

Chapter 13

Industry 4.0 Technologies Adopted by Logistics Companies for Sustainability and Competitiveness

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List of Abbreviations

3PL/ 3PLs Third-Party Logistics Service Provider

AHP Analytic Hierarchy Process

AI Artificial Intelligence

AWS Amazon Web Services

BO Best-to-Others (method in BWM)

BSC Balanced Scorecard

BWM Best-Worst Method

CAGR Compound Annual Growth Rate

CI Consistency Index

CPS Cyber-Physical Systems

CR Consistency Ratio

CS Customer Satisfaction

DS Data Security

EI Efficiency Improvement

FL Flexibility

IMARC The name of a market research company

IoT Internet of Things

MCDM Multi-Criteria Decision-Making

ML Machine Learning

NDI Non-Destructive Inspection

OW Others-to-Worst (method in BWM)

SCM Supply Chain Management

SU Sustainability

UPS United Parcel Service

XR Extended Reality

Introduction

The global logistics industry is transforming significantly due to the rapid adoption of emerging technologies such as Artificial Intelligence (AI), the IoT, Digital Twins, Blockchain, and Autonomous Vehicles. These technologies could revolutionize logistics operations by enhancing efficiency, reducing costs, improving customer satisfaction, and other ways. However, their adoption presents several challenges. For third-party logistics (3PL) companies, especially in diverse and competitive markets like the UK and China, integrating these technologies involves overcoming substantial hurdles, including high implementation costs, data security concerns, regulatory compliance, and workforce adaptation.

The core research problem examines the extent to which 3PL companies adopt these emerging technologies, the specific challenges they face in this process, and the overall impact on their

operational efficiency and strategic competitiveness. This study aims to provide a comparative analysis of the adoption and impact of these technologies in the UK and China, drawing on insights from logistics experts in both countries. In doing so, the research seeks to identify best practices and strategic recommendations for optimizing technology integration in different market contexts.

Industry 4.0 and 5.0 have revolutionized manufacturing and industrial sectors by integrating advanced technologies to enhance productivity, efficiency, and flexibility. Key technologies driving Industry 4.0 and 5.0 include the IoT, Cyber-Physical Systems (CPS), big data analytics, AI, and cloud computing. In Industry 4.0, the IoT involves interconnected devices that collect and exchange data, allowing real-time tracking and monitoring of goods, thereby enhancing inventory management and reducing delays (Sergi *et al.*, 2021). CPS combines physical processes with computational algorithms, enhancing automation and efficiency in logistics operations through advanced machinery and autonomous vehicles (Rahman *et al.*, 2022). Big data analytics entails analyzing vast amounts of data to uncover patterns and insights, enabling logistics providers to optimize routes, forecast demand, and improve decision-making processes (Chen *et al.*, 2021). AI automates and enhances demand forecasting, route optimization, and warehouse management by learning from data and making intelligent decisions (Shee *et al.*, 2021). Cloud computing offers scalable and flexible IT resources, facilitating seamless collaboration, data sharing, and process integration across different locations and systems, ultimately enhancing operational agility and efficiency (Ding *et al.*, 2021). For logistics service

providers, these technologies collectively enable more efficient, responsive, and customer-centric operations, thereby reducing costs and improving service levels.

Understanding the adoption and impact of emerging technologies in logistics can be synthesized into two main areas. Firstly, strategic competitiveness and operational efficiency are crucial in the logistics sector, which is marked by rapid growth and intense competition. Adopting technologies such as AI and IoT can substantially improve operational efficiency by optimizing routes, automating warehouse processes, and enhancing inventory management. These advancements reduce operational costs and improve service delivery, enabling companies to respond swiftly to changing market demands. However, the complexity and cost of implementing these technologies often pose significant barriers, especially for smaller firms lacking the resources of larger, multinational competitors.

Secondly, customer satisfaction and data security are essential to adopting new logistics technologies. In an era where customer expectations are constantly evolving due to the growth of e-commerce, technologies like Digital Twins and Blockchain are crucial for enhancing service reliability, transparency, and security. Digital Twins allow for real-time monitoring and predictive maintenance, significantly enhancing service quality and reducing downtime. Meanwhile, Blockchain technology provides a robust solution for ensuring data integrity and security, which is increasingly important in a digitalized and interconnected world. However, implementing these technologies also presents data privacy and regulatory compliance challenges, particularly in regions with strict data protection laws.

Given these considerations, the research aims to bridge the gap in understanding how these emerging technologies can be effectively integrated into logistics operations across different markets. By focusing on the UK and China, the study provides a nuanced perspective on

technology adoption's strategic and operational impacts, considering regional differences in market conditions, regulatory environments, and technological infrastructure. This understanding is vital for logistics companies looking to navigate the complexities of technology adoption and leverage these innovations to achieve sustained competitive advantage.

The current state of UK 3PL companies

The UK logistics service market is a crucial sector of the economy, characterized by dynamic growth and intense competition. In 2023, the market reached approximately USD 137.86 billion and is expected to grow at a compound annual growth rate (CAGR) of 2.91%, reaching around USD 163.77 billion by 2030 ("United Kingdom freight and logistics market size," MarkWide Research 2024). This growth is fueled by several factors, including the expansion of e-commerce, technological advancements, and evolving customer expectations for faster and more efficient deliveries (MarkWide Research, 2024).

Key players in the UK logistics market include global giants such as DHL Group, DSV A/S, Kuehne + Nagel, United Parcel Service of America, Inc. (UPS), and Wincanton PLC ("United Kingdom freight and logistics market size," 2024; MarkWide Research, 2024). These companies offer a comprehensive range of services, including transportation, warehousing, freight forwarding, and supply chain management, constantly innovating to maintain a competitive edge. The competition is driven by service quality, pricing, geographic reach, technological capabilities, and customer relationships, with logistics companies increasingly adopting digital technologies such as AI, IoT, and automation to enhance operational efficiency and visibility (MarkWide Research, 2024).

The UK logistics market is segmented by transportation modes (roadways, seaways, railways, airways), with roadways currently dominating due to the extensive road network and the demand

for rapid last-mile deliveries (IMARC Group, 2024). The market also varies by end-use sectors, with significant contributions from manufacturing, retail, and e-commerce ("United Kingdom freight and logistics market size," 2024). Due to their strategic locations and well-developed infrastructure, regions such as North West England, London, Manchester, and Birmingham are key logistics hubs (MarkWide Research, 2024). The market dynamics are influenced by regulatory changes, economic conditions, and the need for sustainable practices, with companies increasingly focusing on green logistics to reduce their carbon footprint ("United Kingdom freight and logistics market size," IMARC Group 2024).

The current state of China 3PL companies

The logistics service market in China is a vital component of the economy, characterized by rapid growth and intense competition. By 2023, the market size had reached approximately USD 1.442 trillion and is expected to grow at an annual rate of 6.5%, reaching around USD 2.24 trillion by 2030. This growth is driven by several factors, including the rapid expansion of e-commerce, technological advancements, and rising customer expectations for faster and more efficient deliveries (Zhang *et al.*, 2019).

The Chinese logistics market players include SF Express, JD Logistics, Cainiao Network, Deppon Logistics, and China Post. These companies offer a wide range of services, including transportation, warehousing, freight forwarding, and supply chain management, continuously innovating through technology to maintain a competitive edge. Competition is primarily driven by service quality, pricing, geographic coverage, technological capabilities, and customer relationships (Özdağoğlu, 2022). Logistics companies increasingly adopt digital technologies

such as artificial intelligence, the Internet of Things, and automation to enhance operational efficiency and transparency.

The Chinese logistics market is segmented by modes of transport, such as road, sea, rail, and air, with road transport currently dominating due to the extensive road network and the demand for rapid "last-mile" deliveries. Additionally, the market is segmented by end-use industries, with manufacturing, retail, and e-commerce being major contributors. Cities like Beijing, Shanghai, Shenzhen, and Guangzhou have become key logistics hubs due to their strategic locations and well-developed infrastructure (Dini, Yaghoubi and Bahrami, 2024). Market dynamics are also influenced by regulatory changes, economic conditions, and the need for sustainable practices, with companies increasingly focusing on green logistics to reduce their carbon footprint.

The comparison of various aspects of the logistics sector between the UK and China is presented in the following Table 13.1.

Research aim, objectives, and review of business problem

This chapter aims to investigate the adoption of certain new technologies from Industry 4.0 and 5.0 by third-party logistics companies, assess the impact of these technologies on various areas within these companies, and provide recommendations for applying these technologies to supply chains. To achieve this aim, we determine the extent of the impact of new technologies on third-party logistics companies by conducting a survey of experts in relevant fields in the UK and China and analyzing the survey results. We rank the influence of different technologies and explore which new technologies are more effectively adopted by third-party logistics companies

in different regions and sectors. Based on the aim and objectives outlined above, the research questions are proposed as follows:

- 1 What are the key new technologies from Industry 4.0 and 5.0 that third-party logistics companies in the UK and China have adopted?
- 2 How do these new technologies impact different operational areas within third-party logistics companies?
- 3 Which technologies significantly influence the efficiency and effectiveness of third-party logistics operations in different regions and sectors?
- 4 What are the best practices for adopting these new technologies in supply chains within the logistics industry, considering regional differences between the UK and China?

Regarding research scope, this chapter covers three main research areas: new technologies in Industry 4.0 and 5.0, logistics service, and technology adoption in supply chain management (SCM). For the research gap addressed in this chapter, integrating emerging technologies, particularly those categorized under Industry 4.0 and 5.0, has been extensively discussed in the context of supply chain management. These technologies, including AI, the IoT, Blockchain, Digital Twin, and Autonomous Vehicles, are acclaimed for their potential to revolutionize logistics by improving operational efficiency, enhancing data transparency, and reducing costs (Rejeb *et al.*, 2024; Firoozi and Ajirlou, 2023). However, despite this general optimism, there is a significant divergence in perspectives regarding their adoption.

On the one hand, several studies and industry reports emphasize the transformative benefits of these technologies. For instance, AI is often highlighted for its ability to optimize routing, predict maintenance needs, and improve decision-making processes within logistics operations (Rejeb *et*

al., 2024). Proponents argue that adopting these technologies is crucial for maintaining a competitive advantage in an increasingly digital market.

On the other hand, some researchers and practitioners express concerns about the practical challenges associated with these technologies. These concerns include high implementation costs, integration challenges with existing systems, data security risks, and potential job displacement due to automation (Firoozi and Ajirlou, 2023). Additionally, there are questions about the technological readiness of logistics companies, especially in regions with varying levels of infrastructure development and regulatory support.

While these divergent views are well-documented, there is a noticeable lack of focused studies examining the specific impacts of these technologies on logistics companies. Recent literature reviews indicate that most existing research has either been theoretical or has focused on broader supply chain applications without exploring the unique challenges and opportunities within the logistics sector (Jain and Chou, 2023; Bentalha, Hmioui and Alla, 2023). Therefore, this study aims to fill this gap by examining the impact of emerging technologies in Industry 4.0 and 5.0 on logistics companies, considering both the potential benefits and the challenges these companies face in adopting these innovations.

