INSTITUTO
UNIVERSITÁRIO
DE LISBOA

Artificial Intelligence Driving Intelligent Logistics: Benefits, Challenges, and Drawbacks

Rodrigo César da Silva Gonçalves

Master in Computer Science and Management

Supervisor:
Doctor Luísa Domingues, Assistant Professor,
Iscte – Instituto Universitário de Lisboa

June, 2024

TECHNOLOGY
AND ARCHITECTURE

Department of Information Science and Technology

Artificial Intelligence Driving Intelligent Logistics: Benefits, Challenges, and Drawbacks

Rodrigo César da Silva Gonçalves

Master in Computer Science and Management

Supervisor:
Doctor Luísa Domingues, Assistant Professor,
Iscte – Instituto Universitário de Lisboa

June, 2024

Acknowledgment

The journey of this research marks the end of a significant chapter in my academic life at Iscte, filled with challenges that transformed into opportunities for growth and discovery. As this chapter closes, I reflect on the invaluable lessons learned and the enduring relationships forged along the way.

I am profoundly grateful to my supervisor, Dr. Luísa Domingues, whose wisdom and meticulous guidance have been the cornerstone of my development throughout this process. Her unwavering support and insightful critiques have not only enriched my work but also shaped my professional perspective and academic prowess.

I am also immensely grateful to my family for their unwavering support and encouragement. To my mother and father, thank you for believing in me and providing the love and strength I needed to pursue my passions. To my grandparents, whose wisdom and kindness have always guided me, and to my aunt, whose support has been a constant source of motivation, thank you all for being my pillars of strength.

I extend my appreciation to all the experts who contributed to this research. Your enthusiasm and willingness to share your experiences have been fundamental to the depth and breadth of this study.

This journey of developing and conducting this research has been incredibly impactful and enjoyable. Thank you all for being part of this unforgettable journey. Each of you has left an indelible mark on my life, and for that, I am eternally grateful.

Resumo

Esta investigação examina a integração e aplicação de Inteligência Artificial (IA) na logística, focando-se no impacto neste setor. O objetivo é fornecer uma visão abrangente da integração de IA, destacando benefícios, desafios e potenciais desvantagens, auxiliando decisores e profissionais. Para isso, foram conduzidas uma Revisão de Literatura Multivocal (RLM) e entrevistas com especialistas. A RLM sintetizou a literatura académica e cinzenta, proporcionando uma ampla compreensão do conhecimento existente e identificando lacunas. Os profissionais de IA e logística partilharam experiências e conhecimentos, validando as conclusões da RLM e introduzindo novos dados que enriqueceram o estudo, refletindo o impacto de aplicações e desafios reais. Este estudo categoriza benefícios, desvantagens, desafios e implementações práticas da IA na logística. Os principais benefícios incluem o aumento da eficiência, redução de custos, melhoria na tomada de decisões e gestão avançada de dados. O estudo aborda também desvantagens como a potencial deslocação de empregos, preocupações éticas e dependência de dados de alta qualidade, além de desafios como ecossistemas empresariais complexos e falta de competências em IA. Esta investigação fornece uma base estruturada que auxilia académicos e profissionais a tomar decisões informadas sobre a adoção de IA na logística. Destacando os impactos multifacetados da IA, o estudo enfatiza a necessidade de uma abordagem estratégica e bem-informada. Em última análise, a integração bem-sucedida da IA pode melhorar significativamente o desempenho operacional, fortalecendo a inovação de uma empresa e a sua reputação.

Palavras Chave: *Inteligência Artificial*, *Logística*, *Logística Inteligente*.

Abstract

This research examines the integration and application of Artificial Intelligence (AI) in logistics, focusing on how AI can impact the logistics sector. The primary goal is to provide a comprehensive overview of AI integration, highlighting its benefits, challenges, and potential drawbacks to aid decision-makers and practitioners. To achieve this, a Multivocal Literature Review (MLR) and expert interviews were conducted. The MLR synthesized academic and grey literature, providing a broad understanding of existing knowledge and gaps. The study involved seasoned professionals in AI and logistics who shared their experiences and insights, confirming findings from the MLR and introducing new data that enriched the study's depth, ensuring the study reflects real-world applications impact and challenges. This comprehensive framework categorizes the benefits, drawbacks, challenges, and practical implementations of AI in logistics. Key benefits identified include efficiency enhancement, cost reduction, improved decision-making, and advanced data management. The study also addresses drawbacks such as potential job displacement, ethical concerns, and dependency on high-quality data, as well as challenges like complex business ecosystems and the AI skills shortfall. This research provides a structured framework, assisting academics and practitioners in making informed decisions about AI adoption in logistics. By highlighting the multifaceted impacts of AI, the study emphasizes the need for a strategic and well-informed approach. Ultimately, successful AI integration can significantly enhance operational performance and strengthen a company's reputation.

KEYWORDS: *Artificial Intelligence*, *Logistics*, *Intelligent Logistics.*

Contents

List of Figures

List of Acronyms

AI: Artificial Intelligence

AGV: Automated Guided Vehicle

AR: Augmented Reality

CCTV: Closed-Circuit Television

CSCMP: Council of Supply Chain Management Professionals

DSR: Design Science Research

ETA: Estimated Time of Arrival

GIS: Geographic Information System

IoT: Internet of Things

MLR: Multivocal Literature Review

ORION: On-Road Integrated Optimization and Navigation

OCR: Optical Character Recognition

SLR: Systematic Literature Review

UAV: Unmanned Aerial Vehicle

UGV: Unmanned Ground Vehicle

CHAPTER 1

Introduction

1.1. Problem

The logistics industry stands as a key element in global trade, its development is crucial in shaping international economic growth. As economies grow and infrastructures expand, logistics enterprises witness an evolution, broadening service scopes and perfecting transportation networks. This progression not only triggers a shift in the industry's competitive landscape but also lays the groundwork for digital technology to augment supply chain networks [1].

In parallel with this economic evolution, the integration of Artificial Intelligence (AI) within logistics has emerged as a transformative force. This convergence is not merely a trend but a critical step toward efficiency and innovation in the logistics sector. AI's advent, steering away from traditional logistics models, signifies an inevitable transition poised to redefine operational landscapes. This transition holds immense significance, especially in an era where technological innovation reshapes traditional labor paradigms [2].

However, the integration of AI in logistics presents a dual landscape of promise and danger. While it holds the potential impactful benefits, its implementation raises crucial concerns about readiness and unforeseen drawbacks and challenges. Misaligned adoption risks significant disruptions, impacting both individual companies and the broader economy. Meticulous planning and proficient management are pivotal in navigating this transformative shift effectively [2].

1.2. Motivation and Research Question

The motivations for this study are twofold. First, the increasing complexity of global supply chains, exacerbated by geopolitical tensions and the COVID-19 pandemic, necessitates a more agile and intelligent approach to logistics management. Companies like Unilever, Siemens, and Maersk are leveraging AI to navigate these complexities, highlighting the critical role of AI in modern supply chains [3]. Second, many companies do not fully exploit the digital transformation in logistics, marked by a shift towards AI, due to a lack of understanding and preparedness [4]. These factors underscore the critical need for comprehensive research to explore the benefits, challenges, and drawbacks of AI in logistics.

Therefore, this study initiates a crucial exploration, researching into the depths of AI's integration in logistics. By analyzing its implementation, this research aims to uncover the hidden benefits and reveal the details of challenges and drawbacks. This journey holds profound implications, empowering companies to anticipate, prepare for, and mitigate the hurdles poised by this transformative integration. Through this investigation, the aim is to equip businesses with insights that fortify their strategies and operational frameworks among this evolving landscape.

This investigation intends to provide an answer to the following question: How can the incorporation of AI impact the field of Logistics?

The main goal of this study is to furnish companies with a nuanced and comprehensive overview of the multifaceted landscape of AI integration within the logistics sector. By examining the diverse (i) benefits, the (ii) challenges faced while adopting this integration, and investigating potential (iii) drawbacks, this study aims to serve as a pivotal resource for decision-makers. It endeavors to equip businesses with insights needed to make informed decisions regarding the adoption of AI technologies in their logistics operations.

1.3. Methodological Approach

Alignment with Study Goal: In order to elucidate the potential of AI in logistics, this study adopts the DSR methodology. The choice of DSR it is a strategic alignment with the unique demands and dynamic characteristics inherent to the integration of AI within the logistics domain. This chapter delineates the rationale behind the selection of DSR, detailing how its structure impeccably supports the study's objectives, and paves the way for actionable insights and innovations in the field.

Iterative Process for Evolving Technologies: The study's primary objective is to dissect and understand the nuanced interplay of AI in logistics, exposing its latent benefits and confronting its challenges and drawbacks head-on. Also, because of AI's rapid evolution, this methodology allows continuous improvement and refinement. DSR is instrumental in achieving this due to its inherent problem-centric nature, which insists on research that is deeply relevant and immediately applicable to real-world settings [4], [5].

Emphasis on Creativity and Innovation: The study is angled towards pioneering solutions within AI and logistics. DSR's emphasis on innovation ensures that the research contributes not merely to theoretical knowledge but also to groundbreaking, practical solutions in logistics. This methodology's utility and efficacy focus guarantee that the framework is tailored to real-world problem scenarios, aligning with the study's goal [4], [5].

Integrating Stakeholder Feedback: A critical facet of logistics is its orientation towards pragmatic applications. DSR acknowledges this by integrating stakeholder feedback throughout the research process, thus ensuring that developed solutions are attuned to industry needs and preferences. This feature of DSR aids in bridging the theoretical-practical divide, allowing for a seamless fusion of scholarly insights with practical trials [4], [5].

Rigorous Evaluation Process: To ascertain the validity, reliability, and robustness of the research findings, DSR provides a comprehensive evaluation process. This rigorous assessment is crucial in presenting credible, efficient AI integration strategies for the logistics sector [5].

The DSR methodology emerges as key in this research endeavor, intricately woven into the study's research objectives. It provides a robust scaffold that not only supports but enhances the investigation into AI's role in logistics, ensuring that the outcomes are not only theoretically sound but also practically viable and responsive to the ever-evolving demands of this field.

1.4. Structure and Organization

This study is organized into six main chapters, each designed to thoroughly explore the integration of AI into logistics. The **1. Introduction** sets the stage by outlining the problem statement, motivation behind the study, and the contributions it aims to make to the field of intelligent logistics, along with the methodological approach guiding the research.

Following the introduction, the **2. State of Art** chapter reviews current literature and developments in Logistics, AI, and their integration. This foundational knowledge is crucial for understanding the complexities and dynamics of AI in logistics, discussing its benefits, drawbacks, challenges, and applications, culminating with a summary that sets the context for the study according to the literature.

The **3. Methodology** chapter details the research design and framework used to collect and analyze data, justifying the selection of the DSR methodology and explaining how it informs the research process.

Chapter **4. Data Gathering** elaborates on the process of data collection, including how the expert sample was defined and characterized. It discusses the methodologies for contacting experts, the structure of the interviews, and the strategies employed to engage them effectively to maximize the relevance and quality of the information gathered.

The **5. Results** chapter presents detailed accounts of the interviews conducted with seven experts in the field of logistics and AI, analyzing these to extract valuable insights and implications for both practice and theory in intelligent logistics. This chapter also includes a general analysis that examines the duration of the interviews, the extent of expert participation, and a sentiment analysis for each interview.

The study concludes with **6. Contributions and Prospects**, discussing the study's contributions to intelligent logistics and suggesting avenues for future research. This final chapter reflects on how the insights have been integrated into the existing framework and outlines the potential impact of these findings on the practice and study of AI in logistics.

CHAPTER 2

State of Art

2.1. Logistics

Logistics, within the realm of business transactions, centers on the fundamental consumer experience. It constitutes a pivotal industry globally, acting as a catalyst for international economic advancement. The scale and progress of the logistics industry employs a direct influence on economic landscapes, characterized by a symbiotic relationship between investment in logistics assets and the evolution of network economies [1].

Essentially, logistics represents the materialized flow state of goods traversing from supply origins to their destined endpoints. Traditionally reliant on infrastructure, production tools, and labor, the industry has experienced a transition driven by urbanization and escalated population mobility, igniting a more robust market demand for logistics services [6].

The digital era, especially the rapid surge of e-commerce, has propelled the logistics and transportation sector towards a trajectory of sustainable growth. This evolution is supported by the escalating expectations from enterprises and individuals alike, demanding not just timely delivery but also elevated service quality and innovative delivery methodologies [6]. This evolution is further fueled by the integration of digital technology within supply chain networks, a realm where the scale effect and network economy intersect, fostering transformative potential [1].

The increasing influence of e-commerce, with its government support and exponential developmental trajectory, has significantly shaped and impacted the landscape of the logistics industry. This relationship between e-commerce and logistics manifests as a mutual enhancement, each promoting the other's growth and potential [7].

Logistics can be viewed as a process within the broader supply chain framework, encompassing the planning, implementation, and control of the flow and storage of goods. This process includes three critical components: (i) the Purchase and Supply Chain, which is centered on demand forecasting, needs planning, supply source selection, purchase organization, stockpiling, and inventory management; (ii) Storage is another vital component, encompassing transport management, the actual storage, and the management of packaging. Furthermore; and (iii) the Distribution part of logistics is responsible for supply order management, stocking of finished goods, transport supervision, and the provision of customer service. Historically, before 1950, these components operated as individual departments, but they have evolved and are now interconnected, enhancing efficiency and effectiveness in logistics. Moreover, these components do not adhere to a specific linear order of operation, rather, they are intricately interconnected, meaning that any alteration or improvement in one component can significantly influence the entire logistics process. This interconnectedness underscores the dynamic nature of modern logistics, where changes in one area can reverberate across various stages, necessitating a holistic approach to optimization and management [8].

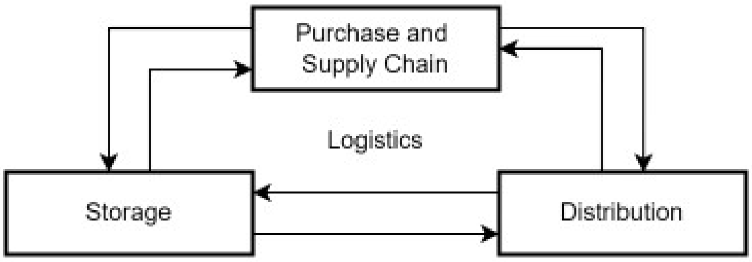

FIGURE 2.1. Logistics as a Process [8]

2.2. Artificial Intelligence

AI stands as a multidimensional technical science born from a fusion of theories, methodologies, technologies, and practical systems. Initially conceptualized in the 1960s, its evolution over more than half a century has led to a mature technological landscape today [9]. Despite its extended development, a unified definition of AI remains elusive, promoting diverse perspectives within academic circles. Fundamentally, AI pursuits to simulate, extend, and augment human intelligence, leveraging mechanical systems or equipment to emulate and amplify human cognitive capabilities [6].

This expansive field intertwines with computer science, drawing significant synergy from its advancement and the progress of allied scientific frontiers. The range of AI's research spans various domains, embracing speech and image recognition, intelligent robotics, and autopilot systems, among others [10]. At its core, AI mirrors human-like intelligence through computer programs, embracing a wide array of applications across industries [2].

Central to AI's essence within the realm of computer science is its pursuit to comprehend intelligence's nature and fabricate intelligent machines capable of mimicking human-like responses. While distinct from human intelligence, AI can emulate and even surpass human cognitive faculties, showcasing its practicality and evolutionary nature. Consequently, this discipline harbors a mixture of uncertainties, contributing to its enigmatic and explorative character [7].

AI's influence extends beyond theoretical realms, penetrating daily life through technologies like intelligent voice systems, driverless technology, and facial recognition, enriching human experiences and improving convenience. Moreover, its integration across sectors such as education, healthcare, marketing, and logistics underscores its role as a catalyst for industrial advancement [11].

In the context of Industry 4.0, AI emerges as a pivotal technology capable of complementing and addressing prevailing challenges alongside additive manufacturing, advanced robotics, drones, the Internet of Things (IoT), and blockchain. This technology harnesses IT systems and algorithms to emulate human intelligence, extracting insights from data for descriptive, predictive, or prescriptive analyses. Its potential lies not only in data extraction but also in optimizing algorithms, thereby offering innovative solutions to prevailing logistical challenges [12].

2.3. Intelligent Logistics: The Integration of Artificial Intelligence in the Logistics sector

Intelligent Logistics covers a transformative integration of technologies within the realm of logistics operations, producing a paradigm shift from conventional methods. This evolution is rooted in the augmentation of logistical workflows with advanced technologies such as AI, leading to a profound alteration in industry standards and business models [6]. The evolution toward what is termed as the "new logistics" represents a departure from traditional practices. This new frontier of logistics manifests distinctive traits: digitalization, networking, automation, intelligence, and flexibility in management [7].

Central to the concept of intelligent logistics is the application of various intelligent technologies, ranging from hardware to the IoT and big data, in order to elevate the logistics system's analytical capabilities, decision-making processes, and overall execution. The core objective lies in fortifying the system's intelligence and automation, thereby optimizing its efficiency and efficacy [11]. Moreover, the integration of AI within logistics conducts a reduction in human labor, both physical and mental, particularly in addressing logistics engineering operational challenges. This integration facilitates a transformation, guiding logistics towards a path defined by improved intelligence and more polished operational independence [7]. It is estimated that the potential incremental value from implementing AI in logistics is 89% [13].

Therefore, the essence of intelligent logistics lies in employing AI and other sophisticated technologies to revolutionize the logistics domain. This transformation goes beyond simply technological integration, instead it represents a fundamental reshaping of logistics frameworks, paving the way for an era defined by elevated intelligence, enhanced efficiency, and increased adaptability.

2.3.1. Benefits

AI integration in Logistics offers some benefits, primarily focusing on Efficiency Enhancement and Cost Reduction, Customer Service Improvement, and Enhanced Decision Making and Data Management.

Efficiency Enhancement and Cost Reduction: The integration of AI in logistics has led to a transformative shift, revolutionizing traditional practices, and emphasizing efficiency through AI-driven solutions. Leveraging intelligent computing, AI optimizes routes, and distribution modes, significantly reducing redundancies while enhancing resource utilization [9], [14].

This technological integration has not only brought about substantial efficiency enhancements and cost reductions but also facilitated swift, data-driven decisions. Businesses employ AI techniques such as Machine Learning to refine processes, respond more agilely to demand, and optimize transportation scheduling, thus aligning with sustainability goals [14], [15].

Simultaneously, the implementation of AI has reshaped logistics by streamlining processes and optimizing resource utilization. Intelligent warehousing technologies, including image recognition and unmanned warehouses, have remarkably reduced labor costs and increased operational efficiency. These advancements collectively pave the way for a more streamlined, cost-effective logistics industry [11].

Customer Service Improvement: In the logistics sector, the integration of AI technologies marks a profound shift in customer service paradigms. Implementing 24-hour customer service managed by AI robot response systems has revolutionized responsiveness and accessibility. This continuous support ensures swift responses to queries, significantly reducing wait times and elevating overall customer satisfaction. Beyond mere responsiveness, AI systems swiftly analyze and address inquiries, providing accurate and relevant information instantly. This precision minimizes errors and ensures reliable support, fostering improved relationships between logistics enterprises and their clientele [1].

In addition, the integration of AI within the logistics sector generates more enhancements that play a pivotal role in streamlining operations, leading to quicker deliveries, adaptable route planning, and heightened responsiveness to customer requirements. The utilization of real-time data analysis and forecasting capabilities is instrumental in pinpointing the most efficient delivery approaches, guaranteeing timely and precise service delivery. Through a comprehensive understanding of historical data and customer preferences, logistics firms can customize their services, providing more focused and efficient solutions [16].

Enhance Decision Making and Data Management: AI has revolutionized logistics, reshaping data management and decision-making processes. Through advanced data analytics and machine learning, companies employ insights from vast datasets, optimizing operations and enhancing efficiency. AI's data analysis proficiency refine logistics operations, enabling informed strategic decisions and precise resource allocation, driving industry competitiveness [9], [14].

By leveraging AI-driven algorithms and data analytics, enterprises gain a comprehensive understanding of their logistics processes. This understanding aids in predicting demand patterns, optimizing resource allocation, and enabling swift responses to market dynamics. AI-powered predictive models mitigate risks by foreseeing potential disruptions, ensuring smoother operations, and fortifying resilience in the face of challenges. The integration of AI equips logistics entities to adapt swiftly and maintain a competitive edge in a dynamic global landscape [1].

Reduce CO2 Emissions: AI-driven optimization strategies have showcased potential decreases in empty running mileages by up to 20%, translating into substantial carbon emission reductions. Additionally, AI's role in real-time route and load optimization has demonstrated fuel consumption reductions of 15%. Integration with electric and autonomous vehicles further enhances these benefits, with AI-managed platooning techniques showing energy consumption reductions of up to 10%. Furthermore, AI-driven backhaul optimization can reduce empty running mileages by 25%, resulting in considerable CO2 emissions reductions. So, the integration of AI in logistics offers a promising avenue for mitigating environmental impact by efficiently managing resources and optimizing operations, thereby contributing to a more sustainable future [17], [18].

