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The Role of Artificial Intelligence in Smart Logistics

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***Abstract*— This research aims to explore the transformative role of Artificial Intelligence (AI) in enhancing smart logistics systems. It explores how AI, combined with other advanced technologies such as Machine Learning (ML), the Internet of Things (IoT), and Big Data, enhances supply chain management, reduces costs, and improves operational efficiency. Additionally, the study highlights the contributions of AI in promoting sustainable practices and addressing challenges within contemporary logistics frameworks.**

The methodology employed is qualitative, involving an extensive review of academic literature, industry reports, and real-world case studies. Data from credible sources, including peer-reviewed journals and industry examples such as DHL and UPS, were analyzed to identify key trends and innovations in smart logistics. Through an interpretive approach, the study provides in-depth insights into the implications of AI-driven technologies for improving logistics operations, customer satisfaction, and decision-making capabilities.

This research underscores the significant impact of AI on logistics transformation, offering a comprehensive understanding of its potential to revolutionize supply chain systems in the face of evolving industrial demands.

Keywords*— *Keywords: Artificial Intelligence, Smart Logistics, Big Data, Machine Learning, E-commerce, Smart Warehouse.

I. INTRODUCTION

Margins, The evolution of logistics has significantly progressed through technological advancements, culminating in the improvement of smart logistics systems. Smart logistics refers to the integration of innovative technologies such as Artificial Intelligence (AI), Machine Learning (ML), the Internet of Things (IoT), and Big Data to optimize supply chain management and enhance operational efficiency [1]. These technologies facilitate real-time data processing, enabling intelligent decision-making and adaptability to dynamic market demands [2].

AI plays a critical role in transforming logistics through predictive analytics, optimized routing, and efficient inventory management, significantly saving costs and enhancing customer satisfaction [3]. Furthermore, the integration of IoT devices with logistics systems enables seamless communication and data sharing, enhancing transparency and traceability across the supply chain [4]. Smart logistics also promotes sustainable practices by reducing fuel consumption and emissions through route optimization [5].

This paper explores the applications and implications of smart technologies in logistics, highlighting advancements in areas such as warehouse automation, predictive maintenance, and customer experience enhancement. By examining current trends and case studies, the study underscores the transformative potential of AI-driven logistics in shaping the future of supply chains.

II. RESEARCH METHODOLOGY

This study utilizes a qualitative research approach to examine the use of Artificial Intelligence (AI) in smart logistics. The research focuses on synthesizing insights from existing literature, case studies, and reports to understand the transformative potential and applications of smart technologies in the logistics sector. By employing a qualitative approach, this research aims to provide an in-depth understanding of how AI and smart technologies are reshaping logistics, emphasizing both theoretical contributions and practical applications.

A. Data Collection

The data was gathered from peer-reviewed journal articles, industry reports, and authoritative sources on AI, logistics, and related technologies. Publications such as those by [15]. [20], and [21] were critically reviewed to identify trends, challenges, and opportunities in smart logistics.

B. Case study examination

According to new implications driven by AI, this research Highlights some successful companies using smart logistics applications such as (DHL, SkyPlanner, and Presenso).

C. Framework

A framework is proposed to investigate the role of AI in Smart Logistics. The proposed framework where Smart Logistics Performance is identified as a dependent variable, while AI Technologies (Machine Learning, IoT, Smart Warehouse, Big Data Analytics) are identified as independent variables.

D. Interpretive Approach

The analysis is interpretive in nature, focusing on understanding the implications of smart logistics for increasing efficiency, reducing cost, and satisfying customers. The findings are contextualized within the broader framework of supply chain management and industrial transformation.