This chapter is divided into six sections. Section 2 explores a range of new technologies, such as AI, the Internet of Things (IoT), digital twins, blockchain, and autonomous vehicles, through a literature review and demonstrates that the impact of these technologies on third-party logistics companies can be quantified across six different areas. Section 3 details the methodology, which involves collecting primary data from experts in different countries using a questionnaire method and employing the Best-Worst Method (BWM) to assess the impact of these technologies on logistics operations. Section 4 presents the results, specifically how these technologies affect

operational efficiency, customer satisfaction, and other key performance indicators, focusing on regional differences between the UK and China. Section 5 discusses these findings, linking them to existing literature and providing strategic recommendations for integrating these technologies into logistics practices. Section 6 concludes the chapter by discussing the managerial implications of the research and suggesting directions for future studies.

Literature Review

Based on the existing literature and statistical evidence, this study focuses on AI, blockchain, the IoT, digital twins, and autonomous driving as the five critical technologies. These technologies are central to Industry 4.0 and 5.0, significantly influencing various sectors and driving industrial evolution.

New technologies in Industry 4.0 and 5.0

The new technologies enable real-time data collection and analysis, facilitating improved decision-making and predictive maintenance. For example, implementing Non-Destructive Inspection (NDI) systems in production lines aids in achieving zero-defect manufacturing by leveraging IoT technologies to convert data from physical assets into valuable information (Martarelli et al., 2023). In the logistics service sector, NDI systems integrated with IoT technologies enable real-time monitoring and predictive maintenance of assets such as containers and vehicles, thereby enhancing operational efficiency and reducing the risk of disruptions (Meyendorf *et al.*, 2023). Furthermore, AI and machine learning (ML) are crucial in processing vast amounts of data to optimize production workflows and develop smart applications (Lampropoulos, 2022). DHL employs AI algorithms to analyze vast amounts of data, including weather patterns, traffic conditions, and vehicle performance, to optimize delivery routes and predict potential delays. This approach has improved delivery efficiency and reduced fuel costs

while also enhancing overall service reliability and customer satisfaction (Olaoye and Henry, 2024). Additionally, integrating these technologies into educational frameworks enhances the learning environment, promoting a collaborative and innovative approach (Periasamy and Umachandran, 2023). As Industry 4.0 continues to evolve, it promises significant advancements in digital automation and production systems, fostering a more connected and efficient industrial landscape (Jiang, 2023).

The term "Industry 5.0" began gaining recognition and acceptance around 2019. It was further solidified as a concept by the European Commission in January 2021 when they released a report outlining Industry 5.0 as a vision for a sustainable, human-centric, and resilient industrial future. This marked a more formal acceptance of the term in the context of industrial evolution (GAJDZIK, 2023). The advent of Industry 5.0 marks the next phase in manufacturing and industrial evolution, emphasizing human-centric approaches and ethical considerations while leveraging advanced technologies. Key technologies driving Industry 5.0 include extended reality (XR), quantum computing, and next-generation connectivity, such as 5G. These technologies are crucial for developing a sustainable and advanced industrial ecosystem, enabling smarter and more efficient processes (Tyagi *et al.*, 2024). These technologies enhance productivity and efficiency while prioritizing human well-being, sustainability, and product and service personalization. Collaborative robots are designed to work alongside humans, assisting with tasks requiring human dexterity and decision-making. These cobots enhance workplace safety and productivity by performing repetitive or hazardous tasks, allowing human workers to focus on more complex and creative activities (Smith et al., 2023). Advanced AI and cognitive

computing enhance decision-making by understanding and reasoning contextually, leading to smarter, more adaptive manufacturing systems.

Firstly, according to a report by the (*Tipping the scales in AI: How leaders capture exponential returns*, 2021), AI is expected to add approximately \$13 trillion to the global economy over the next decade. AI's data analysis, pattern recognition, and intelligent decision-making capabilities have been widely adopted across manufacturing, logistics, and service industries, significantly enhancing production efficiency and operational capabilities (*Tipping the scales in AI: How leaders capture exponential returns*, 2021). This technology optimizes existing workflows and enables the development of new business models. Furthermore, the IoT market is projected to reach \$1.6 trillion by 2025. It highlights its widespread application in real-time data collection and intelligent device interconnectivity, particularly in logistics and supply chain management, where it significantly improves operational efficiency and asset management (Statista, 2017).

Secondly, research on blockchain technology demonstrates its unique advantages in enhancing data security and supply chain transparency. A survey by (PwC, 2020) found that 84% of respondents believe blockchain will significantly increase transparency and security in information management. This is crucial in complex global supply chains, where the technology can substantially reduce fraud risk and operational costs (PwC, 2020). Meanwhile, digital twin technology is rapidly advancing, with the global market size expected to reach \$48.2 billion by 2026 (Markets and Markets, 2021). The widespread adoption of this technology allows companies to monitor physical assets in real-time and conduct virtual simulations, optimizing maintenance strategies, reducing downtime, and enhancing production flexibility and resilience.

Lastly, advancements in autonomous driving technology are revolutionizing the transportation industry. Research by (Gartner, 2023) indicates that autonomous driving technology could

reduce more than 25% of traffic accidents globally by 2030. Autonomous driving improves safety and efficiency and significantly reduces traffic congestion and carbon emissions, contributing to sustainable development goals (Gartner, 2023).

The advantages of five different emerging technologies are presented in Table 13.2. Therefore, selecting these five technologies as the focus of this research is well-supported by extensive literature and statistical data, aligning with the current and future trends of industrial revolutions. The widespread application and continuous advancement of these technologies will continue to shape the future landscape of various industries, providing a solid foundation for achieving a more efficient, intelligent, and sustainable industrial ecosystem.

The impact of new technologies on logistics companies

The integration of new technologies in logistics is transforming the industry by improving efficiency, reducing costs, and enhancing customer satisfaction. Key technologies driving this transformation include autonomous vehicles, AI, IoT, digital twin, and blockchain. For example, implementing AI and IoT in logistics enables real-time tracking, automated warehouse operations, and optimized fleet management, resulting in significant cost reductions and efficiency improvements (Frias *et al.*, 2023). Additionally, the adoption of AI in logistics has affected labor demand, requiring new skill sets and presenting challenges related to workforce re-skilling and unemployment (Wang, Yao and Li, 2023). Digital technologies are crucial in reshaping business models and enhancing service delivery, providing competitive advantages to companies that effectively integrate these innovations (Gregori, 2020). Furthermore, IoT enables logistics companies to create integrated, flexible, and efficient supply chains tailored for e-commerce, enhancing productivity and safety through real-time data analysis (Gowri, 2022). Finally, technological advancements in IT systems and infrastructure facilitate better information

flow and resource management, which is crucial for maintaining high service quality in logistics (Bazaras, Čiziuniene and Vaičiute, 2023). Table 13.3 shows the applications of these technologies in logistics companies.

DHL Supply Chain has implemented IoT technology in its warehouse operations for Tetra Pak in Singapore. This smart warehouse, also functioning as a digital twin, continuously receives real-time data from physical assets. Integrating IoT allows DHL to optimize storage and retrieval processes, improving inventory accuracy and operational efficiency. This implementation has led to faster processing times, with goods stored within 30 minutes of receipt and ready for shipment in 95 minutes, enhancing overall productivity and safety (DHL, 2019).

Maersk Tankers has successfully implemented digital twin technology to optimize vessel performance and reduce emissions. By creating a digital replica of each vessel, they can simulate and predict fuel consumption for specific voyages, allowing the selection of the most efficient routes and speeds. This approach has significantly reduced fuel consumption and greenhouse gas emissions, enhancing operational efficiency across their fleet of over 220 vessels (Dotzer, 2021).

DHL has implemented autonomous driving technology in their logistics operations, especially in warehousing and last-mile delivery. This technology has been key in enhancing operational efficiency and safety. For instance, DHL's use of self-driving vehicles in warehouses facilitates the transportation of goods without manual intervention, reducing human error, improving route optimization, and decreasing motoring costs and environmental impact. Consequently, DHL has reported significant improvements in productivity and cost efficiency (DHL, 2022).

Additionally, integrating autonomous vehicles has enabled more flexible and reliable operations, supporting the growing demand and complexity in logistics services (Sullivan and Kern, 2021).

FedEx has adopted blockchain technology to revolutionize healthcare logistics, ensuring the integrity and security of sensitive medical shipments. Using blockchain, FedEx provides an immutable and transparent ledger for tracking the entire lifecycle of pharmaceutical products.

This enhances traceability, reduces counterfeit drug risks, and ensures compliance with stringent regulatory standards. Blockchain implementation has improved supply chain data accuracy, increased stakeholder trust, and reduced fraud and errors (Hussien *et al.*, 2021).

Amazon uses its AI-driven Package Decision Engine to optimize packaging, significantly reducing waste and improving efficiency. This AI model, built on Amazon Web Services (AWS) cloud, determines the best packaging for each product by analyzing dimensions, materials, and customer feedback. Since its implementation, Amazon has saved over 2 million tons of packaging material globally, enhancing sustainability and operational efficiency (Amazon, 2024).

The importance and problems of new technology adoption

Digital technologies, including autonomous vehicles, AI, IoT, digital twins, and blockchain, significantly streamline logistics operations by enabling real-time tracking, automated warehouse management, and optimized delivery routes. These advancements increase productivity and customer satisfaction by ensuring timely deliveries and minimizing human errors (Akyuz and Bicer, 2022). Furthermore, digital twins in logistics enhance transparency and risk management by creating virtual replicas of physical processes, facilitating real-time monitoring and predictive maintenance (Lin and Yao, 2022). Integrating blockchain technology in logistics further

enhances the transparency and sustainability of supply chains, improving information sharing and risk management (Yontar, 2023).

However, implementing these technologies comes with challenges. The initial costs of deploying advanced technologies can be high, and companies may face issues related to data security, system integration, and workforce adaptation (Irannezhad, 2020). For example, integrating blockchain technology in logistics aims to create a more secure and efficient system. Still, it faces problems due to its nascent stage and the complexity of integrating existing systems (Huang, 2022).

Additionally, the rapid pace of technological change can lead to job displacement, requiring ongoing training and development for employees to acquire new skills and competencies (Krutova, 2022). The COVID-19 pandemic has further highlighted the importance of technology in logistics by accelerating the adoption of logistics technologies to manage disruptions. However, it also introduced new challenges related to costs, safety, and legislative constraints (Klapita *et al.*, 2023).