2.3.2. Drawbacks

Despite its numerous advantages, the implementation of AI in logistics does pose certain drawbacks. These drawbacks include:

Cybersecurity Vulnerabilities: As AI technology integrates various partners within the supply chain, the sharing of crucial and sensitive information increases, thereby elevating the potential for misuse. This network opens paths for cybersecurity infractions where shared data might be exploited by certain partners, posing a considerable threat to the overall performance and security of the supply chain. The extensive linkage among systems heightens the susceptibility to cyber threats, making it essential for companies to address and mitigate these risks effectively post-implementation of AI [15], [19].

Ethical Implications: Ethical concerns primarily revolve around the perpetuation of biases present in the training data. These biases, embedded during the model's training phase due to historical stereotypes, the underrepresentation of minority groups, or the subjectivity of data creators, can skew AI-driven decision-making. This skew can manifest as unfair prioritization of certain suppliers, products, or regions, leading to systemic disparities and unequal opportunities within the supply chain. With AI redefining our work and social paradigms at an unprecedented rate, akin to the societal transformation triggered by the printing press, the need for ethical guardrails is imperative. Absent these, AI is at risk of replicating real-world prejudices, undermining human rights, and exacerbating divisions. The concentrated development of AI technologies in a few countries by homogeneous teams further escalates this issue, overlooking the cultural diversity that is the hallmark of our global society. This is contrasted with the digital divide, where half the world's population remains offline, further complicating the ethical landscape AI must navigate in logistics and beyond [20], [21].

Historical Data Dependency: This common obstacle arises from the fact that AI technologies, particularly machine learning models, are heavily dependent on historical data to predict future patterns and behaviors. While this reliance is necessary, many organizations face the issue of their data infrastructure not being sufficiently developed to support AI algorithms that require high-quality, comprehensive datasets. Incomplete, inaccurate, or outdated data can undermine the performance of AI models, resulting in inefficiencies and suboptimal decision-making in logistics operations. Moreover, an excessive reliance on the past can cause these systems to miss emerging trends or sudden market shifts, leading to further inefficiencies [14], [15], [22].

Robotics Limitations: In the implementation of AI in logistics, robots largely serve auxiliary roles despite technological advancements. Their functions remain restricted to simpler tasks within closed warehouse spaces, unable to fully replace human functions in more complex outdoor environments. Tasks that demand discernment, adaptability, and specialized execution are optimally and sometimes solely undertaken by human resources. The current limitations in technology and regulatory complexities make widespread adoption of fully autonomous warehouses improbable. This constrains robots from assuming more integral roles within warehouse operations, highlighting the need for further technological advancements to broaden their applications [11], [23].

Uncertainty Human-AI Interaction: The ambiguity in human-AI interaction presents a challenge rooted in comprehending and responding to AI-driven processes. AI systems, being sophisticated and evolving, often pose difficulties in understanding their functioning and interaction patterns for human users. This complexity arises from the AI's capacity to continuously learn and adapt, making it less predictable in its responses, which can create uncertainty and challenges in interpreting and effectively engaging with these systems within the supply chain and logistics context [15].

Workforce Displacement: Particularly affecting roles that involve repetitive tasks susceptible to automation. This shift could disrupt traditional job structures, necessitating retraining programs for employees, which will lead to a higher investment in this area. While some jobs might be replaced, there's also the potential for new opportunities in managing and optimizing AI systems. Organizations need proactive strategies to equip workers with skills that complement AI, ensuring a smooth transition and a balanced collaboration between humans and technology [20], [24].

Vulnerability to underperformance: The implementation of AI in supply chain and logistics management brings forth the potential drawback of negatively impacting overall business performance. This concern stems from the intricate nature of AI-related issues, which, if not managed effectively, could result in adverse effects on various business aspects. Factors such as inaccurate decision-making by AI systems, and complexities in recognizing and rectifying errors might collectively contribute to a decline in business performance. The interplay of these challenges within the supply chain and logistics operations poses a risk that could hinder the efficiency and effectiveness of the entire business ecosystem [15].

2.3.3. Challenges

While integrating AI into the Logistics sector, certain challenges arise.

Legal Liability: Legal concerns emerge as significant challenges in the implementation of AI within logistics. There are concerns regarding potential inaccurate decisions made by AI systems, leading to adverse outcomes that could harm businesses. Some jurisdictions treat AI systems similar to entities, attributing responsibility to the owner in case of any resulting harm to the business or its partners. The challenge with liability regulations lies in balancing the protection of individuals from harm while still permitting companies to innovate. This legal context, observed in certain countries like Saudi Arabia where robots like Sophia are granted citizenship, underscores the need for clear delineation of responsibility and liability in scenarios where AI-driven decisions impact stakeholders within the supply chain [15], [25].

Data Management: Acquiring and managing vast amounts of data necessary for training AI systems proves resource-intensive, particularly for smaller supply chain enterprises lacking robust data management processes and technical infrastructure. The quality, diversity, and representativeness of data are crucial for AI applications like ChatGPT to function effectively within various business operations. However, gaps, inaccuracies, or corruption in data can render AI models ineffective or perpetuate existing biases. Compliance with data privacy regulations, such as General Data Protection Regulation in Europe, and evolving copyright rules for AI compounds these challenges, exposing organizations to legal ramifications due to unintentional violations. Without structured data management processes, scalability and the usefulness of AI applications become obstructed, blocking organizations from fully leveraging the potential insights and analyses offered by AI in handling the complexity of logistics operations [20], [26].

Significant Resource Allocation: An AI system operates through a complex network of processors and components, each requiring regular maintenance and periodic replacement for optimal performance. Implementing AI involves not only these ongoing expenses but also initial investments like licenses and infrastructure setup. The upkeep of these systems is time-consuming and resource-intensive, with significant costs stemming from their substantial energy consumption. Staffing costs are crucial, necessitating the hiring or upskilling of personnel to manage and operate AI systems efficiently. Moreover, data acquisition and preparation present additional financial and temporal challenges, as ensuring data quality for training models involves extensive cleaning and annotating. Hidden opportunity costs also emerge from AI projects misaligned with organizational goals, underscoring the importance of strategic planning and alignment in AI initiatives [24], [27].

Technical Gap: The rapid expansion of AI technologies, particularly within logistics, highlights a critical skill gap stemming from a widespread deficiency in in-house technical expertise among many companies. As AI is poised to disrupt and create millions of jobs globally by 2025, organizations face the dual challenge of preparing for future roles while managing current operations efficiently. This skill gap is a significant barrier to implementing AI in logistics, where specific technical competencies and ongoing oversight are essential for seamless operation. The transition to AI technology demands a comprehensive understanding that spans from system development to database design, a requirement that can be daunting due to AI's complexity and the need for continual input. This situation underscores the urgent need for companies to upskill their workforce, ensuring employees possess the requisite technical skills for successful AI integration. Addressing this gap is crucial for taking full advantage of AI's potential to transform supply chain and logistics activities, thereby enabling organizations to navigate the evolution of work driven by AI and other groundbreaking technologies [15], [28].

Complex Business Ecosystems: Integrating AI into logistics goes beyond just adopting new technologies, it involves a fundamental rethinking of business models and strategies. The "Frankenstein effect" happens where disparate AI applications function in silos, leading to a patchwork of uncoordinated elements within a supply chain rather than a streamlined, unified operation. This lack of integration prevents the full potential of AI from being realized, allowing operational inefficiencies to continue. Moreover, AI systems often fall short in understanding the intricate interplay of complex business ecosystems, cultural nuances, and the subtleties of human decision-making. With vast amounts of data, these systems can struggle to navigate and reconcile differing business models, which can hamper the successful overhaul of business operations. Furthermore, Technocentrism exacerbates the issue by prioritizing technology deployment over strategic alignment with business objectives, risking misalignment and underutilization of AI's transformative potential. Compounding these issues is the challenge of scalability, since transitioning AI solutions from successful pilot projects to full-scale operational tools is often hindered by the complex, variable nature of supply chain environments and the necessity for tailored solutions [14], [20].

Errors Recognition: The challenge of complexity and the recognition of errors stem from the intricate nature of AI techniques. These complexities make it notably difficult to identify and rectify mistakes that might occur across the supply chain. Unlike traditional transaction systems that primarily store and collect data, AI continuously learns and evolves, gathering vast amounts of data daily. Consequently, some AI processes become more complex due to the volume of data involved. This complexity poses a challenge in promptly recognizing errors within the AI-driven operations, impacting the efficiency of error detection and resolution across the supply chain. In addition to that, there is also an issue known as AI overreliance, a challenge where humans tend to accept an AI system's recommendations even when they are incorrect. Ideally, a human collaborating with an AI system should enhance decision-making capabilities beyond what each could achieve independently. However, this overreliance on AI suggestions can lead to compromised decisions, highlighting a significant challenge in the interplay between human judgment and AI [15], [29].

2.3.4. Implementations and Applications

This chapter contains examples and implementations of AI in the process of logistics. From Purchase and Supply Chain, Storage, and Distribution, AI technologies are revolutionizing every step of the logistics process. These examples highlight the potential of AI in optimizing logistics operations [4].

- ***Purchase and Supply Chain***

Image Processing: Incorporating image recognition technology significantly enhances the efficiency and cost-effectiveness of document management systems. SF Express, a leading logistics company, exemplifies the transformative potential of this technology through its application in the processing of waybills. By leveraging machine image recognition, SF Express has been able to dramatically reduce the necessity for manual labor involved in the sorting and processing of documents. This automation not only cuts down on the human resources required but also minimizes the likelihood of errors, thereby increasing the accuracy rates of waybill processing to above 90% [9], [11], [24].

AI-Powered Customer Care: The integration of AI-driven customer service, combining voice semantic analysis, data from call centers, and chatbots, significantly enhances real-time voice recognition and response generation. This intelligent system not only offers personalized and efficient service by providing detailed assistance 24/7 in the customer's language but also benefits logistics providers by reducing response times. It minimizes the need for customer service teams, directing customers to products or transferring them directly to a subject matter expert. Consequently, companies can offer more efficient and faster customer service, ensuring a better experience for both customers and the logistics provider [9], [24].

Inventory Management Algorithms: The integration of predictive analytics algorithms within logistics, powered by AI, serves as a cornerstone for enhancing inventory management and achieving a competitive edge. By harnessing both historical and real-time data, AI-driven tools anticipate demand patterns and inventory fluctuations, enabling businesses to optimize inventory levels, minimize stockouts, and streamline supply chain operations. This foresight not only ensures product availability, thereby increasing efficiency and customer satisfaction but also facilitates the identification of defective products or packaging, preventing them from reaching customers and reducing returns. Furthermore, AI enhances inventory visibility through a unified inventory system, supports the automation of restocking processes, and generates predictive inventory alerts. This reduces operational costs and mitigates stockout issues. On a granular level, AI evaluates factors such as seasonal trends, market environments, sales, promotions, and other historical data to forecast demand accurately, avoiding inventory surpluses or shortages. The automation of purchasing processes, including supplier matching and anomaly detection, is also made possible through AI, driving further optimization in the logistics sector and representing a significant competitive advantage [4], [14], [24].

- ***Storage***

Facial Access Control: Implementing facial recognition in warehouse access control offers heightened security, eliminating the limitations of traditional access methods and providing robust surveillance for post-event investigations, guaranteeing safety to all the inventory in the warehouse [11].

Warehouse Robotics: Underpinned by AI and intelligent robotics, is revolutionizing logistics by significantly enhancing efficiency and reducing manual labor across various operations. This sophisticated integration of technology facilitates a seamless flow in goods handling, from accurate picking with intelligent robots to streamlined loading and unloading processes managed by AI-driven systems. These innovations not only optimize the balance in transportation through autonomous driving tech in unmanned trucks but also introduce cutting-edge methods like voice picking and Augmented Reality (AR) visual picking with wearable tech, thereby elevating accuracy and operational speed. Furthermore, the deployment of Automated Guided Vehicles (AGVs) within warehousing operations underscores a significant shift towards minimizing human intervention, enhancing safety, and improving overall efficiency by performing tasks like sorting and goods pallet movement. Innovations such as Pick-to-Light and Put-to-Light systems utilize barcode scanners synced with digital light displays to guide workers, drastically reducing task time and human error. The adoption of voice recognition software for optimizing picking routes exemplifies the potential of AI in navigating the complexities of warehouse logistics, as demonstrated by industry leaders like Amazon, who have been at the forefront of employing AI and robotics to facilitate automated warehousing, underscoring their commitment to innovation and efficiency enhancement [4], [11], [24].

- ***Distribution***

Digital Mapping: Leveraging Geographic Information System (GIS) technology integrated with AI, this approach provides high-precision positioning, precise address matching, and path planning. Such capabilities are pivotal for informed logistics decision-making. Advanced mapping technologies facilitate accurate location tracking and resource allocation, significantly enhancing the efficiency of logistics operations [9], [11].

Smart Roads: Advanced Road systems are revolutionizing the driving experience by integrating a blend of sensors, solar panels, AI, and big data analytics into the infrastructure, resulting in roads that are more efficient, secure, and environmentally friendly. These intelligent technologies are embedded within the road itself, enhancing visibility, generating energy, and maintaining continuous communication with autonomous and connected vehicles. The integration extends to the broader IoT, encompassing a connected ecosystem where courier drivers equipped with smart uniforms and watches drive smart vehicles on these smart roads. This network includes intelligent signage and ensures that every container, pallet, and package is interconnected through AI and IoT sensors, creating a seamless and highly efficient transport environment [24], [30].

Dynamic Routing Technologies: A key area where AI excels is in optimizing backhauls and finding the shortest path to destinations, addressing the challenge of unloaded trucks which account for a significant portion of total miles driven. AI-powered freight apps such as Convoy, Uber Freight, and Doft enable drivers to efficiently find and deliver backhauls, thereby reducing empty return trips and minimizing fuel waste. Additionally, UPS currently utilizes a system called On-Road Integrated Optimization and Navigation (ORION), which features dynamic vehicle routing. This system continually assesses environmental conditions and sends drivers optimized route information to reduce distances. Collectively, ORION saves between ten to twelve miles per driver per day, and UPS estimates that each mile saved daily per driver can represent up to 50 million dollars in savings per year. This optimization not only improves operational efficiency but also reduces CO2 emissions [14], [24], [31].

Predictive Maintenance: By analyzing historical and contemporary data with machine learning algorithms, predictive maintenance strategies offer forecasts and guidance for vehicle upkeep. These methodologies aim to extend the life of the fleet and diminish periods of inactivity. The integration of AI and ML technologies facilitates the examination of data from IoT devices, GPS, and vehicle records, enabling the anticipation of potential vehicle mechanical issues [24].

Unmanned Delivery Technologies: Unmanned Aerial Vehicles (UAVs, Unmanned Ground Vehicles (UGVs), and unmanned warehouses, powered by AI and robotics, are revolutionizing logistics. These innovations not only cut costs but also enhance efficiency through the use of sensor data fusion and advanced algorithms for precise route planning and execution. The technologies extend to autonomously automated vehicles ranging from vans to cars and buses, which are designed to transport goods more quickly and efficiently. While fully autonomous vehicles face challenges in adoption, semi-autonomous vehicles are on the rise, employing systems like platooning. This technique involves autonomous vehicles following a lead truck with a human driver, synchronizing braking, acceleration, and steering, thereby increasing load capacity, and reducing costs. However, many countries mandate a human driver inside the vehicle to fully control and assess potential road hazards. A notable instance of this technology is the autonomous ship developed by Rolls-Royce in collaboration with Intel, capable of recognizing and defining objects in water, monitoring engine conditions, and selecting optimal routes for faster delivery [7], [9], [11], [24].

2.4. Conclusion

The integration of AI within the logistics sector marks the beginning of a new era of Intelligent Logistics, characterized by innovation, optimization, and transformative potential. AI, evolving from its inception in the 1960s, stands today as a multidimensional science, striving to simulate and extend human intelligence through mechanical systems and computational frameworks [9].

Within the logistics sector, this integration reshapes traditional practices, fostering the evolution towards what is termed the "new logistics." This transformation embodies the essence of digitalization, networking, automation, intelligence, and flexibility in management [7]. Intelligent Logistics represents a departure from conventional methodologies, leveraging AI-driven solutions to optimize efficiency, reduce costs, and enhance customer service [6].

The benefits of AI integration in logistics are numerous, covering efficiency enhancement, cost reduction, improved customer service, and refined decision-making processes through data analytics [9], [15], [17]. Notably, the implementations of AI in logistics exhibit remarkable advancements, from unmanned delivery technologies to image processing systems, automated guided vehicles, and enhanced warehouse security [4], [9], [11].

However, drawbacks accompany this integration, ranging from cybersecurity concerns to ethical implications, workforce displacement, and dependence on historical data [19]–[22]. Also, challenges persist during integration, including liability and legal concerns, data management complexities, skill gaps, and the need for restructuring business models [25], [26], [28].

Ethical considerations surrounding biases in AI models and the ambiguity in human-AI interaction underscore the importance of responsible implementation and continual adaptation [15]. Overall, the fusion of AI and logistics leads to Intelligent Logistics, where embracing AI's capabilities while navigating its challenges is pivotal in shaping the future of logistics, ensuring an efficient, responsive, and ethically responsible integration of technology to meet evolving demands and industry standards.

Following this conclusion, Figures 2.2, 2.3, 2.4, and 2.5 present detailed overviews of the application of AI in logistics, each focusing on a different dimension. Figure 2.2 displays the benefits, Figure 2.3 highlights the drawbacks, Figure 2.4 identifies the challenges, and Figure 2.5 illustrates the implementations. Each table includes the categories of the found features, identified in the performed Multivocal Literature Review (MLR). The categories, presented in each figure, were not explicitly identified in the literature but were displayed to aggregate similar features in order to facilitate a more organized and insightful analysis. Additionally, the last column of each table contains the references from which these features were extracted. This segmented approach allows for a clearer and more focused examination of each dimension within the context of AI application in logistics.

Category	Features	Reference(s)
Operational Efficiency Improvement	Automate Routine Tasks	[9, 11, 14]
	Optimize Delivery Routes	[9, 14, 15]
	Streamlining Processes	[11, 14, 15]
	Optimize Resource Utilization	[9, 11, 14]
	Automate Sorting and Picking	[11]
	Optimize Complex Workflows	[14, 15]
Enhance Decision Making	Predictive Analytics	[1]
Data Management Improvement	Analyze Vast Datasets	[9, 14]
Enhanced Customer Satisfaction	Higher Responsiveness to Customer Requirements	[16]
	Provide Tailored 24/7 Customer Service	[1]
Optimized Fuel Consumption	Distribution Path Algorithms	[17, 18]
	AI-driven Backhaul	[17, 18]

FIGURE 2.2. Benefits Insights Framework from MLR

Drawbacks - MLR	Features	Reference(s)
Workforce Displacement/Transformation	Job Losses	[20, 24]
	Loss of Human Touch	[20, 24]
Ethical Implications	Biases Data	[20, 21]
Historical Data Dependency	Dependency on the Quality of Past Data	[14, 15, 22]
	Insufficient Amount of Data	[14, 15, 22]
Vulnerability to underperformance	Inaccurate Decision-making	[15]
	Poor recognition of self-errors	[15]
Cybersecurity Vulnerabilities	Extensive System Interconnectivity	[15, 19]
Technical Restrictions of Robotics	Simple, Limited Tasks in Controlled Environments	[11, 23]
Uncertainty Human-AI Interaction	Complex and Evolving AI Systems	[15]

FIGURE 2.3. Drawbacks Insights Framework from MLR

Challenges - MLR	Features	Reference(s)
Complex Business Ecosystems	Overcoming Siloed Complex Systems Architecture	[14, 20]
	Understanding Human Decision-making	[14, 20]
Renewing Outdated Business Cultures	Address Cultural Nuances and Resistance to Change	[14, 20]
Data Management	Ensure Robust Data Management Processes	[20, 26]
	Acquiring Necessary Amount of Data	[20, 26]
	Eradicate Data Biases	[20, 26]
AI Skills and Knowledge Shortfall	Reduced Number of AI Experts	[15, 28]
Significant Resource Allocation	Significant Investment of Time, Money, and People	[24, 27]
Legal Liability	Accountability for Inaccurate AI-decisions	[15, 25]
Detecting and Correcting AI Errors	Difficult to identify and correct mistakes	[15, 29]

FIGURE 2.4. Challenges Insights Framework from MLR

Category - Process of Logistics	Features	Reference(s)
Purchase and Supply Chain	Forecast Demand and Inventory Management Algorithms	[4, 14, 24]
	Image Processing	[9, 11, 24]
	AI-Powered Customer Care	[9, 24]
Storage	Warehouse Robotic Automation	[4, 11, 24]
	Biometrics Access Control	[11]
Distribution	Dynamic Routing Technologies	[14, 24, 31]
	Vehicles Predictive Maintenance	[24]
	Unmanned Delivery Technologies	[7, 9, 11, 24]
	Digital Mapping	[9, 11]
	Smart Roads	[24, 30]

FIGURE 2.5. Implementations Insights Framework from MLR

CHAPTER 3

Methodology

3.1. Design

The study employs the DSR methodology, chosen for its robust framework that supports the development of innovative, real-world solutions. DSR is particularly crucial for this research because it focuses on creating and critically evaluating artifacts designed to tackle specific problems. This makes it ideal for exploring the complex implications of AI in logistics. The iterative nature of DSR is essential for this study, given the rapid advancements in AI. It allows for the continuous refinement and adaptation of solutions, addressing emerging challenges and opportunities specific to the logistics sector. [4], [32].

