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Analyzing the Operational Efficiency of Online Shopping Platforms Integrated with AI-Powered Intelligent Warehouses

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Abstract. The application and development of AI intelligent technology is the key to solving the current shortage of manpower in online malls and industries, and also improving the overall efficiency of online shopping Platforms operations. Modern people's living and consumption habits have changed, and online shopping focuses on delivery speed, accuracy and delivery quality. Therefore, Intelligent warehousing management plays an important role in the operation of online shopping Platforms. This study mainly uses the network DEA model to analyze the operating efficiency of online shopping platforms Integrated with AI-Powered Intelligent Warehouses. The online shopping platforms operation and management is divided into the AI intelligent warehousing stage and the sales department stage, and based on the operating efficiency weights of the two stages, the total efficiency of the online shopping platforms is measured by a weighted average. According to the empirical analysis results, the AI-Powered intelligent warehousing efficiency weights of all online shopping platforms are higher than the sales efficiency weights, indicating that the key to the overall efficiency of online shopping platforms is the AI-Powered intelligent warehousing operation and management efficiency. Although D1 (Shopee Taiwan) has the highest sales efficiency value and annual transaction volume, its efficiency value in the AI-Powered intelligent warehousing stage is lower than D3, resulting in the total operating efficiency being lower than D3. Therefore, it can be seen that the operating efficiency of the AI-Powered intelligent warehousing department is currently The key to the success or failure of online shopping platforms operations.

Keywords: AI-Powered intelligent warehousing, network DEA model.

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1. Introduction

The rapid advancement of the Internet and technology has shifted global shopping habits, including those in Taiwan. Currently, online shopping has become a widely preferred shopping alternative [9], [19], [7]. For instance, according to a 2022 survey by the Market Intelligence & Consulting Institute (MIC), there was a notable increase in online spending among consumers in Taiwan. Statistically, 43.4% of respondents reported an annual online shopping expenditure between NTD 10,000 and 60,000, marking a 4.1% increase. Furthermore, 18% of respondents spent over NTD 60,000 in 2022, representing a 4.9% rise. Of this group, 9.1% spent between NTD 60,000 and NTD 100,000, while 8.9% were heavy spenders with expenditures exceeding NTD 100,000. These statistics underscore the growing acceptance of online shopping, driven by the widespread use of the Internet and mobile devices. This transition has prompted traditional brick-and-mortar shop operators to undergo digital transformation, shifting their focus from physical stores to their official websites, online shopping platforms, or e-commerce to meet consumer demands. This sentiment is supported by [4], who note the rapid growth of online sales businesses utilizing e-commerce. Additionally, the COVID-19 pandemic, which began in 2020, boosted the online shopping trend. Concerns about virus transmission prompted consumers to minimize in-person shopping trips at physical stores, further fueling the growth of online shopping platforms. As uncertainty persists amid the novel COVID-19, consumers have become more cautious about shopping in public. Moreover, the widespread use of today's technology makes consumers' preference for online shopping predictable [5]. Despite advancements, online shopping platforms still encounter challenges. [31] highlighted one such challenge: the increasingly low availability of warehouse workers for warehouse operations, impacting the picking process. Moreover, [33] stressed the importance of a comprehensive system for online sales, encompassing online communication, logistics management, and customer service. In the context of low-price competition, [33] cautioned that any misstep in the process could lead to a subpar customer experience. [34] also highlighted the pivotal role of warehouses in e-commerce distribution, noting the widespread adoption of warehouse-distribution integration for efficiency. Estimating full-link delivery time remains a key concern in this integrated model, affirming the significance of warehouses in logistics operations.

With the evolution of Internet technology and artificial intelligence (AI), intelligent warehouses, also known as a smart warehouse, are gaining traction. An intelligent warehouse utilizes advanced technologies to improve efficiency, effectiveness, and overall operations. [2] asserted that these facilities aim to enhance overall service quality, productivity, and efficiency while minimizing costs and failures. [6] identified order-picking as a major time-consuming warehouse process, accounting for over 55% of warehouse operational costs. Consequently, efficient warehouse management through technologies has emerged as a significant topic. [23] similarly advocated for enhanced warehousing process management, aligning with the trend of informatization and lean material warehouse management. Hence, exploring the operational efficiency of online shopping platforms, particularly in the context of intelligent warehouses, warrants attention.

