet movers

DHL Supply Chain achieves first commercial deployment of Boston Dynamics' Stretch™ robot to unload trailers and containers in the warehouse

Sources:
Fortune Business Insights (2024): Logistics Robots Market Size, Share & Industry; Savills (2022): Global warehousing costs

Next-Generation Connectivity

The trend of Next-Generation Connectivity is the development and implementation of evolutionary communication and connectivity technologies and their supporting infrastructure. It includes the utilization of various frequencies and bandwidths across the electromagnetic spectrum to help connect, ultimately, everyone and everything everywhere.
This trend expands on the earlier trend of Next-Generation Wireless to include all connection types.

The introduction of wireless internet to the supply chain ushered in the first major wave of digitalization in logistics, from pharma shipment sensors to some of the earliest autonomous mobile robots and indoor localization.

Most recently, fifth generation (5G) mobile networks have become reality, with more and more use cases around the world benefiting from lower latencies and better ability to transfer large amounts of data via cellular networks. The full scale of 5G capabilities is still to be tapped on a global scale and yet 6G network testing is underway and commercial readiness is expected for early 2030.

With the growing number of low Earth orbit (LEO) satellite networks and some 5,000 LEO satellites orbiting planet Earth already at altitudes ranging from 160 to 2,000 km (100 to 1,245 miles), and with 1,700 more satellites per year anticipated to 2030, there are significant additional opportunities for logistics. These resources provide a pathway to connectivity everywhere, bridging the digital divide by providing internet access to remote and underserved regions where terrestrial infrastructure is lacking or insufficient.

With advances in the connectivity space, logistics organizations can attain a new level of speed, accuracy, efficiency, and resilience for the supply chain.

While next-generation wireless had moderately low impact on the logistics industry, next-generation connectivity is expected to have far greater impact. The required technologies exist already and are developing steadily, which indicates they are relatively close to realization.

With vast benefits to be gained from instant and continuous visibility of shipments, assets, and inventory, logistics organizations are paying close attention to this trend and adoption of these technologies continues to accelerate in all supply chain segments around the world.

RELEVANCE TO THE FUTURE OF LOGISTICS

5G & 6G Cellular Networks

By 2022, around one tenth of all connections worldwide used 5G technology and this is set to surpass 50% by 2030. Vast regional disparity is expected, with more than 90% adoption in North America, developed Asia Pacific, Europe, and the Gulf Cooperation Council (GCC) region, but below 20% adoption in sub-Saharan Africa.

At rollout of 5G mobile networks, expectations were high about this technology's transformative nature, but it is questionable whether these have been met. For most use cases, better network stability and smoother data transfers were predicted along with faster data transfers, thanks to lower latency, and – for logistics – enhanced warehouse automation. 5G's low latency and high bandwidth is expected to enable advanced automation technologies to be used for picking, packing, and sorting warehouse goods.

Another example in logistics is a 5G-powered artificial intelligence (AI) warehouse management system. This leverages both 5G technology and AI solutions for robotic inventory management to provide enhanced and efficient multistory warehouse management at optimum standards. In future, there is potential to operate around the clock utilizing 5G technology and AI.

A barrier to 5G developments is the absence of universal standards across companies and countries. This makes scaling difficult and there can be high entry barriers. Also, when the required infrastructure is available, users may be deterred by high costs imposed by network operators.

> *While 5G rollouts are continuing, by the 2030s there will be 6G laboratory tests and early introduction. This newest technology brings the potential to move from the current ecosystem of "Connected Things" to a new ecosystem of "Connected Intelligence." And with this, end-to-end (E2E) mobile communication systems will optimally support AI and machine learning (ML).*

Satellite-Based Connectivity

The global LEO satellite market was valued at just under US$ 4,190 million in 2022. With an expected compound annual growth rate of 18%, this should reach almost $11,348 million by 2028.

While costs remain relatively high, LEO satellites are cheaper than regular satellites and are gaining popularity in Internet of Things (IoT) applications as they provide extensive coverage, reduce delays, and are highly reliable. More and more providers are offering LEO satellite services.

Current applications for these satellites include disaster recovery and resilience in remote areas, providing a resilient communication infrastructure during a natural disaster or other emergencies when terrestrial networks are disrupted. 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, meaning communication can be supported even in cellular "dead zones."

In logistics, maritime shipping is already benefitting from new tracking capabilities and global connectivity to smart containers. In 2023, logistics provider Maersk teamed up with Starlink to use satellite data to track container ships, optimize routes, and improve fuel efficiency, and there are plans to use this connectivity solution to digitize vessel operations.

Private Network Sharing & Slicing

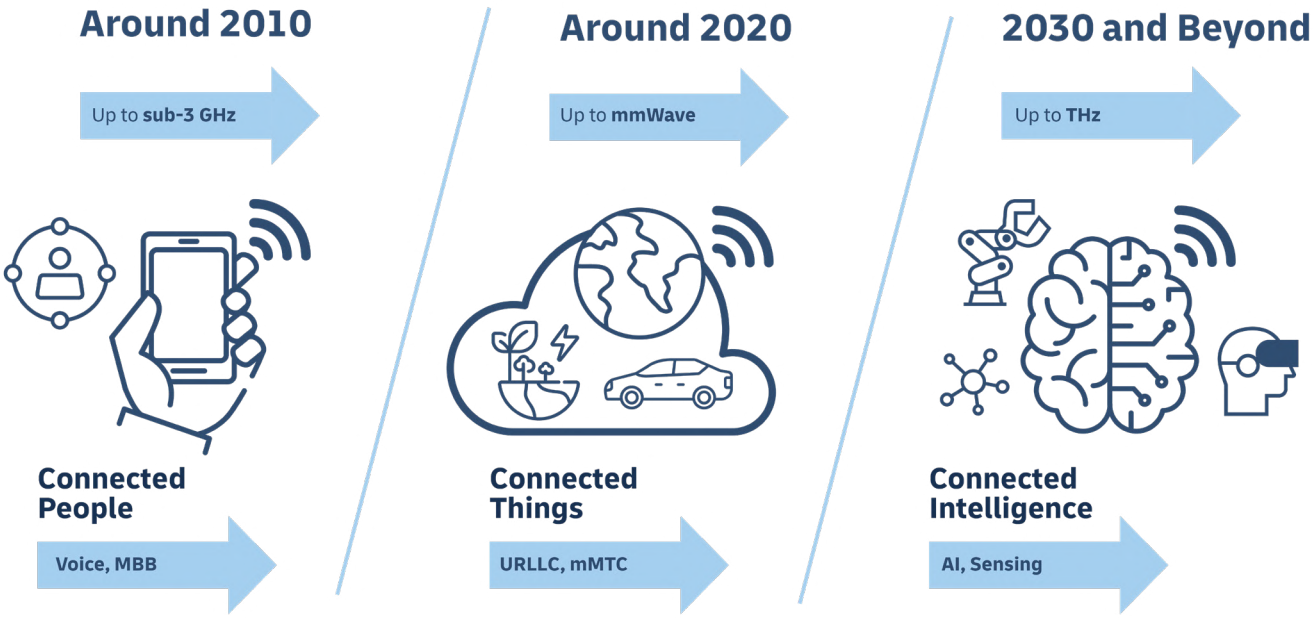
Next-generation connectivity enables private network sharing and slicing, allowing a single network to be used for multiple purposes by isolating channels to guarantee security and enhanced user experience.

A great 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. A similar example of democratization of infrastructure is how Apple AirTags operate – they use the shared network created by all Apple users. In the context of 5G and beyond, network slicing allows a single physical network infrastructure to be divided into multiple virtual networks, providing greater flexibility in the use and 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. All this offers significant benefits for logistics operations, including customized services, quality of service, efficient resource utilization, enhanced security, and resilience.

Recent applications include the Hamburg, Bremerhaven, and Wilhelmshaven Port's private networks, a solution providing committed network resources for the container terminal operator Eurogate's internal data traffic. Another example is the final-mile goods tracking application used by logistics company OnAsset Intelligence, which is based on the Amazon Sidewalk mesh network.

Evolution of next-generation connectivity through the lens of communication



Graphic source: **Huawei (2021): 6G: The next horizon**

SUMMARY & TREND OVERVIEW

Challenges

- Currently, there is a lack of global standards and little or no organizational alignment on frequencies.
- Regulations and inter-political realities are limiting factors for technology capabilities.
- Network and infrastructure security will be critically important to the development of this trend, as each connected device can act as a gateway for cybercriminals.
- Multiple players along the supply chain and a lack of collaboration between organizations may mean multiple tags and sensors are needed for each shipment and supply chains may need to register data through multiple communication networks.

Outlook

The trend of Next-Generation Connectivity brings new ways of connecting and overcoming existing challenges, such as connectivity white spots. It also enables more communication, including machine to machine (M2M), with greater ease of deployment.

In the world of logistics, many connectivity technologies are already deployed today. Some are complementary but there may be many that are redundant, resulting in additional costs. Utilizing existing connectivity technologies and exploiting their convergence with automation, big data, and AI will likely increase the range of potential future use cases.

With new developments, especially the launch of 6G, next-generation connectivity is capable of not just enabling the Connected Intelligence ecosystem but also allowing it to enrich all aspects of logistics operations.

This trend should be monitored to some extent with use cases in some applications that can already be addressed today.

Related Trends

DHL Resources

SmartSolutions IoT

Sources:

IEEE Spectrum (2024): The LEO Satellite Industry Needs More Engineers; Statista (2024): 5G - statistics & facts; Industry Analysis (2024): Global LEO Satellite Market Professional Survey by Types, Applications, and Players, with Regional Growth Rate

Next-Generation Packaging

The trend of Next-Generation Packaging refers to the evolving options for materials used for primary, secondary, and tertiary packaging as well as the technology added to this packaging. These materials and new technologies enable packaging to sense and react to changes in the environment and changes in the packaged contents. This trend also incorporates elements of sustainability, using new packaging materials that are often more bio-based, recyclable, reusable, and biodegradable.

From the continued boom and rise of e-commerce to the global drive for sustainability, the need is growing for smarter and yet cost-efficient packaging solutions with a strong focus on the reduction of CO_2 footprints. In order to meet customer demand, there is emphasis on recyclability, reusability, compostability, and biodegradability and a rising demand for antimicrobial packaging. At the same time, there are pressures to improve package traceability and condition-monitoring. It is increasingly important for logistics organizations to meet these needs.

Propelled by population growth, technological developments, and changing consumer expectations about product packaging, the global packaging market has seen rapid growth in recent years. With a 2023 market size of almost US$ 13 billion, the global next-generation packaging market has a predicted 10-year compound annual growth rate (CAGR) of 6.43%, reaching a market size of almost $24 billion by 2033.

Recent advances in packaging technology include the incorporation of radio-frequency identification (RFID) tags, other Internet of Things (IOT) sensors, and indicators for content conditions, as well as redefining the way packaging materials are sourced.

With developments in this trend set to continue over the next five years, more and more companies are reconsidering the materials and technology used in and for their packaging. As more companies change the ways they use materials and sustainable goods, logistics organizations also need to make adjustments, implementing next-generation packaging practices and reevaluating current operations to ensure new types of packaging can be processed safely through conveyor belts, scanners, and more. And, of course, the contents of this packaging can be delivered to recipients without damage.

Furthermore, the cost of packaging remains a factor that is crucial to extensive scalability. Especially during unstable economic periods, companies may opt for a cheaper solution rather than spending extra on more sustainable and technology-enabled alternatives.

(Active) Packaging & Tracking

Active packaging incorporates additives to maintain or extend product quality and shelf life.

> *Active packaging solutions today account for an over 36% share of the global next-generation packaging market and are predicted to remain dominant for the next 10 years.*

Examples of active packaging include antimicrobial packaging, heating/cooling packaging, items including gas emitters, absorbers and scavengers, moisture/ odor/ flavor-absorbing and releasing packaging, corrosion control packaging, and spoilage retardant items.

These types of packaging are engineered to respond and react to changes in the external and internal atmosphere of a package and are therefore of utmost importance and significance to, for example, the pharmaceutical and nutraceutical industries as well as for lithium-ion batteries.

Logistics organizations, in turn, need to have fresh chain and cold chain operational capabilities in place to ensure product delivery meets the standards set by customers and aligns with varying fresh and cold chain legislation. Logistics companies today are developing more solutions to improve active temperature retention and eliminate reliance on dry ice or liquid nitrogen which have to be handled as dangerous goods, particularly in air freight scenarios. Sensors and IoT monitoring are increasingly used to check various conditions such as temperature, shock, light, humidity, inversion/tilt, location, and thermal runaway. In any case, the use of active trackers is limited by the fact that their batteries are classified as dangerous goods, too, adding complexity to air shipping. Bluetooth trackers represent a cost-effective alternative, leveraging existing infrastructure like smartphones for status monitoring. The small batteries in Bluetooth trackers are not classified as dangerous goods. However, their one-time usage contributes to growing e-waste whereas active trackers can be used in circular solutions.