When logistics companies adopt new technologies, they face multiple challenges. For instance, in the collaboration between Waymo and UPS to pilot autonomous freight trucks, these vehicles have shown limitations in complex urban environments, like difficulty dealing with unexpected pedestrians and non-standard traffic signals. Additionally, varying legal and regulatory landscapes across different states complicate interstate transportation compliance (TechCrunch, 2021). Although these autonomous trucks are equipped with advanced sensor suites and AI-driven navigation systems, they still require human oversight. During trial runs, each truck is accompanied by a safety driver and a technician to monitor the system's performance, indicating the technology is not yet fully reliable for unsupervised operation (Fox (Business, 2021). These

factors highlight technical and regulatory challenges logistics companies encounter when integrating emerging technologies.

In this study, the impact of new technologies on third-party logistics companies (3PLs) is analyzed from six key perspectives: efficiency improvement, cost reduction, data security, customer satisfaction, flexibility, and sustainability. These dimensions encompass the primary application scenarios and benefits of new technologies in the logistics industry. However, these aspects may only partially capture the full impact, and future research should explore other potential areas of influence.

Efficiency Improvement: Efficiency improvement is a crucial aspect of how new technologies affect 3PLs. Logistics companies can optimize and automate processes to boost operational efficiency by leveraging AI, the IoT, and automation. For example, AI algorithms can process large volumes of logistics data to optimize transportation routes and warehouse management, reducing time and resource wastage (Ding *et al.*, 2021). However, efficiency improvement extends beyond operational levels; it may also impact strategic decision-making and organizational agility, which require further investigation.

Cost Reduction: Cost control is a primary concern for logistics companies, and new technologies provide various methods for reducing operational expenses. Blockchain technology, for example, can lower transaction costs and minimize fraud by reducing intermediaries and enhancing transaction transparency (Tsolakis, Zissis and Papaefthimiou, 2022). AI and ML technologies can also optimize inventory management and transportation planning, thereby reducing excess inventory and transportation costs. However, these technologies' high initial

investment costs and implementation challenges are significant factors affecting overall costs, warranting further exploration.

Data Security: Data security has become increasingly important in logistics, particularly when handling sensitive customer and business data. Blockchain technology enhances data security with its decentralized and immutable characteristics (Vaghani, Sood and Yu, 2022).

Nevertheless, data security challenges are increasing with stricter data privacy laws and evolving cyber-attack methods. While data security is a significant benefit of new technologies, it only partially addresses the complexities of modern data environments.

Customer Satisfaction: Customer satisfaction is crucial for logistics companies' reputation and long-term profitability. Through big data analytics and AI, logistics companies can better understand customer needs, offering personalized services and more effective customer support (Chung, 2021). Automated customer service systems and real-time cargo tracking can significantly enhance the customer experience. However, customer satisfaction also depends on factors like service stability and brand reputation, which should be considered when evaluating new technologies.

Flexibility: Flexibility is essential for logistics companies to adapt to market changes and unexpected events. Technologies like digital twins and autonomous driving enhance logistics systems' responsiveness, enabling them to quickly adjust operations to manage demand fluctuations or supply chain disruptions (Woschank, Rauch and Zsifkovits, 2020). However, flexibility is not limited to operational adjustments; it also includes strategic adaptability and organizational change capabilities, which require more theoretical and empirical support.

Sustainability: With the global focus on sustainable development and environmental responsibility, logistics companies seek greener solutions. Technologies such as AI optimization

and autonomous driving help reduce carbon emissions and energy consumption, fostering green logistics (Ghahremani Nahr, Nozari and Sadeghi, 2021). However, sustainability is not limited to environmental impacts; it also includes social and economic sustainability, such as fair trade and employee welfare. These broader sustainability goals need further exploration in the context of new technology applications.

Table 13.4 shows the impact of technologies on different performance areas of third-party logistics companies. In conclusion, these six aspects represent some of the primary areas where new technologies impact third-party logistics companies. Still, they may not fully capture the entire scope of these technologies' effects. Future research should investigate how these technologies influence other areas, such as organizational culture change, employee skill development, and the resilience of global logistics networks, to gain a comprehensive understanding of the potential and challenges of new technologies in the logistics industry (Zhang, Long and von Schaewen, 2021).

The Best and Worst Method

In previous research, the Best and Worst Method (BWM) has been applied in diverse management fields, such as green port management, municipal solid waste management, cloud-based e-learning provider evaluation, urban digitalization, and risk assessment in production-oriented projects (Munim, Sornn-Friese and Dushenko, 2020; Li *et al.*, 2021; Pour, Mesrabadi and Hosseinzadeh, 2020; Vieira *et al.*, 2022; Khan *et al.*, 2023). These applications demonstrate the versatility of the BWM in addressing complex decision-making scenarios across various sectors.

For instance, Munim, Sornn-Friese and Dushenko (2020) combined BWM with the Analytic Network Process to identify optimal governance models for green port management in India. In

municipal solid waste management, Li *et al.*, (2021) utilized BWM to determine the optimal scenarios for effective waste management. Pour, Mesrabadi and Hosseinzadeh (2020) developed a framework for ranking cloud-based e-learning providers, showcasing BWM's utility in evaluating educational services.

Furthermore, Vieira *et al.* (2022) employed BWM with cognitive mapping to measure urban digitalization, offering a multidimensional perspective on urban development. Khan *et al.* (2023) identified critical risk factors in production-oriented projects in the UAE using BWM analysis, whereas Navaei, Sardar and Saati (2023) explored knowledge management implementation in supply chains with a D-number integrated BWM approach.

Dwivedi *et al.*, (2021) integrated BWM with the Balanced Scorecard (BSC) to evaluate the performance of an insurance company, demonstrating BWM's effectiveness in organizational performance assessment. Nyimbili and Erden (2021) conducted a comparative evaluation using GIS-based BWM for emergency facility planning, emphasizing its practical applications in crisis management. Haseli *et al.*, (2021) introduced a novel group decision-making approach with G-BWM for supply chain management, while Ecer and Pamucar (2020) proposed an integrated fuzzy BWM and fuzzy CoCoSo model for sustainable supplier selection.

These studies highlight the broad applicability and robustness of BWM in addressing complex decision-making scenarios across various fields, reinforcing its status as a valuable tool for contemporary management and operational strategies.

Methodology

In this study, the impact of Industry 4.0 and Industry 5.0 technologies on third-party logistics (3PL) companies is assessed through a systematic literature review and expert opinions.

Additionally, the BWM is employed to rank the influence of different technologies on the overall

competitiveness of 3PL companies, as well as to analyze the impact of each technology across various operational areas within these companies. The BWM is preferred over other Multi-Criteria Decision-Making (MCDM) methods in this research for three main reasons: (i) the Best-Worst Method enhances computational accuracy and reduces the risk of bias arising from pairwise comparisons provided by decision-makers; (ii) it utilizes a structured pairwise comparison, which results in more reliable and consistent outcomes; and (iii) it is less time-consuming compared to the Analytic Hierarchy Process (AHP), as it does not require a full pairwise comparison of all factors. Unlike AHP, which can result in inconsistency in pairwise comparison matrices and complicate result processing, the BWM provides a more straightforward, efficient, and dependable approach (Youssef 2020).

While the BWM offers several advantages, it is not without limitations. One of the main challenges is that BWM can still face issues with inconsistency, particularly when there is a significant divergence in expert opinions (Liang, Brunelli, & Rezaei, 2020). In cases where the criteria are not clearly defined or uniformly understood by all decision-makers, the results may reflect these inconsistencies, thereby affecting the overall reliability of the findings (Liang, 2021; Li, Niu, Chen, & Wang, 2021). This inconsistency can be further exacerbated in a group decision-making context, where multiple experts provide input, potentially leading to conflicting judgments (Guo & Qi, 2021). Additionally, the method assumes a level of expertise and judgment from the decision-makers that might not always be present, potentially introducing bias or inaccuracies (Malek & Desai, 2019). Therefore, while BWM provides a more streamlined and

often more reliable approach compared to AHP, its effectiveness depends on the clarity of the criteria and the experience of the decision-makers involved.

By using this method, decision-makers assist researchers in identifying the most important (best) and least important (worst) factors that influence a logistics company's competitiveness and then compare these factors in pairs. This approach is straightforward to implement and computationally efficient. Compared to other MCDM techniques, such as TOPSIS, ANP, and AHP, the BWM provides more reliable and consistent results (Masoomi *et al.*, 2022; Varchandi, Memari, & Jokar, 2024). Figure 13.1 provides the methodological steps followed in this research.

[INSERT Fig. 13.1 Methodological flow diagram]

The BWM is designed to be relatively simple, easy to understand, and capable of aggregating input from multiple decision-makers. In this study, the inputs from various experts are combined using a weighted average approach, ensuring that the consensus reflects the relative importance assigned by each expert, thereby enhancing the robustness of the findings (Rezaei 2015; 2016; Mi et al. 2019).

The primary data for this study was obtained through a questionnaire survey. A total of 15 questionnaires were distributed, and all 15 were returned and deemed valid. The questionnaire indirectly captured experts' attitudes towards various technologies using a scoring method. The experts involved in this survey were either university professors or professionals from relevant companies, each with over 10 years of experience in the fields of logistics and supply chain management. Due to the differing numbers of experts from the UK and China who participated in this study, some of the subsequent analysis will use an averaging method to ensure accurate

comparison of the results. The questionnaire is included in Appendix 1, and the survey results provide the raw data needed for the subsequent BWM analysis.

The steps of the BWM method are as follows (Rezaei 2015, 2016; Gupta, 2024).

Step 1: Identify the Critical Success Factors (CSFs) through literature review and discussions with decision makers. The CSFs are denoted as (C1, C2, C3,, Cn).

Step 2: Decision makers select the best (most important) and worst (least important) CSFs from the list identified in Step 1.

Step 3: Decision makers compare the best CSF with others by forming a Best-to-Others (BO) vector using a 1–9 scale (Table 13.5), where 1 represents equal importance and 9 represents absolute importance over other criteria. The BO vector is expressed as:

where X_{Bj} denotes the importance of Best Criterion B with criterion j .

Step 4: Decision makers then compare the worst CSFs with others by forming an Others-to-Worst (OW) vector using a 1–9 scale, where 1 indicates equal importance and 9 represents absolute importance. The OW vector is expressed as:

where x_{jW} represents the importance of criterion j compared to over worst criterion W .

Step 5: The optimal weights (W_1^* , W_2^* , .., W_n^*) of the decision criteria (CSFs) are computed to minimize the maximum absolute differences for all j within the following set:

$$\left\{ \left| W_B - x_{Bj} W_j \right|, \left| W_j - x_{jW} W_w \right| \right\}$$

The min–max model is formulated as follows:

$$\text{Minmax}_j \left\{ \left| W_B - x_{Bj} W_j \right|, \left| W_j - x_{jW} W_w \right| \right\}$$

subject to,

$$W_j \geq 0 \text{ for all } j$$

Equation (3-3) can be transformed into a linear programming problem as follows:

Minx,

$$\text{Subject to } |W_B - x_{BJW_j}| \leq \xi \text{ for all } j,$$

$$\sum_j W_j = 1,$$

$$W_j \geq 0 \text{ for all } j.$$

Solving Equation (3-4), yields the optimal weights for each criterion and the optimal value of the objective function ξ . A lower ξ indicates more consistency, while a higher ξ indicates less.