Prior literature suggested that existing studies on e-commerce or the operational efficiency of online shopping platforms predominantly focused on inputs and final outputs [14], [13], [28]. For instance, [14] conducted an in-depth analysis using a two-stage methodology to examine the specific influence of competition on the operational efficiency of garment companies (with B2C mode) operating in an e-commerce environment. Their findings revealed that competition significantly increased pure technical efficiency but did not positively impact scale efficiency. However, a limited number of studies have analyzed the impacts of automated picking, packaging, and transportation on the operational efficiency of online shopping platforms during the AI-powered intelligent warehouse phase, where inputs translate to outputs. Thus, this study aims to assess the performance of online shopping platforms in Taiwan in terms of operational efficiency during the AI-powered intelligent warehouse phase, market efficiency, and overall operational efficiency from 2018 to 2023. The outcomes of this investigation can provide a foundation for developing strategies for substantial improvement.

2. Literature Review

2.1. Online shopping platform

The advancement of Internet technology has unlocked new business opportunities for companies to capitalize on new opportunities for profit growth. E-commerce, stemming from the rapid evolution of Internet technology, empowers enterprises to explore expanded business opportunities unrestricted by temporal or spatial limitations. E-commerce is at the forefront of transforming marketing strategies, based on new technologies, and facilitates product information and improved decision-making [26]. Facilitated by shifting consumer behaviors, online shopping platforms have emerged, granting consumers access to various products or service offerings. Consumers can browse products, place orders, make payments, authorize deductions, and communicate online with the platform's customer service. [15] defined e-commerce from four different perspectives:

1. From a communications perspective, e-commerce encompasses delivering goods, services, information, or payments via computer networks or other electronic means.
2. From a business process perspective, e-commerce denotes the application of technology to automate business transactions and workflows.
3. From a service perspective, e-commerce serves as a tool addressing the desire of organizations, consumers, and management to reduce service costs, enhance product quality, and increase the speed of service delivery.
4. From an online perspective, e-commerce provides the capability of buying and selling products and information on the Internet and other digital services.
   The classification above underscores the intrinsic connection between e-commerce and consumers.

Consequently, the majority of subsequent studies on online shopping platforms revolved around the topic: What motivates consumers to engage in online shopping [30], [27], [11], [32], aiming to identify the factors that influence consumers' online shopping behavior for further improvement. However, online shopping entails several drawbacks, as outlined below:

1. Customers are unable to physically inspect the products before purchase.
2. Delivery times may be excessively prolonged at times.
3. Additional shipping charges may inflate the product's overall cost.
4. Sellers often lack personalized attention, increasing the risk of fraud.

5. Concerns arise regarding the security of online banking and credit card passwords.
6. Issues regarding product quality may arise [20].

These disadvantages highlight the pivotal role of warehouses in the operations of online shopping platforms. As sales on online shopping platforms surge, the transition to e-commerce warehouses becomes inevitable due to their advantages, including automated and intelligent operations. Beyond enhancing logistics efficiency and quality, e-commerce warehouses can minimize error rates and time costs, thereby delivering superior customer experiences and efficient delivery services.