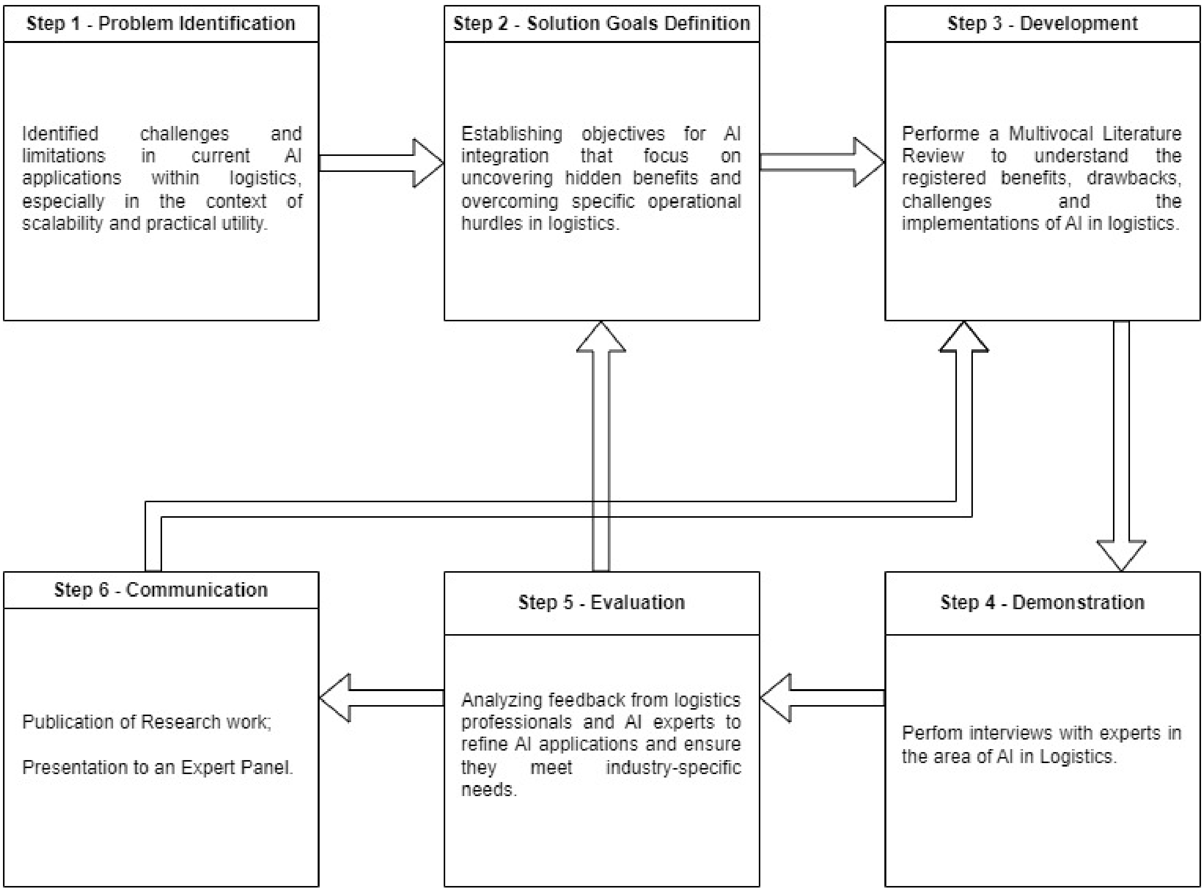

FIGURE 3.1. Diagram of the iterative cycle of the applied DSR methodology in the study

The incorporation of an iterative cycle in the DSR methodology, presented in the Figure 3.1 is a cornerstone of this study, allowing for continuous refinement of solutions based on feedback and emerging insights [4].

In the Problem Identification step, challenges and limitations in current AI applications within logistics were identified, particularly in terms of scalability and practical utility. An unstructured review of the existing literature was conducted to uncover these issues. As AI is relatively new with much still to be discovered, its integration raises both concerns and potential drawbacks alongside its benefits. [4].

The next step, Solution Goals Definition, involves defining the research objectives, which center on an in-depth exploration of the practical benefits and challenges associated with AI adoption in the logistics sector. The aim is to discern concrete operational gains such as process efficiencies, error reduction, and sector-specific innovations stemming from AI integration, thereby offering a nuanced and comprehensive understanding of the technological shift's impacts in logistics.

The Development step incorporates a MLR, starting with the conduction of a Systematic Literature Review (SLR) through the PRISMA guidelines, using the keywords "Artificial Intelligence" and "Logistics" across the following databases: IEEE Xplorer; Scopus; ACM Digital Library; and Web of Science. The initial search yielded 183,894 studies, which were refined through multiple filters. The first filter narrowed the selection to 12,847 studies by requiring both keywords in the title, abstract, or keywords sections. A second filter reduced this number to 194 by requiring the keywords in the titles alone, and a third filter further refined this to 138 studies from 2020 to 2023. After a manual review of titles, abstracts, and conclusions, 14 studies were selected.

In addition to the SLR, the research included a review of grey literature to incorporate more recent and practical insights to the findings from the SLR. These sources were chosen for their recognition by reputable entities and their suggestive titles. This review targeted articles published by governmental organizations such as UNESCO, the European Parliament, and the European Commission, as well as esteemed newspapers like Forbes and Financial Times, and industry-leading companies and consultancies including DHL, Deloitte, McKinsey, IBM, and BCG. Contributions from top universities like Stanford and MIT were also examined. These contributions were extracted from podcasts and posts on the universities' websites, representing grey literature as they are not yet published in traditional academic formats. This selection of grey literature was strategically aimed at updating the SLR with up-to-date details and real-world applications from influential and authoritative sources. From this review, 17 sources were identified, offering practical insights and real-world applications that enriched the research's theoretical findings.

During the Demonstration step, the objective was to identify the benefits, drawbacks, challenges, and implementations of AI in logistics, and to update the findings from the literature review. A series of interviews were conducted with a diverse panel of experts, categorized into six distinct groups to ensure a comprehensive understanding of AI's impact on logistics from multiple perspectives. The goal was to find experts with strong positions on the impact of AI who could provide additional insights. The categories included: (i) CEO and Executive Logistics Leader, who provide strategic insights and overarching industry trends; (ii) Expert from a Logistics Company, offering practical, hands-on knowledge about operational challenges and advancements; (iii) Expert from a Company using Logistics in B2B contexts, sharing how AI influences business-to-business logistics efficiency; (iv) Expert from a Company using Logistics in B2C contexts, highlighting the effects on consumer-facing supply chains; (v) Academic context, providing theoretical and research-based perspectives on AI and logistics; and (vi) Expert from a Logistics Services Consulting Company, who bring a broad view from advising various organizations on best practices and innovation in logistics. This diverse and expert panel was designed to capture a holistic view of AI integration in logistics, encompassing strategic, operational, theoretical, and practical dimensions.

In the Evaluation step, feedback from professionals and experts gathered during the interviews is analyzed to update the identified benefits, drawbacks, challenges, and implementations of AI in logistics. This evaluation process involves combining insights from the MLR and expert interviews to identify common themes, discrepancies, and unique contributions.

Finally, in the Communication step, the research findings will be communicated effectively to ensure broad dissemination and relevance to real-world scenarios. The results of the study will be published in collaboration with Iscte-IUL University, showcasing the comprehensive analysis and insights gained from the research. Additionally, the final results will be shared with all the experts involved in the interviews, providing them with detailed feedback and actionable recommendations. This step ensures that the knowledge generated from the study is not only academically rigorous but also practically valuable, enabling industry experts to leverage AI integration in logistics effectively.

3.2. Interviews Context

3.2.1. Contacting the Experts

After the selection of experts based on their extensive experience and relevance to the study, the initial contact was made through LinkedIn. Given LinkedIn's 300-character limit for connection messages, it was essential to craft concise yet engaging messages that effectively introduced the research and requested an interview. The first message employed is represented in the Appendix A, as "First Message". Subsequently, to appear less intrusive and more considerate of the experts' comfort with the topic, a second message, represented in the Appendix A, as "Second Message", was used.

These messages were designed to be respectful of the experts' time while highlighting the significance of their potential contributions. The response rate was encouraging, and for those who responded positively, follow-up was conducted via email, providing additional details about the research and its objectives. This follow-up ensured that the experts had all necessary information to make an informed decision about their participation. In the subsequent phase, the scheduling of the meetings was handled by the experts themselves, allowing them to choose convenient times, thereby fostering a collaborative and accommodating environment.

3.2.2. Conducting the Interviews

The interviews were conducted live using online meeting platforms such as Microsoft Teams, Google Meet, and Zoom. This choice facilitated real-time interaction, which is crucial for capturing the nuances of expert insights and enabling immediate clarification of any ambiguities. The live format also allowed for a more dynamic and engaging exchange, which is often lacking in asynchronous communication methods.

To enhance the quality and depth of the interviews, an AI assistant from Fireflies.ai, supported by a pro subscription, was used. This AI tool was instrumental in recording and transcribing the conversations, thereby ensuring that no critical points were missed. The AI assistant provided valuable metrics, including speaker identification, keyword extraction, sentiment analysis, and actionable insights. By leveraging these features, the tool facilitated a comprehensive analysis of the interviews, enabling a detailed and accurate understanding of the experts' perspectives.

3.2.3. Interview Structure

The interviews were methodically structured into two distinct parts to balance structured inquiry with open-ended feedback. In the first part, the experts were encouraged to speak freely about the topics of interest, such as the benefits, drawbacks, challenges, and implementations of AI in logistics. This approach was designed to elicit genuine, unfiltered insights, allowing the conversation to flow naturally and organically. By not confining the experts to a rigid structure, the goal was to capture the breadth and depth of their knowledge and experiences.

In the second part of the interview, the summarized table represented in the Appendix A, in Figure 7.1 in, derived from the MLR findings, was presented. This table served as a reference point for the experts to provide their comments, including agreements, disagreements, and suggestions for additions or modifications. This segment was crucial for validating the findings from the literature review and incorporating the experts' practical perspectives. It ensured that the theoretical insights were grounded in real-world applications and experiences, thereby enhancing the robustness and credibility of the research.

3.2.4. Expert Engagement

The engagement of the experts was exemplary, with all participants demonstrating a high level of cooperation and openness. Each interview proceeded smoothly, characterized by meaningful dialogue and the sharing of invaluable insights. The experts' willingness to participate and contribute significantly enriched the research, providing a diverse range of perspectives that were essential for a comprehensive analysis of AI in logistics.

CHAPTER 4

Data Gathering

4.1. Sample Definition

To ensure a comprehensive understanding of AI's impact on logistics, a diverse and expert panel was established. This panel was selected to include individuals who are recognized authorities in their respective fields, each bringing invaluable insights and expertise. The selection process was rigorous, prioritizing leaders and specialists with significant contributions and influence in the logistics and AI sectors. These experts, hailing from prestigious institutions and leading global companies, were chosen to provide a well-rounded and comprehensive perspective on the integration of AI in logistics. The panel was categorized into six distinct groups to cover the full spectrum of relevant expertise:

1 - CEO and Executive Logistics Leader: This category includes a top-level executive who provides strategic insights and industry trends. This leader has extensive experience in managing and guiding logistics operations. Their perspective is crucial as they set the vision and direction for AI integration within their organization, ensuring alignment with long-term business goals. With a background in strategic advisory roles and hands-on leadership in major logistics companies, their insights help to understand the broader industry shifts and strategic challenges that AI presents.

2 - Expert from a Logistics Company: This professional is deeply involved in logistics operations and brings practical, hands-on experience. Their expertise covers the implementation of cutting-edge technologies and sustainable practices in a large logistics firm. They provide detailed accounts of the operational challenges and successes in integrating AI into logistics, highlighting practical issues such as process optimization, technology adoption, and the impact on day-to-day operations. Their role is essential in understanding the practicalities and nuances of AI deployment in the logistics industry.

3 - Expert from a Company using Logistics - B2B: This category focuses on a professional from a business that operates in a business-to-business context, offering insights into how AI affects logistics efficiency, reliability, and cost-effectiveness. This expert works on enhancing supply chain operations through advanced technologies. Their feedback helps to understand AI's impact on supply chain management, inventory control, and operational efficiencies in a B2B environment, providing a perspective on how AI can transform logistics operations within large corporations that rely heavily on logistics.

4 - Expert from a Company using Logistics - B2C: This individual is from a company that delivers products directly to consumers, offering a unique perspective on how AI influences consumer-facing logistics. They provide insights into last-mile delivery, customer service, and order fulfillment. Their experience is particularly valuable in understanding how AI-driven solutions can enhance efficiency, accuracy, and customer satisfaction in consumer logistics. This expert highlights the end-to-end impact of AI on the logistics chain, from warehousing to delivery.

5 - Academic Expert: This academic provides theoretical and research-based perspectives on AI and logistics. Their involvement ensures that the study is grounded in current research and academic rigor. The academic can identify emerging trends, potential future developments, and theoretical frameworks that can be applied to better understand AI's role in logistics. Their insights into ethical considerations, technological advancements, and societal impacts are crucial for a well-rounded analysis of AI integration.

6 - Expert from Consulting Logistics Services: This professional brings a broad view from advising various organizations on best practices and innovations in logistics. They offer a cross-industry perspective, identifying common challenges and successful strategies for AI integration. With experience in strategic consulting and operational optimization, this expert provides practical recommendations based on extensive industry knowledge. Their insights help bridge the gap between theory and practice, offering actionable solutions for effective AI implementation.

By including these six categories, the study aims to capture a holistic view of AI integration in logistics, encompassing strategic, operational, theoretical, and practical dimensions. This diverse panel ensures that the research findings are comprehensive and applicable across different facets of the logistics industry, providing valuable insights that can inform both academic understanding and industry practices. The broad representation of stakeholders supports the creation of inputs that are not only innovative but also grounded in real-world practicality and industry-specific needs.

4.2. Sample Characterization

The sample characterization aims to provide a detailed description of the diverse panel of interviewed experts selected for this study.

1 - Bart De Muynck - Founder & CEO @ Bart De Muynck LLC: based in Texas, United States, is a prominent figure in the supply chain and logistics sector with over 30 years of extensive experience. As the Founder and CEO of Bart De Muynck LLC, he provides strategic advice to logistics tech vendors ranging from startups to industry leaders. His previous roles include Chief Industry Officer at project44, Research

Vice President in Logistics Technology at Gartner, and Enterprise Architect at PepsiCo. Bart is a member of the Forbes Technology Council and the Council of Supply Chain Management Professionals (CSCMP) Executive Inner Circle. He holds a master's degree in business economics from KU Leuven in Belgium. His broad expertise and strategic insights make him an invaluable voice in discussions on the integration of AI in intelligent logistics, and the interviewed for the **CEO and Executive Logistics Leader** category.

2 - Klaus Dohrmann - VP @ DHL: based in Bonn, Germany, is the Vice President and Global Head of Innovation & Trend Research at the DHL Innovation Center. In this role, he leads global initiatives in logistics innovation and trend research, focusing on integrating advanced technologies and sustainable practices into DHL's operations. Previously, Klaus held key positions at DHL, including Vice President of Innovation for Europe and Trend Research. He holds a Doctorate in Economics from the University of Duisburg-Essen, where his research centered on "Green Logistics." Klaus's leadership and innovative approaches have significantly enhanced DHL's operational efficiencies and sustainability, positioning him as a key figure in the logistics industry, and for that, the interviewed for the **Expert from a Logistics Company** category.

3 - Akshay Rastogi - Product Manager Director @ Oracle: based in Bengaluru, India, is a seasoned expert in the supply chain and logistics field with over 14 years of experience. He is the Product Management Director at Oracle, leading the development of IoT Intelligent (SaaS) Applications that enhance real-time visibility and insights across various industries. Previously, Akshay was a Product Manager at Infor and played a key role at HCL Technologies in implementing advanced supply chain solutions. He holds an MBA in Retail and Supply Chain from the Birla Institute of Management Technology. Akshay's expertise and strategic vision drive his commitment to digital transformation and operational excellence in the logistics sector, and so, the interviewed for the **Expert from a Company using Logistics - B2B** category.

4 - Peter Grimvall - Head of Supply Chain Design and Planning @ IKEA: based in Basel, Switzerland, has been recognized for his transformative leadership as Head of Supply Chain Design and Planning at IKEA. He led the integration of AI into IKEA's logistics, optimizing inventory management and improving global service levels through machine learning and AI-driven demand sensing. Prior to IKEA, Peter enhanced logistics at DeLaval and held key roles at Volvo Trucks and Volvo Parts. He now focuses on driving international growth with machine learning solutions at Modulai. Peter holds an MSc in Industrial Engineering and Management from Linköping University and a Certificate in AI from MIT Sloan School of Management. With this, Peter is the interviewed for the **Expert from a Company using Logistics - B2C** category.

5 - Paulo Carvão - Senior Fellow @ Harvard University: originally from Rio de Janeiro, Brazil, and now based in Massachusetts, United States, is a distinguished figure in technology, leadership, and academic world. He is a Senior Fellow at Harvard University, focusing on Tech Policy, Technology and Society, and Social Entrepreneurship. With over three decades at IBM in senior leadership roles, Paulo has influenced strategic directions in public cloud and hardware divisions. His expertise includes digital transformation and AI applications in business. Paulo also contributes to ethical discussions on technology at Harvard's Edmond & Lily Safra Center for Ethics and serves on various advisory boards and venture capital initiatives. He holds a Bachelor of Science in Electrical and Electronics Engineering from the Instituto Militar de Engenharia, an MBA in Marketing from Pontifícia Universidade Católica do Rio de Janeiro, and executive education from The Wharton School. His extensive experience in technology-driven transformations and strategic advisory roles makes him not only a key voice in exploring AI's impact on logistics but also, the interviewed for the **Academic Expert** category.

6.1 - Ignacio Prieto - Strategy and Operations Consultant @ McKinsey: originally from Santiago, Chile and now based in Chicago, Illinois, he specializes in optimizing supply chain processes, including procurement, planning, warehousing, and transportation. Prior to McKinsey, Ignacio interned at Boeing and Amazon, focusing on make/buy decisions and price competitiveness. He also improved procurement and category management as a Corporate Strategy Consultant at Cencosud. Ignacio holds an MBA from the University of Michigan and a degree in Electrical and Electronics Engineering from Pontificia Universidad Católica de Chile. His experience and academic background make him a valuable asset in discussions on intelligent logistics solutions, and also the interviewed for the **Expert from Consulting Logistics Services** category.

6.2 - Julian Fischer - Partner @ McKinsey: based in Munich, Germany, Julian is a Partner at McKinsey with a decade-long focus on enhancing operations and supply chains across industries such as pharmaceuticals and engineering. His expertise encompasses leading tech-enabled transformations to improve service and productivity, including the implementation of advanced planning systems and process mining. Prior to McKinsey, he worked at Knorr-Bremse and BMW in supply chain roles. Julian holds an M.Sc. in Management and Technology from the Technical University of Munich, and an MBA from Université du Québec à Trois-Rivières. Julian is featured as the **Expert from Consulting Logistics Services** category.

4.3. Sample Characterization

In this section, we delve into a detailed analysis of the interviews conducted with industry experts to extract valuable insights and contributions that highlight the impact and integration of AI in logistics. Each interview is reviewed to extract the core themes and perspectives shared by the experts, enabling a deeper understanding of how AI technologies are shaping current and future logistics practices.

To enhance the visualization and comprehension of these insights, word clouds were generated from the transcripts of each interview. These visual representations were organized to include the 50 most common and meaningful words related to the matter at hand. The selection was manually filtered to ensure relevance and focus, thereby providing a succinct graphical depiction of the predominant themes discussed. At the end of each interview section, a summary table will be provided. This table will be similar to the one from the literature review, but it will specifically showcase the new insights gathered from each interview. In the table, new inputs, not found in the original table, will be highlighted in green to distinguish them.

4.3.1. Interview 1

The comprehensive interview with Bart De Muynck delved into the nuanced and transformative impact of AI in logistics. These discussions revealed a wealth of insights, encompassing the strategic applications, practical challenges, and long-term implications of AI technologies.

Bart detailed the application of AI differently in warehousing and transportation sectors. In warehousing, AI-driven robotics automate repetitive tasks like picking and packing, significantly enhancing operational efficiency and addressing labor shortages by performing tasks that traditionally required human intervention. This shift not only speeds up operations but also reduces human error and workplace injuries. For transportation, Bart described AI as "augmented intelligence," enhancing human decision-making and workload management. This form of AI helps logistics professionals handle more tasks efficiently by providing advanced navigational aids, optimizing routes, and foreseeing logistical complications, thereby supporting rather than supplanting human workers.