Intelligent Packaging Solutions for Asset Monitoring

Intelligent packaging systems monitor the internal condition of packaged goods to give information on quality during transportation and storage. Simply defined as packaging which senses and informs, these systems integrate hardware components such as time temperature indicators (TTI), freshness and ripening sensors, and RFID and other tags. This helps maintain the quality of products, contributing to a reduction in global waste. The healthcare and pharmaceutical industries are considered major growth markets, highlighted by the Covid-19 pandemic, as there is a growing need to improve supply chain visibility in these sectors.

Application opportunities for intelligent packaging are not limited to just these industries, however. Within logistics and supply chain operations, smart packaging solutions are vital to goods in many other industries, better protecting them with real-time

tracking as this cuts the risk of theft, last-mile delivery diversion, counterfeiting, and other crimes. Monitoring solutions play a vital role in fresh and cold chain packaging, ensuring temperature stability during transit and enabling shipment status checks upon arrival. Previously, active trackers were often used for location checking but this need is overtaken today by requirements for temperature stability monitoring. An example of this is the Digital Shipping Label & Asset Tracker from the British start-up Envio that lets the shipper remotely track and re-label a shipment using an e-ink digital shipping label. This solution also sends out notifications when a shipment is opened, dropped, or exceeds a temperature threshold.

Modified Atmosphere Packaging

The vast expansion of global shipping and transportation capacity has enabled rapid transportation around the world of perishable goods and atmosphere-sensitive products. Within this complex process to ensure products arrive in best condition, the internal atmosphere of the storage container or packaging must be continuously monitored, maintained, and may need to be changed. As such, the use of modified atmosphere packaging (MAP) becomes central to the effectiveness of transportation and delivery.

The benefits of MAP technology include reducing global food wastage, extending shelf life by days and even weeks, and achieving a more profitable and secure global food supply chain. For nutraceuticals, goods that tend to deteriorate through oxidation can be protected by actively replacing oxygen with nitrogen. The Covid-19 pandemic also highlighted the need for MAP solutions to facilitate global vaccine shipments, particularly controlling and modifying atmospheric temperature during transportation. One example of this is the development of packaging that incorporates internal dry ice.

Green Packaging Alternatives

Sustainable packaging is a significant and evolving topic. It encompasses the optimization of packaging, the utilization of recycled or bio-based materials, and the implementation of circular or refillable systems within the supply chain.

However, there are notable challenges to the adoption of sustainable packaging solutions in the logistics and business-to-business (B2B) sectors, with limited integration beyond specific industries. Wider implementation is hindered by the lack of return services for reusable solutions, the influence of pricing considerations, and more. Research conducted by DHL eCommerce reveals that, while 28% of global customers express willingness to pay for sustainable packaging, an equal percentage would not.

Extensive exploration of innovative alternatives, encompassing water-soluble, edible, plantable, and biodegradable options, is currently underway to effectively address sustainability challenges. In order to

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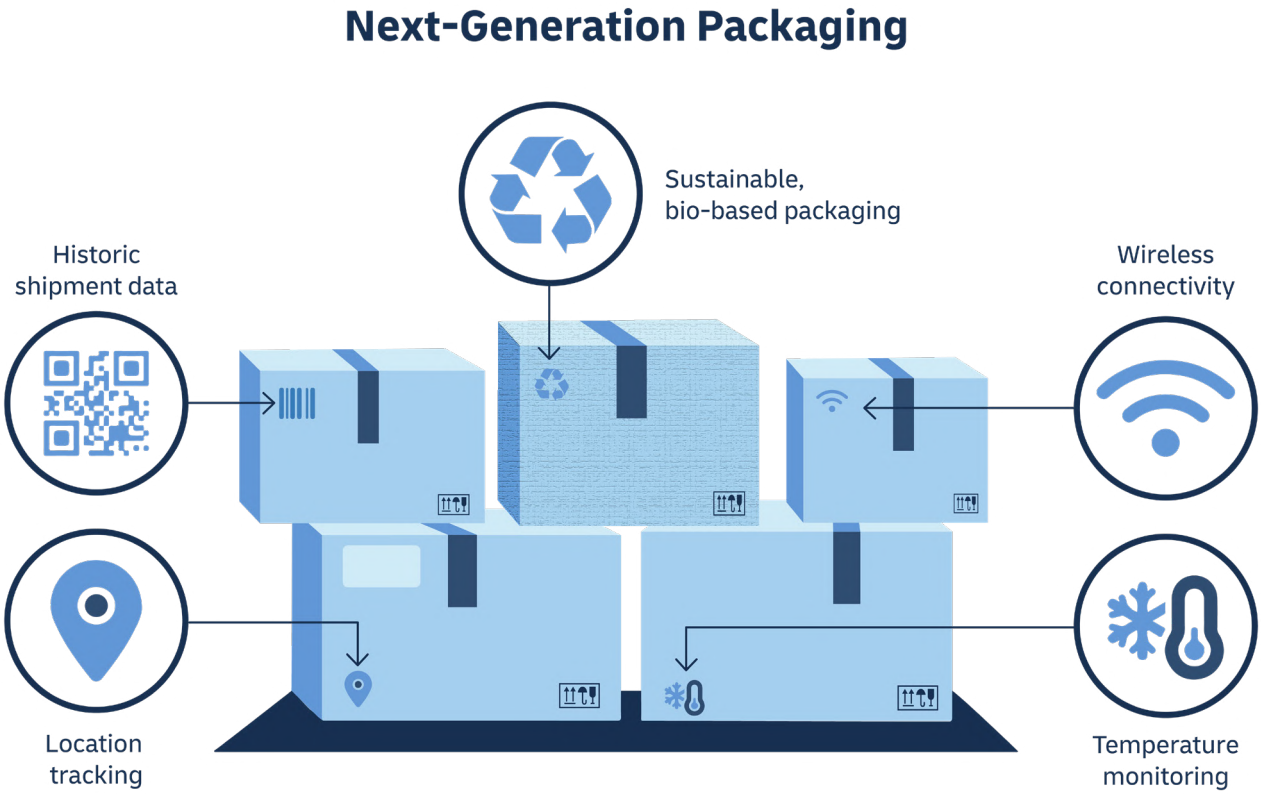
replicate the properties of conventional packaging, these sustainable solutions must be compatible with sensitive products, ensuring the safe storage and delivery of each package's contents.

A growing number of companies are additionally embracing minimalistic packaging approaches, such as employing non-colored kraft box packaging and optimizing package sizes to reduce shipment size, packing material usage, and overall CO_2 emissions. As an example, Continental, the German automotive parts manufacturer, has implemented smaller and more sustainable packaging for its timing belt kits with a water pump, resulting in a 70% package size reduction, reduced CO_2 emissions, and fewer truck trips for logistics.

Regulations and governmental legislation, such as recent new rules on sustainable packaging in the European Union (EU), will drive companies towards adopting green and efficient packaging solutions. This EU agreement sets packaging reduction targets (5% by 2030, 10% by 2035, and 15% by 2040) and mandates EU countries to reduce plastic packaging waste.



Graphic source: **PackMojo (2024): What is Smart Packaging & How Does it Work?**

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 is determined by their environmental impact.
- Different regulations apply in various countries and regions, and specific additional regulations often apply to the multiple components of smart packaging, so significant time and resources are needed to ensure compliance in a fast-changing world.
- The successful implementation of sustainable packaging solutions necessitates substantial investments and collaborative efforts among various supply chain stakeholders, but collaboration is crucial to the adoption of innovative, circular packaging solutions.

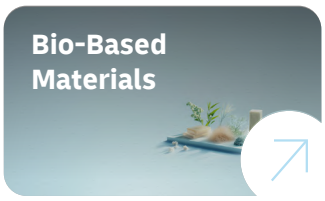
Outlook

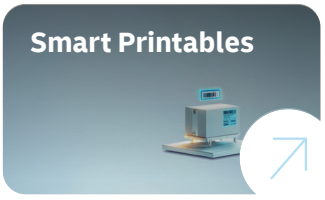
Next-generation packaging has the potential to enhance visibility, boost security, and optimize supply chain reliability, particularly for cold-chain shipments. As technology advances, even more will be achieved, effectively improving the efficiency and dependability of logistics and the supply chain.

Future developments in sustainable packaging will focus on reliability, durability, pricing strategies, and regulatory guidelines to tackle the problems of unrecycled single-use plastic and non-sustainable packaging. The financing of closed-loop solutions will likely play a vital role in promoting a circular economy, minimizing waste and maximizing resource efficiency for a more environmentally responsible and economically viable packaging landscape.

This trend should be carefully monitored with use cases in some applications that can already be addressed today.

Related Trends





DHL Resources

Trend Report: Rethinking Packaging

Exploring the benefits and trade-offs of sustainable packaging

Sources:

Future Market Insights (2023): Next Generation Packaging Market Outlook for 2023 to 2033; European Parliament (2024): Deal on new rules for more sustainable packaging in the EU

Outdoor Autonomous Vehicles

The trend of Outdoor Autonomous Vehicles encapsulates the variety of self-driving vehicles operating primarily outside on land or water, both within private property and on public rights of way. This trend focuses on vehicles that are either completely driverless or at least highly automated with occasional control by a human driver.

Bolstered by rapid developments in artificial intelligence (AI), edge computing, and sensor technologies, self-driving vehicles have come closer to reality in recent years with all modes of highly automated vehicle making an appearance on the market and fully automated vehicles making test debuts.

Successful examples include autonomous delivery robots created by the Estonian robotics company, Starship Technologies which accomplished over 6 million autonomous deliveries by January 2024, reflecting a steady growth trajectory since commercial launch in 2017.

The Outdoor Autonomous Vehicles trend will have high impact in logistics as it will significantly change the operational tasks performed by human workers and alter the way that customers interact with logistics providers in the last mile and elsewhere.

Overall, this trend's realization, however, is quite distant. While implementation has already begun with some use cases on private, gated properties, autonomous driving on public rights of way requires societal confidence. It will take more time before people trust fully autonomous technology and regulations permit unhindered application on a global scale.

Enabling technologies for this trend are improving, particularly in terms of sensors and navigation, but adoption is delayed by regulations, cost, and safety concerns. Outdoor autonomous vehicles are therefore about six or seven years away from wide-spread adoption in logistics, and experts anticipate greater scaling across geographies within 10 years. The impact of these vehicles is likely to be high, especially within countries facing high labor costs and workforce shortages.

Automated Yard Operations

An effective way to increase safety and respond to workforce shortages is to use autonomous tractors to move objects from point to point in the outdoor environment of a logistics yard, port, or the like.

Manually moving assets, containers, and cargo within a yard is repetitive work that adds minimal value, so automation is an excellent alternative. Digitalized processes include the ability to track and sequence movements, ensuring first-in-first-out (FIFO) inventory management. Container location within a facility can be integrated with the yard management system and scheduling, task assignment, and movements can all be planned in advance.

DHL Supply Chain has deployed proof-of-concept EX9 autonomous shunting robots to reduce the arduousness and risk of accidents on site and improve operational performance while enabling a negative CO_2 footprint. Trials at airports are paving the way for their adoption within private property in logistics and the supply chain.

At Frankfurt Airport, a first-of-its-kind trial in 2023 proved an autonomous electric tractor can augment ground handling by towing baggage trailers or cargo trailers along the relatively long apron, driving at a maximum speed of 13 kph (8 mph). In a similar trial which started in 2023 at Singapore's Changi Airport, driverless baggage tractors have been enabling autonomous operations on the tarmac. TractEasy vehicles moved around Terminal 3 without a safety driver and Aurrigo driverless baggage trailers were used in a proof-of-concept trial.

In the Port of Rotterdam, an autonomous yard truck initiative has been launched – a collaboration between Kramer Group, a major depot and container terminal operator, Terberg, Europe's largest manufacturer of yard trucks, and StreetDrone, a leading provider of autonomous yard truck technology. Together, they aim to achieve a new standard for safety, efficiency, and competitiveness at the port, with pilots running in two locations until early 2025.

New Last-Mile Models

The last-mile segment of supply chains is expensive, representing about 53% of today's total shipping costs. With the number of online orders consistently rising and straining delivery services, outdoor autonomous vehicles are seen as a solution that cuts costs while keeping up with demand.

Examples include DHL's autonomous last-mile express deliveries in Tallinn, Estonia using a robot created by freight autonomy startup Clevon. This initiative was launched in late 2022 and by September 2023 the autonomous robot carrier had delivered more than 1,500 packages. Meanwhile, in Latin America a delivery robot called ADA is helping in the last mile by autonomously calling and riding solo in elevators to deliver orders in Brazilian cities – a successful initiative between iFood and the country's first autonomous delivery startup, Synkar.