2.2. Intelligent Warehouse

For online shopping platforms, warehouse management encompasses the systematic control of the flow, distribution, packaging, picking, storage, and classified processing of goods within the warehouse. Warehouses play an important role in the industry supply chain, as well as the production of any industrial unit. The whole flow of a company runs smoothly with respect to its warehouse, as it is used to store, manage, and track the goods [17]. To enhance efficiency, resources and procedures should be fully leveraged. As technology advances, warehouse management has shifted from traditional to automatic warehousing. Subsequently, the advent of Industry 4.0 has paved the way for intelligent warehouses, facilitated by advancements in the Internet of Things (IoT), AI, cloud computing, and big data analytics. Integrating software and hardware, along with sensors, automated drivers, and IoT, intelligent warehouses are expected to reduce labor costs and enhance accuracy and traceability. As outlined by [24], a smart warehouse embodies the future of intelligent warehousing, fostering flexible, reconfigurable, and agile warehousing environments by automating warehousing activities and running diagnostics for equipment repair and improvement, facilitated by seamless communication among computer systems, mobile devices, machinery, automated guided vehicles (AGVs), and equipment on the warehouse floor. Key components of a smart warehouse include (1) cyber-physical systems, (2) cloud computing services, (3) Internet of Things (IoT), (4) automated control platforms, (5) warehouse management systems (WMS), and (6) collaborative robots (“cobots”). In other words, intelligent warehouses leverage diverse sensors, radio-frequency identification (RFID), and network technology, alongside automated logistics equipment, to ensure automatic data scraping, identification, early warning, and management in inbound and outbound processes, thereby substantially reducing warehousing costs, optimizing efficiency, and enhancing intelligent management. For instance, the AI-powered automated storage/retrieval system developed by the [8] anticipates demands by stocking popular products in advance using AI-driven data computation based on factors such as season, weather, festivals, and regions. This helps enterprises seize business opportunities proactively. Furthermore, once orders are placed, the system optimizes batch picking and sequencing based on order relevance models, ensuring timely collection and shipping for each order, thus fulfilling tasks precisely. In today’s landscape, where consumers demand rapid and accurate order delivery, intelligent warehouses enhance accuracy and traceability and minimize order errors and omissions, ensuring timely product delivery. Additionally, they significantly reduce labor costs by facilitating rapid and accurate order fulfillment. Despite their advantages, intelligent warehouses face certain development constraints, as outlined by [10]:

1. The cost of building a smart warehouse is more expensive than the traditional warehouses.
2. The transition to a smart warehouse is time-consuming and requires a lot of effort.
3. The transition to a smart warehouse requires the support of top management.

Therefore, comprehensively assessing the impact of intelligent warehouse integration on the overall operational efficiency of online shopping platforms is another key focus of this study.

2.3. Relevant Studies

Relevant literature reveals that studies on intelligent warehouses mainly focus on the application and development of smart warehouse management systems across different countries [18], [29], [12], [21], [35]. For instance, [18] proposed an Internet-of-Things (IoT)-based architecture for real-time warehouse management, dividing the warehouse into multiple domains. Architecture viewpoints were employed to present models based on context diagrams, functional views, and operational views tailored to stakeholder needs. Furthermore, certain studies explore new technologies capable of multi-tasking and providing economic benefits [16], [3], [25], [22]. For example, [3] explored the use of drones for various applications in smart warehouse management. Some studies delved into the impact of IoT on warehouse management, discussing both its advantages and disadvantages. Despite the broad spectrum of studies explored above, few studies specifically examined the impact of intelligent warehouses as inputs on enterprise operational efficiency. As [10] highlighted, the cost of constructing a smart warehouse is a crucial consideration. For online shopping platforms striving for operational success, optimizing the inputs and outputs during the operational phase of intelligent warehouses indirectly influences the market efficiency of these platforms in the second phase and their overall operational efficiency. Therefore, further exploration in this regard is warranted.