One of the standout benefits of AI, as highlighted by Bart, is its role in improving safety across logistics operations. He explained how AI-equipped autonomous vehicles and robotic systems in warehouses reduce risk by minimizing the human role in potentially hazardous environments. These technologies are designed to detect and navigate around obstacles, reducing workplace accidents. Therefore, mitigating risks in both warehouse facilities and on the road. Moreover, AI's predictive maintenance capabilities ensure machinery operates within safety parameters, proactively addressing potential failures before they pose risks.

Bart discussed the transformation of the workforce due to AI, noting both the potential displacement of jobs and the creation of more engaging, high-value roles. He emphasized that while AI might reduce the need for human involvement in mundane tasks, it simultaneously creates opportunities for employees to engage in more complex, decision-making roles that require human insight. Bart also highlighted that talent attraction is boosted because employees usually prefer to work at companies that employ modern technologies like AI. The ethical implementation of AI, according to Bart, involves strategies that enhance jobs and worker satisfaction without leading to significant job loss, promoting a positive transition within the workforce.

The interview revealed AI's critical role in managing the vast amounts of data generated in logistics operations. Bart pointed out that AI systems excel in aggregating, organizing, and analyzing data to ensure its accuracy and utility. High-quality data is crucial for effective decision-making in logistics, where predictive analytics can forecast potential issues and suggest strategic responses. This ability to derive accurate insights from data helps logistics operations reduce waste, optimize resources, and improve overall efficiency.

Bart highlighted several challenges in integrating AI into the conservative logistics sector, including cultural resistance and the need for substantial organizational change. The adaptation required to incorporate AI technologies involves not only technological updates but also shifts in corporate culture and employee training. He noted that these changes require strong leadership and a clear vision for the future of logistics operations.

Discussing the potential drawbacks associated with AI, Bart emphasized the importance of robust cybersecurity measures to protect against the misuse of AI technologies. He detailed how AI systems could be exploited for malicious purposes if not adequately safeguarded, making cybersecurity a critical component of any AI implementation in logistics.

Looking to the future, Bart expressed a strong belief in the strategic benefits of AI in logistics, noting its potential to drive significant innovations in customer service and operational efficiency. He envisioned a logistics industry increasingly driven by data and analytics, with AI at the forefront of creating competitive advantages and adapting to rapidly changing market conditions.

The word cloud generated from the interview with Bart De Muynck, represented on Figure 4.1, visually encapsulates the key themes and terms discussed regarding the integration of AI in logistics.

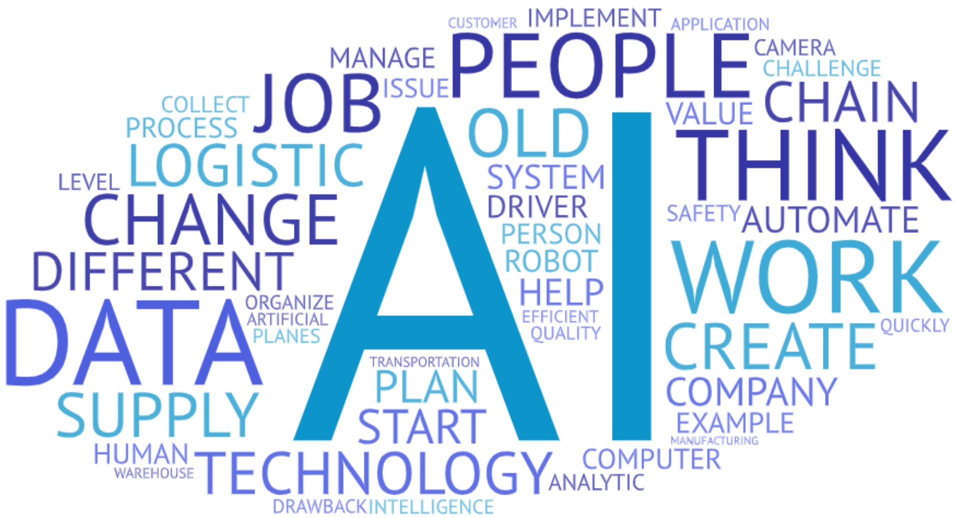

FIGURE 4.1. Word Cloud for Interview 1

Prominently featured words such as "Technology," "Data," "Logistics," "Supply & Chain", and "AI" highlight the central focus of the discussion on how AI is revolutionizing the logistics industry. Words like "Change," "Implement," "Challenge," and "Plan" underscore the dynamic nature of this technological integration, emphasizing both the opportunities and obstacles faced by logistics professionals.

The presence of terms like "Safety," "Work," "People," and "Job" reflects the significant impact of AI on workforce dynamics, safety improvements, and job transformation within the logistics sector. The word "Think" invites a reflection on the strategic thinking required to effectively integrate AI technologies into existing logistic frameworks, pointing towards a future where AI not only augments but transforms industry practices.

In conclusion, the dimensions and features discussed in the interview with Bart are as follows. The benefits are Efficiency Enhancement and Cost Reduction, Enhance Decision Making and Data Management, with Talent Retention and Attraction and Overall Safety being new entries compared to the MLR findings. The drawbacks include Cybersecurity Vulnerabilities, Ethical Implications, Workforce Displacement. The challenges are Data Management, Technical Gap, and Complex Business Ecosystems. The implementations for Purchase and Supply Chain process include Inventory Management Algorithms, for Storage include Warehouse Robotics, and, as a new entry compared to the MLR findings, Unmanned Machinery Technologies, and for the Distribution, Unmanned Delivery Technologies, Dynamic Routing Technologies, and Predictive Maintenance.

4.3.2. Interview 2

The comprehensive insights from Klaus Dohrmann on the integration of AI in logistics provide a rich exploration of AI's transformative potential across various operational spectrums. His detailed discussion highlights the multifaceted applications of AI, including advanced predictive analytics, the facilitation of enhanced customer service, and the improvement of safety and security protocols.

Klaus began by emphasizing the importance of defining AI and its applications. He categorically broke down AI into several key areas such as generative AI, computer vision AI, sound AI, and AI analytics, discussing each in context of their specific uses and maturity levels within logistics.

Generative AI, as noted by Klaus Dohrmann, finds its applications primarily in areas that are not unique to logistics but are common across various industries, such as back-office processes, legal frameworks, sales, and customer interactions. Despite its benefits, generative AI does not present a distinct advantage in logistics over other sectors. Klaus emphasizes that while generative AI offers substantial benefits to industries like insurance, finance, and banking, its impact within logistics is relatively modest. This perspective underscores the broader utility of generative AI in automating routine tasks and enhancing customer service, yet it highlights the industry-specific limitations in leveraging these technologies for unique logistics challenges.

In contrast, computer vision AI, according to Klaus, promises the most substantial impact on logistics. This technology is employed extensively for operational efficiencies—tracking assets, monitoring shipments, and improving safety protocols through image and video data analytics. This broad range of use cases shows how computer vision AI not only enhances operational efficiency but also plays a crucial role in compliance monitoring, ensuring that both personnel and machinery operate within safe parameters.

Klaus also highlighted sound AI's utility in predictive maintenance, which is particularly effective in monitoring the health of conveyor belts and sorting systems through sound data. This application is crucial for preemptively addressing maintenance needs, thereby minimizing downtime and extending the lifespan of essential machinery.

AI analytics is celebrated for advancing beyond traditional big data analytics, providing deeper, faster insights that significantly boost operational decision-making. Klaus discusses how AI enhances the efficiency of logistical operations by optimizing routes, managing inventories, and forecasting demands with greater precision.

However, Klaus candidly addresses the substantial challenges associated with AI integration. The initial financial outlay and the scale of organizational change required are non-trivial, coupled with high resource allocation needs that further complicate rapid deployment and adoption. Integrating AI into existing logistic frameworks is not merely a technical upgrade but a comprehensive shift involving extensive training, adjustments in business processes, and a transformation in corporate culture. The slow adoption rates in traditionally conservative logistics sectors compound these challenges, as does the need for ongoing education and adaptation among the workforce.

Moreover, Klaus delves into the ethical implications and security concerns brought forth by AI applications. He highlights the dual nature of enhanced security and surveillance capabilities, while they improve safety and compliance, they also raise significant privacy issues. The ethical deployment of AI must consider the balance between operational benefits and the rights of individuals, ensuring that data collection and monitoring do not infringe on privacy.

The discussion also covers the potential drawbacks once AI systems are implemented, including the dependency on high-quality data. Poor data quality can lead to inaccurate analytics, potentially compromising decision-making processes. Additionally, the integration of AI can lead to workforce displacement, creating a need for careful management of human resources.

The word cloud generated from the interview with Klaus Dohrmann visually encapsulates the core themes and concepts discussed regarding the integration of AI in logistics.

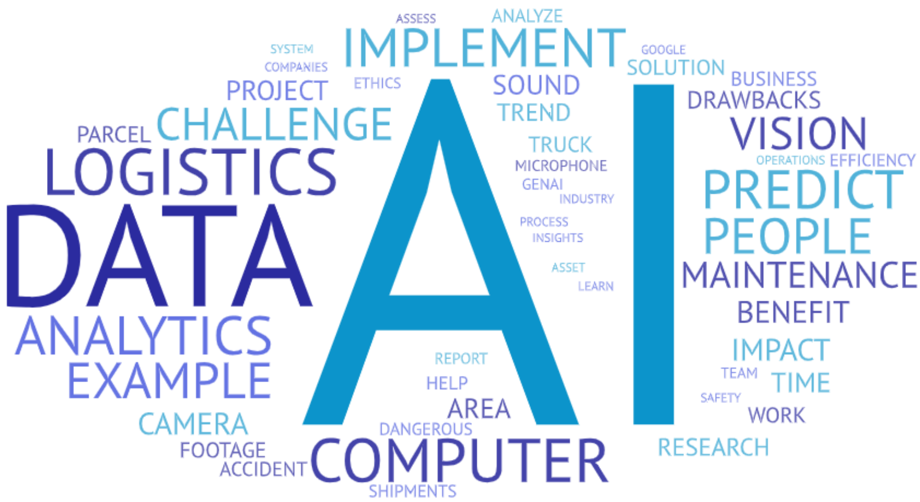

Figure 4.2. Word Cloud for Interview 2

Highlighted words such as "Computer & Vision," "Data," "Logistics," "Predict & Maintenance," and "AI" highlight the critical focus areas that Klaus identified as transformative for the logistics sector.

Words like "Implement," "Challenge," "Efficiency," and "Analytics" underscore the multifaceted impact of AI technology. These terms not only reflect the potential improvements AI can bring in terms of operational efficiency and data handling but also hint at the complexities involved in integrating advanced technologies within existing systems.

The presence of "Camera," "Microphone," and "Sound" indicates specific AI applications discussed by Klaus, particularly in the realms of computer vision and sound AI for monitoring and predictive maintenance. These applications are crucial for enhancing safety, optimizing asset use, and preventing system failures before they occur.

The inclusion of "Ethics," "Drawbacks," and "Dangerous" points to the thoughtful considerations necessary when deploying AI. These terms suggest an awareness of the potential ethical dilemmas and risks associated with widespread AI adoption in logistics, emphasizing the need for responsible implementation strategies.

In conclusion, the dimensions and features discussed in the interview with Klaus are as follows. The benefits are Efficiency Enhancement and Cost Reduction, Customer Service Improvement, Enhance Decision Making and Data Management, with Improve Safety and Compliance being new entries compared to the MLR findings. The drawbacks include Ethical Implications, Historical Data Dependency, Workforce Displacement and, Vulnerability to underperformance. The challenges are Technical Gap, Significant Resource Allocation, and Complex Business Ecosystems. The implementations for Purchase and Supply Chain process include Image Processing, AI-Powered Customer Care and, Inventory Management Algorithms, for Storage include as new entries compared to the MLR findings, Computer Vision and Warehouse Equipment Predictive Maintenance, and for the Distribution, Vehicles Predictive Maintenance, and Dynamic Routing Technologies.

4.3.3. Interview 3

The interview with Akshay Rastogi delves deeply into the transformative impacts of AI in logistics, focusing on how AI can enhance human performance and optimize logistical operations. His extensive insights shed light on various AI applications, emphasizing their strategic importance in the logistics sector.

Akshay opens the discussion by articulating the general philosophy of AI, which aims to augment human capabilities and improve operational efficiencies across sectors, including logistics. He highlights that AI's power lies in its ability to analyze vast amounts of data and utilize intricate contexts for decision-making far beyond human capability. This enhances operations by allowing historical data analysis over long periods, which can drastically influence planning and execution strategies in logistics.

He specifically points out the critical role of AI in predictive analytics for logistics, focusing on its utility in forecasting lead times and managing transit schedules. This application of AI enables logistics operations to predict and plan with remarkable accuracy, reducing delays and increasing the efficiency of the supply chain.

Moreover, Akshay discusses AI's capability to optimize resource management, particularly within warehousing operations. AI systems can predict demand fluctuations and accordingly adjust labor and resource allocation, which not only optimizes costs but also ensures efficiency during peak and off-peak periods.

However, Akshay does not shy away from addressing the challenges and potential drawbacks of AI. He emphasizes the "garbage in, garbage out" principle, pointing out that the effectiveness of AI is heavily dependent on the quality of the data fed into it. This serves as a critical reminder of the need for accurate, high-quality data to leverage AI's full potential effectively.

He also discusses the misconceptions around AI, particularly the fear of workforce displacement. Akshay argues that AI does not necessarily displace workers but rather reallocates them to more strategic roles, transforming the nature of work from repetitive tasks to roles that require higher-level decision-making.

Additionally, Akshay notes the importance of designing AI systems that are tailored to specific logistical needs to avoid underperformance. The design process is crucial as it determines how well the AI system will perform in real-world scenarios. Poorly designed systems can lead to inefficiencies and fail to deliver the expected benefits.

The word cloud generated from the interview with Akshay Rastogi vividly encapsulates key themes and vocabulary central to his discussion on AI in logistics.

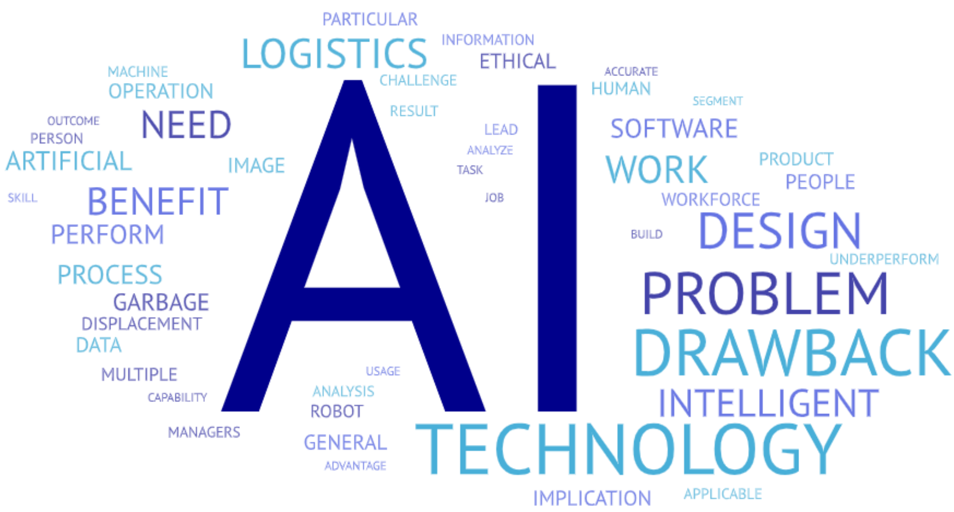

Figure 4.3. Word Cloud for Interview 3

Featured words like "AI," "Technology," "Logistics," and "Design" highlight the overarching context of the discussion, emphasizing the sophisticated integration of technology in logistical operations.

Words such as "Benefit," "Problem," and "Drawback" underscore a balanced view of AI, indicating that while AI presents significant advantages for logistics, it also comes with its own set of challenges and potential issues. This balanced perspective is crucial for understanding the dual nature of technological adoption in complex environments like logistics.

"Intelligent," and "Perform" reflect the forward-looking and efficiency-driven aspects of AI applications, suggesting a focus on enhancing operational capabilities and predictive analytics to improve decision-making and process optimization.

"Displacement" and "Workforce" point to discussions around the socio-economic impacts of AI, particularly the implications for job roles and employment within the logistics sector. These terms suggest an awareness of the need to manage technological transition thoughtfully, ensuring that workforce displacement is addressed through re-skilling or process redesign.

"Ethical," "Problem," and "Garbage" indicate a conversation about the challenges and ethical considerations in AI deployment, such as data quality ("Garbage in, garbage out") and the ethical implications of automation and surveillance technologies.

Based on the analysis conducted, the dimensions and features discussed in the interview with Akshay are as follows. The benefits are Efficiency Enhancement and Cost Reduction, Enhance Decision Making and Data Management, and Reduce CO2 Emissions. The drawbacks include Historical Data Dependency, Workforce Displacement and, Vulnerability to underperformance. The challenges are Data Management and, Complex Business Ecosystems. The implementations for Purchase and Supply Chain process include Inventory Management Algorithms, for Storage include Warehouse Robotics, and for the Distribution, as a new entry compared to the MLR findings, Forecasting Lead Time.

4.3.4. Interview 4

In the interview with Peter Grimvall, a nuanced discussion unfolds on the strategic integration of AI in logistics, highlighting both its transformative benefits and the essential considerations for its implementation.

Peter emphasizes that the true value of AI in logistics derives from its targeted application to specific operational challenges, rather than a broad, indiscriminate deployment. He identifies crucial areas like inventory management and supply chain optimization where AI can dramatically enhance efficiency and accuracy. This targeted application helps in automating processes such as order tracking and delivery scheduling, which not only accelerates operations but also minimizes errors, leading to more reliable service delivery. Additionally, Peter highlights AI's predictive capabilities, which allow for advanced forecasting of logistics demands. This predictive power helps companies better manage resource allocation, improving responsiveness and operational agility.

Furthermore, AI's role in facilitating data-driven decision-making is underscored by Peter. He describes how leveraging extensive data analysis through AI provides deep insights that can guide strategic decisions, significantly impacting the planning and execution phases in logistics. This approach ensures that operations are not just faster but also smarter, with a high degree of precision in managing logistics workflows.

However, the integration of AI into logistics faces some challenges. Peter discusses the practical difficulties in aligning AI technologies with actual business needs, noting the risks of mismatches where AI solutions fail to fully comprehend or address the nuanced demands of logistics operations. He also touches on the customization of AI tools, which involves tailoring algorithms and machine learning models to specific business processes and objectives, ensuring that the AI implementation is as effective as possible.

Ethical considerations and the impact on the workforce also form a critical part of the conversation. Peter addresses the potential drawbacks of AI, including concerns around data privacy and the risk of job displacement due to increased automation. He advocates for a balanced approach to AI adoption, which considers ethical issues and includes strategies for workforce development and adaptation. This approach ensures that while logistics operations benefit from enhanced efficiencies, they also remain mindful of the broader social and ethical implications of deploying advanced technologies.

The word cloud from Peter Grimvall's interview visually emphasizes the key themes discussed about AI's role in logistics.

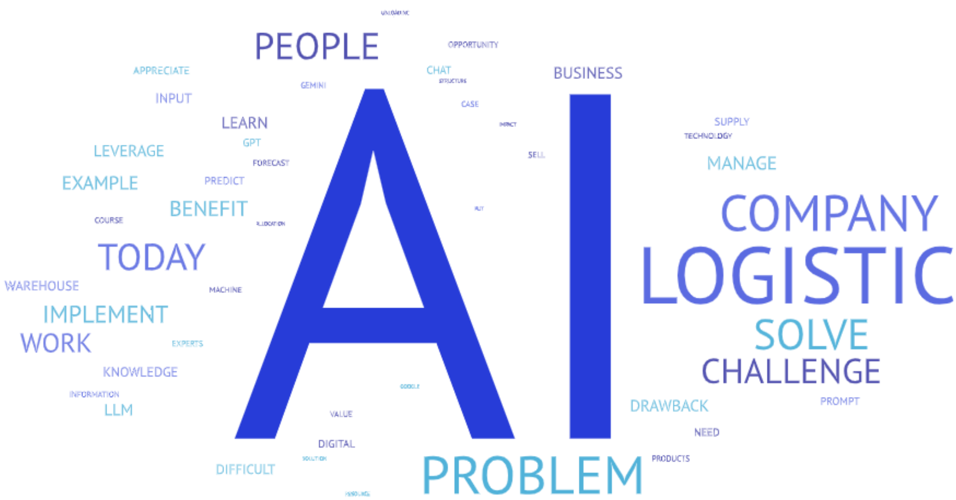

FIGURE 4.4. Word Cloud for Interview 4

Central terms like "AI," "Logistic," "People," and "Company" highlight the focus on applying AI to enhance logistics operations and its implications for the workforce. The prominence of words such as "Benefit," "Challenge," "Implement," and "Problem" reflects Peter's insights on both the advantages and hurdles of AI integration. He stresses the need for AI solutions to be tailored specifically to logistical challenges to maximize efficiency and mitigate issues like job displacement.