> *Proving the scalability of last-mile autonomous delivery is a JD Logistics fleet of over 600 vehicles across 30 cities in China, including 100 indoor delivery robots deployed in malls and office buildings in more than 10 cities.*

JD Logistics' Generation Five Autonomous Delivery vehicles can carry up to 200 kg (440 lb), travel up to 100 km (62 miles) per charge, and some are equipped with an advanced cold and heating storage system for food deliveries to customers' doorsteps.

Also in China, Cainiao – the logistics arm of Alibaba Group – broke a new record for autonomous last-mile delivery in China. By March 2023, Cainiao's autonomous Xiaomanlv logistics robots had delivered more than 29 million orders.

These examples illustrate the range of automated solutions for logistics providers to investigate and implement to help manage costs, service levels, and environmental impact in the last mile.

Long-Haul Autonomy

The growing shortage of drivers globally is a huge challenge. Added to this, mechanical or vehicle failures are not the main cause of road accidents, but humans are. Drivers can lose focus especially on long, monotonous journeys; they get tired and they may exceed the speed limit. Often, excess carbon emissions are attributed to poor driving habits like aggressive acceleration.

Together, this provides a compelling opportunity to use automation for long-haul trucking. Although there is a very limited number of roads and highways that currently allow fully autonomous trucking, it is possible for trucks with drivers to deliver and pick up from locations serviced by autonomous trucks. And in the next few years, more highways are expected to allow autonomous trucking.

Long-haul autonomy lowers reliance on human drivers and will likely reduce accident rates and carbon emissions. It enables better planning and scheduling, and more dependable estimated times of arrival (ETAs). For drivers, it also promises a better work-life balance with fewer (potentially even no) long-haul trips and more focus on operating within their local area to support the long-distance journeys undertaken by autonomous vehicles.

In the US, Maersk and Kodiak Robotics have launched a commercial autonomous trucking lane between Houston and Oklahoma City. Autonomous vehicles with 53-foot (16-m) trailers make four round trips per week on a 24-hours-a-day, four-days-a-week basis.

Also in the US, an innovative DHL-Volvo partnership aims to operate hub-to-hub autonomous transportation by creating autonomous freight corridors in Texas running from Dallas Forth Worth to El Paso and from Dallas to Houston.

In China, a TuSimple trial in 2023 showcased the country's first fully autonomous semi-truck run on open public roads without a human inside the vehicle and without human intervention. Conducted on designated public roads approved by the Shanghai government, the vehicle's route include the Yangshan deep-water port logistics park and Donghai Bridge, one of the world's longest cross-sea bridges. The vehicle travelled over 62 km (38.5 miles) and navigated complex road and weather conditions in both urban and highway environments within the port area, including traffic signals, on-ramps, off-ramps, lane changes, emergency lane vehicles, partial lane closures, fog, and crosswinds. This demonstration of Level 4 autonomy was the result of two years of intense development.

RELEVANCE TO THE FUTURE OF LOGISTICS

How will autonomous vessels work?

Benefits & Challenges

Autonomous ships are hot. Their development is capturing the enthusiasm of more and more companies. There is a long way to go, but autonomous ships have a great deal of potential. It is not a matter of IF, but only of WHEN they will become a reality. Take a look at the benefits and challenges in this graphical overview.

Ship Design

Present day ships cannot function without a crew, but the presence of the crew also strongly limits design freedom. Autonomous ships, therefore, require a complete re-evaluation of many design criteria and technical solutions to meet these criteria.

Autonomous Smart Control Systems

By gathering numerous types of data through different sensors, smart control systems can address several concerns with a perfect approach. On board smart controllers not only can plan suitable paths for the autonomous vessels, they are also able to navigate the ship. Moreover, smart controllers can be adopted for on-board power and propulsion systems to control the power and energy management processes.

Capacity

Ships without crew do not require life support systems and can carry more cargo.

Health Detection

With the use of different fault-detection and isolation strategies and algorithms, autonomous vessels can detect faults related to different on-board components. In addition, by cooperating with the smart control system the effect of such faults on the overall system can be restricted.

70% Accidents — Human Error

At least 70% of all incidents at sea are (partly) caused by human error. Autonomous shipping should therefore lead to a drastic reduction of the number of incidents, casualties and maritime pollution.

40% — Less Crew Cost

For a typical Dutch short sea ship, the crew makes up about 40% of the total costs. Removing the crew therefore has a large potential for cost savings.

Terminals

Autonomous ship operations could be aligned with the operations inside automated container terminals so that quay cranes and automated guided vehicles could be scheduled to load/unload and transport containers from the autonomous ships in the most efficient way.

Crew Shortage

By 2025, a shortage of approximately 150.000 maritime officers is expected. Autonomous shipping can help to solve this problem.

Autonomous Coordination

Thanks to distributed control algorithms autonomous vessels are able to collaborate appropriately to carry out different tasks and operations. These vessels are able to communicate and cooperate to optimally operate while several issues such as safety, environmental situations and concerns, fuel consumption and dynamical restrictions regarding each vessel are considered.

+5 knots

-5 knots

Legal

All international ship-related law implicitly or explicitly assumes that ships have a crew and a captain. Changes to the legal framework are, therefore, required to make autonomous shipping possible. Given the way e.g. IMO works, this is a challenging and long-term process.

Fleet Logistics / Control Center

Operations of fleets of autonomous ships can be monitored from on-shore control centers; such control centers can moreover be linked to control and supervision centers for road, rail, and air transport, in order to optimize transportation chain-wide logistics performance.

Source: **Ali Haseltalab et al. (2017): Autonomous Ship Systems: from Theory to Practice**

Graphic source: **Ali Haseltalab et al. (2017): Autonomous Ship Systems: from Theory to Practice**

SUMMARY & TREND OVERVIEW

Challenges

- Legal restrictions in various regions may prevent or slow adoption.
- Potential hacking and the risk of software bugs raise security and safety concerns.
- The cost advantages of self-driving solutions may be difficult to calculate; there are often high implementation costs and it can be hard to fiscally quantify the benefits of consistency, efficiency, accuracy, and sustainability.
- Upskilling and retraining programs may be needed for employees who are affected by the introduction of driverless vehicles.

Outlook

The trend of Outdoor Autonomous Vehicles is slowly advancing towards broader adoption in logistics. Numerous countries such as China, Germany, Japan, and the US have already approved the limited testing and piloting of outdoor autonomous vehicles on public and private roads. Such approvals will encourage logistics organizations to actively adopt self-driving vehicle technology in facilities and in supply chain transportation segments. While it may still be many more years before fully autonomous vehicles handle outdoor operations, we here at DHL anticipate highly autonomous vehicles with occasional human guidance will be commonplace in many locations within the decade especially in yard operations.

This trend should be carefully monitored with developments and use cases on the horizon.

Related Trends

DHL Resources

The big benefits of 5G technology in logistics

DHL & EHang jointly launched AAV Delivery Solution | EHang

Remote Operation

The trend of Remote Operation refers to the use of telecommunications technology to remotely control and operate devices or machines located in a different physical location from the operator. This can include the use of remote control devices, sensors, and other technologies to transmit data between the operator and the machine.

The global remote operation market was estimated to be US$ 403 million in 2022 and is expected to reach $3.19 billion by 2032 at a compound annual growth rate (CAGR) of 23.1%. Key drivers of this market include the growing adoption of industrial automation, rising demand for unmanned vehicles and drones, the development of these types of autonomous vehicles, and the growing trends of smart manufacturing and Industry 4.0.

These developments are driven by advances in artificial intelligence (AI) and machine learning (specifically their integration which enables predictive analytics, autonomous decision making, and adaptive control systems) and connectivity improvements in 5G and other networks and low-latency communication technologies (facilitating real-time remote operations with reliable connectivity). In addition, advances in computer vision and sensor technology are paving the way for application in an ever-widening range of scenarios; for example, remote operation of various robotic arms and hands to tackle different manual tasks.

The ability to operate a system or machine at a distance is already proving useful is a broad range of applications. In logistics, it supports remote operation of unmanned forklifts, tuggers, yard trucks, and robots. In healthcare, it enables remote surgeries, patient care, and precise interventions. For manufacturers and companies involved in mining, it allows remote operation of heavy machinery and equipment, sometimes for intricate operations, in hazardous and what can be remote environments. The automotive industry uses telerobotics for testing, quality control, and even autonomous vehicle operations. In agriculture, remote operation systems support remote handling of robots for crop monitoring and spraying. And, in space exploration, these systems enable astronauts to explore uncharted territories, conduct experiments, and repair equipment remotely.

The adoption timeline for this trend in logistics is within the next five years. With the increasing uptake of unmanned vehicles and robots in warehouses and logistics operations, a cost-effective and safe way to monitor and use these assets is through remote operation, whenever possible and reasonable.

The impact of remote operation on the logistics industry will be rather low. While ways of working will continue to change, the supply chain will not be significantly affected. With a shifting demographics in the workforce (with older workers retiring and digital natives entering the workforce), the possibility of remote operation and remote work has broader appeal to the younger workforce and opens an even wider pool of talent.

RELEVANCE TO THE FUTURE OF LOGISTICS

Remote Operations as Safety Fallbacks

Remote operations represent a valuable addition to autonomous driving. Autonomous vehicles require AI models to be trained and it is challenging to ensure each vehicle responds correctly in every different driving scenario. Standard control processes can certainly be performed by AI but, when a situation gets tricky and requires complex decision making, a remote human operator can take over.

A common scenario that may require human intervention is that of a double-parked delivery vehicle. If the autonomous van is prevented from driving over a solid line, it will remain where it is until the remote operator intervenes. Another scenario is when a construction site has not yet been incorporated into the automated system. A remote operator would need to guide all vehicles safely into and out of this location. And a further scenario requiring human intervention is the decision on whether an autonomous vehicle can safely overtake a stalled moving truck that is blocking a lane.

Examples of remote operations as safety fallbacks include the six autonomous yard trucks deployed in the Port of Rotterdam – a pilot project between partners StreetDrone and Terberg to alleviate several hazards and challenges in the port and enable the workforce to move containers with greater precision, efficiency, and safety. The pilot runs until early 2025, after which the partners aim to scale operations rapidly and add several additional autonomous yard trucks to the fleet.

StreetDrone is also partnering with Nissan to trial 40-ton self-driving trucks, aiming to prove last-mile delivery capabilities. Uniquely, 5G enables the removal of any safety drivers from these vehicles and remote operations will be used to overcome abnormal situations.

Norwegian chemical company Yara and its technology partner Kongsberg have created the world's first fully electric and crewless cargo ship with zero emissions – MV Yara Birkeland. It uses cloud technologies to provide all required data to an on-shore remote operations office, allowing human takeover if this is ever needed.

Examples of remote operations with autonomous robots include systems created by Sarcos Technology and Robotics Corp that augment humans to improve worker safety and efficiency.

> *In a successful trial for the US Navy, two robot types were remotely operated to work at height both on board and alongside a ship – they performed visual inspections, removed rust and paint, and undertook various other repairs.*

Meanwhile, up to 2,000 little AI-powered sidewalk food-delivery bots will be deployed across the US via the Uber Eats platform by partners Serve Robotics and Ottopia. A remote assistance platform using remote operation software will enable human operators to monitor the fleet and lend a hand if the bots ever run into a complex or unpredictable safety situation.

RELEVANCE TO THE FUTURE OF LOGISTICS

Remotely Controlled Vehicles

The COVID-19 pandemic made the option of remote work essential across businesses and functions. This presented technology providers with an opportunity, finding ways to maintain operations while also ensuring employee safety in various environments.

Examples of remotely controlled vehicles include material-handling forklifts, tuggers, and the like. Solutions from Phantom Auto as well as Teleo allow one person to control multiple machines, with supervised autonomy, from the comfort of a command center.

Germany has its first remote-controlled inland waterway shipping center, a Seafar solution that enable captains on dry land to remotely navigate vessels on inland waterways. In another solution, Europe's first smart railway logistics terminal, East-West Gate located in Hungary, leverages the 5G network and AI. One worker can control four cranes at the same time from an office location, boosting efficiency by 20% and attracting new people to the role of crane operator.

Similarly, remote operations will enable truck drivers to steer vehicles from their desk, making the job more attractive by creating a better work-life balance and providing a safer workplace.

Remote-Controlled Operations Using Digital Twins

Further efficiency in remote operations can be achieved by using digital twins. A virtual representation of the physical elements of machinery, facilities, or an entire production system eliminates the need for a human to physically go to a location to undertake any task.

RELEVANCE TO THE FUTURE OF LOGISTICS

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 operate troubleshooting on the digital twin before deciding on the best course of action at the actual site.

In another example, a researcher from the University of Edinburgh has demonstrated human-robot interaction, with VR and digital twin-based remote operation of a robotic arm. The researcher used a VR headset to control the robot arm located 320 km (200 miles) away through cloud using VR and deep-learning technology.