Once the optimal weights and the objective function ξ are obtained, it is crucial to assess the consistency of expert input using the CR, which measures the reliability of expert comparisons.

The CR value ensures that the judgments are consistent rather than random.

The formula for calculating the CR is given by Equation (3-5):

where:

ξ^* represents the optimal value of the objective function obtained from the BWM (Best-Worst Method) optimization model.

The Consistency Index (CI) is a predefined benchmark value that varies depending on the number of criteria considered. The CI values are derived from random index tables based on the number of elements being compared.

Following the previous process, the weight of each technology's impact on different aspects of third-party logistics companies can be calculated individually. By repeating this process, the respective weights for each technology can be determined. Consequently, it is possible to ascertain which aspect of third-party logistics companies is most significantly affected by each

technology. This allows for further analysis to identify which technology is most crucial for third-party logistics companies.

Steps for Calculating the Consistency Ratio:

1. Determine the Consistency Index: The Consistency Index is obtained from a random index table, which provides a benchmark value based on the size of the matrix (number of criteria).

This benchmark helps in comparing the consistency of the pairwise comparisons.

2. Compute the Optimal Objective Function Value (ξ^*): Using the BWM model, solve the linear programming problem to find the optimal value of the objective function ξ^* . This value reflects the level of inconsistency in the pairwise comparisons.

3. Calculate the Consistency Ratio: Divide the optimal value ξ^* by the corresponding CI for the given number of criteria. The resulting CR value provides a quantitative measure of consistency. A CR value of less than 0.1 (or 10%) is generally considered acceptable, indicating that the level of inconsistency is within reasonable bounds.

In summary, the BWM is used to determine the optimal weights of decision criteria by systematically comparing the most important (best) and least important (worst) criteria on a 1-9 scale. The method aims to minimize the maximum absolute differences between these comparisons through a linear programming model, yielding the optimal weights (W^*) and the objective function value (ξ^*). To ensure the reliability of these comparisons, the CR is calculated by dividing ξ^* by a predefined CI. A low CR value indicates a high level of consistency, confirming that the decision-making process is sound. This structured approach allows for a clear

identification of the most influential criteria or technologies affecting third-party logistics companies.

Findings

Overview of the Impact of New Technologies on 3PL Companies

After collecting and summarizing the questionnaires, Table 13.6 presents the summary of inputs from experts. Due to the confidentiality agreement with the experts, it is not possible to display responses from each expert in detail. Additionally, the data in Table 13.6 have been anonymized and are only used to illustrate the questionnaire response rate; they do not represent the actual data.

From Table 13.6, we can see that each expert first selected the area they believed would have the greatest impact and then the area they thought would have the least impact on logistics companies. They then rated each area accordingly. An area that is either the same or of equal importance to another is rated as 1, while an area that is far more important is rated as 9. This process is repeated for each technology until all five technologies have been rated. Once summarized, a comprehensive base table is created, and all subsequent analyses are conducted based on this base table.

In the BWM calculation of the scores in the base table, we used an Excel spreadsheet, with the table design shown in Figure 13.2. The table design follows the method proposed in Rezaei's (2016) paper. The spreadsheet is first divided into five separate sheets, each corresponding to a different technology type. The names of each field are entered into the top green table, followed

by the scores given by the experts, which are filled into the middle green table. The resulting solutions are generated in the yellow table at the bottom.

[INSERT Fig. 13.2 BWM Excel calculation]

After completing the calculations, the data in the table are automatically updated, and the bar chart below is simultaneously refreshed. Consistency Ratio is also calculated in the table to ensure the accuracy of the results.

The adoption of the BWM to rank the impact of emerging technologies on third-party logistics (3PL) companies provides a structured and nuanced approach to understanding technological influences in the logistics sector. By engaging 15 seasoned decision-makers from China and the United Kingdom, this study gains insights from experts with a deep understanding of the industry. The diversity of perspectives, encompassing both academic and practical expertise, enhances the reliability of the findings.

After solving each table and aggregating the results, preliminary summary results similar to those in Table 13.7 are obtained. For digital twins, Efficiency Improvement has the highest weight at 3.668, followed by flexibility at 3.191. The lowest weight is Sustainability, at 1.690.

The scores in Table 13.7 reflect the weight values assigned by each expert to the impact of different technologies across various domains within the company. This table uses the SUM formula at the bottom to calculate the total score for each expert within a specific domain. This score reflects the extent to which a particular technology is believed to impact that domain; a higher score indicates that the technology is considered more important within that domain. The values from all the tables for the five technologies are then consolidated to create Table 13.8. The results reveal distinct trends across the six key operational areas for 3PL companies. The larger the value, the greater the impact of the technology on third-party logistics companies

within that domain. For example, in terms of Efficiency Improvement, digital twins have the highest weight at 3.668, while autonomous driving has the highest weight at 2.569 in terms of cost reduction. The cells highlighted in yellow in Table 13.8 represent the maximum values in each column.

Table 13.8 shows that the technologies with the greatest impact on different areas of third-party logistics companies are listed on the right side of the table. The prominence of Digital Twin technology in Efficiency Improvement and Flexibility suggests that the ability to simulate and optimize logistics processes in a virtual environment is increasingly critical. This technology enables 3PL companies to streamline operations, reduce downtime, and quickly adapt to changes, which is crucial in an industry where agility and precision are key competitive advantages.

In contrast, the dominance of Autonomous Vehicles in Cost Reduction and Sustainability highlights a paradigm shift towards automation and eco-friendly practices. The potential of autonomous vehicles to reduce labor costs, fuel consumption, and emissions positions them as a transformative force in logistics. However, the lower impact of Autonomous Vehicles in other domains, such as Flexibility, may indicate that while these technologies excel in specific areas, they may not yet offer the same level of adaptability and integration as other technologies.

The strong performance of Blockchain in Data Security underscores the growing importance of secure and transparent data management in the logistics sector. With the increasing complexity of global supply chains, the ability to track and verify transactions with immutable records is

becoming a cornerstone of trust and compliance. This suggests that 3PL companies recognize the need to invest in technologies that enhance the integrity and security of their operations.

Artificial Intelligence's leadership in Customer Satisfaction further emphasizes the role of AI in enhancing customer experiences through predictive analytics, personalized services, and efficient problem-solving. AI's capability to process vast amounts of data and generate actionable insights allows 3PL companies to anticipate customer needs and respond proactively, which is essential in maintaining competitive service levels.

[INSERT Fig. 13.3 Proportion of total score]

The aggregation of these results in Figure 13.3 shows that new technologies have the greatest overall impact on Efficiency Improvement, with a high rate of 22%, with the 12% lowest impact on Sustainability. This suggests that while efficiency gains are a primary focus for 3PL companies, sustainability initiatives may require further technological advancements or broader industry adoption to achieve similar levels of impact. The relatively lower emphasis on sustainability could reflect the current market dynamics, where cost-efficiency and operational effectiveness remain dominant drivers, despite increasing regulatory and societal pressures for greener practices.

By analyzing the best and worst technologies chosen by all experts, Table 13.9 is created to reflect the experts' preferences for different technologies across various domains. A higher number of selections indicates a greater perceived importance of that technology within the respective domain.

Digital Twin technology is highly rated for Efficiency Improvement (5 "BEST" votes) and Flexibility (4 "BEST" votes), highlighting its effectiveness in enhancing operations and adapting to various logistical needs. However, it is perceived poorly in Customer Satisfaction (0 "BEST"

votes and 5 "WORST" votes), indicating that it does not directly improve customer-facing outcomes. For Cost Reduction, Data Security, and Sustainability, Digital Twin shows a balanced performance with moderate votes, suggesting it provides some benefits but is not the leading technology in these areas.

AI is particularly valued for Cost Reduction (5 "BEST" votes) and Efficiency Improvement (3 "BEST" votes), reflecting its ability to lower operational costs and streamline logistics processes through automation. However, AI is less effective for Sustainability (0 "BEST" votes and 4 "WORST" votes), indicating that it is not typically associated with environmental benefits. It shows mixed results in Customer Satisfaction and Flexibility (3-2 "BEST" votes and 2-2 "WORST" votes), suggesting that while it has potential, it is not the primary technology for enhancing these areas.

Blockchain is highly regarded for Data Security (8 "BEST" votes and 0 "WORST" votes), making it the preferred choice for secure data management within logistics. However, it is not seen as effective for Cost Reduction (0 "BEST" votes and 4 "WORST" votes) or Customer Satisfaction (0 "BEST" votes and 5 "WORST" votes), indicating that it might not contribute significantly to reducing costs or enhancing customer experiences. Blockchain also shows a moderate impact in Efficiency Improvement, Flexibility, and Sustainability, with mixed votes indicating that while it offers some benefits, it is not a primary driver in these areas.

IoT is viewed as highly effective for Efficiency Improvement (5 "BEST" votes), reflecting its strength in connecting devices and improving operational processes. However, it scores low in Data Security (1 "BEST" vote and 4 "WORST" votes) and Sustainability (1 "BEST" vote and 5 "WORST" votes), suggesting concerns about security risks and environmental impact. For Cost

Reduction, Customer Satisfaction, and Flexibility, IoT receives a mix of votes, showing that while it can offer some advantages, it is not the most effective technology in these categories. Autonomous Vehicles are highly rated for Efficiency Improvement (5 "BEST" votes) and Cost Reduction (4 "BEST" votes), indicating their potential for automating transport and reducing labor costs. However, they score poorly in Data Security (5 "WORST" votes), highlighting concerns about cybersecurity risks and system vulnerabilities. The technology has mixed reviews in Customer Satisfaction, Flexibility, and Sustainability (2-1-3 "BEST" votes and 2-1-3 "WORST" votes), suggesting that while it has some advantages, it is not the most effective for these outcomes.

The next step involves focusing on the number of best choices and calculating their total, sum the numbers in Table 13.8 above, which is 138. Then, the number of expert selections corresponding to each domain is determined. For instance, the number of expert selections for Efficiency Improvement is 41. By dividing this number by the total of 138, a weight of 0.297 is obtained. This weight represents the impact of the Efficiency Improvement domain on the overall company. By performing this calculation for each domain, the values presented in Table 13.10 can be derived.

