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The Reshaping of Modern Retail Logistics by Artificial Intelligence: A Literature Review of E-commerce Distribution Centres

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Abstract. The explosive growth of e-commerce has placed significant demands on logistics services, particularly in terms of response speed, accuracy, and cost control. Traditional warehousing models are no longer sufficient to meet the increasing requirements. Artificial intelligence technology has become an inevitable choice for the industry to build core competitiveness. This paper reviews recent literature to explore how artificial intelligence can reshape modern e-commerce distribution centres. By analysing the transformative application of machine learning, computer vision, and robotics in practice, the study shows that artificial intelligence is transforming distribution processes, moving from manual labour to algorithm-driven workflows. Through accurate demand prediction, automated warehouse operations, dynamic route optimisation, and intelligent decision-making, AI transforms distribution centres from cost centres to value generators, thereby enhancing supply chain agility and intelligence. Despite challenges such as high initial investment costs and complex system integration, the deep integration of artificial intelligence and technologies such as the Internet of Things is accelerating industry-wide advancement. By constructing the framework of "process deconstruction-technology application-mode reshaping", this study provides a theoretical perspective for the evolution of intelligent logistics and demonstrates the significance of artificial intelligence in reshaping the modern retail logistics mode.

Keywords: Artificial Intelligence, E-commerce Fulfilment Centres, Intelligent Retail Logistics, Robotics, Algorithm-Driven Introduction.

1. Introduction

Propelled by the digital economy, global e-commerce has witnessed explosive growth. The expansion extends beyond the increasing number of transactions to basically reshape consumer views on logistics services. In addition, consumers put more emphasis on delivery accuracy and cost visibility [1]. The move from a "fast, efficient, and economical" pattern to an "ultra-fast, accurate, and flexible" pattern places unprecedented pressure on retail logistics systems. The traditional warehousing model, commonly associated with high-volume storage, slow turnover, and linear operations, has shown to be lacking and overloaded in dealing with the large, fragmented, and

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highly dynamic e-commerce order flows. Shortcomings in order processing performance, persistently high error rates, and the difficult balance between cost and speed show that the traditional model cannot meet the new-age needs.

Given the high demands placed on logistics systems by current e-commerce development, the introduction of AI and automation technologies has become an inevitable trend for industry transformation and a vital element in building core competitiveness [2]. These technologies are essentially transforming all segments, from warehouse operations to last-mile delivery, and shifting logistics operations from a labor-intensive model to a technology-and data-driven one [3]. Artificial intelligence is more than an assistant and turns into the 'operational brain' for the efficient and accurate running of modern e-commerce distribution centers. With data perception, intelligent decision-selection, and automated functions, AI systematically arranges the end-to-end process from inventory handling to order fulfillment. As such, it serves as the vital mechanism for balancing a high-touch customer experience and operational efficiency in today's fluctuating supply chain environment.

Using the result of the preceding analysis, this paper intends to study the powerful impact of artificial intelligence on core processes in e-commerce distribution centers and look into how these technological novelties are re-designing the whole retail logistics ecosystem. The research is designed with three targets in mind. First, it wants to explain the key operational processes and value-creation mechanisms of e-commerce distribution centers. Second, it will investigate the innovative applications, operational frameworks, and real value created by artificial intelligence technology along the supply chain. Third, based on the previous findings, it will discuss the new logistics service models impelled by artificial intelligence, like omni-channel distribution and instant retailing, which are redefining service standards and competitive atmospheres.

2. The evolution and theoretical foundations of e-commerce fulfilment centres

2.1. From warehouse to fulfilment centre: concept, function and evolution

E-commerce distribution centres are highly specialised logistic points constructed to satisfy the needs of e-commerce orders with high sensitivity in terms of time, low-order batches, and high order frequencies. Compared to classical warehouses, distribution centres are created to be able to deliver orders fast and fulfill them correctly and in minimum time by taking into consideration the bulk and long-term storage. On an operational level, the basic component moves off of traditional stores that depend on either boxes or pallets as the fundamental units to instant picking and delivery of single items. Thus, distribution centre has greatly increased the processing speed and enhanced the operational flexibility and executive ability. It is actually a lean order-driven processing system as opposed to a warehouse. The distribution centres are currently geared at data and artificial intelligence where they are strongly focused on machine learning, Internet of things, and robotics to achieve predictive features, decision-making, and self-optimisation.