Driverless vehicle remote operation

	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

Graphic source: **EE Times (2023): Next Time You Hear „Teleoperation", You'll Know a Lot More**

SUMMARY & TREND OVERVIEW

Challenges

- The absence of physical sensing makes it difficult for the remote operator to take an informed decision on behalf of an autonomous vehicle.
- When remotely operating both autonomous vehicles and machinery, the lack of human cognition and perception may present a “blind spot” in situational awareness, spatial awareness, and/or depth perception.
- If there is a malfunction that cannot be supported or resolved remotely, this introduces a security and IT risk; a flexible, agile response would be required from the human operator.
- It will be challenging for remote operators to maintain their attention over a long period of time, due to the lack of physical stimuli and overwhelming amounts of information.

Outlook

With a significant rise in demand for autonomous vehicles and growing adoption of remote-controlled operations in logistics, this trend will likely be realized within the next five years.

Remote operations not only improve efficiency and safety when carrying out certain tasks but also address the challenge of labor shortages in the industry by allowing a single remote operator to control multiple vehicles from one location.

This trend should be passively monitored with use cases in some applications that can already be addressed today.

Related Trends

Sources:
EIN Presswire (2023): Teleoperations Market to Reach US$ 3.19 Billion, Globally, by 2032 at 23.1% CAGR: ABB Ltd. , Alphabet Inc

Renewable Energy Infrastructure

The Renewable Energy Infrastructure trend refers to developing sufficient and reliable networks for efficient generation, transmission, distribution, and storage of energy generated by and from solar, wind, and geothermal sources, hydropower, ocean power, biomass, and hydrogen from renewable processes. Applications range from electric vehicle (EV) and hydrogen charging stations to entire networks such as energy carrier grids.

Concerns about climate change are driving the shift from fossil-fuel based power generation and usage towards renewable power generation and consumption. Renewables account for an increasing proportion of the power mix, estimated to be 45-50% of generation by 2030 and 65-85% by 2050. Particularly in emerging markets, where energy needs and electrification are growing apace, demand for electricity is expected to more than double from 25,000 TWh in 2022 to between 52,000 and 71,000 TWh by 2050.

As homes, businesses, and industries steadily switch from fossil fuels to electricity-based systems for transportation, heating, industrial processes, and more, the rise of renewables and the associated increasing electrification are putting strain on the electric grid infrastructure. Its power generation, transmission, storage, and distribution systems need to be upgraded and expanded to accommodate growing demand. According to the IEA, governments and businesses must collaborate to ensure the world's electricity grids are ready for the new global energy economy.

The logistics industry is strongly impacted by this trend and will also play a key role in setting up and maintaining the future renewable energy infrastructure. Logistics companies encounter signifi-cant challenges stemming from the escalating electricity demand brought about by vehicle electrification. This is particularly evident in the case of delivery truck and van fleets, necessitating robust charging infrastructure. Furthermore, the pursuit of carbon-neutral buildings adds to these challenges, with warehouses, distribution centers, and other supply chain facilities requiring energy-efficient technologies, practices, and the integration of onsite renewable power generation and storage.

While organizations focus on expanding their own onsite renewable energy infrastructure, they are also dependent on government initiatives and regulation to expand the overall infrastructure, including public charging points along transportation routes. In many countries, governments are already strengthening the renewable energy infrastructure through appropriate policies and measures, but implementation often takes several years.

Distributed Energy Resources

Small-scale energy resources, such as solar panels, wind turbines, and energy storage systems that are usually situated near sites of electricity use are referred to as distributed energy resources (DERs). They can help logistics organizations reduce the carbon footprint and cut energy costs by generating electricity onsite, reducing reliance on grid electricity.

DERs create new power system opportunities but also new challenges, particularly when a grid has not been properly prepared. Many orgnizations have installed rooftop solar panels, which have proved highly effective and some organizations are using small wind-power systems. However, utilization is likely to increase as new, more cost-effective solutions become available.

For example, the US startup Aeromine Technologies has developed a bladeless wind energy solution for rooftops that captures and amplifies wind as it strikes the side of a building, accelerating its flow over a flat roof. The wind passes through a pair of aerodynamic fins (similar to those on a race car) to maximize wind speed. As it passes through, the wind creates a vacuum at the base of the unit, which spins an enclosed propeller and generates power.

Meanwhile a startup in Spain, Vortex Bladeless, is developing a new wind power-generating technology without blades, gears, or shafts, encouraging a new urban opportunity for wind power. Instead, the light cylindrical machines oscillate perpendicular to the wind stream, creating an aeroelastic resonance in which energy can be harnessed from the wind.

On-site energy storage is a challenge for companies using solar panels or wind power solutions for their facilities and buildings, but so-called gravity batteries like those from the British company Gravitricity offer an innovative solution. When there is a surplus of green energy, gravity serves as a storage device by pulling a weight upwards via electric motors and, as soon as demand increases, for example at night, this weight can be lowered to release the stored energy.

RELEVANCE TO THE FUTURE OF LOGISTICS

Logistics Hubs As Power Distribution Centers

The electricity grid is evolving from a traditional one-way flow of energy to a future power market where everyone can generate and consume energy. And this goes beyond installing DERs to generate clean energy onsite; it also includes the ever-increasing installation of onsite charging stations for electric cars, vans, and even electric trucks. In the near future, this will also include vehicle-to-grid (V2G) technology allowing EVs to not only consume electricity from the grid but also supply electricity back to the grid. In essence, it allows EV batteries to serve as energy storage devices that can be utilized to support the stability of the electricity grid.

With these changes, logistics centers will ultimately become virtual power plants and storage facilities connected to the grid system. Future energy management systems must consider issues such as the size of the grid connection (average and peak power consumption of the electrical loads that will be connected to the grid), the AC/DC charging infrastructure (charging power, energy needed for given number of vehicles), and the sizing of the DERs (number of solar panels or capacity of energy storage).

Although this future demand for energy management will require technological advancements and grid investments, it will also open up new opportunities.

> *Examples include the opportunity for energy trading in the electricity market (if permitted) to generate additional revenue by optimizing energy usage, generation, and storage, and by providing energy to the market when needed and demand energy when there is overcapacity.*

As power distribution centers, logistics organizations can collaborate and partner with energy companies, local governments, and other stakeholders to develop innovative energy solutions. This can involve exploring shared energy infrastructure, joint investment in renewable projects, and participating in energy exchange programs.

Charging Infrastructure for Electric Trucks

Electrification of long-haul heavy-duty transportation is an important lever for reducing carbon emissions in logistics, and all major truck manufacturers now offer fully electric trucks. However, the existing infrastructure for these vehicles is insufficient in many places. These trucks need DC fast-charging facilities to keep charging times below 1.5 hours, but expanding the charging infrastructure to provide rapid charging is restricted by high costs, limited grid capacity, and associated power peaks.

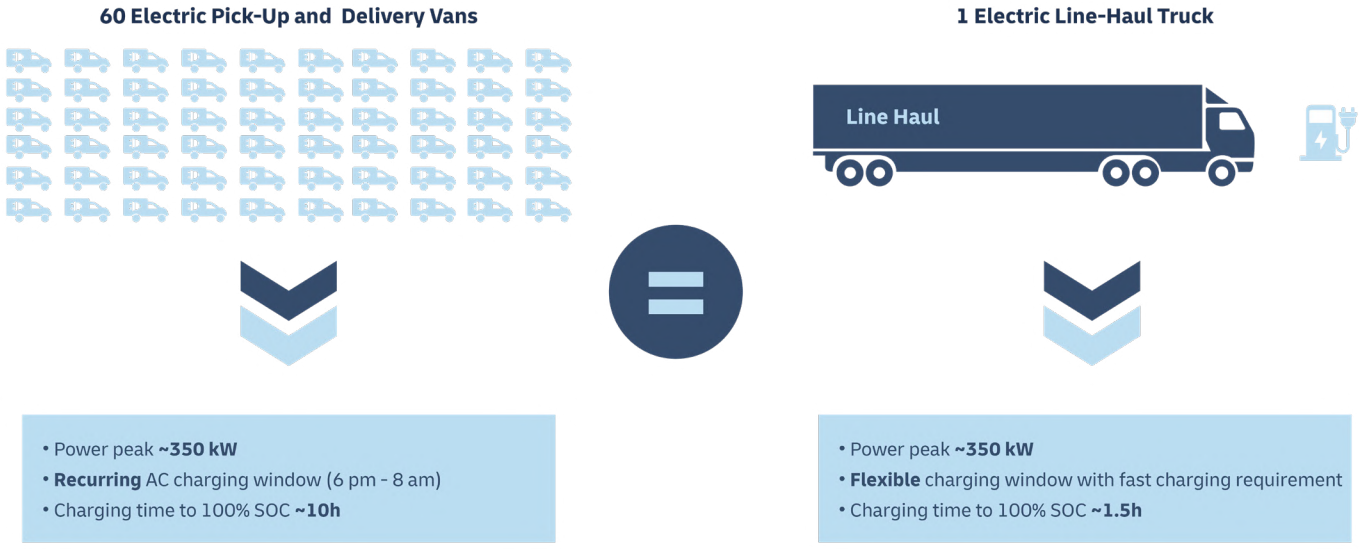
RELEVANCE TO THE FUTURE OF LOGISTICS

Electric trucks will massively impact future electrification. For example, one DHL linehaul truck requires as much electricity as 60 pick-up and delivery vans due to higher mileage and average electric consumption.

Battery swapping as a bridging solution can compensate for unsatisfactory charging speeds. The Chinese battery manufacturer and technology company CATL has released a battery-swapping solution for heavy-duty electric trucks. This system, called Qiji Energy, consists of exchange stations, battery packs, and a cloud platform. The battery-swapping process is said to take only a few minutes.

Alongside innovations like these, there are government initiatives to improve the electric truck charging infrastructure. The US trucking-as-a-service startup WattEV will build three electric truck-charging depots in California using US$ 75.6 million in federal grants. All three depots will include solar panels and battery storage to provide clean power and reduce their hefty draw on power grids.

One line-haul truck requires as much electricity as 60 pick-up and delivery vans due to higher mileage and average electric consumption



Graphic source: **DHL (2024)**

SUMMARY & TREND OVERVIEW

Challenges

- The expansion of the renewable energy infrastructure involves multiple stakeholders and many regulatory frameworks, so effective coordination and planning are required.
- The implementation of V2G and smart energy management necessitates the presence of advanced smart grids, which are currently lacking.
- The realization of large-scale infrastructure projects spans over several years.
- Developing renewable energy infrastructure often requires high initial investment, which is a major hurdle for project implementation and scaling.
- Logistics relies on governments and their policies to ensure grid stability, as the intermittent nature of renewable energy sources puts strain on the grid.

Outlook

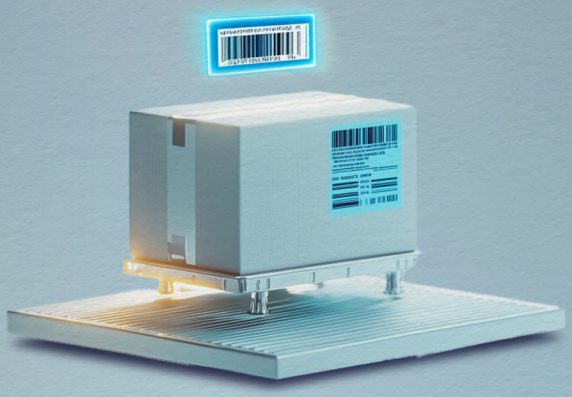
Renewable power generation and vehicle electrification are further expanding and, with this, there is greater need for a capable infrastructure. This foundation is particularly important for logistics organizations, with their growing fleets of electric vehicles and as they increase onsite power generation and storage systems.

Today's renewable energy infrastructure and especially the electricity grid are not yet up to the demands of tomorrow in most parts of the world. However, expansion requires government commitment and investment and always takes place over a long period of time.

This trend should be actively monitored with developments and use cases on the horizon.

Related Trends

Source:
McKinsey (2024): Global Energy Perspective 2023: Power outlook



Smart Printables

The trend of Smart Printables refers to the next generation of smart labels made of printed paper, plastic, or fabric and upgraded with special intelligent inlay technology. This technology digitally captures and communicates more information than is printed on the physical label and can be attached to any product, shipment, or asset.

As the next generation of smart labels, smart printables will be both smart and printable. The anticipated technologies to be integrated in these labels include printed batteries, ever-smaller microchips, and efficient communication capabilities with the outside world via Bluetooth Low Energy (BLE) and cellular technology (LTE-M and NB-IOT low-power wide-area networks).

For example, special printing techniques will be used to layer battery components such as electrodes on a substrate in a precise pattern, allowing each printed battery device to be thin, flexible, and customizable in size and shape for various applications. With BLE and an LTE-M or NB-IOT wireless connectivity protocol, less power is needed to support data uploads from the device, further increasing the smart printable's battery life.