Based on the data in Table 13.10, Efficiency Improvement has the highest impact weight of 0.297, indicating that it is the most critical factor for third-party logistics companies, accounting for nearly 30% of the overall influence. Flexibility follows with a weight of 0.225, underscoring its significant role in enabling companies to adapt to changing demands and contributing about 22.5% to the overall impact. Cost Reduction and Data Security have moderate weights of 0.159 and 0.152, respectively, highlighting their importance in maintaining profitability and protecting sensitive information, with each contributing around 15% to the overall impact. Customer

Satisfaction has a lower impact weight of 0.101, suggesting it is considered less critical, contributing about 10% to the overall influence. Sustainability has the lowest weight of 0.065, reflecting its lower priority in the current logistics landscape, with a contribution of just 6.5%. This distribution of weights suggests that logistics companies should prioritize efficiency and flexibility while also considering cost, security, and customer satisfaction, with sustainability being a lesser immediate concern.

The selection of all expert preferences in Table 13.9 and the resulting weights in Table 13.10 provide further insights into the strategic priorities of 3PL companies. The consistent favoring of Digital Twin technology across various domains highlights its versatility and potential as a cornerstone technology for the future of logistics. Meanwhile, the varying importance of technologies such as Blockchain and AI across different domains suggests that while these technologies are recognized for their specific strengths, their broader application may still be evolving.

The final scores in Table 13.11 indicate that Digital Twin technology has the most significant overall impact, suggesting that its potential to drive efficiency and flexibility makes it a top priority for 3PL companies. The strong performance of the Digital Twin and Internet of Things as the second and third most impactful technologies reinforces the trend towards digitization and automation in logistics. The lower ranking of Blockchain and Autonomous Vehicles, despite their specific strengths, suggests that these technologies may still be in the early stages of adoption or require further development to achieve their full potential in the logistics industry.

Validation of Results and Further Analysis

The robustness of the results is further reinforced by the validation of the CR for each expert's input. Adherence to Rezaei's (2016) methodology ensures that the findings are not only

statistically sound but also reflect a high degree of internal consistency among the experts' assessments. Figure 13.4 reflects that consistency ratios were below the threshold for all experts, indicating a strong consensus and reliability in the evaluation process. This, in turn, provides confidence in the strategic insights derived from the study.

[INSERT Fig. 13.4 Expert Consistency Ratio line chart]

As the number of experts from China and the UK differs, the total score obtained by summing the weights of experts from each country needs to be averaged based on the number of experts. This ensures that all values are within the same range, making the processed data more intuitive and easier to analyze. The comparison of expert opinions from China and the UK in Table 13.12 and Table 13.13 reveals significant regional differences in the perceived importance of various technologies.

These differences may be attributed to several factors, including varying levels of technological infrastructure, regulatory environments, and market demands in each country. For example, the preference for Digital Twin technology in Efficiency Improvement among Chinese experts may reflect the country's focus on rapid industrial modernization and the need for advanced tools to manage complex logistics networks. In contrast, the British experts' preference for Artificial Intelligence in the same domain could indicate a greater emphasis on leveraging AI for process optimization and decision support.

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Intelligence in the same domain could indicate a greater emphasis on leveraging AI for process optimization and decision support.

Based on the data from Table 13.12 and Table 13.13, a radar chart can be drawn to illustrate the impact of various technologies on different areas of third-party logistics companies. Figure 13.5 and Figure 13.6 represent the views of UK experts and Chinese experts on various technologies, respectively. In Figure 13.5, it is evident that, for example, Digital Twin technology has a significant impact in the Flexibility area, as it stands out prominently in this domain.

[INSERT Fig. 13.5 UK experts weight radar chart]

These differences may be attributed to several factors, including varying levels of technological infrastructure, regulatory environments, and market demands in each country. For example, the preference for Digital Twin technology in Efficiency Improvement among Chinese experts may reflect the country's focus on rapid industrial modernization and the need for advanced tools to manage complex logistics networks. In contrast, the British experts' preference for Artificial Intelligence in the same domain could indicate a greater emphasis on leveraging AI for process optimization and decision support. Similarly, Figure 13.6 shows that blockchain technology has a substantial influence in data security for Chinese experts.

[INSERT Fig. 13.6 Chinese experts weight radar map]

The consensus on the importance of Autonomous Vehicles for Cost Reduction in both countries suggests a shared recognition of the potential for automation to drive cost efficiencies. However, the preferences for technologies in Customer Satisfaction and Sustainability reveal different strategic priorities. For Customer Satisfaction, Chinese experts favor AI for its ability to enhance customer engagement, while British experts prefer IoT for its capability to provide real-time data and insights, which can improve service quality and responsiveness. Regarding Sustainability,

Chinese experts see Autonomous Vehicles as crucial for improving environmental performance, whereas British experts value Digital Twin technology for its role in optimizing resource use and reducing waste through predictive maintenance and better planning.

These regional variations underscore the importance of context in the adoption and impact of new technologies. For 3PL companies operating in different markets, it is crucial to tailor their technological strategies to align with local conditions and priorities. The findings suggest that while there is broad consensus on the importance of certain technologies, such as Digital Twin and AI, the specific applications and benefits of these technologies may vary depending on regional factors.

Overall, examining Figure 13.5 and Figure 13.6 reveals that UK experts tend to give higher ratings to a new technology within a specific domain, while Chinese experts provide more balanced scores across different domains. This difference could be attributed to regional variations arising from cultural differences and distinct logistics models or may be influenced by the differing numbers of experts from each country. This phenomenon could be explored further in future research.

In conclusion, the detailed analysis provided in this chapter highlights the critical role of emerging technologies in shaping the future of 3PL companies. As shown earlier in Table 13.11, Digital Twin technology has the greatest impact on third-party logistics companies, followed by Artificial Intelligence. As indicated in Table 13.14, overall, Digital Twin technology is identified as the most influential for both Efficiency Improvement and Flexibility. Autonomous Vehicles are recognized as the leading technology for Cost Reduction and Sustainability. Blockchain is highlighted as the key technology for enhancing Data Security, while Artificial Intelligence is considered the most impactful for improving Customer Satisfaction. The study not only

identifies the technologies with the most significant impact but also offers insights into the strategic considerations that 3PL companies must navigate as they integrate these technologies into their operations. The regional differences observed in expert opinions further emphasize the need for a nuanced approach to technology adoption, one that considers both global trends and local market dynamics. As 3PL companies continue to evolve in response to technological advancements, this study provides a valuable roadmap for understanding and leveraging these innovations to achieve sustained competitive advantage.

Discussion

This research provides a comprehensive analysis of the impact that emerging technologies—namely Digital Twin, AI, IoT, Blockchain, and Autonomous Vehicles—have on 3PL companies in the UK and China. Using the BWM (Rezaei's 2016) for evaluation, this study highlights the varying degrees to which these technologies influence critical operational aspects of logistics, including efficiency, cost management, data security, customer satisfaction, and sustainability. The findings broadly align with existing literature regarding the transformative potential of Industry 4.0 and Industry 5.0 technologies in the logistics sector. Industry 4.0 technologies, such as Digital Twin and Artificial Intelligence, are widely recognized as key drivers for enhancing operational efficiency and customer experience. Meanwhile, Industry 5.0 further emphasizes the importance of human-machine collaboration, personalized services, and sustainability (Ghobakhloo *et al.*, 2022). The integrated application of these technologies, as demonstrated in this research, aligns well with the insights and predictions found in the literature.

Detailed analysis of the application of new technologies

Digital Twin Technology emerged as the most significant among the technologies studied, particularly in terms of Efficiency Improvement and Flexibility. The prominence of Digital Twin

technology is supported by existing literature, such as Jones *et al.* (2020), who emphasized its role in enabling real-time simulation and optimization of logistics processes. This study corroborates those findings, demonstrating that Digital Twin technology not only enhances operational efficiency but also significantly reduces downtime and operational disruptions. This impact is particularly pronounced in complex logistical environments where agility and precision are critical competitive factors. Anderson (2023) also highlighted the ability of Digital Twin technology to improve flexibility, allowing logistics companies to adapt swiftly to changing market demands—a conclusion further supported by this research. The ability to conduct predictive maintenance and optimize resource allocation underscores the role of Digital Twin as a cornerstone technology for modern logistics.

AI demonstrated a substantial impact on customer satisfaction, reflecting its critical role in enhancing customer service and experience. This research corroborates Anderson's (2023) findings, which highlighted AI's role in improving customer satisfaction through predictive analytics and personalized services. AI's capability to process and analyze vast amounts of data allows logistics companies to offer more personalized services, improve delivery accuracy, and predict customer needs with greater precision. The study further illustrates how AI-driven tools, such as predictive analytics, chatbots, and dynamic routing systems, contribute to higher customer satisfaction by ensuring timely deliveries, reducing errors, and providing real-time updates (Singh, 2023). Furthermore, AI's role in demand forecasting and inventory management is pivotal, as it helps companies better anticipate market fluctuations and manage supply chain disruptions, thus maintaining service quality even in volatile conditions.

Blockchain technology stood out in the domain of Data Security, aligning with the literature that recognizes Blockchain's potential to revolutionize data security and transparency in supply

chains (Yontar, 2023). The research findings indicate that Blockchain's decentralized and immutable ledger system is highly effective in enhancing the transparency and security of transactions within the logistics sector. This technology is particularly crucial in a globalized supply chain environment where the integrity and traceability of data are paramount. The ability of Blockchain to provide a secure and transparent record of all transactions mitigates the risks associated with fraud, data breaches, and compliance failures.

Autonomous Vehicles were identified as crucial for Cost Reduction and Sustainability, findings that align with the literature's perspective on their potential benefits (Sullivan and Kern, 2021).

Autonomous vehicles, particularly in last-mile delivery and intra-warehouse transportation, have the potential to drastically reduce labor costs and improve fuel efficiency. The research suggests that by minimizing human intervention and optimizing routing, these vehicles can lead to substantial cost savings and lower environmental impact through reduced emissions. However, similar to findings by Bonab (2021), this study also identifies significant challenges in their broader integration, such as technology reliability, regulatory hurdles, and public acceptance. These challenges suggest that while Autonomous Vehicles are seen as a transformative force in logistics, their full potential will only be realized when these barriers are addressed through further technological advancements and supportive regulatory frameworks.

IoT, though slightly less dominant compared to the other technologies, plays a critical role in creating interconnected and smart logistics systems. The IoT enables real-time monitoring of goods, fleet management, and warehouse operations, which enhances overall operational visibility and control. This research highlights the IoT's contribution to improving supply chain integration and efficiency, particularly through its ability to collect and analyze data from various touchpoints across the logistics network. The IoT's role in predictive maintenance and asset

tracking further underscores its importance, especially in enhancing operational reliability and reducing downtime (Gayialis *et al.*, 2020).