2.2. Artificial intelligence technology stack

Deep learning algorithms can be used to formulate decisions that are intelligent and automated in distribution centres through the use of real-time data. Such systems combine machine learning to predict demand and optimise processes, computer vision to identify items and quality control and robotics to process. This move has improved visibility, flexibility, and reliability in the supply chain to a great extent, which has led to low operational costs and greater efficiency [4].

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3. Application and evaluation of AI across all stages of e-commerce distribution centres

3.1. Intelligent receiving and storage

Computer vision (CV) technology has a radical impact in the receiving phase of the distribution centres and enhances the efficiency and accuracy of operation. Computer vision systems may also be able to automatically recognize and classify goods received by their integration with high-definition cameras and image recognition algorithms. Since goods are passed through the conveyor belt, the system scans shipping labels, whereby the product details are quickly and correctly identified to complete inventory registration, cutting down the time of the inventory entering and handling many procedures. Besides mere identification, computer vision can also provide overall visual checking of goods by matching them with standard packages, which allows closer looking and intelligent awareness of some sort of unusual characteristics like damage, dents, or dirt on the package. Indicatively, Cheng et al. emphasized the need to perform automated checks on cargo condition with the help of a vision system to prevent the lack of workflow due to broken goods in the future [5]. This integration of automated damage detection will ensure that the wrong goods do not enter the warehouse, hence the decline of future disputes, returns, and missed operations. It has further developed a visual audit trail, which facilitates traceability and accountability of managing warehouses, and has made the overall process of receiving digitised and intelligent.

With the goods having been obtained, the warehouse applies the scientific organisation of shelves and storage procedures, which primarily determine the likelihood of future order completion. Under predictive analytics, the smart recommendations on how the merchandise should be arranged are realized on multi-dimensional product attributes (that is, physical attributes, like size, weight, shelf life, etc.) and dynamic sales information. Intelligent warehousing systems research can also forecast the volume of sales and the turnover rates of goods in the future by incorporating machine learning-based models like the one proposed by Zhang et al. [6]. By following such predictions, the algorithm is able to place the items intelligently in the most effective storage location. The general idea is to put the products at high demand nearer to the picking point or to put commonly bought products together and thus, minimizing staff picking time [4].

3.2. Intelligent storage and inventory management

The essence of intelligent warehousing is to create an image of a digital twin that is perfectly aligned with the physical warehouse and which is constantly updated. This model is used to compile multidimensional data, including the position of the cargo, stock numbers, position of the equipment and its state of operation in real time, with the assistance of the IoT sensors, RFID electronic tags, and warehouse management systems. The visualisation technology has transformed the traditional inventory management entirely: managers can instinctively see the overall operations in the warehouse on the digital screen of the control centre, not only the general layout of the warehouse but the exact position of a particular commodity; indeed, global visual management in many ways becomes real.

Digital twins actually achieve the claims of real-time synchronisation and natural-to-use display of inventory information, but they also offer trusted facility of data aid that can be conveniently used in the future to support the intelligent decision-making process. To take an example, an automatic warning that appears when the quantity in the inventory falls below the safety margin, which helps to prevent shortages or backlog of the warehouse inventory caused by delay or oversight of information, even at the expense of enterprises optimisation of inventory structure and decreasing

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the cost of warehouses, will significantly improve the accuracy of the stock quantity and improve the transparency of inventory management.

With the help of machine learning algorithms based on real-time data of the digital twins, the smart inventory system can correctly forecast the demand of different materials, and replenish them intelligently. As an illustration, Huang et al. have applied backpropagation neural networks to determine adequate historical sales, seasonality, market activity, and macroeconomic indicators to obtain accurate short- to medium-term demand forecasts [7].