This special intelligent inlay technology is likely to have significant impact on logistics and the supply chain. For example, it can help minimize manual touchpoints, enable end-to-end visibility, support proof of delivery, increase speed and throughput in distribution centers, and accelerate order picking in fulfillment centers.

Advances in this technology are still in the mid-future as the stability of printed batteries must improve before scaled deployment in logistics operations. Also, the challenge of global coverage is yet to be overcome before anticipated end-to-end use cases are achievable. As this technology is still in an early stage of development, commercial viability is uncertain until deployment price points can be defined.

RELEVANCE TO THE FUTURE OF LOGISTICS

End-to-End Visibility & Efficiency

With rising demand for shipment visibility, live location tracking of goods can be achieved with smart printables. This capability is highly relevant to the customer experience and to logistics operations. It also equips manufacturers to track products (particularly high-value goods) from production through delivery to end users.

The startup Sensos, founded by Sony Semiconductors, offers a solution that enables customers, manufacturers, and logistics experts to know shipment location and condition (including temperature, humidity, and shock) in real time via an active cellular tracker. Coming in a thin sub-5mm form factor, its cellular label is an innovative step towards smart printables.

The software startup Tag-N-Trac has taken an alternative approach. With printable BLE-based labels, its solution uses the existing shipping label printing infrastructure, integrated with current operations via normal smartphones or plug-and-play gateways.

Smart printables have potential to enhance end-to-end supply chain visibility and increase speed and efficiency in logistics operations. As the process involves decentralized printing and placing labels on each shipment, scalability is relatively quick and easy, and there will be no need for a complex and costly scanning infrastructure in the supply chain.

Combatting Counterfeits & Providing Proof of Delivery

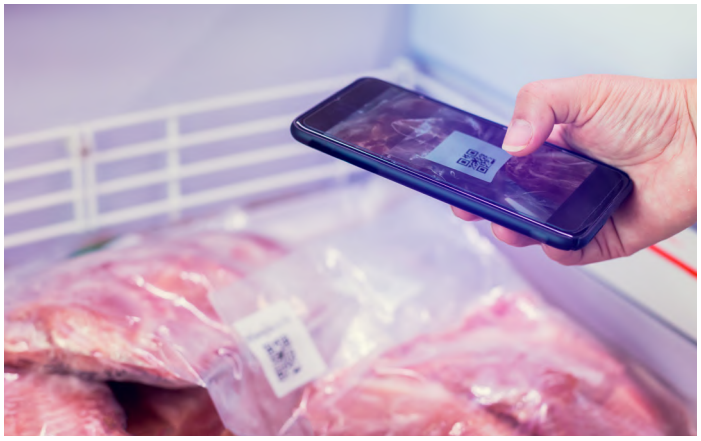
In addition to location tracking and condition monitoring, there are also applications for smart printables to address a historically common challenge in the supply chain: counterfeit products. Particularly in the pharmaceutical, nutraceutical, and cosmetics sectors, counterfeit products pose a severe threat to corporate reputations and consumer health.

> *Covert features typically used to tackle counterfeiting are found in labels that use UV ink, taggant inks, and infrared ink (which is often used for pharmaceutical and nutraceutical shipments). These inks are only visible to or detected by more sophisticated hand-held readers.*

Smart printables can also be used as a hidden measure, allowing manufacturers to monitor and ensure genuine goods do not fall out of the authorized supply chain. In addition, these devices can provide proof of shipment delivery and evidence of product use.

Tying each product's unique identifier to blockchain technology can also achieve a new level of security.

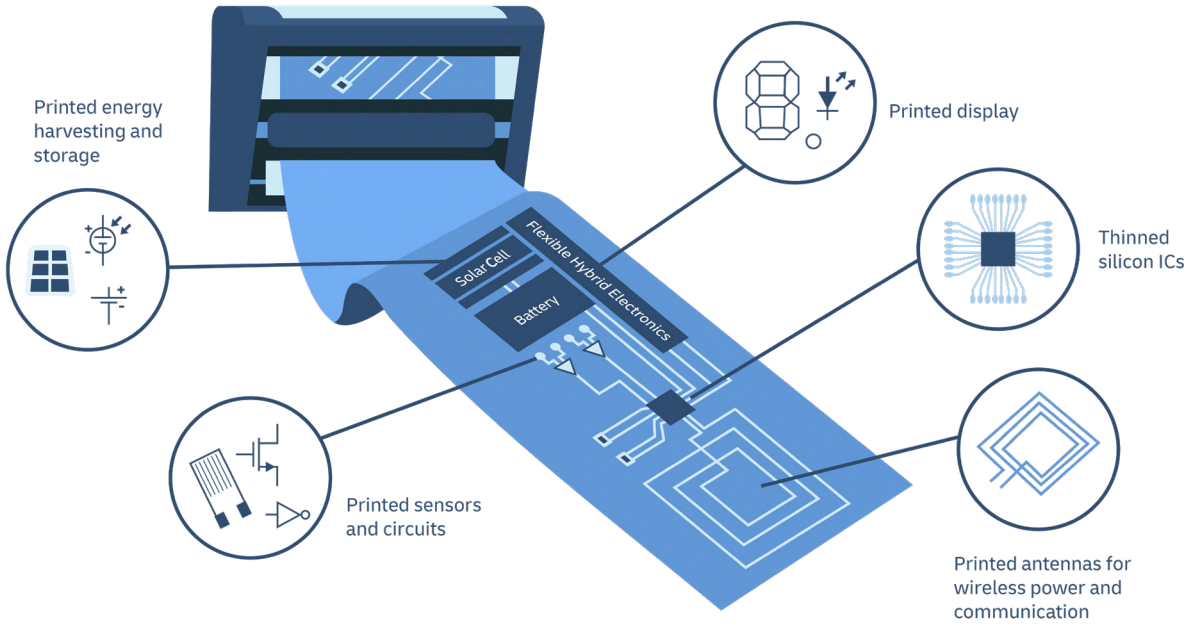
Perishable Goods Quality Control



For groceries and nutraceuticals, there are increasing applications for smart printables which enable the supply chain to contribute to product freshness and quality. For example, color-changing technology can be used in labels to clearly highlight item condition – information that is useful to businesses and consumers. Similar applications can help assure cold-chain integrity.

Taking that a step further, new opportunities for smart printables can be envisioned. For example, they can be placed on prescription pill containers to track and monitor location and use – an innovation that may help improve patient care and outcomes.

Printable electronics and batteries enable next-generation labeling solution



Graphic source: **Khan, Yasser et al. (2019): A New Frontier of Printed Electronics: Flexible Hybrid Electronics**

SUMMARY & TREND OVERVIEW

Challenges

- Technology stability has yet to be achieved for printable electronics and printed battery devices, and connectivity is not yet available everywhere.
- Single-use labels that are powered by batteries represent electronic waste – a sustainability challenge for organizations; these devices must be disposed of in a green, safe manner.
- Relatively high price points are stalling large-scale implementation; costs will likely reduce in later stages of this technology and when there are higher production volumes.
- As smart printables enable data transfer, they also introduce the risk of data tampering; this can be mitigated by pairing certain applications with, for example, blockchain technology but may increase the cost and complexity of implementation.

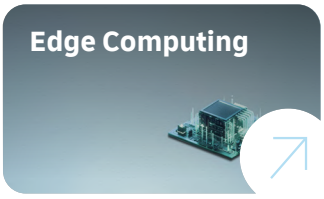
Outlook

Today, smart printables usage is only economical for niche applications such as high-value shipments. The reality is that this special intelligent inlay technology is not yet mature enough nor are any current solutions globally scalable.

Here at DHL, we anticipate mass uptake will be aligned with improvements in printed battery technology, particularly more reliable battery life, reductions in unit printing prices, and further developments such as sensor technology covering all sides of a parcel or box to maximize security. And before widespread airfreight use, airlines will have to allow smart printables on cargo. We expect that, one day, smart printables will be deployed by the millions.

This trend should be actively monitored with developments and use cases on the horizon.

Related Trends



DHL Resources

Smart Printables: What the future of smart labels means for logistics

Stationary 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 devices often take the form of or resemble robotic arms.

The first stationary robots were introduced in the late 1950s, primarily in manufacturing and automotive production. More recently, for logistics applications the continued development of sensor technologies and artificial intelligence (AI) has resulted in increased throughput of market offerings across a broad range of use cases.

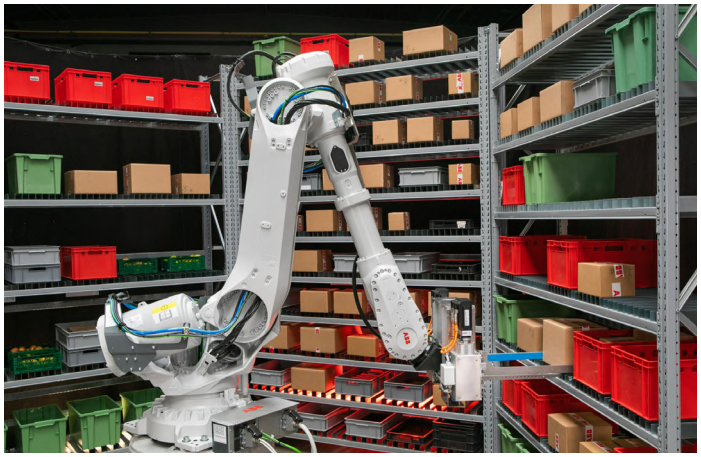
Stationary robots can be considered in two types – collaborative and industrial. Collaborative robots are designed for flexible applications that require interaction with humans. Industrial robots are used mainly in applications require a high payload, long range, and high speed, and they usually operate in a segregated area surrounded by security fencing. As machine learning and perception technology continue to develop in laboratory and real-world settings, we at DHL see more applications of interoperability across mobile and stationary robotic systems in logistics.

Especially in light of labor shortages and demand volatility, many companies are realizing the significant economic potential of implementing stationary robots for repetitive logistics processes. Several logistics organizations are now implementing or actively engaged in testing stationary robotic systems in applications such as (de)palletization as well as sortation, picking, and singulation.

Based on anticipated further development of stationary robotics hardware and software and larger-scale production, we here at DHL expect companies will be able to extensively scale these solutions within the next 2 to 4 years. This will have a high impact on the logistics industry.

RELEVANCE TO THE FUTURE OF LOGISTICS

Automated Shipment Sorting



Sorting shipments is a very repetitive, monotonous task that nevertheless requires high-quality output. Operators who are required to perform this task for hours on end in the warehouse tend to lose concentration after a certain amount of time; their work becomes prone to error, leading to additional rework costs. Sorting is therefore an ideal application for automation, particularly the implementation of stationary sorting robots. These devices often use cameras and AI capabilities to differentiate shipments and use pre-defined characteristics to classify and sort them.

While some automated sortation systems use a series of independently moving robots, often called a table-sorting (t-sort) system, other solutions like FlexBuffer by ABB Robotics leverage robotics arms, dynamic racking systems, and inbound and outbound conveyors to provide a comprehensive sorting system for uniform or mixed goods.

Automated sortation solutions can help a facility meet its throughput requirements for order fulfillment. At the same time, they also guarantee proper handling of shipments to prevent sorting errors and protect against damage to outbound orders.

Robotic Picking & Placing

The manual separation and alignment of parcels, letters, cartons, and flyers to prepare them for further processing downstream is very monotonous and labor intensive. The automation of this process via stationary robots has gained a lot of traction in recent years. Robotic induction, the act of picking an item and placing it with a specific orientation on a conveyer belt as well as identifying its characteristics, is a very scalable solution given its widespread applicability.

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 across the world.

> *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.*

With this automation, the manual burden of highly repetitive tasks in operations is reduced, allowing a shift of focus to upskilling workers who are responsible for singulation. However, robotic solution providers will need to continue to prove laboratory throughput rates in operations where the package mix is high.