Furthermore, this research adds a critical layer of analysis by exploring regional differences in technology adoption between UK and Chinese experts, an area that has been relatively underexplored in existing literature. While both regions recognize the importance of these technologies, the emphasis on different technologies for various operational goals suggests that regional market dynamics and regulatory environments play a crucial role in shaping technological priorities. For example, Chinese experts prioritize Digital Twin technology primarily for its role in enhancing operational efficiency, likely reflecting China's broader industrial focus on rapid modernization and the optimization of complex supply chains. In contrast, UK experts place greater emphasis on AI for its ability to refine and optimize processes, suggesting a more mature market focus where operational fine-tuning and customer engagement are key drivers.

Strategic Integration of Emerging Technologies in Global Logistics Operations

The integration of emerging technologies into logistics operations presents profound implications for companies striving to maintain competitiveness in an increasingly digital and automated global market. Digital Twin technology stands out as a critical tool for logistics companies, offering unparalleled advantages in simulating and optimizing logistics processes within a virtual environment. This capability not only streamlines operations and reduces downtime but also enhances a company's ability to adapt swiftly to changes in market demand or supply chain disruptions. For instance, a recent study by Tao *et al.* (2019) demonstrates how Digital Twin technology can significantly improve supply chain resilience and flexibility by providing real-time insights and predictive analytics. Companies investing in Digital Twin technology can

expect significant improvements in both operational resilience and flexibility, enabling them to respond more effectively to the dynamic challenges of the logistics industry.

In parallel, AI plays a pivotal role in transforming the customer experience. AI's ability to process vast datasets and generate actionable insights allows logistics companies to offer more personalized services, which are crucial in maintaining high levels of customer satisfaction—a key competitive differentiator in the logistics sector. According to a study by Kuo and Smith (2020), AI-driven solutions have been shown to enhance customer satisfaction through improved service delivery and demand forecasting. By leveraging AI, companies can optimize their operations from demand forecasting to dynamic routing, ensuring that services are both timely and accurate, thereby enhancing overall customer satisfaction and loyalty.

IoT and Blockchain technologies, while still evolving, are equally important in creating integrated, transparent, and secure supply chains. The IoT's role in real-time monitoring and management of logistics operations enhances operational visibility and control, contributing to more efficient and responsive supply chains. Ivanov *et al.* (2021) highlight the significant impact of IoT on enhancing the efficiency and responsiveness of supply chains through real-time monitoring and predictive maintenance. Blockchain, with its decentralized and immutable ledger system, significantly enhances the security and transparency of data across the logistics network. This is particularly important in managing the complexity of global logistics, where the integrity and traceability of information are paramount for compliance and risk management.

However, despite these clear benefits, the adoption of these advanced technologies is not without significant challenges. The initial investment required for deploying technologies such as Digital Twin and AI is substantial, often demanding considerable capital and a long-term strategic commitment from companies. This financial burden can be a barrier, particularly for small to

medium-sized enterprises (SMEs) in the logistics sector. Moreover, the integration of these technologies into existing legacy systems poses additional challenges, including potential disruptions during the transition phase and the complexity of ensuring compatibility with current operations. Raut *et al.* (2019) discuss the challenges and financial implications of integrating advanced technologies into logistics, particularly for SMEs, and emphasizes the need for strategic planning and phased implementation to mitigate risks.

Data security concerns, especially with IoT and Blockchain, further complicate the adoption process. As logistics operations become increasingly digital, the risk of cyber threats escalates, necessitating robust security measures to protect sensitive data and maintain the integrity of supply chain operations. Companies must also address the challenge of workforce adaptation, as the successful implementation of these technologies requires employees to develop new skills and competencies. This necessitates ongoing training and development initiatives, which can be resource-intensive and time-consuming. Mittal, Khan and Tzeng (2022) emphasize the importance of cybersecurity in logistics and the need for continuous workforce training to manage the challenges posed by digital transformation.

The regional differences highlighted by this research underscore the importance of contextualizing technology adoption strategies. The preferences expressed by experts in the UK and China reveal how local market dynamics, regulatory environments, and industrial priorities shape the adoption and implementation of these technologies. For example, Chinese experts' preference for Digital Twin technology reflects the country's focus on rapid industrial modernization and the optimization of complex supply chains. In contrast, UK experts emphasize AI's role in refining and optimizing processes, suggesting a more mature market approach that prioritizes operational fine-tuning and customer engagement. Zhang et al. (2020)

explore the regional variations in technology adoption within the logistics sector, highlighting the different strategic priorities in China and the UK.

For logistics companies operating across multiple regions, it is crucial to tailor their technological strategies to align with these local conditions. This requires a deep understanding of regional market demands, regulatory frameworks, and industrial objectives to ensure that technology integration is both effective and efficient. By doing so, companies can better navigate the challenges associated with technology adoption and leverage the unique advantages offered by each technology in different contexts. This approach is supported by a study by Gupta and Venkatesh (2019), who recommend a localized strategy for technology adoption to maximize the effectiveness and return on investment.

Strategic recommendations for logistics companies based on these findings include prioritizing the adoption of Digital Twin and AI technologies, given their broad impact across multiple operational areas. A phased approach is recommended, starting with technologies that offer the quickest return on investment. For instance, AI can be leveraged to enhance customer satisfaction through improved service delivery, while Digital Twin technology can be deployed to optimize operational efficiency. As these technologies become more embedded within company operations, further investments in IoT and Blockchain can be pursued to strengthen data transparency, security, and overall supply chain resilience. Autonomous Vehicles, although promising, should be adopted with caution. Pilot programs in controlled environments are advisable to refine the technology and address potential challenges related to reliability, regulatory compliance, and public acceptance. Once these challenges are mitigated, broader implementation can be considered. This strategic roadmap will enable logistics companies to capitalize on the benefits of emerging technologies while managing the associated risks, ensuring

a sustainable and competitive edge in the rapidly evolving logistics landscape. This phased approach to technology adoption is further supported by the findings of Zhou et al. (2021), which suggest that logistics companies should initially focus on technologies that offer the highest potential for ROI before expanding their technological investments.

Conclusion

The primary contribution of this research lies in its examination of the impact of emerging technologies within the frameworks of Industry 4.0 and Industry 5.0 on third-party logistics (3PL) companies. By focusing on key technologies such as Digital Twin, AI, IoT, Blockchain, and Autonomous Vehicles, this study provides a nuanced understanding of how these innovations are reshaping the logistics sector. At the same time, these technologies are ranked according to their importance, from most to least important: Digital Twins, the Internet of Things, Artificial Intelligence, Blockchain, and Autonomous Vehicles. For instance, Giri et al. (2021) highlight the role of Digital Twins, AI and IoT in enhancing operational efficiencies in 3PL companies, further supporting the findings of this study. The analysis offers a strategic framework that logistics companies can utilize to prioritize the adoption of these technologies, thereby enhancing operational efficiency, customer satisfaction, data security, and sustainability. A secondary, yet significant, contribution is the exploration of regional differences in technology adoption between the UK and China. By shedding light on how local market dynamics, regulatory environments, and industrial priorities influence the adoption of these technologies, the research enriches the existing body of knowledge on global logistics strategies. Wang, Li and Zhan (2020) provide evidence of how China's regulatory environment shapes the adoption of Blockchain in logistics, underscoring the regional nuances discussed in this research. This comparative analysis is particularly valuable for multinational logistics companies, as it

underscores the importance of tailoring technology implementation strategies to align with regional contexts.

Despite these valuable insights, the research is not without its limitations. A key limitation is the reliance on expert opinions, which, while providing depth and specialized insights, may introduce bias due to the subjective nature of expert judgment. The relatively small sample size of experts further exacerbates this issue, as it may not fully capture the diversity of perspectives within the logistics industry. Expert-driven studies often face challenges in achieving broad generalizability (Kache and Seuring, 2017), a concern that is relevant here. Additionally, the focus on the UK and China, while providing important regional insights, limits the generalizability of the findings. The specific technological infrastructures, regulatory frameworks, and market conditions in these countries may not be reflective of other regions, particularly those with different levels of technological development or distinct regulatory challenges.

Another limitation relates to the dynamic nature of technology adoption. The rapidly evolving landscape of Industry 4.0 and 5.0 technologies means that the findings of this study may quickly become outdated as new technologies emerge and existing ones mature. Recent research by Schwab (2020) echoes this concern, noting that the pace of technological advancement poses a significant challenge for longitudinal studies. Furthermore, the study does not fully address the implementation challenges associated with integrating these technologies into existing logistics operations, such as the need for legacy system compatibility and the potential for operational disruption during the transition phase.

Lastly, the study touches only briefly on the ethical implications of adopting advanced technologies, such as data privacy concerns. As logistics companies increasingly rely on

automation and data-driven decision-making, these ethical considerations will become increasingly important. For example, Smith & Anderson (2022) discuss the ethical challenges posed by automation in logistics, particularly in terms of data privacy concerns, which highlights the need for deeper exploration in future research. Future research should delve deeper into these areas, exploring strategies for ensuring robust data protection measures are in place.

In summary, while this research makes substantial contributions to understanding the impact of emerging technologies on logistics, it is essential to recognize its limitations. These limitations suggest several avenues for future research, including expanding the geographic scope, increasing the diversity of expert opinions, and exploring the long-term implications and ethical challenges associated with these technologies. By addressing these areas, future studies can build on the foundation laid by this research, offering even more comprehensive insights into the evolving logistics landscape.

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Figures

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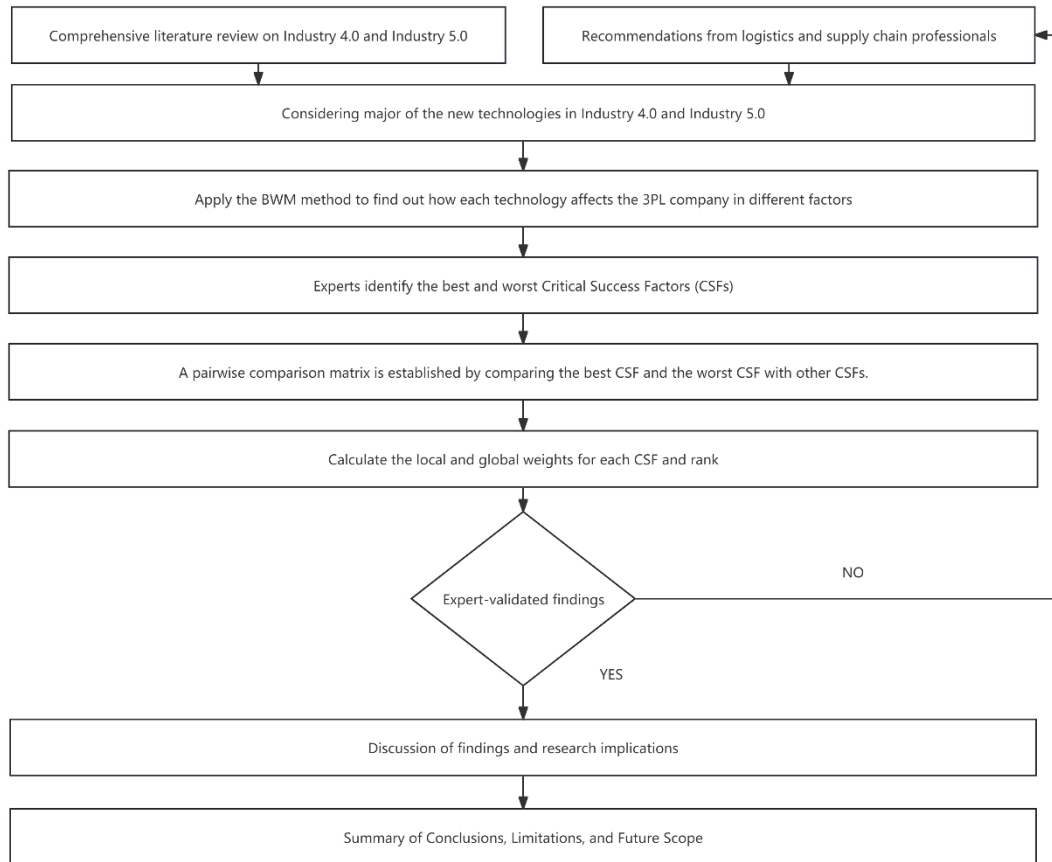