III. Definition and characteristics of Artificial Intelligence (AI)

Artificial Intelligence (AI) is the simulation of human intelligence by machines that can think, learn, and perform tasks such as comprehending language, problem-solving, and decision-making that usually require human intelligence [6]. AI possesses some inherent attributes that make it a breakthrough technology. AI systems can improve their performance by learning from data and adapting over time, improving their performance with experience. Many AI systems operate autonomously, requiring minimal human intervention to perform their tasks [6]. AI is efficient at solving problems by applying complex algorithms to effectively handle challenging situations. Furthermore, AI can comprehend, translate, and compose human language due to its natural language processing capabilities [7]. In combination, these features illustrate AI's adaptability and promise in a variety of fields[8].

Advances in AI can reduce the need for human interaction at work, optimize inventory placement, detect fraud in real time, and conserve energy. Various types of artificial intelligence technology include big data intelligence, swarm intelligence, autonomous intelligence, and self-adaptive intelligence [9]. Another key AI technology is predictive analytics, which examines historical data to forecast future events through statistical algorithms and machine learning techniques. Predictive analytics is used in supply chain management (SCM) to anticipate potential disruptions, such as delivery delays or supply shortages, allowing businesses to take proactive measures. Maintaining seamless supply chain operations, especially in extremely variable industries, requires this capacity. Predictive analytics helps businesses reduce risks and improve operational resilience by anticipating possible problems and optimizing logistics [10].

IV. The development of Smart Logistics using AI

Traditionally, the term logistics has been used to describe how to manage the flow of material and information [11], encompassing a wide range of essential services including warehousing, material handling, packing, supply/demand planning, order fulfillment, and inventory management [12]. The logistics industry is changing due to advancements in technology that are making the sector more complex. It is also conceivable to establish a direct link between logistics and the different stages of the industrial revolution [5]. The first logistics revolution was driven by the introduction of steam power, which brought about major structural changes by enabling new production techniques and reducing trade and transportation barriers. Logistics 2.0 was brought about by the Second Industrial Revolution characterized by electricity and factory assembly line labor. As a result, transaction systems had to be improved to handle the growth of global trade. Innovations such as railroads and steamships facilitated long-distance transportation. Electronic developments led to the automation of production during the third wave of industrialization. As a result, the demands of Logistics 3.0 rose, necessitating the faster, more accurate, and more economical handling of larger volumes. Blockchain, the Internet of Things (IoT), and artificial intelligence have the potential to improve traditional logistics operations by transforming them into a digitally monitored and networked framework [2].

V. Smart logistics

Smart technologies (STs) which include Artificial Intelligence (AI) machine learning (ML) and Big Data (BD) utilize technologies to develop an understanding of an entity, like a system through the use of information and communication technologies like the Internet of Things (IoT) as well as Blockchain (BC), among other tools [1]. The revolution of smart logistics helps solve logistics problems by offering new opportunities. Some STs technologies like communication technology (ICT) and the Internet of Things (IoT) can significantly adapt to any amount of data that solves the difficult transaction relationship to optimize any mathematical analysis [13]. The expression Smart Logistics is widely utilized, describing logistics systems that are adaptable and capable of responding to market fluctuations and customer needs. Smart logistics is a term we are using these decades which reflects our new advantage in using key technological components and digital tools for logistics such as Cyber-Physical Systems (CPSs) and the Industrial Internet of Things (IIoT). These technologies can easily improve the overall logistics operation and the whole supply chain performance. As well as facilitating more activities supporting tracing cargo or materials either inside or outside the factories, real-time tracking activities will optimize logistics management [14]. Although, STs aim to achieve customer needs and delivery preferences through information and communication in a green way that can directly enhance performance in all industries. Smart logistics is the movement of commodity-based organization, planning, and control activities to reach the most effective type of data that facilitates traffic structure and navigation for optimal traffic system use. In addition, Coordination of the flow of information from one place to another is referred to as logistics. Inventory control, shipping, packing, material management, temporary social security, and storage are all included in logistics [4].

VI. Applications of smart technologies in logistics

Now all applications we use daily are automated with STs technologies that enhance operation efficiency, time, and cost reduction. Recently applications have helped in many areas such as smart cities, smart retailing, smart homes, smart manufacturing, and smart ports [1]. These applications are used to facilitate our lives in all forms like online search in shopping, online smart retailing for goods and services, online smart manufacturing in addition to smart warehouse optimization.