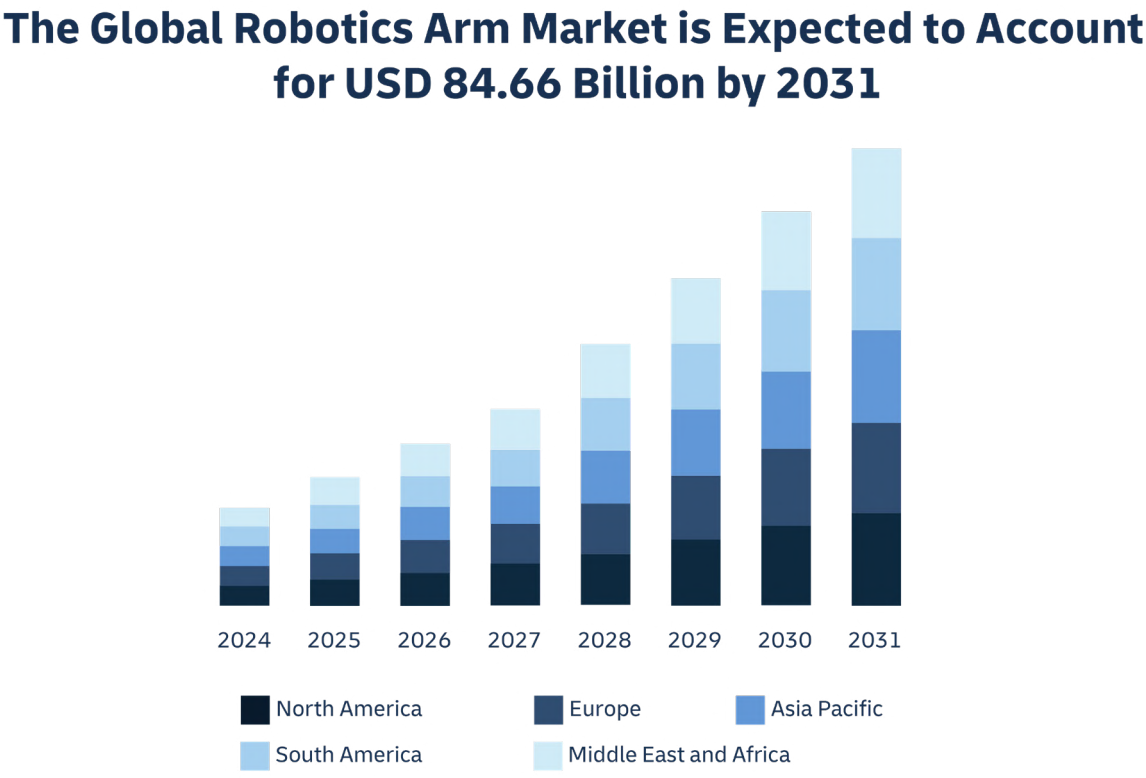
Palletizing & Depalletizing

Stationary robotics hold great potential for the automation of palletizing and depalletizing in inbound and outbound warehouse or hub operations.

Distinction should be made between uniform and mixed (de)palletizing. While uniform (de)palletizing is the movement of same-shaped, unvarying goods from and onto a pallet, mixed (de)palletizing describes the handling of pallets with items of various sizes and weights. In general mixed (de)palletizing is more complex than uniform (de)palletizing as it requires much more powerful AI to stack disparate, unwieldy packages as securely and efficiently as possible.

In Jirny, Czech Republic, DHL Supply Chain has implemented a collaborative robotic arm by Universal Robots to palletize goods from two production lines, with a separate Fanuc industrial robotic arm in Jažlovice for similar functions.

Currently, stationary robots that can palletize and depalletize individual shipments are already widely deployed. Mixed depalletizing solutions are also reaching maturity, and at DHL we expect to see widespread use of stationary robots for mixed palletizing throughout the logistics industry in the near future.



Graphic source: **Databridge Market Research (2024): Global Robotics Arm Market - Industry Trends and Forecast to 2031**

SUMMARY & TREND OVERVIEW

Challenges

- Stationary robots are usually designed to handle specific shapes of package and are not designed to handle a wide variety of sizes and weights.
- Under real-world conditions, many stationary robots fail to achieve the throughput rates indicated by laboratory experiments.
- Brownfield facilities may lack the required technical infrastructure, necessitating costly changes to implement stationary robots on a broad scale.
- Even with progressive automation of processes, a human being will always be needed to oversee and support applications; this means that complete automation without human supervision is unlikely in the near future.
- When stationary robots are added, facilities require more safety infrastructure and – with each new automation investment – this infrastructure must be reevaluated.

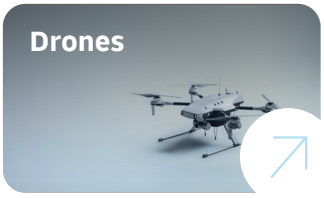
Outlook

The growing number of successful proofs of concept and pilot projects using stationary logistics robotics across a wide range of industries and environments is increasing the future implementation of stationary robotic systems.

The development of stationary robotics has not yet reached its peak and it is anticipated to be advanced by the heightened capabilities of camera systems and machine learning algorithms. As a result, widespread deployment will eventually lead to more complex applications such as robotic orchestration of an end-to-end process by introducing automated handoffs between both stationary and mobile robotic solutions.

This trend should be actively monitored with implementations available for many use cases today.

Related Trends



DHL Resources

DHL and AWL collaborated to develop cutting-edge robot depalletizer

DHL Supply Chain introduces robotic arms to its distribution centers in Jirny and Jažlovice

DHL Supply Chain Korea | Robotic Arm Packing Solution

Sustainable Fuels

The trend of Sustainable Fuels refers to energy sources that can be produced and consumed in a manner that minimizes negative environmental impacts; these fuels are used to power vehicles, machinery, and other equipment. Typically derived from renewable or low-carbon sources, sustainable fuels include conventional biofuels, such as ethanol and biodiesel, drop-in fuels such as hydrotreated vegetable oil (HVO), and more advanced synthetic fuels like electrofuels (e-fuels) and e-kerosene.

Demand for sustainable fuels is projected to grow as the world strives to meet decarbonization targets. They are highly applicable in the transportation industry – providing a much-needed alternative to fossil fuel usage – and could support faster decarbonization of existing fleets in the near term. Sustainable fuels are projected to play a particularly important role in aviation and maritime shipping, while passenger cars, commercial vehicles, and other sectors will rely more on electrification.

Sustainable fuels are currently the most effective solution for decarbonizing supply chains at scale. During 'production' of sustainable fuels, CO_2 is absorbed from the air. Only this previously absorbed CO_2 is released during combustion of the fuel, making it a closed carbon cycle. However, as the fuels are produced from renewable sources, they do not contribute to the net increase of CO_2 in the atmosphere.

Production capacities of sustainable fuel production are expected to grow substantially in the next few years as producers react to proposed mandates and growing demand. To date, over US$ 150 billion of sustainable fuel production capacity investments have been announced.

There are two types of sustainable fuels: biofuels and synthetic fuels. Their environmental impact varies depending on the respective source, the production process, and where they are used, such as in air, ocean, or road freight.

These fuels are so called drop-in fuels, which means they can be used directly in existing vehicles and infrastructure without any modifications. This contrasts with non-drop-in fuels, which require modifications in order to be used (such as liquified natural gas).

Biofuels use raw materials such as feedstock and agricultural waste that absorb carbon dioxide when being produced. When burned in an engine, they release the same amount of carbon dioxide as absorbed, making the process of combustion carbon neutral.

Synthetic fuels, or e-fuels, are made using captured carbon dioxide emissions and hydrogen. Here too, the carbon dioxide released when e-fuels are burned is equal to the amount taken out of the atmosphere

to produce the fuel. E-fuels are considered carbon neutral if the hydrogen is produced with green electricity.

Synthetic fuels will not become abundant until enough green electricity is available. However, biofuels are available now and being scaled up rapidly across the air, ocean, and road freight sectors as production sites ramp up worldwide. Here at DHL, we believe now is the time to switch away from fossil fuels to help meet environmental goals and emissions requirements.

Sustainable Aviation Fuels

In aviation, sustainable aviation fuels (SAFs) are considered by the industry as the only option today to replace fossil fuels in wide-body long-distance airplanes from a technical point of view, as hydrogen and battery options are currently still in early stages of development.

Today's SAFs can, for example, reduce air freight emissions by 70-99% in some cases. Production is ramping up, so companies can switch from fossil fuels now to meet decarbonization targets in the short- and mid-term.

Although the use of SAFs is currently the most promising emissions-reduction solution for air cargo, availability and high cost are barriers to widespread adoption. SAFs are fuels from renewable sources such as biomass, animal fats, oils, and, alcohol which can be blended with conventional kerosene. Initiatives like the Clean Skies for Tomorrow coalition, led by the World Economic Forum, bring together stakeholders across the aviation industry to drive carbon-neutral flying in future, leveraging the availability and use of SAF.

> *In 2023, SAF volumes reached over 600 million liters (0.5 Mt), double the 300 million liters (0.25 Mt) produced in 2022, but still amounting to only 0.2% of the annual aviation fuel demand.*

In October 2023, DHL Express and World Energy agreed a global partnership to speed up aviation decarbonization via SAF certificates (SAFc). Within the terms of a seven-year agreement – one of the longest and largest in the aviation industry to date – the partners intend to provide 668 million liters (0.6Mt) of SAF to replace jet fossil fuel. This will enable DHL to reduce approximately 1.7 million tons of CO_2e on a lifecycle basis, equivalent to one year of carbon-neutral operation of the entire DHL Americas aviation network.

Another area of sustainable aviation research is the use of hydrogen fuel. 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.

Road Transportation

Electric vehicles (EVs) are already a widespread sustainable solution for road transportation. However, this applies mostly to smaller vehicles travelling short to medium distances, due to the still-limited range and long charging times of EVs.

While battery electric trucks for long-haul, heavyweight cargo are already on the market, there is limited availability of suitable models with the required range and payload capacity. This means the industry continues to rely on combustion engines running on fossil fuels.

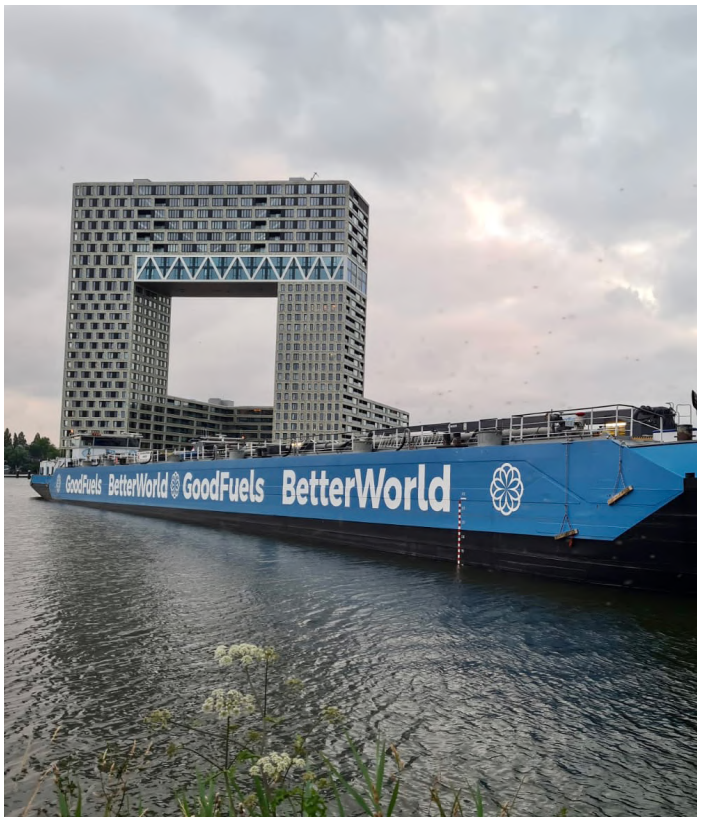
Sustainable fuels offer advantages over electrification in terms of utilizing existing vehicles and infrastructure. This is reflected in the International Energy Agency (IEA) forecast that the share of biofuels in road transportation will rise from 5% in 2022 to 12% in 2035 and – anticipating electric vehicles will subsequently be used almost exclusively – then fall to 3% in 2050.

Sustainable fuels for trucks are mainly biodiesel or hydrotreated vegetable oil (HVO). The former is derived from vegetable oils or recycled fats from, for example, the catering industry. Truck biodiesel is also known as fatty acid methyl esters (FAME) and this can be used directly or blended with conventional diesel fossil fuel. In the European Union, blends of up to 7% FAME biodiesel are common. The other type of sustainable fuel for trucks, HVO, is vegetable oil that has been treated with hydrogen; interestingly, after reaction with hydrogen, the properties of the oil are very similar to those of diesel. And like biodiesel, HVO can be blended with conventional diesel or can replace it completely.

Another type of sustainable fuel that is in early stages of development and commercialization is electrofuels (e-fuels), a class of synthetic fuels manufactured using captured carbon dioxide or carbon monoxide with hydrogen from water split by low-carbon electricity sources including wind and solar. Adoption of these drop-in replacement fuels is currently limited.

Helping to boost uptake of sustainable fuels, governments in several countries are supporting biofuel production and consumption for road transportation. In addition, the major companies historically producing fossil fuels are increasingly shifting focus towards the production of biofuels and e-fuels; examples include Neste, TotalEnergies, and Shell.