Fig. 13.1 Figure Methodological flow diagram

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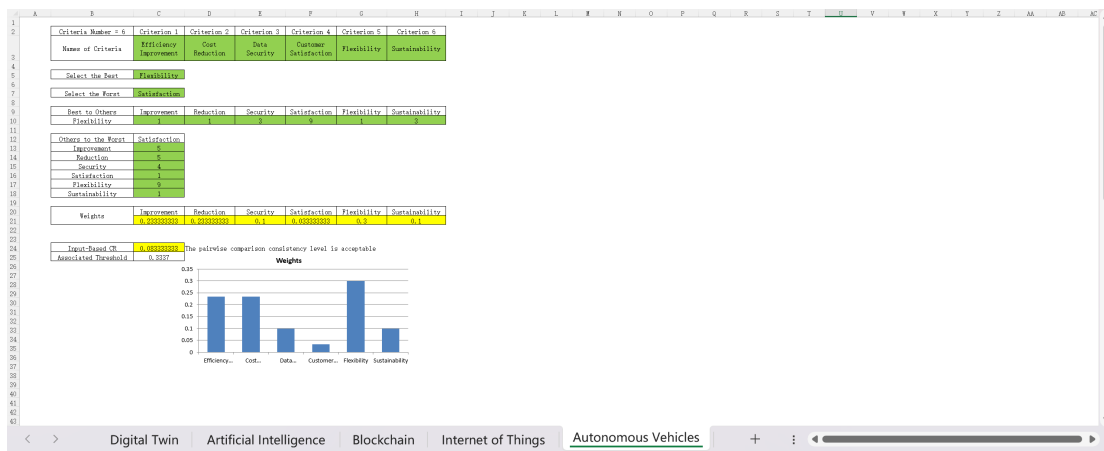


Fig. 13.2 BWM Excel calculation

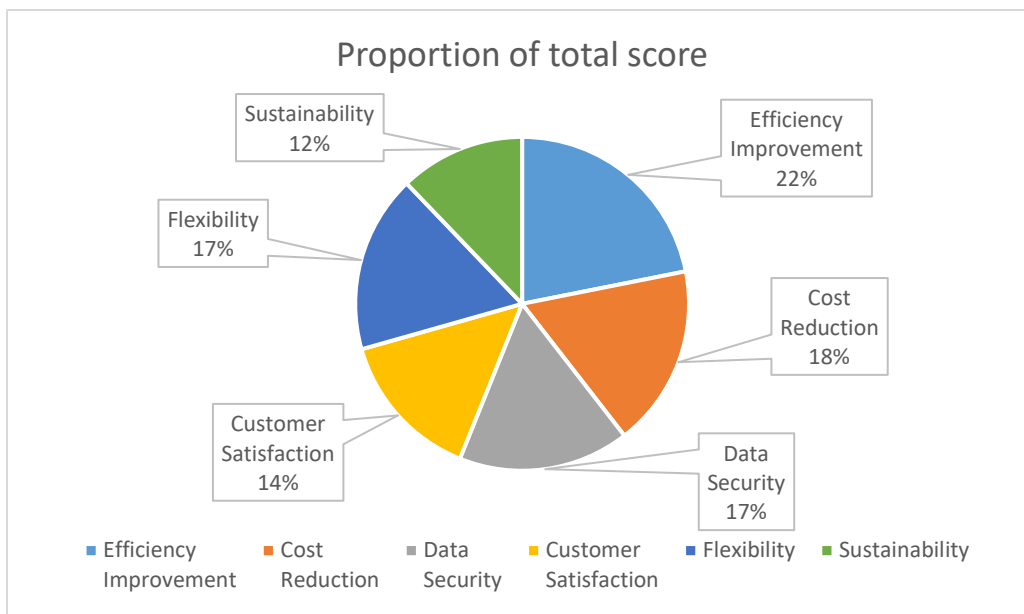


Fig. 13.3 Proportion of Total Score

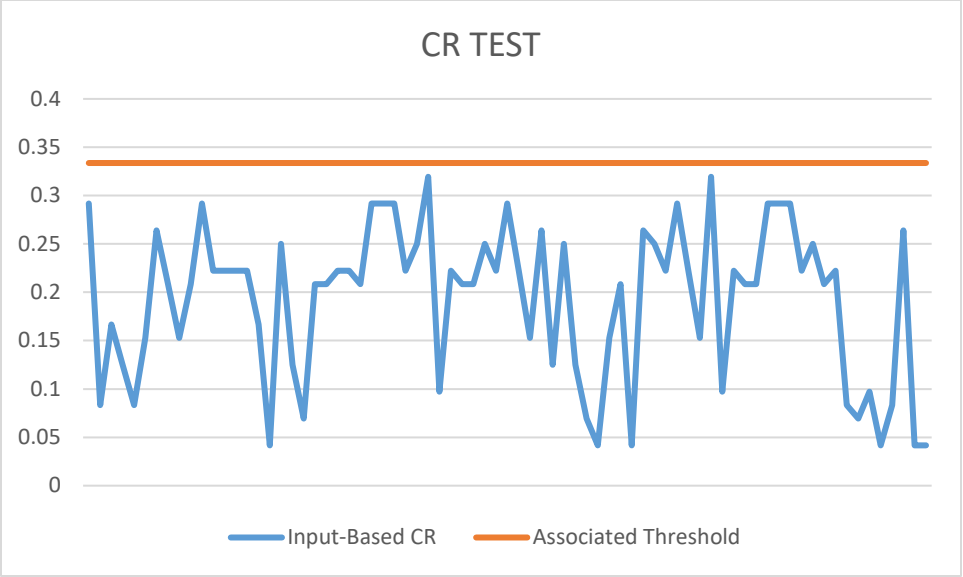


Fig 13.4 Experts’ consistency ratio (CR) line chart

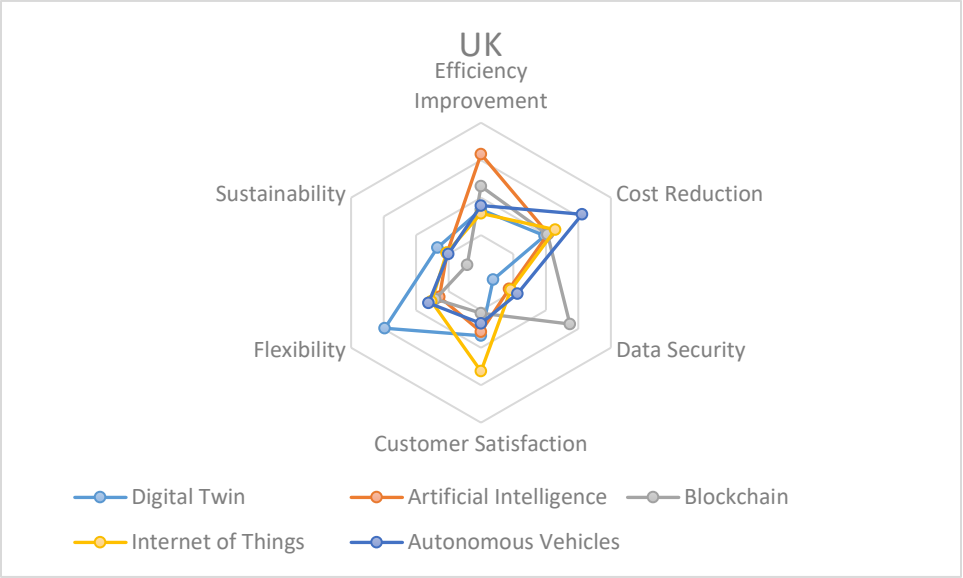


Fig 13.5 UK experts’ weight radar chart

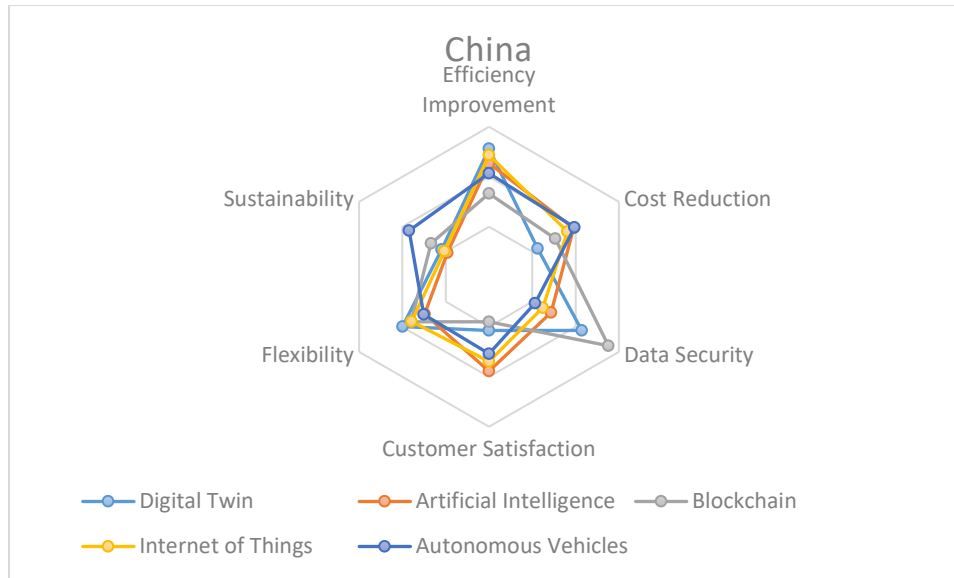


Fig 13.6 Chinese experts' weight radar chart

Tables

Table 13.1 Comparison of the logistics market between the UK and China

Aspect	UK Logistics Market	China Logistics Market
Market Size (2023)	USD 137.86 billion	USD 1.442 trillion
Expected Market Size (2030)	USD 163.77 billion	USD 2.24 trillion
CAGR (2023-2030)	2.91%	6.50%
Key Players	DHL Group, DSV A/S, Kuehne + Nagel, UPS, Wincanton PLC	SF Express, JD Logistics, Cainiao Network, Deppon Logistics, China Post
Main Competitive Factors	Service Quality, Pricing, Geographical Reach, Technological Capabilities, Customer Relationships	Service Quality, Pricing, Geographical Coverage, Technological Capabilities, Customer Relationships
Major Logistics Hubs	Northwest England, London, Manchester, Birmingham	Beijing, Shanghai, Shenzhen, Guangzhou
Market Dynamics Influences	Regulatory changes, Economic conditions, Sustainable practices.	
Key Services	Transport, Warehousing, Freight Forwarding, Supply Chain Management	
Key End-Use Sectors	Manufacturing, Retail, E-commerce.	
Dominant Transport Mode	Roadways	

Aspect	UK Logistics Market	China Logistics Market
Digital Technologies Adopted	AI, IoT, Blockchain, Digital Twin, Autonomous Vehicles.	