A. Big Data and Machine Learning

Machine Learning (ML) is the creation of computing technology that improves independently utilizing experience. Generally, ML is divided into two: gradient learning algorithms

(e.g., gradient descent) and gradient-free learning algorithms (e.g., extreme learning machines) [1]. ML is a merged part of Artificial Intelligence (AI) which means that it has some of its components like automation detection of databases. However, using ML is more efficient for algorithms that adapt to a large database. Moreover, Deep Learning (DL) is a subcategory of ML as they have the same features in processing information, communication, as well as analysis, and classification [15]. To enhance learning through an application one needs a dataset for training purposes called training data. Additionally, another dataset is needed for testing to evaluate the effectiveness of the algorithms. BD can handle data with large, large amounts, vary, and is difficult to structure [1].

B. Smart Warehouse

Warehouses are the primary stage in supply chain management to enhance the smoothness of logistics operations in any industry. It has the main role in defining the company's competitiveness as it reduces the logistics cost, which is the most important cost among all other activities that are done in production cost [16]. Warehouses that use automation and a range of technologies (e.g., AI, ML robotics, etc.) to optimize their operational footprint and minimize latency [17]. Warehouse Automation: AI-powered robotics have achieved higher speeds and reduced the incidence of errors during order selection and inventory handling, consequently increasing warehouse productivity by 30–50% [18].

Fig. 1 The number of publications with keywords related to the smart warehouse [19].

The number of publications has grown since 2010, as shown in Fig. 1. This indicates a growing interest in particular areas related to smart warehouses. Publications show a growth trend on average. New warehousing technologies have emerged and been implemented, contributing to the growing trend. The trend shows that articles in 2015–2020 are more orientated towards new equipment like RMFS, AVS/RS, and SBS but there is also a difference between the years of publication with 2000–2014 and 2015–2020 [18]. An increase follows this in articles associated with warehouse operations management and optimization from 2018 to 2020. The rise of articles indicates the improvement of operation management and warehouse development that increased using the new warehouse technologies recently [19].

The layout is built in such a way that it smooths inbound and outbound materials, including Docks, picking storage, and racking systems for storing items. There is further capacity in the building for pallets which are normally put on the racking system inside the warehouse, considering the size of the same. The warehouse is equipped with three unloading and loading docks and open spaces for storage. It is observed from Fig. 1. that the trucks carrying delivery/pickup of goods and RMs arrive at one of the goods required and are collected or delivered by the operators from/to their storage area to/from Loading/unloading docks. The inspector shall inspect the inbound and outbound items regarding quality, quantity, packaging, and invoices. On the contrary, an Inventory encoder updates inventories in the system in both cases, In and out. Besides, the forklift operators know how to control the handling process as well as where to stock the goods, usually closer to the docks. Traditional Warehouse: Characteristics The warehouse is installed in such a way as to work with an area in which certain factors limit the surface available and to meet all the needs of daily activities in the warehouse [16]. The layout has been designed to cover the following needs of the most important areas in the warehouse:

- Loading and unloading areas.
- Reception area for new receipts.
- Storage area for storing items.
- Picking an area for assembly.
- Dispatch area for delivery.

C. Artificial Intelligence

Artificial Intelligence, which incorporates human cognition into a computer program, was defined a long time ago and is said to be the culmination of computer science and engineering of intelligent computer systems [20]. AI in logistics can reduce operational costs by as much as 20-40% resulting from the automation of processes, better routing, and maintenance tasks [21]. There are AI-driven systems for route optimization, which have decreased fuel & delays enabling a 15-25% increase in delivery efficiency [20].