Sustainable Marine Fuels



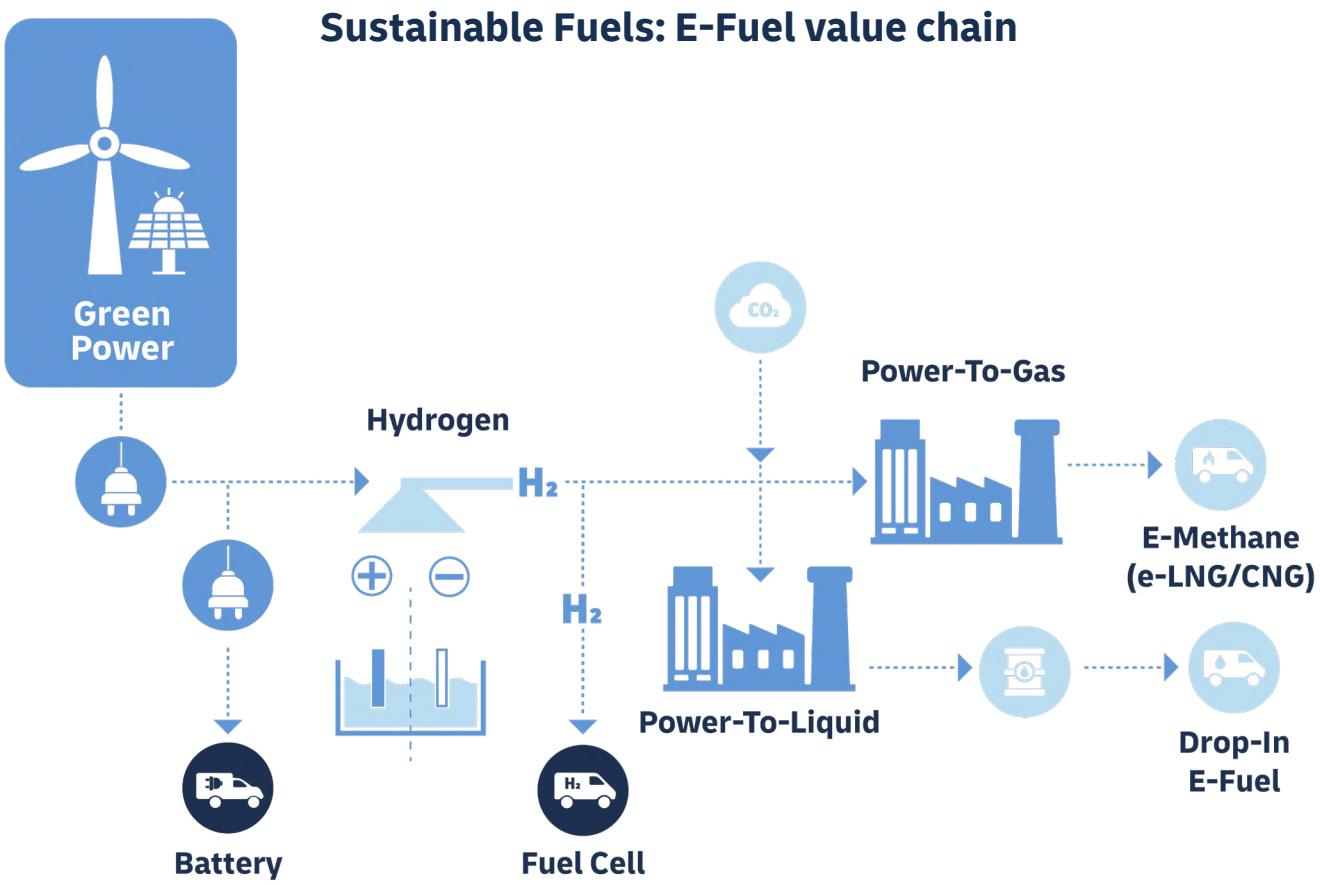
International maritime transportation accounts for approximately 3% of global greenhouse gas (GHG) emissions, and this includes a wide variety of vessels, from small recreational boats to massive, ocean-going container ships.

More than 90% of global goods are carried by cargo ships, and many of these ships are powered by heavy fuel oil (HFO), a residual fuel produced from petroleum refining which emits relatively large amounts of GHG when combusted. Sustainable marine fuels (SMFs) are a recognized pathway for lowering GHG emissions compared to HFO and other petroleum-based marine fuels.

Compared to traditional petroleum-based marine fuels, sustainable alternatives emit lower levels of sulfur and other toxic air pollutants during combustion. This helps reduce the negative impact on air quality for the millions of people living near seaports, without

requiring expensive emissions controls for marine engines. Overall, vessels powered by SMFs represent the cleanest mode of transportation per kilogram of moved goods available today. An example of SMF innovation is provided by the Dutch startup, GoodFuels. The company produces sustainable second-generation biofuels from certified waste or residue feedstock. Its innovative process addresses land-use challenges and ensures no impact on food production or deforestation. GoodFuels biofuel oil is an effective substitute for low-sulfur fuel oil or heavy fuel in vessels, effectively eliminating sulfur emissions and significantly reducing CO_2 emissions.

Looking ahead, Lloyd's Register, the maritime shipping advisory firm, projects two different future scenarios. In one, the marine biofuels share increases significantly over time, reaching 11% by 2030 and 79% by 2050. In the other scenario, the hydrogen-based e-fuel e-ammonia is the leading candidate for decarbonizing shipping; on average, it can make up 14% of the total fuel mix by 2030 and reach 66% by 2050.



Graphic source: **DHL (2024)**

SUMMARY & TREND OVERVIEW

Challenges

- Biofuel production volumes are restricted by the limited availability of feedstock, and e-fuel volumes will only increase when sufficient amounts of green electricity become available.
- Production of sustainable fuels from agricultural crops can create competition for land and resources, impacting food security and potentially driving deforestation, habitat loss, and biodiversity decline, all of which have a negative climate impact.
- Lack of consistent standards and definitions make it difficult to verify sustainability claims and navigate complex certification processes.
- Demand for sustainable fuels exceeds current supply by far; production processes can be expensive and require further technological advances to reduce costs.
- Governments, suppliers, and shippers find it difficult to fully understand the opportunities and challenges of sustainable fuels due to various complexities including multiple fuel types, technology pathways, and available materials.

Outlook

Here at DHL, we recognize sustainable fuels will play a critical role in efforts to reduce the environmental impact of transportation. 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.

This trend should be actively monitored with use cases in some applications that can already be addressed today.

Related Trends

DHL Resources

DHL Global Forwarding and GoodShipping accelerate sustainable shipping via insetting with 60 million liters of sustainable marine fuel

DHL takes green logistics to the next level with Formula 1® launching a first truck fleet powered by biofuel to reduce carbon footprint

Sources:

McKinsey (2024): Global Energy Perspective 2023: Sustainable fuels outlook; IATA (2023): SAF Volumes Growing but Still Missing Opportunities; DHL (2023): DHL Express and World Energy agree to global partnership to speed up aviation decarbonization via Sustainable Aviation Fuel Certificates; LR (2023): Shipping industry faces two alternative decarbonisation paths with hydrogen-based fuels and biofuels vying for prominence; IEA (2023): Road Transport - Net Zero Emissions Guide

Vehicle Electrification

The trend of Vehicle Electrification refers to the replacement of traditional internal combustion engines (ICEs) in various vehicle types with electric powertrains. This involves the adoption of electric motors and batteries or fuel cells to power the vehicle, which reduces or eliminates reliance on fossil fuels. Vehicle electrification not only cuts carbon emissions and air pollution but also promotes sustainability in the transportation sector.

One of the biggest levers in achieving net-zero emissions is electrification – in other words, transitioning various applications and sectors to use electricity instead of fossil fuels as the primary source of power. This involves replacing traditional or non-electric systems with electric alternatives.

Vehicle electrification is an important area of focus for logistics. Road freight is responsible for around 70% of the 3.4 billion metric tons of emissions generated during overland transportation. Fortunately, developments in green technologies, such as battery electric vehicles (BEVs) and hydrogen fuel-cell electric vehicles (FCEVs) are advancing at an accelerated pace.

Based on today's energy, climate and industrial policy settings, the number of EVs will grow from less than 45 million in 2023 to 250 million in 2030 and reach 525 million in 2035. As a result, more than one in four vehicles on the road will be electric by 2035.

The global outlook for vehicle electrification is promising for a variety of reasons. There is growing demand both from industry and private households wanting to become more sustainable. In support of this, many governments have implemented policies and incentives to encourage uptake of electric vehicles, such as subsidies, tax incentives, and stricter emission standards.

Another reason for this positive global outlook is significant progress with related technologies. There have been improvements in battery capacity and the charging infrastructure, as well as cost reductions that make EVs more accessible and attractive. Manufacturers are increasingly investing in EV development and many major automakers have announced plans to transition to fully electric vehicle lineups in the coming years.

Vehicle electrification is especially important in the transportation sector, with its potential to greatly reduce CO_2 emissions. However, realization of this trend varies along the supply chain and between different vehicles and modes of transportation. For example, the trend is relatively mature in last-mile transportation but vehicle electrification has yet to be widely adopted in long-haul, air, and ocean transportation.

Electrified Vans & Trucks

Much progress has been made in electrifying and decarbonizing last-mile transportation using electric vans. For example, at DHL 37.6% of our pick-up and delivery vehicles are electric with the aim to increase this share to 60% in 2030.

Today's market already offers a diverse array of electric vans, each designed to meet specific needs in the supply chain. From compact models adept at navigating narrow urban streets to larger variants equipped for more cargo capacity, this versatility allows logistics organizations to integrate different models into various stages of operations, from distribution center transits to final delivery.

While the last mile of logistics is close to adopting widespread electrification, with solutions expanding and the wait for existing non-electric vehicle contracts coming to an end, the situation is different for middle-mile and long-haul transportation. Although there are some electrification developments, these are still restricted by range limitations and insufficient charging infrastructure.

> *In particular, grid connection is the main limiting factor for the further roll-out of e-trucks as, in main markets, the process of grid extension can take up to six years.*

Truck electrification is being driven by established companies such as Volvo and Mercedes-Benz, the e-mobility frontrunner Tesla, and startups such as Nikola. Improvements are underway as, for example, in October 2023 the Mercedes-Benz eActros truck was launched with a range of up to 400 km (248 miles).

Also, solutions exist to bridge the transition from diesel trucking to fully electric. The US startup Revoy offers a SixWheel electric add-on that attaches between any diesel semi-truck trailer to provide an independent electric powertrain, turning it into a hybrid vehicle. Just like a pedal-assist bike, when the truck 'pedals,' the SixWheel 'assists'.

Fuel-Cell Electric Vehicles

In the realm of road transportation, it is predicted that there will be a mixture of different technologies, as no single alternative drive technology has emerged as the clear winner. Therefore, it remains crucial for logistics organizations to maintain a technology-neutral approach and continue testing various sustainable solutions.

This includes not only battery electric trucks but also hydrogen fuel-cell electric trucks, which excel at longer distances due to their larger range (up to 1,000 km or 620 miles), quick refueling capabilities (less than 15 minutes), and fit for heavy, energy-demanding assignments.

These trucks generate electricity from fuel cells powered by hydrogen, stored in the tanks of the truck. An electrochemical reaction (combining hydrogen and oxygen) occurs inside the fuel cells which generates electricity, heat, and water. This means that, unlike a battery electric truck, a fuel-cell electric truck does not need to charge up from an external electricity source – ideal in countries with a limited electric grid and few opportunities for fast battery charging. Transportation over long distances generates no exhaust emissions except water and, if the hydrogen used is produced with energy from renewables, these are zero-emission journeys.

However, there are several restrictions on the widescale roll-out of these hydrogen fuel-cell electric trucks. Firstly, there is limited availability of hydrogen refueling stations (only 1,100 globally in 2023), and secondly it remains relatively expensive and energy-intense to produce general and green hydrogen. A third restriction is the cost of producing and implementing fuel-cell systems is currently higher than with internal combustion engine systems and for battery electric vehicles. Finally, to date there is only a limited range of truck models to choose from. One example of a production-ready hydrogen fuel-cell truck is the special-purpose commercial vehicle made by Paul Nutzfahrzeuge, currently being used by DHL Group in a distribution and line-haul pilot project in Germany.