Table 13.2 Different technologies and their advantages

Technology	Advantages
Artificial Intelligence	Enhances production efficiency, optimizes workflows, enables new business models
Internet of Things	Improves operational efficiency, real-time data collection, intelligent device interconnectivity
Blockchain Technology	Increases transparency and security, reduces fraud risk, lowers operational costs
Digital Twin Technology	Real-time monitoring of physical assets, optimizes maintenance strategies, reduces downtime
Autonomous Driving Technology	Improves safety and efficiency, reduces traffic congestion and carbon emissions

Table 13.3 The application of different technologies in logistics companies

Company	IoT	Digital Twin	Autonomous Driving	Blockchain	AI
DHL Supply Chain	warehouse	Predictive maintenance in logistics	Self-driving delivery robots	Supply chain transparency	Automated sorting and routing
Maersk	Smart shipping containers	Reduce vessel emissions		“TradeLens” for supply chain	Predictive maintenance for ships
DHL	Connected vehicles	Real-time shipment tracking	Last mile	Secure data sharing	Route optimization
FedEx	Smart sensors for package tracking		Autonomous delivery vehicles	Blockchain for supply chain visibility	Healthcare logistics with AI
Amazon	Warehouse automation	Digital twins for warehouse optimization	Self-driving delivery vans	Blockchain for AWS services	Packaging and product recommendations with AI

Table 13.4 The impact of different technologies on six areas of 3PL companies

Impact Area	Description
Efficiency Improvement	New technologies like AI, IoT, and automation optimize processes, boosting operational efficiency. They also impact strategic decision-making and organizational agility.
Cost Reduction	Technologies such as blockchain and AI reduce costs by minimizing intermediaries, enhancing transparency, and optimizing inventory management. Initial investment costs remain a challenge.
Data Security	Blockchain enhances data security with decentralized, immutable features. However, evolving cyber threats and stricter data laws require ongoing attention.
Customer Satisfaction	Big data analytics and AI improve understanding of customer needs, offering personalized services and enhancing customer support, though factors like service stability also play a role.
Flexibility	Technologies like digital twins and autonomous driving improve responsiveness and adaptability to market changes and disruptions, but strategic adaptability requires further study.
Sustainability	AI optimization and autonomous driving reduce carbon emissions, promoting green logistics. Broader sustainability goals include social and economic factors that need further exploration.

Table 13.5 Scale used for comparison (Rezaei 2015)

Value	Scale
1	Equal Importance
2	Somewhat between Equal and Moderate
3	Moderately more important than
4	Somewhat between Moderate and Strong
5	Strongly more important than other
6	Somewhat between Strong and Very strong
7	Very strongly important than other
8	Somewhat between Very strong and Absolute
9	Absolutely more important than other

$X_B = (x_{B1}, x_{B2}, \dots, x_{Bn})$	(3-1)

$X_w = (x_{1W}, x_{2W}, \dots, x_{nW})$	(3-2)

$\sum_j w_j = 1$	(3-3)

$ w_j - x_{jw} w_w \leq \xi \text{ for all } j,$	(3-4)

ConsistencyRatio(CR) = $\frac{\xi^*}{\text{ConsistencyIndex(CI)}}$	(3-5)

Table 13.6 Summary of some experts' questionnaire results

Expert		1	2	3	4	5
Digital Twin	Best	Sustainability	Efficiency Improvement	Data Security	Efficiency Improvement	Flexibility
	Efficiency Improvement	2	1	2	1	7
	Cost Reduction	3	4	9	3	2
	Data Security	5	1	1	4	9
	Customer Satisfaction	9	1	3	7	7
	Flexibility	3	5	5	3	1
	Sustainability	1	9	5	9	8
	Worst	Customer Satisfaction	Sustainability	Cost Reduction	Sustainability	Data Security
	Efficiency Improvement	6	9	5	9	3
	Cost Reduction	4	2	1	6	2
	Data Security	6	9	9	5	1
	Customer Satisfaction	1	9	6	3	3
	Flexibility	7	4	6	5	9
	Sustainability	9	1	5	1	3

Table 13.7 Illustration of results for Digital Twin Technology

Digital Twin	Efficiency Improvement	Cost Reduction	Data Security	Customer Satisfaction	Flexibility	Sustainability
	0.224	0.149	0.090	0.030	0.149	0.358
	0.277	0.080	0.277	0.277	0.064	0.026
	0.238	0.032	0.381	0.159	0.095	0.095
	0.429	0.167	0.125	0.072	0.167	0.040
	0.084	0.203	0.055	0.084	0.499	0.074
	0.203	0.102	0.087	0.043	0.497	0.068
	0.149	0.149	0.460	0.036	0.085	0.120
	0.381	0.030	0.163	0.163	0.098	0.163
	0.471	0.187	0.042	0.080	0.140	0.080
	0.141	0.085	0.394	0.211	0.122	0.047
	0.381	0.030	0.163	0.163	0.098	0.163
	0.149	0.149	0.460	0.036	0.085	0.120
	0.203	0.102	0.087	0.043	0.497	0.068
	0.171	0.085	0.043	0.171	0.427	0.103
	0.165	0.307	0.031	0.165	0.165	0.165
SUM	3.668	1.857	2.861	1.733	3.191	1.690

Table 13.8 The total score of each technology in different areas

	Efficiency Improvement	Cost Reduction	Data Security	Customer Satisfaction	Flexibility	Sustainability
Digital Twin	3.668	1.857	2.861	1.733	3.191	1.690
Artificial Intelligence	3.584	2.955	2.039	2.771	2.190	1.460
Blockchain	2.626	2.398	4.137	1.391	2.621	1.828
Internet of Things	3.480	2.815	1.797	2.729	2.628	1.551
Autonomous Vehicles	3.049	3.192	1.605	2.270	2.286	2.598

Table 13.9 Experts' Best and Worst Choices

		Efficiency Improvement	Cost Reduction	Data Security	Customer Satisfaction	Flexibility	Sustainability
Digital Twin	Best	5	1	4	0	4	1
	Worst	0	3	4	5	0	3
Artificial Intelligence	Best	3	5	2	3	2	0
	Worst	0	3	4	2	2	4
Blockchain	Best	2	0	8	0	3	2

		Efficiency Improvement	Cost Reduction	Data Security	Customer Satisfaction	Flexibility	Sustainability
	Worst	0	4	0	5	0	6
Internet of Things	Best	5	4	1	3	1	1
	Worst	0	3	4	3	0	5
Autonomous Vehicles	Best	5	4	0	2	1	3
	Worst	2	2	5	2	1	3

Table 13.10 The impact weight of each area on the company

Efficiency Improvement	Cost Reduction	Data Security	Customer Satisfaction	Flexibility	Sustainability
0.297	0.159	0.152	0.101	0.225	0.065

Table 13.11 Rankings and ratings rankings for different technologies

Ranking	Technology	Total weight
1	Digital Twin	2.82
2	Internet of Things	2.72
3	Artificial Intelligence	2.71
4	Blockchain	2.64
5	Autonomous Vehicles	2.57

Table 13.12 UK expert weight average

UK						
	Efficiency Improvement	Cost Reduction	Data Security	Customer Satisfaction	Flexibility	Sustainability
Digital Twin	0.168	0.196	0.037	0.168	0.296	0.134
Artificial Intelligence	0.316	0.207	0.086	0.158	0.128	0.105
Blockchain	0.231	0.205	0.274	0.108	0.141	0.042
Internet of Things	0.158	0.229	0.091	0.263	0.152	0.106
Autonomous Vehicles	0.179	0.311	0.112	0.135	0.162	0.100

Table 13.13 Chinese expert weight average

China						
	Efficiency Improvement	Cost Reduction	Data Security	Customer Satisfaction	Flexibility	Sustainability
Digital Twin	0.256	0.113	0.214	0.107	0.200	0.109
Artificial Intelligence	0.227	0.196	0.144	0.189	0.149	0.096
Blockchain	0.167	0.153	0.276	0.090	0.180	0.134
Internet of Things	0.243	0.181	0.124	0.169	0.179	0.103
Autonomous Vehicles	0.207	0.198	0.106	0.154	0.151	0.184

Table 13.14 Technologies that have the greatest impact in six areas of the company

Number	Key Performance Area	Technology
1	Efficiency Improvement	Digital Twin
2	Cost Reduction	Autonomous Vehicles
3	Data Security	Blockchain
4	Customer Satisfaction	Artificial Intelligence
5	Flexibility	Digital Twin
6	Sustainability	Autonomous Vehicles

E-only Contents

Abstract

Due to the emergence of Industry 4.0 and 5.0, numerous emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Digital Twins, Blockchain, and Autonomous Vehicles are increasingly impacting various aspects of the global logistics industry, which is undergoing significant transformation. These technologies can potentially enhance operational efficiency, reduce costs, improve customer satisfaction, and foster a more responsive and sustainable logistics environment. However, their adoption presents considerable challenges, particularly for third-party logistics (3PL) companies in highly competitive markets like the UK and China. These challenges include high implementation costs, data security risks, regulatory compliance issues, and the need for the workforce to adapt to new technological environments.

This study provides a comparative analysis of the application and impact of these technologies on 3PL companies in the UK and China. Drawing on insights from logistics experts using the Best-Worst method, the research identifies best practices and offers strategic recommendations for optimizing technology integration within different market contexts. The research findings indicate that digital twins have the greatest impact on third-party logistics companies.

Additionally, the study explores the varying degrees of influence that different technologies exert on various areas within third-party logistics companies. This study contributes to a deeper understanding of how emerging technologies can be effectively integrated into the operations of third-party logistics companies to enhance competitiveness and operational efficiency while also considering regional differences in market conditions, regulatory environments, and technological implementation, paving the way for further in-depth research.



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