The analysis reveals the pivotal insights extracted from Peter's discussion, the dimensions and features discussed are as follows. The benefits are Efficiency Enhancement and Cost Reduction, Customer Service Improvement and, Enhance Decision Making and Data Management. The drawbacks include Ethical Implications, Workforce Displacement and, Vulnerability to underperformance. The challenges are Technical Gap and, Complex Business Ecosystems. The implementations for Purchase and Supply Chain process include Inventory Management Algorithms, for Storage include Warehouse Robotics, and for the Distribution, Dynamic Routing Technologies, and as a new entry compared to the MLR findings, Forecasting Lead Time.

4.3.5. Interview 5

In an insightful discussion, Paulo Carvão delves into the complexities of integrating AI in logistics, combining his extensive technology and business management experience to explore AI's transformative potential and the challenges it poses. He articulates how AI can significantly enhance productivity across both personal and business aspects, suggesting that AI can contribute substantially to economic growth by streamlining operations and increasing GDP through improved efficiencies in supply chain management. This includes optimizing processes such as inventory management and transportation logistics, which not only accelerate operations but also enhance accuracy and service delivery.

Paulo highlights AI's capability to reduce waste and its environmental impact, particularly in the food industry, where AI can minimize spoilage and ensure short-lived goods are delivered timely, thus reducing waste. Moreover, by optimizing transportation routes and schedules, AI can reduce unnecessary shipments and optimize fuel usage, leading to lesser environmental impacts.

However, the implementation of AI comes with its set of challenges, including high costs and the necessity to modernize legacy systems. Paulo also emphasizes that integrating AI with existing infrastructures poses significant hurdles and stresses the importance of high-quality data and the establishment of data standards for effective AI application. AI systems are only as good as the data they process, which makes the foundational aspects of data management critical to AI's success in logistics.

The ethical considerations and workforce impacts are pivotal in Paulo's discourse. He discusses the potential for AI to perpetuate existing biases if not carefully managed and the impact on the workforce due to AI-driven automation. He underlines the importance of thoughtful corporate and government policies to manage job transitions, ensuring that workers are reskilled or upskilled to adapt to new roles necessitated by AI advancements.

Paulo also articulates potential drawbacks such as the risks of job displacement and the perpetuation of biases through AI applications. He stresses the necessity for maintaining ethical AI practices to ensure that technological advancements do not exacerbate existing social inequalities or labor issues.

During the interview, Paulo Carvao provided critical insights on the terminology used in AI applications within logistics, specifically recommending a modification in the terminology from "Facial Access Control" to "Biometrics Access Control" in the literature insights table, represented on Figure 7.1. He highlighted the importance of this change to align with regulatory standards, particularly under the EU AI Act, where "facial recognition" is categorized as high-risk and faces stringent restrictions. Paulo advised that using "biometrics" not only broadens the scope but also circumvents the legal challenges associated with facial recognition technologies, ensuring compliance and mitigating potential legal issues.

The word cloud represented in the Figure 4.5 was generated from Paulo Carvao's interview, visually summarizing the key themes discussed regarding the integration of AI in logistics.

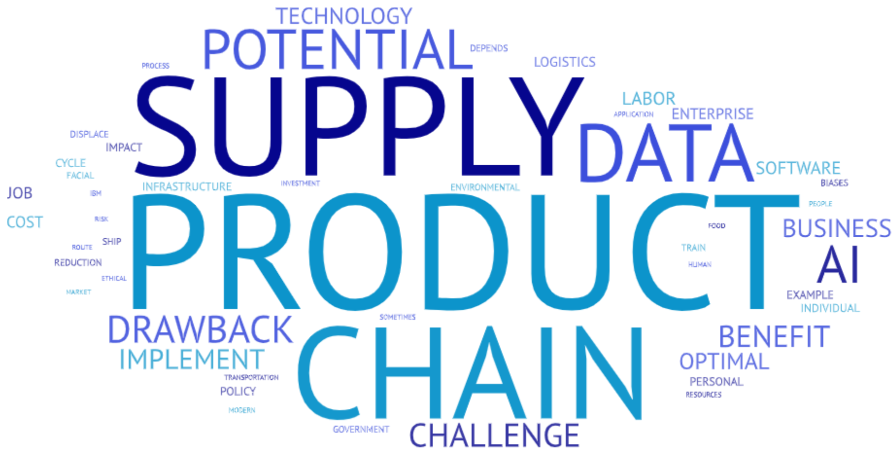

FIGURE 4.5. Word Cloud for Interview 5

Central terms like "Supply & Chain", "AI", and "Product" emphasize the focus on optimizing logistics processes through AI. "Data" and "Technology" reflect the crucial need for robust infrastructure and high-quality data for AI effectiveness. The presence of "Challenge" and "Drawback" in the cloud highlights the complexities and potential negative impacts, such as ethical issues and workforce displacement. Words like "Implement" and "Impact" suggest discussions on the practical application and significant effects of AI within businesses.

In conclusion, the dimensions and features discussed in the interview with Paulo are as follows. The benefits are Efficiency Enhancement and Cost Reduction, Enhance Decision Making and Data Management, Reduce CO2 Emissions and as a new entry compared to the MLR findings, Waste Reduction. The drawbacks include Ethical Implications, Historical Data Dependency, and Workforce Displacement. The challenges are Data Management, Significant Resource Allocation, Technical Gap and, Complex Business Ecosystems. The implementations for Purchase and Supply Chain process include Inventory Management Algorithms, for Storage include Warehouse Robotics, and as a new entry compared to the MLR findings, Biometrics Access Control and for the Distribution, Dynamic Routing Technologies.

4.3.6. Interview 6.1

Ignacio Prieto's interview offers a comprehensive examination of the transformative impact of AI in logistics, emphasizing how AI enhances operational efficiencies across various segments from procurement to customer interactions.

Ignacio introduces the innovative concept of autonomous sourcing, which leverages AI to automate procurement for high-volume, low-cost items. This automation process not only streamlines purchasing activities but also secures competitive pricing by handling routine tasks that typically do not warrant extensive human intervention. The result is a significant reduction in time and an increase in efficiency within the procurement process.

He delves into AI's role in revolutionizing demand planning and order management through predictive forecasting. By integrating diverse data sources, AI provides precise demand forecasts, optimizing inventory management substantially. Beyond inventory, AI's utility extends to customer service, automating order input and tracking, thus enhancing the customer experience with timely updates and efficient issue resolution.

In warehousing, Ignacio highlights AI's potential to refine the picking process and manage temporary labor more effectively. AI can quickly generate training materials tailored to temporary workers, thereby minimizing the training duration and maximizing operational efficiency. This use of AI not only speeds up the training process but also ensures high productivity from the get-go.

AI also plays a crucial role in transportation, particularly through improved route planning and freight auditing. Ignacio discusses AI's ability to scrutinize shipping documents to ensure billing accuracy and adherence to contracted rates, which can lead to substantial cost savings by preventing overcharges.

Despite these advancements, Ignacio points out the challenges, such as the significant initial investments required for AI integration and the continuous need for high-quality data management. He also addresses the ethical considerations associated with AI, including its impact on employment and privacy concerns, advocating for a cautious approach to mitigate potential adverse effects.

Looking ahead, Ignacio envisions AI as a key driver of efficiency and innovation in logistics. However, he underscores that the successful integration of AI hinges on overcoming initial implementation challenges and addressing ethical concerns thoughtfully. A strategic approach that includes robust data management and an understanding of technology's broader impacts is crucial for leveraging AI's full potential in logistics.

The word cloud generated from Ignacio Prieto's interview, represented in Figure 4.6, vividly encapsulates the breadth of topics discussed, emphasizing the diverse aspects of AI applications within logistics.
Prieto's interview highlights key concepts such as "AI", "Logistic", and "Company", emphasizing the discussion on integrating AI technologies in logistics operations. Terms like "Implement" and "Challenge" reflect practical applications and potential obstacles in AI deployment. "Data" and "Maintenance" underscore the importance of data management and system upkeep for effective AI functionality. Ethical considerations are suggested by "Ethics," addressing concerns such as privacy and workforce impact.

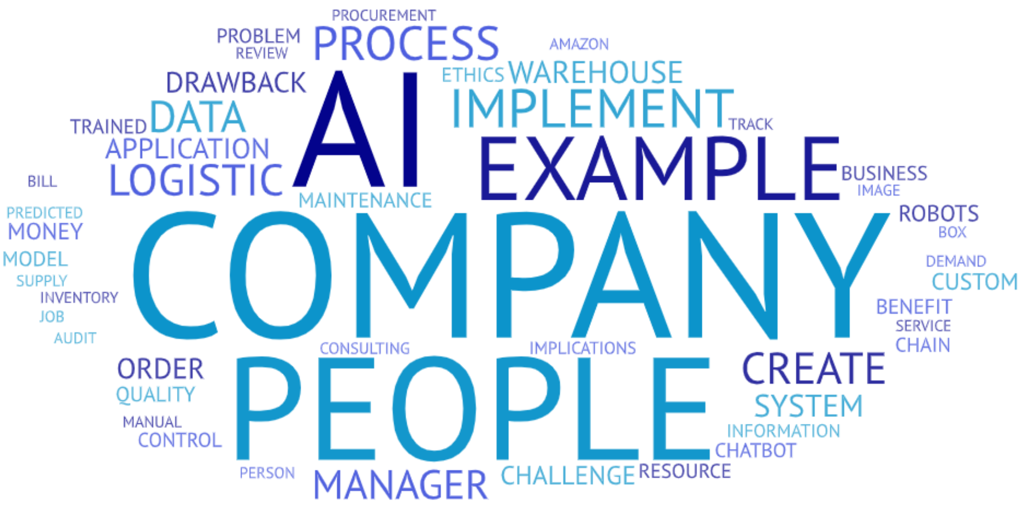

Figure 4.6. Word Cloud for Interview 6.1

Based on the analysis conducted, the dimensions and features discussed in the interview with Ignacio are as follows. The benefits are Efficiency Enhancement and Cost Reduction, Customer Service Improvement, Enhance Decision Making and Data Management, as new entries compared to the MLR findings, Improve Compliance and Workers Training Efficiency. The drawbacks include Ethical Implications, Historical Data Dependency, and Workforce Displacement. The challenges are Data Management, Significant Resource Allocation and Complex Business Ecosystems. The implementations for Purchase and Supply Chain process include Image Processing, AI-Powered Customer Care, and Inventory Management Algorithms, for Storage include Warehouse Robotics, and for the Distribution, Dynamic Routing Technologies, and as a new entry compared to the MLR findings, Forecasting Lead Time.

4.3.7. Interview 6.2

All interviews in this study were conducted in a free-form manner, allowing experts to address topics they deemed most relevant in any way they found important. However, Julian Fischer's interview stood out because he chose a different approach, focusing more on the structural and guideline aspects of AI in logistics rather than on specific use cases and examples. This made his contributions uniquely insightful but more theoretical compared to other expert interviews.

Julian emphasized the importance of clear definitions and structural understanding in logistics and AI. He pointed out the common confusion between logistics and supply chain management and stressed the necessity of distinguishing between different components like planning, transport, and warehousing. Julian's advice highlighted the need for precise terminology to ensure clarity in academic and professional discussions.

Furthermore, Julian discussed the broader categorization of AI technologies and their applications, urging a detailed classification to avoid generalizations that could lead to misinterpretations in research findings. He advised on the potential benefits of AI in improving service, reducing costs, and optimizing capital but cautioned against making overly specific or unfounded claims about these benefits without substantial evidence from detailed use cases.

Throughout the discussion, Julian remained focused on the academic rigor and practical relevance of the research, suggesting that a well-structured approach in defining and discussing AI and logistics could significantly enhance the utility and impact of the findings. His input was oriented towards ensuring that the research would not only meet academic standards but also offer tangible insights and solutions applicable in real-world scenarios.

The word cloud generated from Julian Fischer's interview, represented in Figure 4.7, visually encapsulates the key themes and terminology that dominated the discussion.

Figure 4.7. Word Cloud for Interview 6.2

Central terms like "efficiency," "benefit," "process," and "management" reflect the anticipated advantages and operational impacts of AI. Words such as "challenge," "cost," "implement," and "planning" highlight the practical considerations and strategic planning essential for AI adoption in logistics. This visualization succinctly captures the essential aspects of Julian's insights, emphasizing the need for precise definitions and structured approaches in the field.

This interview, unlike others, did not directly contribute to the findings table used in the study. Instead, it provided valuable insights that will aid in restructuring the table and inform future work, ensuring the research remains relevant and precisely aligned with industry and academic standards.

4.4. General Analysis

In this section, insights drawn from the interviews with various experts in the field of logistics and AI are synthesized. This synthesis is visualized through a series of graphs generated from data extracted by the Fireflies AI assistant, providing an overarching view of the interview dynamics.
The graph, represented in the Appendix B, in Figure 7.2, shows that the average interview duration was 33 minutes and 17 seconds, with the shortest session lasting 25 minutes and the longest extending to 46 minutes. These figures reflect a high level of engagement and fluid conversation flow, demonstrating that the experts were collaborative and committed to providing thorough insights.
The data, represented on graph in the Appendix B, in Figure 7.3, reveals that experts provided the majority of the content during the discussions, with their contributions averaging 73% across all interviews. This significant level of expert involvement highlights their commitment to discussing AI in logistics comprehensively and their eagerness to provide detailed insights beyond simple answers.

The sentiment analysis, represented in the Appendix B, in Figure 7.4, reveals a predominance of positive, 45%, and neutral, 46%, responses throughout the interviews, underscoring the significant benefits AI is currently offering in logistics. The positive sentiment predominantly reflects the various advantages and enhancements that AI introduces to logistic operations. In contrast, the neutral sentiment is largely attributed to the factual statements and use-case discussions that provide a detailed look at AI applications. The 9% negative sentiment corresponds directly to the discussions of challenges and drawbacks, emphasizing the realistic obstacles and concerns associated with the implementation of AI technologies, thus ensuring a comprehensive and balanced perspective on AI in logistics.

CHAPTER 5

Results

This chapter synthesizes insights gathered from in-depth interviews with leading experts in the fields of logistics and AI. The primary objective was to enrich and refine the initial framework derived from the MLR by integrating firsthand expert perspectives.

The contributions were grouped and categorized by topics to provide detailed information for each benefit, drawback, challenge, and implementation discussed in the interviews.

5.1. Benefits

Operational Efficiency Improvement: The incorporation of AI revolutionizes operational efficiency in logistics by automating routine tasks and optimizing complex workflows. Robotics enhance warehousing operations by automating sorting and picking, which increases speed and accuracy. In transportation, AI algorithms optimize delivery routes by analyzing real-time traffic data, weather conditions, and vehicle performance. This optimization reduces downtime and accelerates delivery speed, crucial for efficiently managing resources and reducing operational costs. The experts emphasized that these improvements lead to substantial cost savings and increased throughput, allowing logistics operations to scale effectively without a corresponding increase in labor costs.

Enhance Decision Making: AI's capability to analyze vast datasets provides logistics managers with insights that significantly enhance decision-making. For example, AI systems can predict market trends and consumer behaviors, enabling companies to adjust their strategies proactively. This includes stocking up in anticipation of increased demand, or rerouting shipments to avoid delays caused by unforeseen disruptions. This proactive approach helps maintain service continuity and operational resilience, crucial for maintaining competitive advantage in a volatile market. Experts highlighted that AI's ability to process and analyze large datasets in real-time supports quick and accurate decision-making, which is vital for responding to the dynamic nature of logistics operations.

Data Management Improvement: The quality of data is crucial in logistics operations where AI is involved, as the accuracy of AI outputs heavily depends on the quality of the input data. AI enhances data management by automating the integration and analysis of data from various sources, such as IoT devices and transactional databases. This provides a more accurate view of inventory levels, logistics activities, and customer demand patterns, leading to improved operational planning and efficiency. Experts noted that high-quality data is critical for predictive analytics and decision-making processes, ensuring that logistical operations are both efficient and effective.

Enhanced Customer Satisfaction: AI significantly boosts customer satisfaction by enhancing the accuracy and reliability of Estimated Time of Arrival (ETA) predictions and personalizing customer interactions. AI-driven systems analyze vast data to predict delivery times accurately, allowing companies to manage customer expectations effectively. Additionally, AI-driven chatbots offer 24/7 customer support, handling inquiries and resolving issues promptly, enhancing the overall customer service experience and fostering customer loyalty. The experts emphasized that these improvements lead to higher customer satisfaction and retention rates, as customers receive their deliveries on time and have their issues resolved quickly and efficiently.

Optimized Fuel Consumption: Integrating AI significantly reduces logistics costs and environmental impact by optimizing fuel consumption. By analyzing historical data and current operating conditions, AI algorithms can suggest the most fuel-efficient routes and recommend the best speeds to drive at, considering factors like vehicle load and terrain. This not only cuts fuel costs but also reduces the carbon footprint of logistics operations, supporting broader environmental sustainability goals.

Compliance Optimization: AI facilitates compliance within logistics by automating the tracking and adherence to changing regulations across different regions. This includes environmental, safety, and transportation laws, ensuring seamless adaptation to new legal requirements without extensive manual oversight, thus minimizing the risk of compliance failures. The use of AI in monitoring compliance through systems like Closed-Circuit Television (CCTV) helps assess safety protocols and operational standards in real-time, demonstrating AI's crucial role in maintaining rigorous compliance standards. Experts noted that this real-time monitoring and compliance ensure that logistics operations remain within legal frameworks, reducing the risk of fines and legal issues.

Comprehensive Safety Improvements: Implementing AI enhances safety within logistics operations through continuous monitoring and predictive analytics. Predictive analytics anticipate equipment failures or potential safety hazards, allowing AI-driven systems to schedule preventive maintenance and suggest safety enhancements before incidents occur. Additionally, AI systems monitor driver behavior, using cameras and sensors to detect signs of fatigue or distraction, such as closing eyes or swerving, and provide real-time alerts to prevent accidents. This proactive management significantly reduces accident likelihood and enhances overall operational safety. Experts highlighted that these AI-driven safety improvements protect not only logistics drivers but also other road users, ensuring a safer environment for all involved. AI's ability to monitor and predict potential issues in real-time ensures that safety standards are consistently met, protecting both people and goods.

Strengthened Talent Acquisition and Retention: AI systems not only streamline the hiring process by efficiently sorting through applications to identify the best candidates but also help in retaining talent by identifying patterns that may indicate dissatisfaction or potential departures. Experts also noted that young professionals are particularly attracted to companies that leverage advanced technologies, as they view these companies as innovative and forward-thinking.

Reduction of Perishable Goods Spoilage: The integration of AI minimizes spoilage of perishable goods in logistics through real-time monitoring and automated environmental adjustments during transportation and storage. By continuously monitoring conditions such as temperature and humidity, AI ensures that perishable items are kept in optimal conditions throughout their journey, significantly reducing waste. Additionally, AI optimizes routes to ensure the fastest and safest delivery paths for perishable goods, further reducing the risk of spoilage. Experts emphasized that these capabilities lead to significant cost savings and higher quality of perishable goods upon delivery.

Accelerated Employee Training Processes: AI transforms employee training in logistics by replacing outdated manuals with customized, interactive training modules. These AI-driven platforms adapt to specific operational procedures, ensuring that training is directly applicable and relevant. For example, one expert noted that many companies still rely on extensive manuals for training, which vary significantly between companies. AI streamlines this by providing efficient, tailored training programs. This not only accelerates the training process but also enhances its effectiveness, enabling new employees to achieve operational proficiency quicker and with greater confidence. Experts highlighted that these AI-driven training modules make it easier for employees to understand and adapt to company-specific processes, leading to higher overall productivity and job satisfaction.

5.2. Drawbacks

Workforce Displacement/Transformation: The integration of AI in logistics significantly impacts workforce dynamics, leading to both displacement and transformation of roles. Automation of repetitive tasks can lead to workforce displacement, particularly in roles that involve routine and manual activities. As AI takes over these tasks, there is a potential reduction in the need for human workers in these areas. However, the experts highlighted that this displacement is often coupled with the transformation of job roles, requiring employees to adapt to new technologies and acquire new skills. The need for retraining and reskilling is paramount, as employees must transition to roles that involve managing and working alongside AI systems. While some traditional jobs may be reduced, new opportunities in AI management, data analysis, and system maintenance emerge, creating a dynamic shift in the workforce structure .

Additionally, the experts stressed that companies must develop strategies to support this transition, ensuring that employees are equipped with the necessary skills to thrive in an AI-enhanced environment. This includes providing ongoing training and professional development opportunities, as well as fostering a culture of continuous learning. The transformation is not merely about reducing headcount but about enhancing the capabilities and productivity of the existing workforce.

Ethical Implications: AI in logistics raises several ethical concerns, primarily related to bias, data privacy, and the potential misuse of AI technologies. The experts pointed out that AI systems can inadvertently perpetuate existing biases present in the training data, leading to unfair or discriminatory outcomes. This is particularly concerning in logistics, where decisions influenced by biased data can affect hiring practices, resource allocation, and service delivery. Ensuring the ethical use of AI requires rigorous oversight, transparency in AI decision-making processes, and the implementation of fairness measures to mitigate bias.