3. Research Method

3.1. Establishment of a model structure

As modern high-tech automation industries progress, the majority of prior studies on the operational efficiency of online shopping platforms primarily focused on the relative efficiency of inputs (e.g., labor, capital, and other variable inputs) translating into final outputs (e.g., revenue). However, they overlooked the impact of automated picking, packaging, and transportation on the operational efficiency of online shopping platforms during the AI-powered intelligent warehouse phase, where inputs translate into final outputs. Due to input and output process differences between online shopping platforms, the corresponding automated management skills and resource allocation vary. In the operational phase of AI-powered intelligent warehouses, labor costs are reduced, and transportation durations are shortened. Furthermore, by leveraging AI technology, automation is achieved in transportation, warehousing, packaging, loading and unloading, flow, processing, distribution, and data services, thereby gathering relevant big data. AI-powered intelligent warehouses automatically optimize and rectify management based on big data, further enhancing the operational efficiency of online shopping platforms. Optimizing inputs and outputs during the operational phase of these warehouses indirectly impacts the market efficiency of online shopping platforms in the second phase, thereby influencing the overall operational efficiency. Thus, online shopping platforms exhibit varying operational efficiencies across different operational phases, which, in turn, mutually influence one another. This underscores the need for further exploration in this area. This study employed the Dynamic Network Slacks-Based Measure (SBM) Data Envelopment Analysis (DEA) model proposed by [1] for empirical analysis. The main focus was on evaluating the operational efficiency of AI-powered intelligent warehouses utilized by online shopping platforms in Taiwan, assessing the market efficiency of these platforms, and gauging their overall operational efficiency. This assessment was based on the total profits generated by a two-stage dynamic model over multiple years. In this study, the operational benefits derived from AI-powered intelligent warehouses in the first phase served as the basis for formulating operational strategies and allocating resources for online shopping platforms in the second phase. This study primarily examined the performance of Taiwan's online shopping platforms in terms of the operational efficiency of AI-powered intelligent warehouses, market efficiency, and overall operational efficiency from 2018 to 2023.

3.2. Network DEA model for online shopping platforms

Assumption: An online shopping platform comprises three interconnected departments facilitated by an AI-powered intelligent warehouse operation (or intermediate goods). Each department is characterized by its own set of inputs and outputs. As depicted in Figure 1, Link1$-$ $>$2 refers to the utilization of a portion of Department 1's output as part of Department 2's input. Similarly, Link1$-$ $>$3 and Link2$-$ $>$3 carry similar implications, as explained earlier.

As depicted in the figure, the network DEA model addresses the online shopping platform's internal production translation, representing a secondary production activity featuring interconnection and mutual influence between departments.

In this study, the Decision Making Unit (DMU) symbolizes the online shopping platform in the input-output analysis. The efficiency of the online shopping platform during the AI-powered intelligent warehouse phase and the platform's market efficiency are denoted as θ_o^{A*} and θ_o^{B*}, respectively. The mathematical model is formulated as follows:

$$\begin{aligned}&\theta_o^{A*} = max\frac{\sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{d0}^{AB}}{\sum_{i=1}^{i_A} v_i^A x_{io}^A + \sum_{i=1}^{i_s} v_i^s x_{io}^s},\\ &\sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{dj}^{AB} \leq \sum_{i=1}^{i_A} v_i^A x_{ij}^A + \sum_{i=1}^{i_s} v_i^s x_{ij}^s \forall j, U_{ij}^{\alpha} \leq L_{ij}^{\alpha} \forall j,\\ &\eta_d^{AB}, v_i^A, v_i^s \geq \varepsilon\end{aligned} \tag{1}$$

In Equation (1), the denominator of the objective function signifies the inputs during the AI-powered intelligent warehouse phase, while the numerator represents the outputs.

$$\begin{aligned}&\theta_o^{B*} = max\frac{\sum_{r=1}^{r_B} u_r^B y_{r0}^B}{\sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{do}^{AB} + \sum_{i=1}^{i_B} v_i^B x_{io}^B + \sum_{i=1}^{i_s} (1-\alpha_{io}) v_i^s x_{io}^s},\\ &\sum_{r=1}^{r_B} u_r^B y_{rj}^B \leq \sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{dj}^{AB} + \sum_{i=1}^{i_c} v_i^B x_{ij}^B + \sum_{i=1}^{i_s} (1-\alpha_{io}) v_i^s x_{ij}^s \forall j,\\ &U_{ij}^{\alpha} \leq \alpha_{ij} \leq L_{ij}^{\alpha} \forall j,\\ &\eta_d^{AB}, u_r^B, v_r^B, v_i^B, v_i^s \geq \varepsilon\end{aligned} \tag{2}$$