Integrating Artificial Intelligence into smart logistics optimizes productivity, enhances flexibility & facilitates decision-making. With its adeptness at quickly processing and accurately interpreting large volumes of data, AI allows on-the-spot tracking of operations thus reducing wait time. It makes it more efficient to perform tasks such as monitoring supply levels, predicting customer needs, and routing vehicles, all of which lower operational costs [20]. AI has shown that compared with traditional approaches, where a single management model is applied, machine learning or deep learning processes historical and current data and adjusts to situations requiring intervention, for instance where there are unexpected delays or demand fluctuations [22]. Moreover, AI improves the scalability and flexibility of a logistics system through its predictive capabilities by anticipating demand spikes and allowing the system to scale its resources as needed [20]. According to Fig.

2. artificial intelligence is expected to contribute 31.3% of Saudi Arabia's GDP from 2018 to 2030.

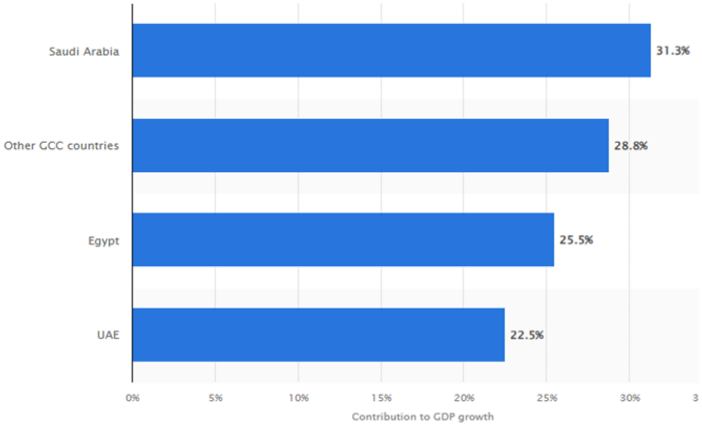

Fig. 2. Forecasted contribution of artificial intelligence to gross domestic product growth in the Middle East and North Africa region between 2018 and 2030, by country [24].

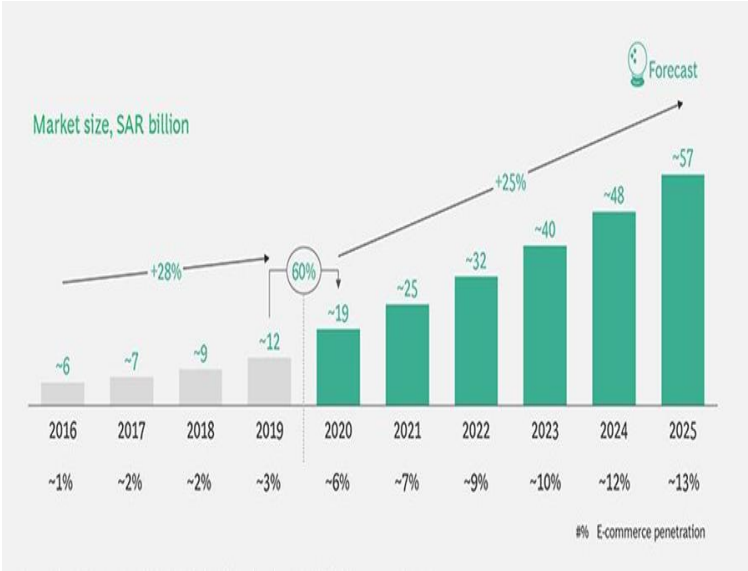

Fig.3 Increased number of users of e-commerce in billion [23].