Furthermore, the ethical implications extend to the handling of data privacy. The vast amounts of data collected and analyzed by AI systems necessitate stringent data protection protocols to prevent misuse and ensure compliance with privacy regulations. The experts emphasized the importance of maintaining transparency with stakeholders about how data is used and ensuring that AI applications adhere to ethical standards that protect individual rights and promote trust.

Historical Data Dependency: The AI's reliance on historical data for training and decision-making presents a significant drawback, particularly when the quality and relevance of this data are in question. The experts noted that AI systems are only as good as the data they are trained on. If the historical data contains inaccuracies, biases, or is not representative of current conditions, the AI's predictions and recommendations can be flawed. This dependency can lead to suboptimal decisions in logistics, such as incorrect inventory forecasts, inefficient routing, and poor demand predictions .

Moreover, the rapidly changing nature of logistics operations means that historical data may quickly become outdated. AI systems must continuously update and validate their data sources to remain effective. The experts suggested that integrating real-time data feeds and employing advanced data cleansing techniques can help mitigate these issues, ensuring that AI systems have access to accurate and relevant information for their analyses

Vulnerability to underperformance: AI systems in logistics can underperform if not properly designed, implemented, and maintained. The experts highlighted that AI's effectiveness is highly dependent on the quality of its deployment and the specific use cases it addresses. Poorly designed AI systems can lead to incorrect decisions, inefficiencies, and even operational disruptions. This underperformance can stem from several factors, including inadequate training data, insufficient integration with existing systems, and a lack of continuous monitoring and optimization.

Additionally, AI systems require regular updates and maintenance to adapt to evolving operational conditions and emerging challenges. The experts emphasized the need for robust implementation strategies and ongoing support to ensure that AI systems perform as expected and deliver the intended benefits. Without proper oversight and iterative improvements, AI can fail to meet its potential, resulting in wasted investments and missed opportunities for enhancement.

Cybersecurity Vulnerabilities: The integration of AI in logistics introduces new cybersecurity risks, as AI systems can be targeted by malicious actors seeking to exploit their capabilities. The experts noted that AI technologies can be used to enhance cybersecurity defenses, but they also present new attack vectors that need to be addressed. For instance, AI systems can be vulnerable to data breaches, hacking, and the manipulation of AI algorithms to produce false or misleading outcomes.

One specific concern is the potential for AI to be used in cyber attacks, such as through the creation of sophisticated phishing schemes or the automation of hacking attempts. AI's ability to rapidly analyze and process data can be leveraged by attackers to identify vulnerabilities and exploit them at scale. The experts stressed the importance of implementing robust cybersecurity measures, including regular security audits, encryption, and multi-layered defense strategies, to protect AI systems and the sensitive data they handle .

5.3. Challenges

Complex Business Ecosystems: Integrating AI into complex business ecosystems presents significant challenges due to the intricacy and interconnectivity of logistics operations. The experts pointed out that logistics often involves multiple stakeholders, including suppliers, carriers, warehouse operators, and customers, each with their own systems and processes. This complexity can hinder the seamless integration of AI technologies, as aligning these diverse elements requires robust data-sharing agreements, interoperability standards, and synchronized workflows. Achieving this level of coordination is particularly challenging in environments where legacy systems are prevalent, and data silos are common. Overcoming these barriers necessitates a comprehensive strategy that includes stakeholder collaboration, investment in compatible technologies, and the development of standardized protocols to facilitate data exchange.

Moreover, the dynamic nature of logistics operations means that AI systems must be adaptable and capable of real-time decision-making. This requires not only sophisticated algorithms but also the continuous updating and refining of AI models to reflect the latest operational data and trends. The experts emphasized that without this flexibility, AI solutions might struggle to cope with the evolving demands of complex logistics networks, potentially leading to suboptimal performance and inefficiencies.

Renewing Outdated Business Cultures: The shift towards AI in logistics is often impeded by entrenched business cultures resistant to change. The experts highlighted that many logistics companies have long-standing traditions and processes that are deeply rooted in their operations. Employees accustomed to these established ways may be reluctant to adopt new technologies, perceiving them as threats to their job security or as disruptions to their familiar workflows. This resistance can be particularly pronounced in industries where manual processes have been the norm for decades. Overcoming this cultural inertia requires not only technological investment but also significant effort in change management, including clear communication of the benefits of AI, comprehensive training programs, and the promotion of a culture that values innovation and continuous improvement.

Furthermore, logistics is considered one of the more conservative areas within supply chain management, often holding on to "ancient" methods and systems. Transitioning from these outdated practices to modern AI-driven processes requires a significant mindset shift and organizational restructuring. Experts noted that successful adoption of AI depends on strong leadership and a willingness to embrace change at all levels of the organization. Leadership must not only advocate for the adoption of new technologies but also facilitate the necessary organizational changes to support these technologies. This includes fostering a culture of openness to new ideas and continuous improvement, essential for staying competitive in a rapidly evolving industry.

Data Management: Effective data management is a critical challenge in implementing AI in logistics. The experts emphasized that AI systems rely heavily on high-quality data to function correctly. However, logistics operations often deal with vast amounts of data from diverse sources, including sensors, transactional systems, and external partners. Ensuring the accuracy, consistency, and timeliness of this data is a significant challenge. Poor data quality can lead to incorrect predictions and decisions, undermining the effectiveness of AI applications. Additionally, integrating data from disparate sources often requires sophisticated data integration and cleansing processes, which can be resource-intensive and complex.

Moreover, data governance is essential to maintain the integrity and security of data used by AI systems. The experts pointed out that establishing robust data governance frameworks involves defining clear policies and procedures for data management, including data ownership, access controls, and compliance with regulatory requirements. This is particularly important in logistics, where data privacy and security are critical concerns. Ensuring that AI systems adhere to these frameworks helps mitigate risks associated with data breaches and unauthorized access, thereby safeguarding the sensitive information handled in logistics operations.

AI Skills and Knowledge Shortfall: The shortage of AI skills and knowledge within the logistics industry is a major barrier to the successful implementation of AI technologies. The experts noted that while AI has the potential to revolutionize logistics, the industry often lacks the specialized expertise required to develop, deploy, and maintain AI systems. This skills gap is particularly evident in areas such as data science, machine learning, and AI-driven process optimization. Companies may struggle to find qualified personnel who can bridge the gap between traditional logistics operations and advanced AI technologies. Addressing this shortfall requires targeted investments in education and training programs to build the necessary skill sets within the workforce.

Additionally, fostering collaboration between logistics professionals and AI experts is crucial to overcoming this challenge. The experts emphasized the importance of interdisciplinary teams that combine domain knowledge with technical expertise. These teams can work together to identify relevant use cases, develop tailored AI solutions, and ensure that these solutions are effectively integrated into logistics processes. By promoting such collaborations and investing in skill development, logistics companies can better leverage AI to enhance their operations.

Significant Resource Allocation: Implementing AI in logistics requires substantial resource allocation, which can be a significant challenge for many companies. The experts highlighted that developing and deploying AI solutions involves considerable financial investment, including costs associated with purchasing AI technologies, upgrading infrastructure, and training staff. Additionally, the ongoing maintenance and optimization of AI systems require continuous investment to ensure their effectiveness and relevance. For smaller logistics companies with limited budgets, these costs can be prohibitive, making it difficult to compete with larger organizations that have greater financial resources.

Moreover, the successful integration of AI into logistics operations demands a strategic approach to resource allocation. This includes not only financial resources but also the allocation of time and human capital. The experts emphasized that companies must carefully plan and prioritize their AI initiatives, focusing on projects that offer the highest potential return on investment. This strategic focus helps ensure that resources are used efficiently and that AI implementations deliver tangible benefits. However, achieving this balance can be challenging, particularly in dynamic and resource-constrained environments.

5.4. Implementations

5.4.1. Procurement

Forecast Demand and Inventory Management Algorithms: AI-driven demand forecasting and inventory management algorithms significantly enhance the efficiency and accuracy of procurement processes in logistics. The experts highlighted that traditional forecasting methods, which rely heavily on historical sales data and manual adjustments, often fall short in today's rapidly changing market conditions. AI algorithms, on the other hand, can analyze a multitude of data sources in real-time, including sales trends, market indicators, weather patterns, and even social media signals. This comprehensive analysis enables more precise demand forecasts, reducing instances of overstocking or stockouts and optimizing inventory levels accordingly.

Furthermore, these AI systems are capable of continuously learning and adapting to new data, refining their predictive accuracy over time. This adaptability is crucial in logistics, where demand can be highly volatile. Experts noted that implementing AI for demand forecasting not only improves inventory management but also enhances the overall agility of the supply chain. This leads to better alignment of supply with demand, minimizing waste, and ensuring that the right products are available at the right time, ultimately driving down costs and improving service levels.

Image Processing: Image processing technologies powered by AI play a crucial role in automating document management and enhancing accuracy in logistics operations. Experts explained that AI-driven image processing can be used to automate the sorting and processing of various documents, such as waybills, invoices, and delivery receipts. By converting paper documents into digital formats and extracting relevant data through Optical Character Recognition (OCR), AI minimizes human error and significantly speeds up the document handling process. This automation not only reduces labor costs but also ensures higher accuracy and efficiency in managing documentation.

Moreover, AI-based image processing can enhance quality control within warehouses by enabling automated inspection of goods. For instance, cameras equipped with AI can scan products and pallets to identify any discrepancies or damages, ensuring that only quality goods are dispatched. This capability is particularly valuable in environments with high volumes of inventory, where manual inspection would be impractical and time-consuming. The experts emphasized that the integration of AI in image processing helps maintain high standards of accuracy and quality, which are critical for customer satisfaction and operational efficiency.

AI-Powered Customer Care: AI-powered customer care solutions are transforming how logistics companies interact with their customers, providing personalized and efficient service at scale. The experts noted that AI-driven chatbots and virtual assistants can handle a wide range of customer inquiries, from tracking shipments to processing returns, without the need for human intervention. These systems are available 24/7, ensuring that customers receive prompt responses regardless of time zones or business hours. By automating routine customer service tasks, AI allows human agents to focus on more complex issues, thereby improving overall service quality and efficiency.

Additionally, AI-powered customer care systems can analyze customer interactions to gain insights into common issues and preferences, enabling proactive service improvements. For example, AI can identify recurring problems and suggest solutions to prevent them in the future. The experts highlighted that such systems not only enhance the customer experience but also provide valuable data that can inform strategic decisions and drive continuous improvement in service delivery. The integration of AI in customer care is thus a key component of modern logistics operations, contributing to higher customer satisfaction and loyalty.

5.4.2. Warehousing

Warehouse Robotic Automation: Warehouse robotic automation represents a significant advancement in the efficiency and accuracy of warehousing operations. The experts highlighted the widespread adoption of automated robots for tasks such as picking, packing, and sorting. These robots, ranging from large automated forklifts to smaller units like the Kiva robots used by Amazon, are designed to handle repetitive tasks with precision and speed. This automation not only reduces labor costs but also minimizes human error, ensuring a higher level of accuracy in order fulfillment. By automating these routine tasks, companies can focus their human workforce on more complex and value-added activities, thereby increasing overall productivity.

Additionally, the integration of AI with robotic systems enables these machines to learn and adapt to new tasks and environments. This adaptability is crucial in dynamic warehouse settings where inventory levels and product types can frequently change. Experts noted that the use of AI-driven robots in warehouses has resulted in significant improvements in operational efficiency, reducing the time required for order processing and improving the speed and accuracy of inventory management.

Biometrics Access Control: Biometrics access control is another important implementation of AI in warehousing, enhancing security and operational efficiency. The experts emphasized that using biometric systems such as fingerprint scanners and facial recognition for access control ensures that only authorized personnel can enter sensitive areas of the warehouse. This technology not only enhances security but also streamlines the access process, reducing the time employees spend on traditional security checks.

Furthermore, biometric access control systems can be integrated with other warehouse management systems to provide real-time tracking of personnel movements within the facility. This integration allows for better monitoring of employee activities, helping to ensure compliance with safety protocols and operational procedures. By leveraging biometric technology, warehouses can enhance their security measures while also improving the efficiency of their operations.

Computer Vision: These technologies are revolutionizing various aspects of warehousing by enabling automated visual inspection and data collection. Experts pointed out that AI-driven computer vision systems can analyze footage from CCTV cameras to monitor warehouse operations in real-time. This technology can identify potential safety hazards, such as forklifts operating too close to workers or unauthorized access to restricted areas, and alert supervisors to take immediate action.

In addition to safety monitoring, computer vision can be used for inventory management. Cameras can scan shelves and pallets to verify stock levels, detect misplaced items, and ensure that products are stored correctly. This automated inspection process reduces the need for manual stock checks, saving time and reducing the likelihood of human error. The experts emphasized that computer vision not only improves operational efficiency but also enhances the accuracy and reliability of warehouse management.

Warehouse Equipment Predictive Maintenance: Predictive maintenance powered by AI is transforming the way warehouse equipment is managed and maintained. The experts noted that traditional maintenance schedules, based on fixed intervals, often result in either premature servicing or unexpected breakdowns. AI-driven predictive maintenance systems, however, analyze data from sensors embedded in warehouse equipment to predict when maintenance is actually needed. This approach helps in identifying potential issues before they lead to equipment failure, thereby reducing downtime and maintenance costs.

These systems can monitor various parameters, such as vibration, temperature, and usage patterns, to detect signs of wear and tear. When the system identifies anomalies that suggest impending failure, it can automatically schedule maintenance activities, ensuring that repairs are conducted just in time. The experts highlighted that implementing predictive maintenance in warehouses not only extends the lifespan of equipment but also enhances overall operational efficiency by minimizing unexpected disruptions.

Unmanned Machinery: The use of unmanned machinery, including drones and AGVs, is becoming increasingly common in modern warehouses. The experts described how drones are used for inventory management, performing tasks such as stocktaking and locating items in large warehouse spaces. These drones can quickly scan barcodes and Radio-frequency identification tags, providing real-time updates to the inventory management system. This not only speeds up the stocktaking process but also improves accuracy by reducing human errors.

AGVs are another example of unmanned machinery that is transforming warehouse operations. These vehicles can transport goods throughout the warehouse without human intervention, following predefined paths or dynamically adjusting routes based on real-time data. AGVs enhance efficiency by ensuring that materials are moved swiftly and safely, reducing the risk of accidents and improving workflow. The experts emphasized that the integration of unmanned machinery in warehouses significantly enhances productivity and operational efficiency, allowing companies to handle larger volumes of goods more effectively.

5.4.3. Distribution

Dynamic Routing Technologies: Dynamic routing technologies are a significant advancement in distribution, optimizing delivery routes based on real-time data. The experts emphasized that AI-driven dynamic routing systems can analyze various factors such as traffic conditions, weather forecasts, and delivery windows to adjust routes in real-time. This capability ensures that deliveries are made efficiently, reducing fuel consumption and improving delivery times. By continuously updating routes, these systems help logistics companies respond to unforeseen events, such as traffic jams or road closures, thereby maintaining high service levels and reducing operational costs.

Moreover, dynamic routing technologies enhance the flexibility and responsiveness of logistics operations. The experts noted that these systems can integrate with other logistics management tools, providing a holistic view of the supply chain and enabling better coordination among different distribution channels. This integration facilitates more accurate scheduling, better resource utilization, and improved customer satisfaction by ensuring timely deliveries even in complex and dynamic environments.

Forecasting Lead Times (ETA): AI technologies for forecasting lead times, or ETA (Estimated Time of Arrival), are crucial for improving the reliability and transparency of distribution services. Experts discussed how AI algorithms can predict ETAs more accurately by analyzing historical data, real-time traffic information, and other relevant variables. This enhanced accuracy helps logistics companies provide more reliable delivery estimates to their customers, thereby improving trust and satisfaction.

Additionally, AI-driven ETA forecasting allows for proactive management of delivery schedules. The experts highlighted that these systems can identify potential delays early and suggest alternative routes or delivery windows to mitigate their impact. By providing precise ETAs and timely updates, AI helps logistics companies manage customer expectations better and optimize their delivery operations to meet tight deadlines.

Vehicles Predictive Maintenance: AI-powered predictive maintenance for vehicles is transforming the maintenance strategies in logistics. Experts explained that these systems use data from sensors embedded in vehicles to monitor their condition and predict when maintenance is needed. This proactive approach helps prevent unexpected breakdowns by identifying issues before they become critical, thereby reducing downtime and maintenance costs.

Predictive maintenance systems analyze various parameters such as engine performance, tire pressure, and brake conditions to detect signs of wear and tear. When anomalies are detected, the system can schedule maintenance activities at the most convenient times, minimizing disruptions to the delivery schedule. The experts noted that this approach not only extends the lifespan of the vehicles but also enhances the overall efficiency and reliability of the logistics operations.

Unmanned Delivery Technologies: Unmanned delivery technologies, such as drones and autonomous vehicles, represent a cutting-edge implementation of AI in distribution. Experts described how drones are used for last-mile delivery in areas that are difficult to access by traditional vehicles. These drones can deliver small packages quickly and efficiently, reducing delivery times and operational costs. Autonomous delivery vehicles, on the other hand, can navigate urban environments and deliver larger consignments without human intervention.

The integration of unmanned delivery technologies not only improves the speed and efficiency of deliveries but also reduces the reliance on human labor, which can be particularly beneficial during peak demand periods or labor shortages. The experts emphasized that while there are regulatory and technical challenges to overcome, the potential benefits of unmanned delivery technologies make them a promising solution for future logistics operations.

5.5. Conclusion

The integration of the experts' perspectives expanded the content and enhanced the structure of the table, making it more specific and relevant to current industry practices. It now reflects a broader spectrum of benefits, drawbacks, challenges, and implementations of AI in logistics, as viewed through the lens of seasoned professionals. Each entry has been updated to incorporate nuanced understandings and practical experiences shared by the experts. This process involved not only adding new elements to the table but also reevaluating and refining existing ones to ensure they accurately represent the dynamic and evolving nature of AI in logistics.

New entries due to the interviews include benefits such as compliance optimization, comprehensive safety improvements, strengthened talent acquisition and retention, reduction of perishable goods spoilage, and accelerated employee training processes. In terms of implementations, the additions are computer vision, warehouse equipment predictive maintenance, unmanned machinery, and forecasting lead times (ETA).

It is important to note that some entries from the original table, derived from the MLR, were not further discussed in the interviews. As a result, no additional insights were added in this chapter beyond what was already established in the State of the Art. Despite not being discussed in depth, the interview structure allowed for validation of these entries, ensuring they remain relevant and accurate. These confirmed entries without further details include drawbacks such as the technical restrictions of robotics and uncertainty in human-AI interaction. For challenges, legal liability and detecting and correcting AI errors were validated. Additionally, implementations such as digital mapping and smart roads were confirmed without additional elaboration.

Furthermore, the restructuring included a revision of the nomenclature used to describe various elements. This change was implemented to ensure that the terminology is precise and tailored to industry standards, thereby enhancing clarity and applicability for practitioners and researchers alike. By adopting industry-specific language, the table now offers a more practical and actionable resource that aligns closely with current logistical and AI practices.

Thus, the initial version of the figure that represented the insights framework from the MLR has been updated and can be seen in the following figures 5.1, 5.2, 5.3, and 5.4. These updated figures serve as a crucial convergence point where theory meets practice, offering a comprehensive overview of the potential and limitations of AI in logistics as articulated by those at the forefront of the industry.

In the Appendix C, are shown graphs that illustrates the frequency and distribution of mentioned features across the four dimensions: benefits (Figure 7.5), drawbacks (Figure 7.6), challenges (Figure 7.7), and implementations (Figure 7.8). Distinct colors are used for each entry to enhance clarity and readability. In the implementations graph, a different approach is taken to categorize the data. The entries are grouped using shades of three main colors: blue for procurement, red for warehousing, and green for distribution. This color-coding helps to visually distinguish between the different logistics categories and emphasizes the areas where AI implementations are most prevalent.

The analysis of benefits (Figure 5.1) reveals that the MLR provides a strong foundation, mentioning a wide array of benefits AI brings to logistics. However, the expert interviews significantly enhance this understanding by introducing new benefits that reflect recent industry practices and emerging trends. Notably, the benefits were the only category where the interviews added more entries in terms of quantity compared to the MLR. The consistent mentions of these new benefits across the interviews highlight their growing importance in the logistics industry.

The figure related to drawbacks (Figure 5.2) highlights key concerns associated with AI in logistics, as identified by both the MLR and the expert interviews. The most frequently mentioned drawbacks across all sources are workforce displacement/transformation and ethical implications. These concerns are consistently recognized in both the MLR and the interviews, indicating their widespread acknowledgment as significant issues in the industry.

Challenges (Figure 5.3) associated with implementing AI in logistics were extensively covered by the MLR, with expert interviews adding further depth and specificity. Complex business ecosystems and renewing outdated business cultures were the most commonly mentioned challenges, highlighted consistently across both the MLR and the interviews. This reflects the ongoing structural and cultural barriers that organizations face in integrating AI technologies.