Air & Ocean Transportation

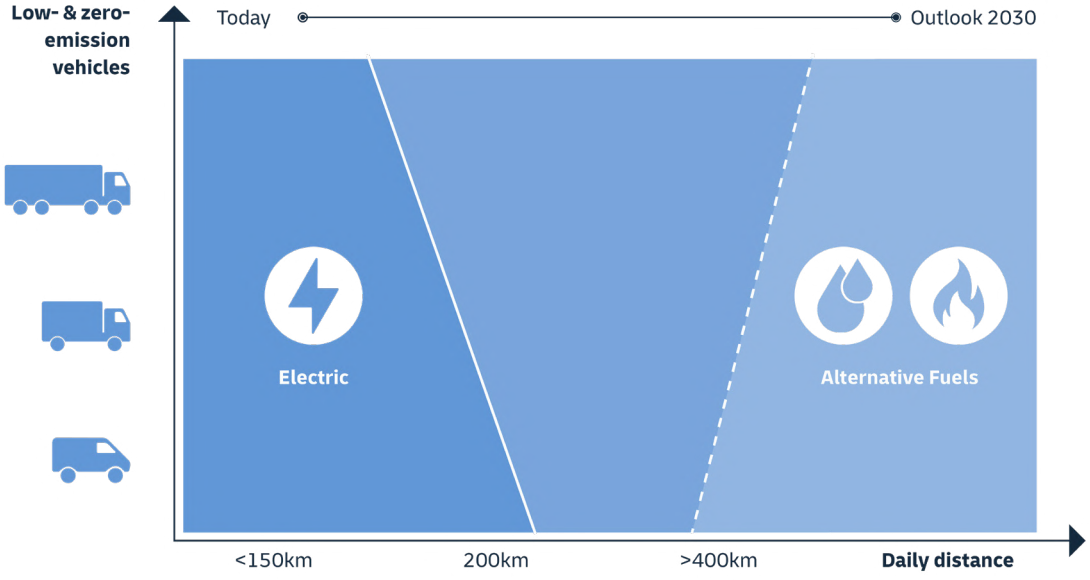
To reduce the environmental impact of air transportation, companies can choose to use sustainable aviation fuel (SAF). An additional option is to create electric airplane engines. The Alice electric aircraft from the startup Eviation, scheduled for market launch in 2024, can be used for short-haul flights and is likely to become a viable sustainable solution for national and even regional air transportation. DHL Express has therefore ordered 12 airplanes with a range of 460 km (250 nm) to kick-off the electrification of its fleet.

Another area of sustainable aviation research is the use of hydrogen fuel. Startups like H2FLY and ZeroAvia are working on concepts but experts do not expect commercial application of sub-regional and regional hydrogen fuel-cell aircraft before 2030.

Also, the carbon-intensive shipping industry is looking into vessel electrification. Ferries, tugs, and inland waterway vessels can easily benefit from full electric propulsion.

DHL is piloting the use of an electrically powered solar ship in Berlin, Germany, which has already delivered more than 50,000 parcels in the capital since October 2022. Meanwhile, the world's first fully autonomous cargo ship is all electric: the MV Yara Birkeland, commissioned by Norway-based chemical company Yara International, is powered by a 7 MWh battery. It is designed to replace 40,000 trips carried out by diesel trucks per year, has a top speed of 13 knots, and can carry 103 standard-sized containers.

The borders of electric vehicles will be pushed over time



Graphic source: **DHL (2024)**

SUMMARY & TREND OVERVIEW

Challenges

- Infrastructure is holding back vehicle electrification – although the number of EV charging stations is growing, it is not yet comparable with conventional gas (filling) stations and there may be limits on power grid expansion; hydrogen refueling stations are almost non-existent globally.
- Electrified drive systems on average still have a much shorter range than vehicles with combustion engines running on fossil fuels.
- EVs often have reduced payload capacity due to the weight of their battery systems – a limitation of particular importance in trucks and airplanes as it can impact the ability to transport heavy cargo efficiently.
- Compared to conventional counterparts, EVs generally have a higher upfront cost; this cost differential is challenging for logistics companies in terms of fleet acquisition and operational expenses.
- Despite a clear sustainability advantage over fossil fuel solutions, EVs have some downsides in terms of natural resources – minerals must be extracted, manufacturing is energy intensive, and there are battery disposal challenges.

Outlook

Many solutions for vehicle electrification are already available but some industry-revolutionary technologies are still in pilot phase and not yet scalable.

However, with sufficient market demand, rapid development is achievable. This is clearly evidenced by the progress and expansion of BEVs for ground transportation. Investment in research and development (R&D) and infrastructure, as well as corporate commitment to new solutions, will be crucial to achiev-ing timely sustainability solutions.

This trend should be carefully monitored with use cases in some applications that can already be addressed today.

Related Trends

DHL Resources

The making of a sustainable vehicle fleet

DHL Group deploying hydrogen trucks in Germany

Sources:

IEA (2024): Global EV Outlook 2024; IEA (2023): Global Hydrogen Review 2023

Wearable Sensors

The trend of Wearable Sensors encompasses sensors that are worn on, close to, or even in the human body with the purpose of tracking body movement or vital functions. Depending on the type of information to be captured, different sensors like gyroscopes and accelerometers are integrated into wearable products, from badges and wristbands to smartglasses and clothing.

For many individuals, it has become hard to imagine doing sports without a fitness tracker or smartwatch to track performance via built-in sensors. The technology holds a lot of potential especially within the healthcare sector where wearable sensors could, for example, pave the way for improved remote diagnostics being able to capture physiological data and transmit it via low-power wide-area-network (LPWAN) technology.

Wearable sensors are continuously developing to become smaller in size. This opens new possibilities; for example, they can be worn as part of a person's clothing or even integrated in the human body. Biolinq, a California-based startup, for instance, recently raised US$ 58 million for its development of the world's smallest biosensor worn just beneath the skin to measure a person's glucose levels.

Many companies, including those in the logistics industry, have started to recognize the value of extracting data from wearable sensors for industrial applications, particularly in the realm of employee health and safety. As such, many logistics organizations have begun procuring various forms of smart wearable devices and setting up wireless communication infrastructure in their facilities, like Bluetooth Low Energy (BLE), Wi-Fi, or – if a real-time location system (RTLS) is needed – even ultra-wideband (UWB).

While the impact of this trend on the logistics industry is expected to be moderately low, wearable sensors represent one of the building blocks towards making better, data-based decisions. Already today wearable sensors are leveraged within logistics to provide valuable insights, making working environments safer and more efficient. It is important to note that many applications involving wearable sensors are already technically feasible. However, anonymity and data protection are very important and must be considered, which can often be a limiting factor.

Location Identification

The ability to track employee location opens an array of application fields. There are various health and safety (H&S)-related use cases such as the localization of a worker in the event of a person-down alert. Also, to prevent accidents between pedestrians and forklifts inside an operational facility, a collision warning can be issued both to the worker and the driver so they can take preventative action – a use case that requires high accuracy and data transmission in real time.

Another interesting use case is leveraging wearable sensors for automated reporting. The collection of data about an operational employee's time spent in certain physical areas of a facility that serve multiple customers can automate the capturing of work hours attributable to each customer; this also allows for a fully automated billing process.

> *In addition, wearable sensors can automate access control within a facility, restricting access to certain areas or to the use of particular vehicles and tools based on the individual's experience or training level.*

Typically the trade-off between cost and the required accuracy as well as speed of data transmission dictates which type of technology is used for localization. While ultra-wideband-based solutions provide high-accuracy tracking in real time, the high cost of the required devices and infrastructure makes it unrealistic to scale. Where BLE can offer sufficient accuracy, it is preferred due to the lower cost of implementation. Sonitor for example, a Norwegian startup, is leveraging BLE or ultrasound technology to make use of real-time indoor localization for automated labor reporting, geo-fencing, or indoor navigation purposes.

Process Intelligence

Optimizing operational processes is essential, especially for those where visibility is typically lacking. It is therefore very useful for companies to deploy wearable sensors capable of automating the collection of data and insights during logistics operations.

For example DHL Supply Chain is already using Motion-Mining®, a general data protection regulation (GDPR)-compliant solution developed by a German startup, that leverages data collected from purpose-built wearable devices during a temporary installation to identify process waste and improvement potential. The automation of data collection leads to larger, more detailed data sets which are free from observation biases. Data can be automatically analyzed using algorithms to generate detailed insights and enable data-based decision making.

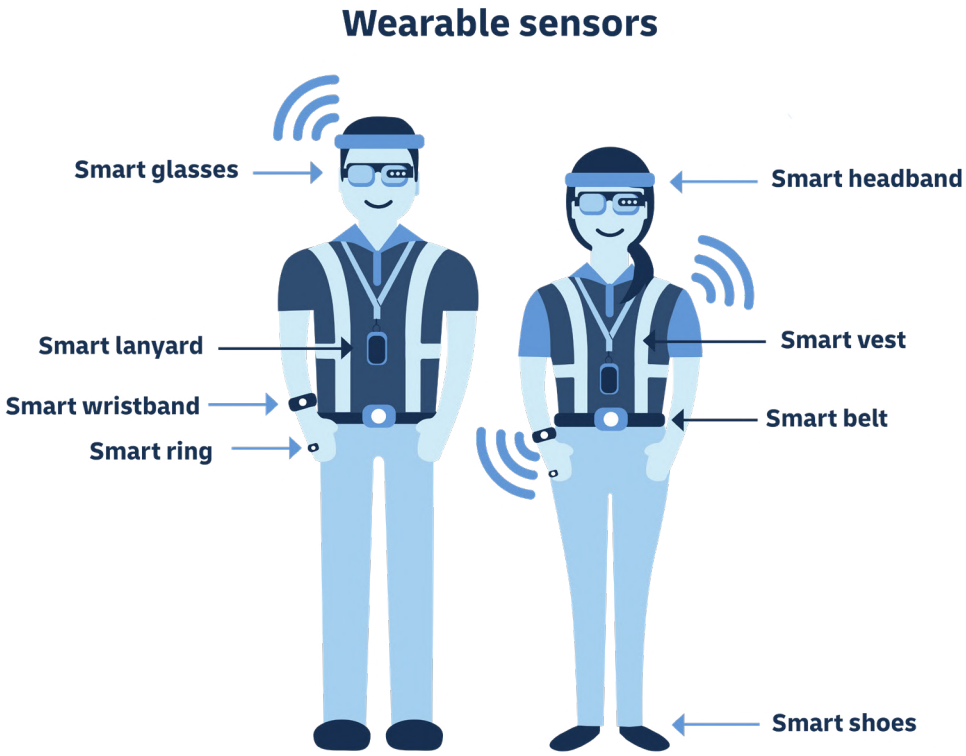
As more and more wearable devices such as smartglasses and wearable scanners get implemented in logistics operations, new possibilities open up to generate insights on a more permanent, continuous basis leveraging the built-in sensors of these devices. For example ProGlove, a startup known for its wearable scanners, offers a platform called ProGlove Insights alongside its products to provide useful process insights that boost visibility.

Ergonomic Health

Ergonomic hazards in the workplace are one of the main causes of musculoskeletal disorders (MSDs) which are the most common work-related health issue in the European Union (EU). This results in high costs for the organization as workers require sick leave and may have to retire early. Wearable sensors can be used to lower the MSD risk in two ways – either by using data-driven insights to evaluate and mitigate the ergonomic risk of a process or workplace or by training employees to adjust their actions to more ergonomically friendly movements.

Soter Analytics and Kinetic are two examples of providers that offer wearable sensors for ergonomic training purposes. The idea is to give real-time feedback to a user by vibrating or beeping when a hazardous movement such as bending and twisting is performed. These solutions create awareness and trigger a change in behavior over time, reducing the amount of hazardous movements performed.

Also, vital body data captured through wearable sensors has various applications such as fatigue detection and alerting when certain stress levels are reached. The sensitivity of this type of data calls for strict anonymization in order to obtain user acceptance.



Graphic source: **Kong, Xiang (2019): Industrial wearable system: the human-centric empowering technology in Industry 4.0**

SUMMARY & TREND OVERVIEW

Challenges

- Wearable sensors raise data protection concerns about sharing personal and performance information with the employer; to succeed, solution providers must ensure GDPR-compliant anonymization of data.
- As more wearable sensor use cases arrive, there is a risk of overloading the employee with wearables and sensors; where possible, companies should avoid introducing new hardware for every new application.
- Infrastructure requirements are highly dependent on the level of precision and the frequency of data sharing required; especially for RTLS use cases, infrastructure investment is significant and may not provide sufficient return on investment for a single application.

Outlook

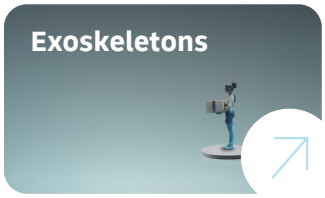
As more wearable devices such as smartglasses for vision picking and wearable scanners are introduced into logistics operations, here at DHL we are already starting to see decisions to leverage data from built-in sensors rather than introduce new purpose-built devices for each and every use case.

For use cases requiring accurate localization of employees, we still see cost as a limiting factor to scalability. In future, however, we anticipate a democratization of devices and support infrastructure, bringing down the cost per use case, with generic gateways lowering the entry barrier for these kinds of applications.

We also see technological advancements – like the miniaturization of electronic components and flexible printed circuit boards (PCBs) and increases in battery life – accelerating the subtle integration of sensors into clothing. Relatedly, but in another direction and further into the future, we anticipate the development and possible movement of sensors from on the human body to inside the body as multifunctional implants.

This trend should be passively monitored with implementations available for many use cases today.

Related Trends



DHL Resources

Leveraging Wearable Sensors for Process Optimization | Pilot Project with MotionMiners

Sources:

MedCity News (2024): Bioliq Snags $58M for 'Smallest Biosensor in the World'

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