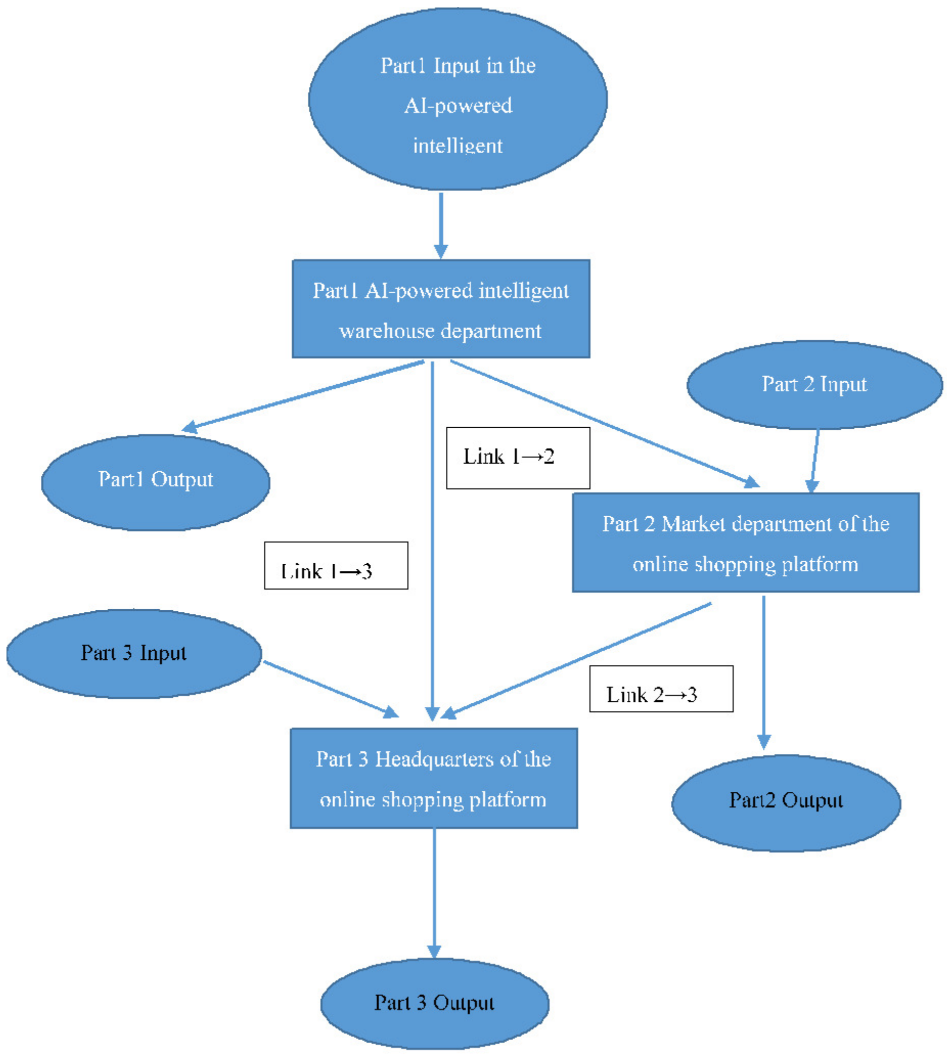

Fig. 1. Network DEA model of the online shopping platform

In Equation (2), the denominator of the objective function represents the inputs during the market operation phase of the online shopping platform, while the numerator signifies the outputs.

$$\begin{aligned} w_A &= \frac{\sum_{i=1}^{i_A} v_i^A x_{io}^A + \sum_{i=1}^{i_s} \alpha_{io} v_i^s x_{io}^s}{\sum_{i=1}^{i_A} v_i^A x_{io}^A + \sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{do}^{AB} + \sum_{i=1}^{i_B} v_i^B x_{io}^B + \sum_{i=1}^{i_s} v_i^s x_{io}^s}, \\ w_B &= \frac{\sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{do}^{AB} + \sum_{i=1}^{i_B} v_i^B x_{io}^B + \sum_{i=1}^{i_s} (1-\alpha_{io}) v_i^s x_{io}^s}{\sum_{i=1}^{i_A} v_i^A x_{io}^A + \sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{do}^{AB} + \sum_{i=1}^{i_B} v_i^B x_{io}^B + \sum_{i=1}^{i_s} v_i^s x_{io}^s} \end{aligned} \tag{3}$$