Machine learning is more effective to capture the complex and changing demand laws and produce higher forecast results compared to traditional statistical methods. As the forecast results indicate, the optimal replenishment time and quantity of various materials will be automatically computed by the system and replenishment proposals generated or purchase orders issued as well as the most optimal point in terms of purchase cost, inventory cost and out of stock loss are minimised based on the results of the forecast. Such a model would not only decrease the huge sum of money that is prevented in stock but would also work to lessen the financial strain; the shortages within the above-mentioned inventory would be avoided by this model. According to the relevant research, the intelligent inventory management transforms the warehouse into active planning instead of passive response, allows for a dynamic optimisation of the inventory level, and provides flexible and efficient supply chain functioning [5,6].

3.3. Intelligent order picking

The fundamental operation of a distribution centre is order picking and its effectiveness and accuracy create a direct proportionality concerning the speed and cost of processing. The peculiarities of e-commerce orders include large volumes, the number of details and time. The previous mode of picking that is based on manual memory and paper records can no longer apply. The order picking is on a path of becoming smarter and more automated as artificial intelligence and robotics technology converge. The three areas of evolution, which are predominantly traced in this evolution, pertain to: products-to-people robotic systems, order batch processing algorithms, order route optimisation algorithms, and visual-aided picking technology.

It is the goods-to-people robot system that has transformed the conventional mode of operation, which is people-to-goods, and has brought massive efficiency. Easy moving items like autonomous mobile robots (AMRs) can manipulate the movement of heavy things through this system. The most typical example is a working model at Amazon Robotics hundreds of robots are involved to transfer shelf units at the instruction of an order management system. In picking items in an order, the system orders the robot to move the racks to a picking station, where the pickers take the necessary number of items as commanded, which will enable the pickers to concentrate on picking activities, hence increasing efficiency. Research has depicted that through efficient robot scheduling and route planning, the system manages to deal with warehouse congestion and maximise total throughput [5].

The algorithms of the intelligent picking system include route optimisation and order batch processing, and they can address the complex optimization problems that are combinatoric in nature. In the case of incessant orders, the AI algorithm should merge numerous orders into picking batches and map the best picker or robot picking path, respectively. It compares to the solution of the classical vehicle routing problem (VRP) when the route with the shortest distance/time is calculated, such as order priority, product weight, volume and accessibility to the route in different conditions. Such problems are addressed with the help of intelligent algorithms (including genetic algorithms). The process of generating and optimising solutions and selecting the best solution is repeated through the constant creation and optimization of solutions by performing the "selection, crossover

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and mutation" mechanism in biological evolution [8]. Task planning system has the ability to recalculate new orders immediately they come. By dynamically changing the distribution of tasks and considering all the factors (location of employees, task volume, urgency of task orders, etc.), they will be able to minimise the time to complete all orders and enhance efficiency.

Concisely, intelligent order picking, or robots, versus manual processing, managed to form an efficient, precise and adaptable cooperative system, and algorithmic optimisation of decision-making and visual technology to assist manual operations is realised and applied. This has been created through technology integration within the warehouse operations model helps the distribution centres address the challenges of modern e-commerce.

3.4. Intelligent packaging and sorting

Automated packaging systems identify product dimensions and accurately match packaging materials by combining visual measurement technology with artificial intelligence algorithms. The shape data of the product is captured using a high-resolution camera, and image processing algorithms are employed to calculate the length, width, height, and volume, based on which the automated packaging system selects the packaging method with the highest space utilisation from a predefined library of packaging specifications. For those items with irregular shapes, the system will simulate various placement methods to determine the ideal packaging location. This approach not only solves the problem of oversized packaging but also reduces the use of filling materials, thereby reducing logistics costs. Studies have shown that the introduction of an automatic packaging system can reduce the packaging material consumption of the company by 23% on average and improve the packaging efficiency by about 40%, which proves the optimisation effect of intelligent technology on logistics operations [9]. This technological innovation transforms the packaging process from relying on human expertise to data-driven decision-making, supporting green logistics and sustainability.