The implementations (Figure 5.4) provides a detailed view of how AI is being applied across different logistics areas, categorized by procurement, warehousing, and distribution. The graph indicates that distribution is the logistics category with the most mentions, as evidenced by the predominance of green shades. This suggests a significant emphasis on optimizing the movement and delivery of goods, which is crucial for improving overall logistics efficiency. Key implementations in this category include dynamic routing technologies, and forecasting lead times (ETA), highlighting the industry's efforts to enhance delivery accuracy and route optimization.

Category	Features	MLR	1	2	3	4	5	6.1
Operational Efficiency Improvement	Automate Routine Tasks	[9, 11, 14]	X	X	X	X	X	X
	Optimize Delivery Routes	[9, 14, 15]	X	X	X	X	X	X
	Streamlining Processes	[11, 14, 15]	X	X	X	X	X	X
	Optimize Resource Utilization	[9, 11, 14]	X	X	X	X	X	X
	Automate Sorting and Picking	[11]	X					X
	Optimize Complex Workflows	[14, 15]				X		X
Enhance Decision Making	Predictive Analytics	[1]	X	X	X	X	X	X
	Minimize Errors		X	X	X	X	X	X
Data Management Improvement	Analyze Vast Datasets	[9, 14]	X	X	X	X		X
	Improve Data Quality		X	X	X		X	X
Enhanced Customer Satisfaction	Higher Responsiveness to Customer Requirements	[16]		X		X		X
	Provide Tailored 24/7 Customer Service	[1]		X				
Optimized Fuel Consumption	Distribution Path Algorithms	[17, 18]			X		X	
	AI-driven Backhaul	[17, 18]					X	
Compliance Optimization	Ensure Safety Standards			X				
	Billing Accuracy							X
Comprehensive Safety Improvements	Autonomous Vehicles and Robotics Systems		X					
	Predictive Maintenance on Potential Failures		X					
	Computer Vision to Operate in Safety Parameters			X				
Strengthened Talent Acquisition and Retention	Employment of Modern Technologies		X					
	Positive Transition to AI-related Jobs		X					
Reduction of Perishable Goods Spoilage	Short-lived Goods Delivered Timely						X	
Accelerated Employee Training Processes	Tailored Training Materials							X

FIGURE 5.1. Benefits With Detailed Features from MLR and Interviews

Category	Features	MLR	1	2	3	4	5	6.1
Workforce Displacement/Transformation	Job Losses	[20, 24]	X	X	X	X	X	X
	Need of Job Transformation		X	X	X	X	X	
	Loss of Human Touch	[20, 24]	X			X	X	
Ethical Implications	Need for Fair Workforce Strategy		X	X		X	X	
	Privacy Data Concerns		X	X			X	X
	Biases Data	[20, 21]				X	X	
Historical Data Dependency	Dependency on the Quality of Past Data	[14, 15, 22]		X	X		X	X
	Insufficient Amount of Data	[14, 15, 22]						
Vulnerability to underperformance	Inaccurate Decision-making	[15]		X	X	X		
	Poor recognition of self-errors	[15]						
	Inadequate AI System Architecture				X			
Cybersecurity Vulnerabilities	Extensive System Interconnectivity	[15, 19]	X					
	Inappropriate use of AI		X					
Technical Restrictions of Robotics	Simple, Limited Tasks in Controlled Environments	[11, 23]						
Uncertainty Human-AI Interaction	Complex and Evolving AI Systems	[15]						

FIGURE 5.2. Drawbacks With Detailed Features from MLR and Interviews

Category	Features	MLR	1	2	3	4	5	6.1
Complex Business Ecosystems	Overcoming Siloed Complex Systems Architecture	[14, 20]	X	X	X		X	
	Comprehend business-specific needs			X	X	X		X
	Understanding Human Decision-making	[14, 20]						
Renewing Outdated Business Cultures	Address Cultural Nuances and Resistance to Change	[14, 20]	X	X	X	X	X	X
Data Management	Ensure Robust Data Management Processes	[20, 26]	X		X		X	X
	Acquiring Necessary Amount of Data	[20, 26]						
	Eradicate Data Biases	[20, 26]						
AI Skills and Knowledge Shortfall	Reduced Number of AI Experts	[15, 28]	X	X		X	X	
Significant Resource Allocation	Significant Investment of Time, Money, and People	[24, 27]		X			X	X
Legal Liability	Accountability for Inaccurate AI-decisions	[15, 25]						
Detecting and Correcting AI Errors	Difficult to identify and correct mistakes	[15, 29]						

FIGURE 5.3. Challenges With Detailed Features from MLR and Interviews

Category - Process of Logistics	Features	MLR	1	2	3	4	5	6.1
Purchase and Supply Chain	Forecast Demand and Inventory Management Algorithms	[4, 14, 24]	X	X	X	X	X	X
	Image Processing	[9, 11, 24]		X				X
	AI-Powered Customer Care	[9, 24]		X				X
Storage	Warehouse Robotic Automation	[4, 11, 24]	X		X	X	X	X
	Biometrics Access Control	[11]					X	
	Computer Vision			X				
	Warehouse Equipment Predictive Maintenance			X				
	Unmanned Machinery		X					
Distribution	Dynamic Routing Technologies	[14, 24, 31]	X	X		X	X	X
	Forecasting Lead Times (ETA)				X	X		X
	Vehicles Predictive Maintenance	[24]	X	X				
	Unmanned Delivery Technologies	[7, 9, 11, 24]	X					
	Digital Mapping	[9, 11]						
	Smart Roads	[24, 30]						

FIGURE 5.4. Implementations With Detailed Features from MLR and Interviews

Ultimately, the full analysis culminated in a concise framework represented in Figure 5.5, providing a clear and comprehensive summary of the key insights and findings.

Intelligent Logistics: The Integration of Artificial Intelligence in the Logistics sector	Benefits		Operational Efficiency Improvement
			Enhance Decision Making
			Data Management Improvement
			Enhanced Customer Satisfaction
			Optimized Fuel Consumption
			Compliance Optimization
			Comprehensive Safety Improvements
			Strengthened Talent Acquisition and Retention
			Reduction of Perishable Goods Spoilage
			Accelerated Employee Training Processes
	Drawbacks		Workforce Displacement/Transformation
			Ethical Implications
			Historical Data Dependency
			Vulnerability to underperformance
			Cybersecurity Vulnerabilities
			Technical Restrictions of Robotics
			Uncertainty Human-AI Interaction
	Challenges		Complex Business Ecosystems
			Renewing Outdated Business Cultures
			Data Management
			AI Skills and Knowledge Shortfall
			Significant Resource Allocation
			Legal Liability
			Detecting and Correcting AI Errors
	Implementations	Procurement	Forecast Demand and Inventory Management Algorithms
			Image Processing
			AI-Powered Customer Care
		Warehousing	Warehouse Robotic Automation
			Biometrics Access Control
			Computer Vision
			Warehouse Equipment Predictive Maintenance
			Unmanned Machinery
		Distribution	Dynamic Routing Technologies
			Forecasting Lead Times (ETA)
			Vehicles Predictive Maintenance
			Unmanned Delivery Technologies
			Digital Mapping
			Smart Roads

FIGURE 5.5. Final Framework from Study Insights: Intelligent Logistics Benefits, Drawbacks, Challenges and Implementations

CHAPTER 6

Contributions and Prospects

This research explores the integration and application of AI in logistics, addressing the critical question of how AI can impact the logistics sector. The primary goal of this study is to provide companies with a nuanced and comprehensive overview of the multifaceted landscape of AI integration within the logistics industry. By examining diverse benefits, challenges encountered during this integration, and potential drawbacks, this study seeks to offer a valuable resource for decision-makers and practitioners looking to navigate the complexities of AI adoption in logistics.

To achieve this goal, a MLR combined with interviews with industry experts was employed to gather both theoretical and practical insights. The MLR synthesized academic and grey literature, providing a broad understanding of existing knowledge and gaps. Concurrently, expert interviews validated these insights and brought additional practical perspectives to light, ensuring the study reflects real-world applications and challenges.

The experts involved in this study were seasoned professionals in AI and logistics, generously sharing their experiences and perspectives. Their contributions not only confirmed the findings from the MLR but also highlighted new aspects, enriching the study's depth and breadth. These expert insights were crucial in understanding the practical nuances and implications of AI integration in logistics, offering a more grounded and detailed perspective.

The resulting comprehensive framework categorizes the benefits, drawbacks, challenges, and practical implementations of AI in logistics. This framework aims to bridge the gap between theory and practice, providing clear guidance on the potential and limitations of AI in logistics. Key benefits identified include efficiency enhancement, cost reduction, improved decision-making, and advanced data management capabilities. Additionally, the study addresses significant drawbacks such as potential job displacement, ethical concerns, and the dependency on high-quality data. It also highlights challenges like navigating complex business ecosystems, managing vast amounts of data, and addressing the AI skills shortfall within the industry.

Furthermore, this study contributes to the field by offering a structured and actionable framework, aimed at assisting both academics and practitioners. It prepares businesses with the insights necessary to make informed decisions about adopting AI technologies in their logistics operations. Emphasizing the importance of understanding both the opportunities and risks involved, this research equips decision-makers with a balanced view of AI's transformative potential in logistics.

In conclusion, this study not only sheds light on the intricate process of AI integration in logistics but also provides a practical roadmap for organizations aiming to leverage AI for competitive advantage. By highlighting the multifaceted impacts of AI this research underscores the importance of a strategic and informed approach to AI adoption in the logistics sector. Through its comprehensive analysis this study stands as a pivotal resource for anyone looking to understand and implement AI in logistics effectively. Ultimately, the successful integration of AI in logistics can significantly enhance operational performance and strengthen a company's reputation.

6.1. Future work

As AI evolves, it brings forth new capabilities in logistics while also posing new drawbacks and challenges. Ongoing research must remain vigilant about these developments, weighing both the benefits and risks of AI advancements. Regular updates to AI applications are essential for leveraging innovations while managing potential pitfalls.

An important insight from interview 6.2 underscores the necessity of specificity in research and implementation. Future studies could profit from a targeted exploration of specific logistical domains like last-mile delivery, warehouse automation, or supply chain resilience. Such focused inquiries promise actionable insights and the development of practical solutions.

Tailoring AI implementations to specific logistical processes and evaluating their outcomes could yield deeper insights and more nuanced integration strategies. This approach may involve piloting AI-driven solutions in real-world scenarios to observe their direct impacts, laying a solid foundation for scaling successful initiatives.

Furthermore, future research should address the ethical and societal dimensions of AI in logistics. Ensuring fairness, transparency, and privacy protection will be paramount as AI technologies become more widespread. Crafting frameworks and guidelines to navigate these ethical considerations will be integral to ongoing research endeavors.

To finalize, while this research provides a comprehensive foundation, the evolving landscape of AI offers continuous opportunities for exploration. By focusing on specific areas, updating frameworks regularly, and addressing ethical concerns, future research can advance the integration of AI in logistics in a balanced and responsible manner.

References

[1] H. Liu, S. Islam, X. Liu, and J. Wang, "Strategy-oriented digital transformation of logistics enterprises: The roles of artificial intelligence and blockchain," en, in *2020 5th International Conference on Innovative Technologies in Intelligent Systems and Industrial Applications (CITISIA)*, Sydney, Australia: IEEE, 2020.

[2] X. Zhu, N. Liu, and Y. Shi, "Artificial intelligence technology in modern logistics system," en, *International Journal of Technology, Policy and Management*, pp. 66–81, 2022.

[3] O. Telling, "Multinationals turn to generative ai to manage supply chains," en, *Financial Times*, p. 1, 2023. [Online]. Available: `https://www.ft.com/content/b7fafed2-9d00-49b0-a281-c1002b139865#comments-anchor`.

[4] B. De Muynck, "The true role of ai in logistics," en, *Forbes*, p. 1, 2023. [Online]. Available: `https://www.forbes.com/sites/forbestechcouncil/2023/08/17/the-true-role-of-ai-in-logistics/`.

[5] J. Dias, "Analysis of design science research methodology and entrepreneurship connections," en, *Instituto Superior Técnico, Universidade Técnica de Lisboa, Portugal*, p. 8, 2013.

[6] X. Gong, "Optimization algorithm of logistics warehousing and distribution path based on artificial intelligence technology," en, in *2022 International Symposium on Advances in Informatics, Electronics and Education (ISAIEE)*, Frankfurt, Germany: IEEE, 2022.

[7] J. Shi, *Research on Optimization of Cross-Border e-Commerce Logistics Distribution Network in the Context of Artificial Intelligence*, en. Mobile Information Systems, 2022.

[8] A. Szymonik, *Logistics and Supply Chain Management.* Feb. 2012.

[9] C. Mu and X. Wang, "Research on the development path of logistics and express delivery industry in the era of artificial intelligence," en, in *2020 International Conference on Urban Engineering and Management Science (ICUEMS)*, Zhuhai, China: IEEE, 2020.

[10] X. Zhang, "A comparative study on the influence of artificial intelligence robot distribution and traditional logistics distribution mode," en, *Journal of Physics*, Conference Series, 2021.

[11] X. Du, "Research on the artificial intelligence applied in logistics warehousing," en, in *ACM International Conference Proceeding Series*, Virtual, Online: Association for Computing Machinery, 2020, pp. 140–144.

[12] V. Carlan and T. Vanelslander, “Economic aspects of introducing artificial intelligence solutions in logistics and port sectors: The data entry case,” en, in *FRONTIERS IN FUTURE TRANSPORTATION*, V. Carlan and T. Vanelslander, Eds., vol. 2, Antwerp, Belgium: FRONTIERS MEDIA SA, 2021.

[13] J. M. J. Bughin, “The promise and challenge of the age of artificial intelligence,” en, *McKinsey*, p. 1, 2018. [Online]. Available: `https://www.mckinsey.com/featured-insights/artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence`.

[14] Y. C. Maria Jesus Saenz and Ç. K. Yalçın. “Ai-driven supply chains: 3 cases | mit scale webinar | english,” MIT Center for Transportation & Logistics. (2024), [Online]. Available: `https://www.youtube.com/watch?v=w1Rde0vXg7k`.

[15] A. Shatat and A. Shatat, “The use of artificial intelligence capabilities in logistics and supply chain management: Major challenges and key benefits,” en, in *2022 ASU International Conference in Emerging Technologies for Sustainability and Intelligent Systems (ICETSIS)*, Manama, Bahrain: IEEE, 2022.

[16] M. Foster and S. Rhoden, *The integration of automation and artificial intelligence into the logistics sector a caribbean perspective. worldwide hospitality and tourism themes*, en, 2020.

[17] K. Vitasek, “What’s the difference between logistics and supply chain management? (and why it matters),” en, *Forbes*, p. 1, 2023. [Online]. Available: `https://www.forbes.com/sites/katevitasek/2023/08/18/whats-the-difference-between-logistics-and-supply-chain-management-and-why-it-matters/?sh=4b924e314d63`.

[18] J. P. S. C.-S. S. C. U. A. R. K. S. B. Peter Gailhofer; Anke Herold, “The role of artificial intelligence in the european green deal,” en, *European Parliament, Policy Department*, p. 70, 2021. [Online]. Available: `https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2021)662906`.

[19] S. C. E. Y. R. S. A. S. S. Z. S. A. D. O. Klier, “Navigating rising cyber risks in transportation and logistics,” en, *BCG*, p. 1, 2021. [Online]. Available: `https://www.bcg.com/publications/2021/navigating-rising-cyber-risks-in-transportation-and-logistics`.

[20] R. Richey, S. Chowdhury, B. Davis-Sramek, M. Giannakis, and Y. Dwivedi, “Artif icial intelligence in logistics and supply chain management: A primer and roadmap for research,” en, *Journal of Business Logistics*, 2023.

[21] UNESCO, “Unesco’s recommendation on the ethics of artificial intelligence: Key facts,” en, p. 10, 2021. [Online]. Available: `https://unesdoc.unesco.org/ark:/48223/pf0000385082.locale=en`.

[22] J. McKendrick, “The data paradox: Artificial intelligence needs data; data needs ai,” en, *Forbes*, p. 1, 2021. [Online]. Available: `https://www.forbes.com/sites/`

joemckendrick/2021/06/27/the-data-paradox-artificial-intelligence-needs-data-data-needs-ai/.

[23] DHL, "We, robot: How humans and ai are working together in logistics," en, p. 1, 2022. [Online]. Available: https://www.dhl.com/global-en/delivered/digitalization/ai-in-logistics.html.

[24] J. C. F. e. J. C. V. Ana Lúcia Martins, "88 vozes sobre inteligência artificial," pt, in Associação Indeg Projetos ISCTE e Oficina do Livro, 2023, ch. O papel da inteligência artificial nos transportes e na logística, pp. 49–57.

[25] E. COMMISSION, "Report on the safety and liability implications of artificial intelligence, the internet of things and robotics," en, p. 18, 2020. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0064.

[26] K. Ramachandran, "Data management barriers to ai success - is a holistic data modernization approach the answer?" en, *Deloitte*, p. 1, 2020. [Online]. Available: https://www2.deloitte.com/us/en/insights/industry/technology/ai-and-data-management.html.

[27] R. Peeler, "The hidden costs of implementing ai in enterprise," en, *Forbes*, p. 1, 2023. [Online]. Available: https://www.forbes.com/sites/forbestechcouncil/2023/08/31/the-hidden-costs-of-implementing-ai-in-enterprise/.

[28] I. Bird, "Reskilling your workforce in the time of ai," en, *IBM*, p. 1, 2023. [Online]. Available: https://www.ibm.com/blog/reskilling-your-workforce-in-the-time-of-ai/.

[29] K. Miller, "Ai overreliance is a problem. are explanations a solution?" en, *Stanford University*, p. 1, 2023. [Online]. Available: https://hai.stanford.edu/news/ai-overreliance-problem-are-explanations-solution.

[30] C. Gordon, "The rise of ai in the transportation and logistics industry," en, *Forbes*, p. 1, 2021. [Online]. Available: https://www.forbes.com/sites/cindygordon/2021/09/05/the-rise-of-ai-in-the-transportation-and-logistics-industry/?sh=74151c127869.

[31] D. Fedortchenko, "How logistics procedure optimization with ai can help diminish the transportation sector's environmental impact," en, *Forbes*, p. 1, 2022. [Online]. Available: https://www.forbes.com/sites/forbestechcouncil/2022/01/28/how-logistics-procedure-optimization-with-ai-can-help-diminish-the-transportation-sectors-environmental-impact/?sh=13c6c82a3a03.

[32] J. P.
bibinitperiod S. R. Alan R. Hevner Salvatore T. March, "Design science in information systems research," en, *MIS Quarterly*, p. 33, 2004.

CHAPTER 7

Appendices

7.1. Appendix A - Methodology

First Message: *"Hi [Name of the expert], I'm exploring AI's potential in logistics for my thesis and greatly admire your work in this field. I'd be honored to discuss your insights and experiences in a brief interview. Your expertise would greatly enrich my research. Let me know if you need any further information. Thank you!"*

Second Message: *"Hi [Name of the expert], I'm exploring the impact of AI in logistics on my thesis and seeking insights from experts, namely benefits, drawbacks, and challenges. Given your expertise, do you think your experiences could contribute? If so, would you be open to a brief interview? Let me know if you need more info."*

Intelligent Logistics	Benefits		Efficiency Enhancement and Cost Reduction	[9]; [14]; [11]; [13]; [14].
			Customer Service Improvement	[1]; [15].
			Enhance Decision Making and Data Management	[1]; [9]; [13].
			Reduce CO2 Emissions	[16]; [17].
	Drawbacks		Cybersecurity Vulnerabilities	[14]; [18].
			Ethical Implications	[19]; [20].
			Historical Data Dependency	[13]; [14]; [21].
			Robotics Limitations	[11]; [22].
			Uncertainty Human-AI Interaction	[14].
			Workforce Displacement	[19]; [23].
			Vulnerability to underperformance	[14].
	Challenges		Legal Liability	[14]; [24].
			Data Management	[19]; [25].
			Significant Resource Allocation	[23]; [26].
			Technical Gap	[14]; [27].
			Complex Business Ecosystems	[13]; [19].
			Errors Recognition	[14]; [28].
	Implementations	Purchase and Supply Chain	Image Processing	[9]; [11]; [23].
			AI-Powered Customer Care	[9]; [23].
			Inventory Management Algorithms	[9]; [13]; [23].
		Storage	Facial Access Control	[11].
			Warehouse Robotics	[4]; [11]; [23].
		Distribution	Digital Mapping	[9]; [11].
			Smart Roads	[23]; [29].
			Dynamic Routing Technologies	[13]; [23]; [30].
			Predictive Maintenance	[23].
			Unmanned Delivery Technologies	[7]; [9]; [11]; [23].