As per the mathematical equations outlined above, concerning the weight values for the AI-powered intelligent warehouse phase of the online shopping platform and the market operation phase, assuming equal weight values are assigned to the intermediate goods between these two phases, denoted as (Z1), (Z2), and (Z3): $\eta_1^A = \eta_1^B = \eta$; $\eta_2^A = \eta_2^B = \eta; \eta_3^A = \eta_3^B = \eta$. Additionally, it is assumed that the weights assigned to shared inputs are equal: $v_4^A = v_4^B = v_4$. Based on these assumptions, the total operational efficiency value (θ_o^{AB}) for the aforementioned two phases of the online shopping platform is the weighted aggregate of the efficiency (θ_o^A) during the AI-powered intelligent warehouse phase of the online shopping platform and the market efficiency (θ_o^B)), as shown in Equation (4):

$$\theta_o^{AB} = w_A\theta_o^A + w_B\theta_o^B = \frac{\sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{d0}^{AB} + \sum_{r=1}^{r_B} u_r^B y_{r0}^B}{\sum_{i=1}^{i_A} v_i^A x_{io}^A + \sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{do}^{AB} + \sum_{i=1}^{i_B} v_i^B x_{io}^B + \sum_{i=1}^{i_s} v_i^s x_{io}^s} \tag{4}$$

The mathematical model for the overall efficiency of the online shopping platform is presented in Equation (5):

$$\begin{aligned} &\theta_o^{ABC*} = max \frac{\sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{d0}^{AB} + \sum_{r=1}^{r_B} u_r^B y_{r0}^B}{\sum_{i=1}^{i_A} v_i^A x_{io}^A + \sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{do}^{AB} + \sum_{i=1}^{i_B} v_i^B x_{io}^B + \sum_{i=1}^{i_s} v_i^s x_{io}^s}, \\ &\sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{dj}^{AB} \leq \sum_{i=1}^{i_A} v_i^A x_{ij}^A + \sum_{i=1}^{i_s} v_i^s x_{ij}^s \forall j, \\ &\sum_{r=1}^{r_B} u_r^B y_{rj}^B \leq \sum_{d=1}^{d_{AB}} \eta_d^{AB} Z_{dj}^{AB} + \sum_{i=1}^{i_c} v_i^B x_{ij}^B + \sum_{i=1}^{i_s} (1 - \alpha_{io}) v_i^s x_{ij}^s \forall j, \\ &U_{ij}^\alpha \leq \alpha_{ij} \leq L_{ij}^\alpha \forall j, \\ &\eta_d^{AB}, u_r^B, v_r^B, v_i^B, v_i^s \geq \varepsilon \end{aligned} \tag{5}$$

This study mainly analyzes the top seven online shopping platforms in Taiwan in terms of turnover for the year 2023, including D1: Shopee (Taiwan); D2: PChome eBay; D3: momo.com; D4: PChome 24h; D5: Books.com; D6: Yahoo!Kimo; and D7: Taiwan Rakuten Ichiba. Input and output variable data were sourced from the Global Information Network of the Ministry of Economic Affairs, R.O.C. and from the financial statements disclosed by these online shopping platforms. The data spans from 2021 to 2023.

This paper employed a network DEA model to define input and output variables, as outlined in Table 1. During the AI-powered intelligent warehouse phase, inputs include the warehouse area and AI automation costs, while the shipment volume serves as the output variable. During the second phase, the inputs of the sales department comprise the output (shipment volume) from the first phase, the number of employees, and operating expenses. The output variable during this phase is earnings per share (EPS), with the net profit acting as a carry-over from the previous years to analyze efficiency changes.

4. Network DEA Empirical Results

This study employed DEA-SOLVER Professional 16.0 to define the online shopping platform's production model as variable returns to scale. Additionally, a network DEA model was utilized to investigate the operational efficiency of online shopping platforms in Taiwan, specifically focusing on the operational efficiency of AI-powered intelligent warehouses within these platforms and their sales departments. Furthermore, this study assessed departments and online shopping platforms exhibiting low operational efficiency and proposed optimization strategies accordingly.