In the warehouse distribution scheduling process, artificial intelligence reconstructs traditional decision-making models using a multi-objective optimisation algorithm that balances multiple factors, including delivery cost, time efficiency, destination distance, and carrier reliability. For example, when transporting high-value goods, the algorithm prioritises carriers that offer full insurance; For general goods with less time requirements, it matches economical transportation solutions. Based on historical logistics data analysed using machine learning algorithms, the model optimises decisions by examining variables such as on-time delivery rates and loss rates for different routes. The intelligent algorithm also integrates external variables such as weather and traffic conditions. When unexpected congestion occurs on a route, the system recalculates the optimal alternative route [8]. This dynamic scheduling capability provides logistics networks with resilience against disruptions and balances transportation costs with service quality.

3.5. Intelligent returns processing

Reverse logistics is a significant aspect of an e-commerce distribution centre, yet it has always been very expensive to maintain and complicated. These steps involved in the return process include: commodity recycling, testing, sorting, re-warehousing, etc. Furthermore, the end-disposition handling the goods will rely on the integrity of the goods, e.g., fully usable and severely damaged. The manual judgment that was applied traditionally is not only subjective and arbitrary but also inefficient, resulting in wastage of resources. This is particularly clear in the fast-moving consumer goods sector: in most scenarios, the reverse logistics costs represent over 15 per cent of the overall

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operating expenses of the enterprises because of high rates of returns and low product shelf life [1]. All these issues demonstrate that the process of returning should be optimized as soon as possible with smart solutions. Computer vision, natural language processing, and predictive models are AI technologies that allow automatically recognizing the reasons of returns and real-time monitoring of the processing status of products, making the overall process of return related optimization possible. The level of efficiency and the cost of labour, as well as the rates of the judgment error, can be improved, and reverse-logistics strategies are capable of constant optimization, with the use of such AI technologies. As an illustration, through the history of returns, the enterprises will gain the chance to forecast which categories will be returned more often and act in advance by creating and preparing requisite response plans.

4. Discussion

4.1. Model transformation: from "people searching for goods" to 'algorithm-driven'

Artificial intelligence is transforming distribution centres from cost centres into data-driven value and analysis centres. With the combination of IoT, big data, and machine learning algorithms, it will convert the spatial and dynamic processes occurring in the work of the warehouse into so-called intelligent agents that can constantly create and supply feedback data.

The machine learning-driven intelligent warehousing system is able to automatically forecast the demand of products using the historical sales data and optimise the storage layouts of the warehouse. Considering the example, it is possible to put high-frequency items in easily reachable places and locate related items nearby to enhance the efficiency of operations [6]. This algorithmic model of goods-to-people as an improvement of the outdated model of people-to-goods, which is based on manual experience, will enable a qualitative improvement in operational efficiency, and the distributed centre will also become a supply chain decision centre rather than a mere implementation centre.

Artificial intelligence not only streamlines internal processes but also delivers proper analysis of the procurement and production plans far ahead of the supply chain by processing huge volumes of operational information. Studies indicate that the fundamental worth of artificial intelligence to the supply chain is that it can dramatically enhance the visibility, agility, and reliability of the entire network [4]. This allows the distribution centres to keep track of supply chain status on-the-fly, is able to rapidly simulate and implement contingency plans to respond to sudden demand or disruption in the logistics, and increases supply chain resilience. Equipped with data empowerment, the centres will become analytics centres that will generate value, improve customer experience and make better decisions throughout the supply chain.