FIGURE 7.1. MLR Insights Framework: Intelligent Logistics Benefits, Drawbacks, Challenges and Implementations

7.2. Appendix B - Data Gathering

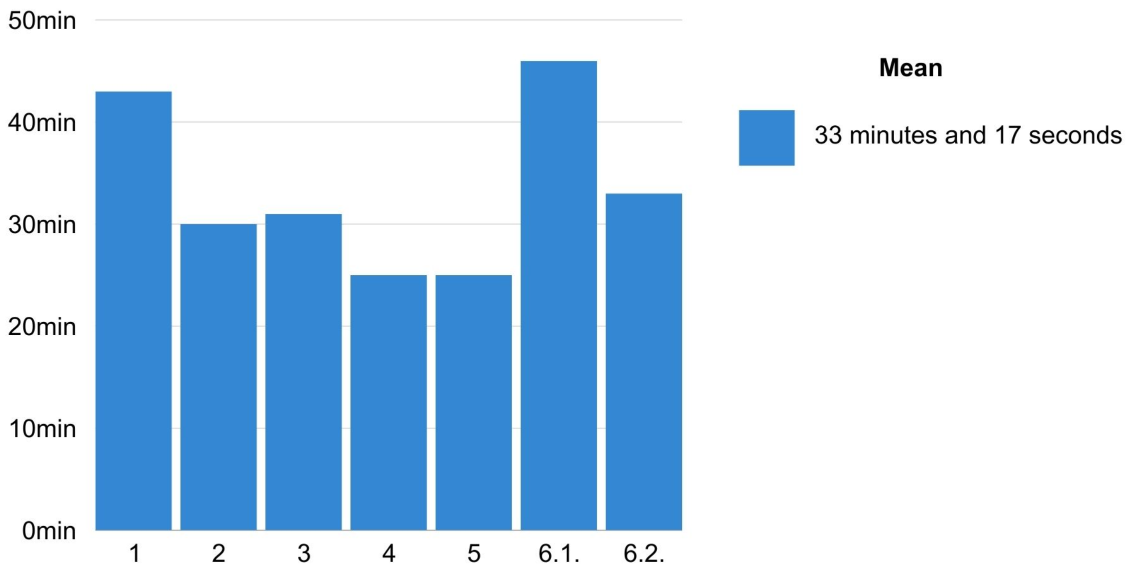

FIGURE 7.2. Duration in Minutes by Interview

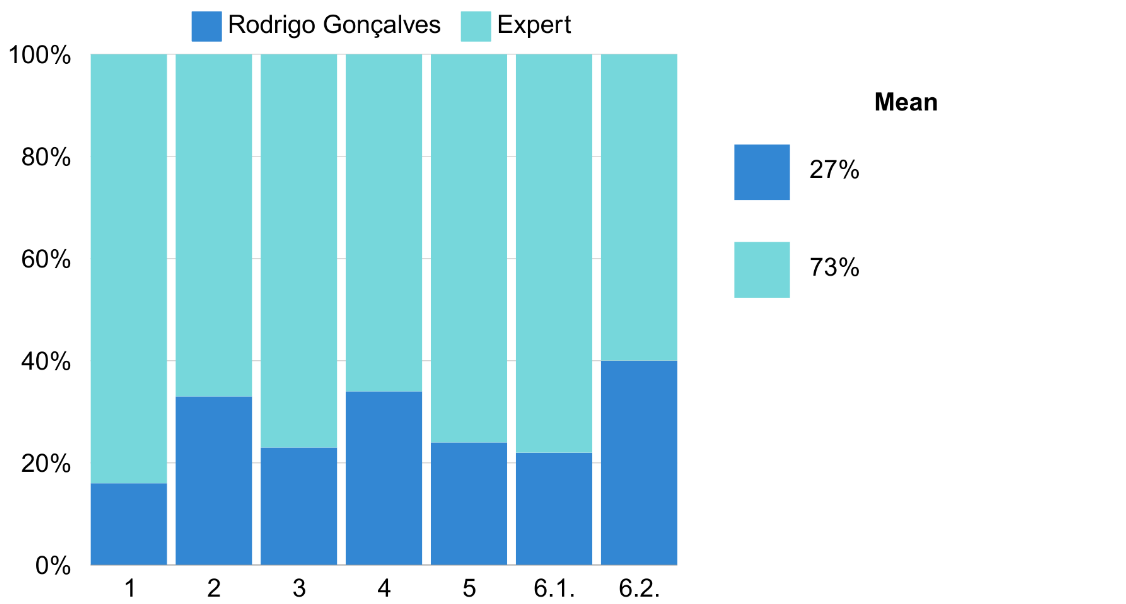

FIGURE 7.3. Contribution by Interview Participants by Interview

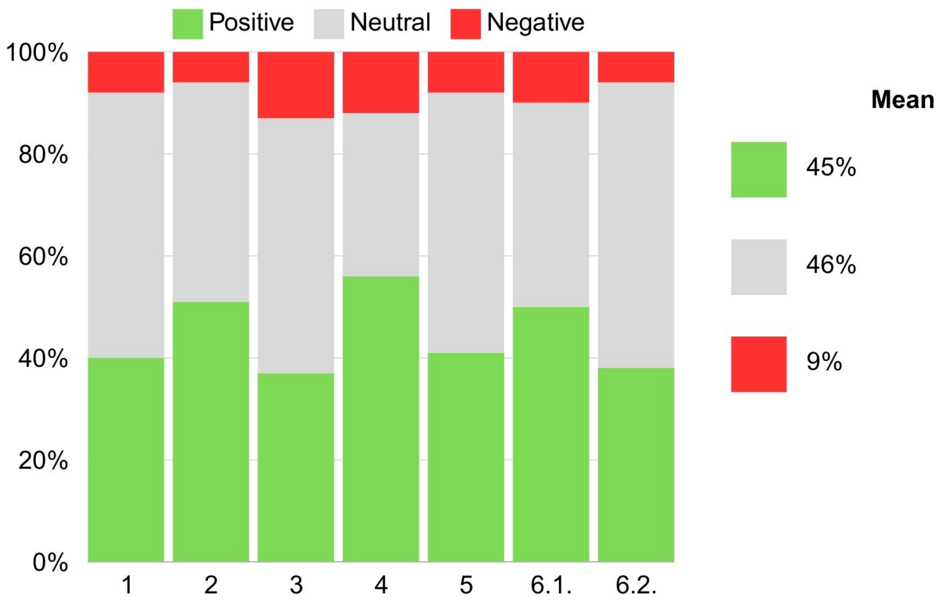

FIGURE 7.4. Sentimental Analysis by Interview

7.3. Appendix C - Results

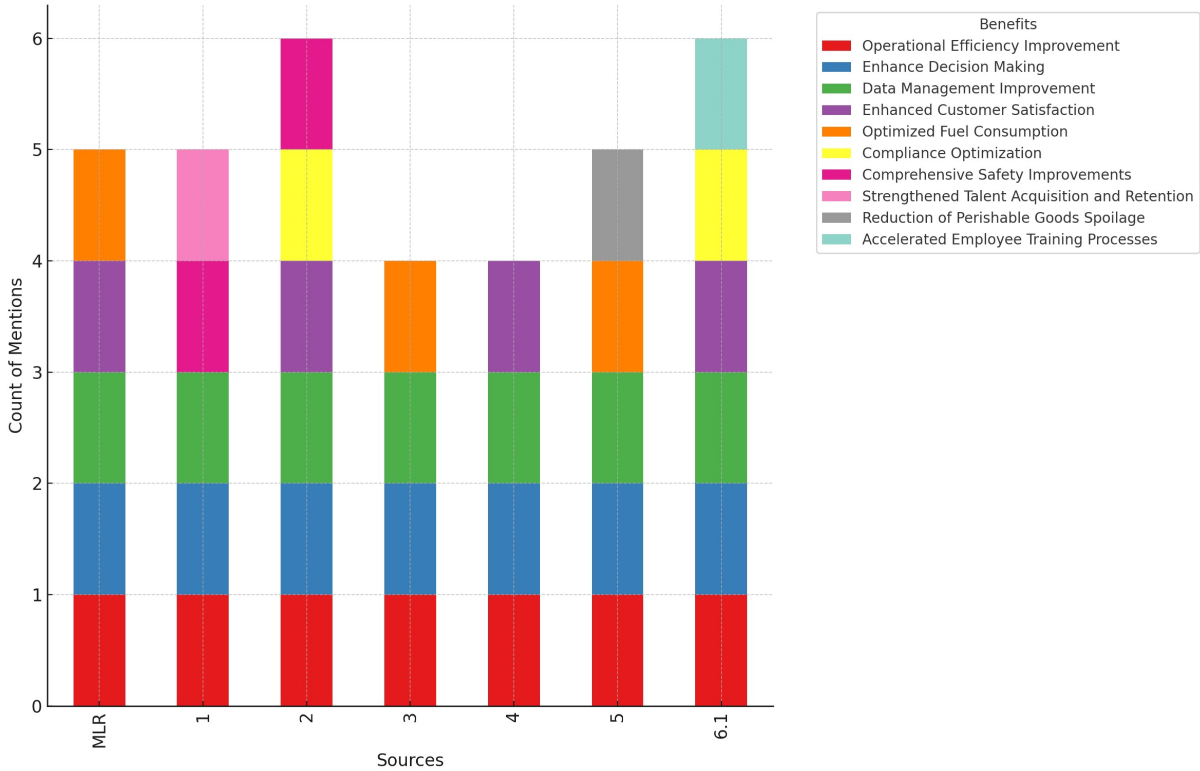

FIGURE 7.5. Benefits mentioned by source

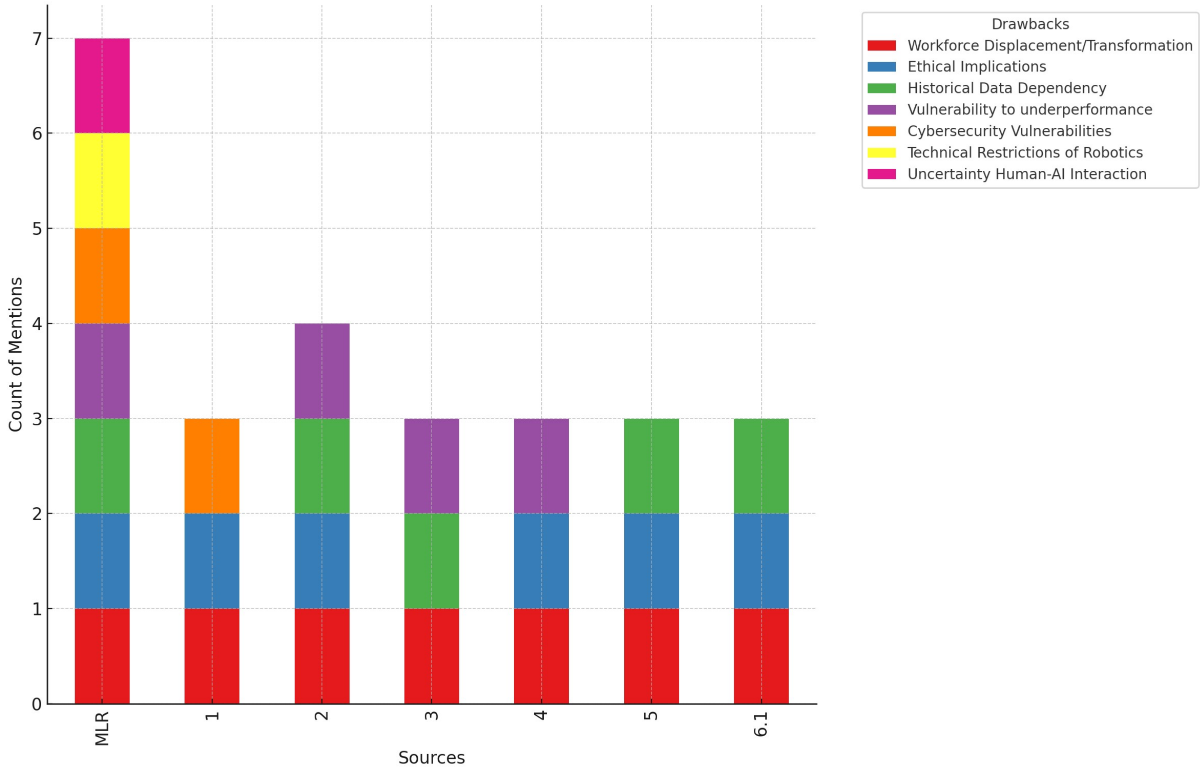

FIGURE 7.6. Drawbacks mentioned by source

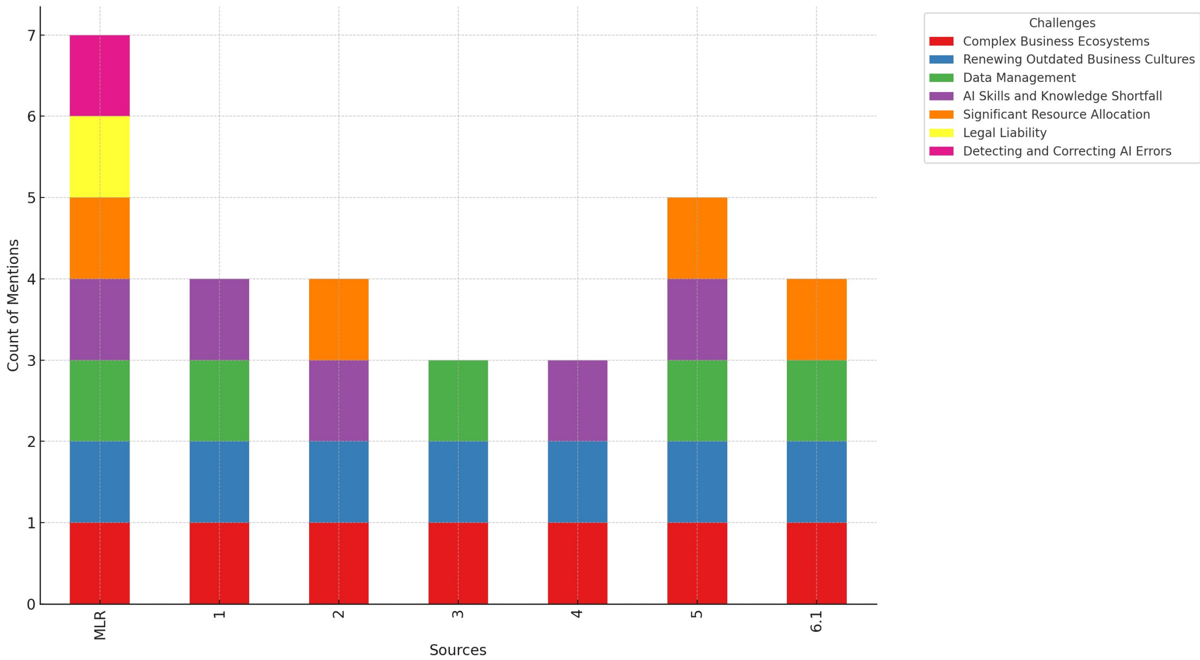

FIGURE 7.7. Challenges mentioned by source

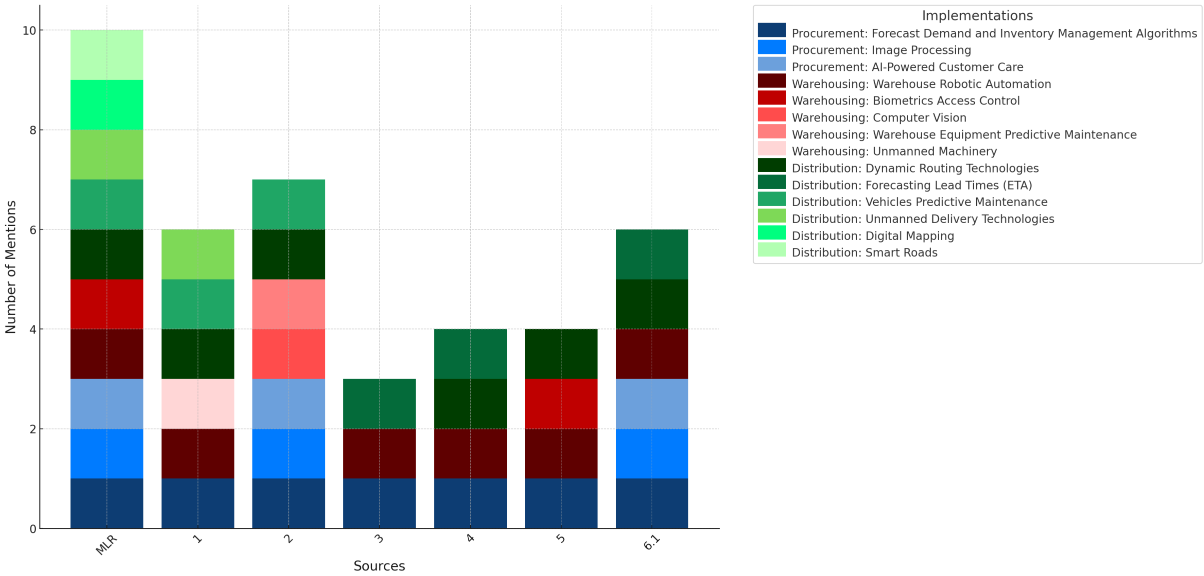

FIGURE 7.8. Implementations mentioned by source by Logistics Area

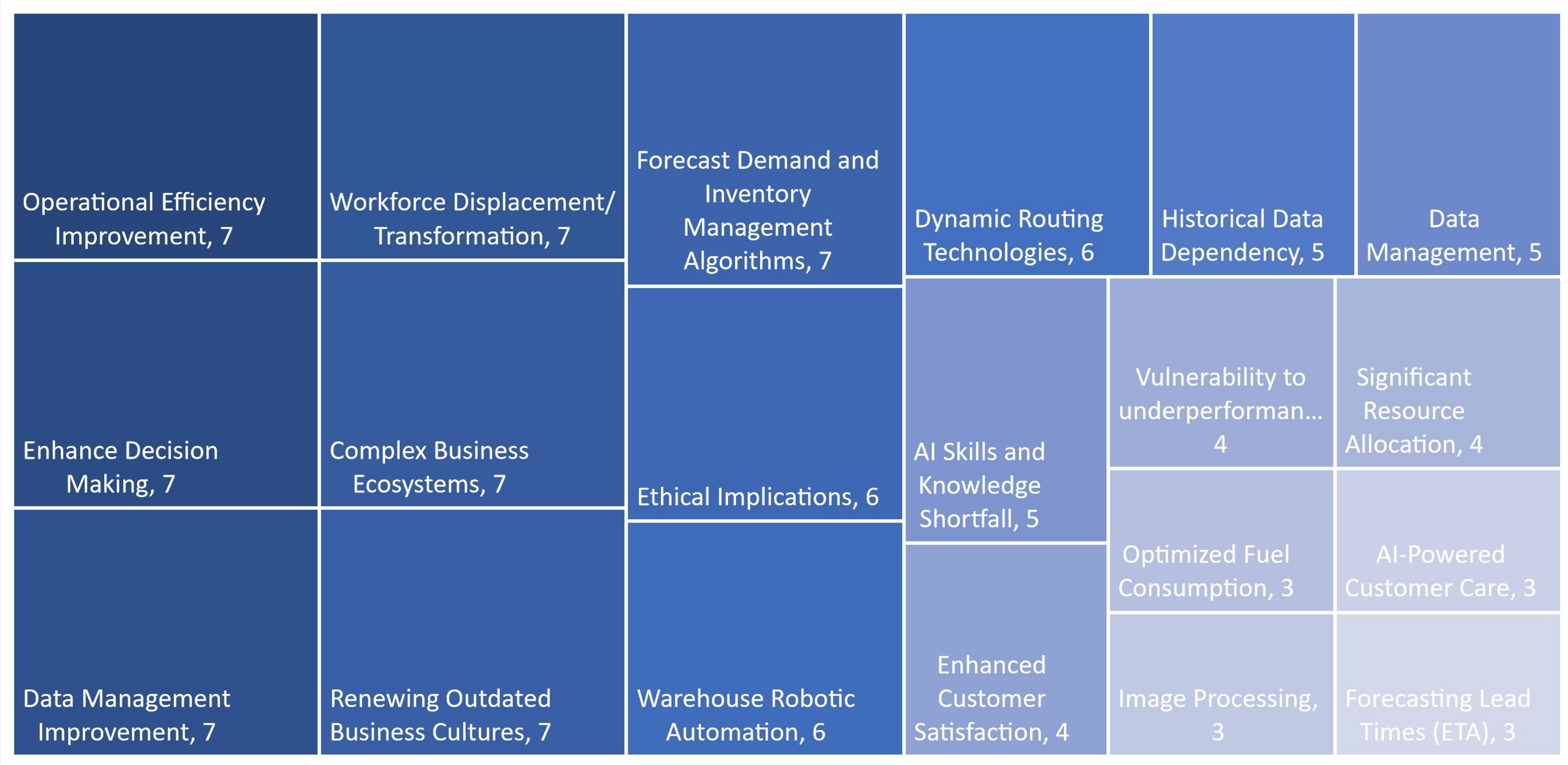

Figure 7.9. Treemap Visualization of the Top 20 Most Mentioned in the Final Framework Categories Based on Interviews and MLR (Entry, Occurrence)