VII. E-COMMERCE GROWTH TRENDS USING ARTIFICIAL INTELLIGENCE

In Saudi Arabia, the E-commerce market has experienced enormous growth during the COVID-19. According to figure (3) the number of e-commerce is expected to hit SAR 50 billion by 2025 A 7% and a 5% additional growth is anticipated, respectively, due to the effects of the pandemic between 2020-2022 and 2023-2025. The trend, however, gained momentum during the coronavirus pandemic as the movement was curtailed and so did social isolation. Fast food, traditional restaurants, and other retailers rapidly adopted the trend of utilizing various mobile applications to attract additional customers and adopting the new trends provided by e-business trends. The model was quickly adopted by some of the retailers, including Carrefour and Hyper Panda, which included free home delivery with certain limitations, to attract the customer base. E-commerce in Saudi Arabia is still in its early stages. In 2020, it accounted for just 6% of total retail sales, compared to leading e-commerce markets, whose global penetration reached 18% in 2020 [23]. However, AI plays a global role in the logistics market that is expected to enhance the operation by 2030 with $20.91 billion, From the years 2023 to 2030 the market will significantly increase compound annual growth rate (CAGR) of 21.1% [23]. Demand forecasting systems with AI capabilities can increase accuracy by up to 85%, preventing stockouts or overstocking [23]. Customer Experience: By offering real-time updates and answering questions 40% quicker, AI-powered chatbots and tracking systems have raised customer satisfaction ratings [23].

VIII. SUCCESSFUL COMPANIES USING SMART LOGISTICS APPLICATIONS

STs are now impacting the logistics sectors and transportation systems in a very rapid manner. Back in 2016, DHL named six technological breakthroughs that are expected to transform logistics by 2030 which include 'Big Data', Sensor Technology, Augmented Reality, 3D printing, Robots, and Drones. Thus, for example, DHL implemented its smart warehouses in three locations in Europe (Germany, Netherlands, and Poland) for which success was announced not only by boosting operational capabilities but also by providing support for operational data visualization. Through pilot sites, DHL also stated that they had clear insights into how well their warehouses were operating. Just recently, UPS unveiled its intelligent warehouse technology to enhance efficiency in distribution centers by harnessing the capabilities of autonomous technologies such as autonomous mobile robots, autonomous guided vehicles, automated sorting systems, etc [1]. DHL research explains their notion about digital twins in logistics. The advancement of artificial intelligence propelled digital twinning and cyber-physical systems toward the creation of more value. Today, all the data that DHL possesses from sensors, historical performance, and input about the behavior is exposed to integration with spatial models to allow predicting the behavior once several inputs are altered. The data and prediction capabilities of AI make the spatial model come alive [20].

SkyPlanner APS has integrated Artificial intelligence into the advanced scheduling and planning process enhancing performance in the work order. One of the capacities is AI which enables scheduling and sequencing of work orders most effectively and economically possible. Other relevant details that can improve the overall productivity of the job are also taken into account. For instance, in many productions, it is

reasonable to arrange processes where the same materials or tools are required in a chain [20].

Presenso's functions are related to the prediction of maintenance using machine learning and deep learning algorithms for accurate failure prediction Presenso incorporates efficient predictive maintenance strategies that logistic companies can harness realistic savings and yield maximization. Stream and transmit data from machines to Clouds for analysis in real-time. Presenso does not just provide unsupervised deep learning neural network abstractions, it stitches events to components in the machines and can forecast failures that are in the process of happening. Additionally, it also contains useful features where information on the time to failure and its position in the machine is located [20].

IX. Conclusion

It is intelligent logistics that, with the aid of AI, drives efficiency and reduces costs in modern integrated supply chains, while boosting sustainability. AI itself makes predictive analytics, optimized routing, and better inventory management possible to significantly improve the reliability and speed of delivery. It automates routine tasks, minimizes human error, and improves decision-making abilities in a way that streamlines logistics operations, reduces environmental impact due to route optimization, and cuts fuel consumption. These advancements are fostering a greener logistics industry. As AI continues to evolve, it will further provide greater opportunities for innovation and efficiency in smart logistics; it will improve our lives by guaranteeing quicker deliveries, shaving off costs, ensuring sustainability, and generally increasing the effectiveness of worldwide supply chains. Conclusion: AI across smart logistics stands as a transformation driver, which will continue to strengthen the logistic service quality and our day-to-day experience.

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