4.2. Empowering new retail models

4.2.1. Omni-channel fulfilment

The use of artificial intelligence combines the inventory of various locations, online stores, physical stores, and regional warehouses, and creates an overall inventory picture by creating a completely new platform of inventory visibility and allowing intelligent provisioning as the key technology breed of the omni-channel distribution. In the case of an online order, the AI algorithm is developed to generate the best delivery solution in real time. This computation holistically considers the availability in the store nearest to the customer, the efficiency of the employees to pick up goods at

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the store, and the expenses of delivery to make an intelligent decision when deciding to either ship out of the warehouse or out of the closest store. This smart workload is not only efficient since it has the potential to maximise distributed inventory resources and minimise delivery time, but also appropriate in lowering the overall inventory expenditures and transportation losses made during the long distances, and giving the customers a better shopping experience [6].

4.2.2. Instant retail

The realisation of instant retail relies on accurate AI forecasting and dynamic scheduling. Through data analysis, such as community orders, weather conditions and real-time traffic, artificial intelligence predicts short-term demand and guides warehouses to accurately adjust inventory. After placing an order, the AI scheduling system minimises the total delivery time, ensures minute-level delivery commitments, and optimises delivery cost control by optimising picking and delivery routes, generating delivery locations, order priorities and traffic conditions [10].

4.3. Challenges and limitations

Diverse implementation of AI in distribution centres can be challenged in various aspects: high initial investment amounts, technological complexity due to integration with current systems, unavailability of multidisciplinary talents with skills in AI, data science, and logistics, rising risks of loss of data security and privacy, and no interpretability of the algorithmic decision-making process, which impact credibility and compliance [11]. All these things hamper the further implementation of AI technology.

4.4. Future outlook

The future of artificial intelligence use in the logistics distribution centres will be more efficient. Regarding the technology, the complete integration of AI and the Internet of Things will allow the unmanned warehouse to be even more automated, and the technology of the digital twin will be used to make the simulation, prediction and optimisation more accurate. In the latter, which are at the cutting edge of the research, advanced machine learning techniques provide real-time decision-making in a dynamic environment with sudden changes in orders or equipment. Human-machine cooperation will become the new normal course of action, and the abundance of data analysis and the routine repetitive planning activities will be performed by AI, whereas the human resource will deal with the abnormal cases, process optimisation, and the strategic decision-making process, putting all their inherent strengths into play. As generative AI, including large language models, is developed, human-computer interaction will become more natural, and administrators will also be enabled to acquire operational insights or give instructions in the form of natural language instructions. Introduction of the artificial intelligence technology in the distribution centre has enhanced the agility and flexibility of the supply chain and stimulated creation of an intelligent supply chain system.

5. Conclusion

Artificial intelligence has developed to a supportive tool, and now it is the key point and the core of the modern e-commerce distribution centres as it is radically changing the logistics of retailing. The combination of machine learning, computer vision and robotic automation gives AI the ability to optimize all operations, including those in the goods receiving or final delivery process and

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transform the labour-focused, experience-oriented model of work to the data-oriented goods-to-person system. This change improves consistency, speed and efficiency of resources at the operational level. It also involves using the distribution centres as value-creating nodes instead of cost sinks, tactically positioning supply chains as responsive to agility and making great decisions. Finally, AI encourages a real-time-response logistics model and dynamic optimisation and accurate service provision.

This research contributes to theory and practice of intelligent logistics. In theory, it hypothesises a deconstruct-apply-remodel model that explains how AI changes as a means to optimise operational efficiency to an engine of business model transformation and creates an archetypal theoretical tradition in this area. Practically, this research offers an action plan that is quite straightforward to logistics firms, retailers, and technology providers, as the interaction between organisational change, process innovation, and technology adaptation is the key to successful AI integration.

The research conclusions are based to a great extent on the existing literature, which makes the conclusions short of a socio-technical lens, including the ethical considerations and issues of labour restructuring that come with the extensive implementation of the artificial intelligence systems. The case studies should be used in the future to investigate organisational adaptation during implementation of AI. It would be more insightful to the policy and practice of efficiency to enlarge the field of research in which efficiency issues are taken into account and macro-level ones like labour rights and industry regulation.

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