Based on the empirical findings presented in Table 2 concerning the efficiency during the AI-powered intelligent warehouse phase, D3, momo.com, reported the highest operational efficiency value, reaching 1.000. This indicates that momo.com has effectively

Table 1. Definition of input and output variables

	Variable	Variable definition description	Unit
Inputs during the AI-powered intelligent warehouse phase	Area of the intelligent warehouse	Floor area of the warehouse	Ping
	AI automation equipment inputs	RFID, light sensors, and infrared sensors	Million US
Intermediate output	Shipment volume	Annual average shipment volume of the intelligent warehouse	Pieces
Inputs during the online sales phase	Number of employees	Number of employees	People
	Operating expenses	Including water and electricity charges	Million US
Interdepartmental Link	Operating income	Net revenue after deducting sales returns and discounts	Million US
Final output	EPS	Net profit after tax number of common shares outstanding	US
Inter-period carry over	Profit	Presented in the financial statements Net profit after tax	Million US

leveraged the automation systems of its AI-powered intelligent warehouse to optimally allocate input-output resources. Moreover, D3 outperforms D1, Shopee, in terms of the operational efficiency of the intelligent warehouse, despite the latter's higher popularity and sales volume, suggesting potential for improvement in D1's AI-powered intelligent warehouse operations. Conversely, the lowest efficiency in the AI-powered intelligent warehouse operations phase was observed for D7, Taiwan Rakuten Ichiba, attributed to its comparatively smaller scale of automation equipment input and suboptimal input-output configuration, according to the descriptive statistics.

As AI technology continues to advance year by year, from 2021 to 2023, all seven online shopping platforms experienced growth in the operational efficiency of intelligent warehouses, highlighting their reliance and emphasis on AI-powered intelligent warehouses. Furthermore, AI-powered intelligent warehouses accelerate the pace and development of both the logistics and online shopping industries by integrating various functions such as transportation, distribution, and information services, thereby optimizing product distribution and logistics resource allocation. Additionally, by integrating with the logistics industry, AI-powered intelligent warehouses centralize dispersed product resources, harnessing overall and scale advantages to modernize, specialize, and complement traditional logistics enterprises, thus fostering the operational efficiency of AI-powered intelligent warehouses.

As social and economic landscapes evolve and consumer shopping behaviors change, the demand for online shopping increasingly prioritizes efficiency, accuracy, and speed. AI-powered intelligent warehouses, leveraging IT, integrate sensory systems into processes such as transportation, warehousing, packaging, loading and unloading, flow, pro-

Table 2. Analysis of the operational efficiency of online shopping platforms during the AI-powered intelligent warehouse phase between 2021 and 2023

DMU	2021	2022	2023	Efficiency value	Ranking
D1	1.000	1.000	0.903	0.986	2
D2	0.632	1.000	0.981	0.852	3
D3	1.000	1.000	1.000	1.000	1
D4	0.756	0.684	0.976	0.826	4
D5	0.561	0.651	0.792	0.702	6
D6	0.512	0.686	0.852	0.738	5
D7	0.486	0.628	0.725	0.638	7
Average value	0.703	0.822	0.896	0.815	NA
Maximum value	1.000	1.000	1.000	1.000	NA
Minimum value	0.486	0.628	0.725	0.638	NA
Standard deviation	0.012	0.026	0.01	0.020	NA

cessing, and distribution. Equipped with logistics and distribution systems that collect and analyze data, they process and optimize decisions based on the analysis results, thereby meeting online shoppers' cognitive and purchasing demands. Consequently, the operational efficiency of AI-powered intelligent warehouses in online shopping platforms significantly influences both the operational efficiency of sales departments of these platforms and consumers' willingness to shop online.

According to Table 3, D1 emerges as the leader in online sales efficiency among the selected online shopping platforms, with an operational efficiency value of 1.000. Analysis suggests that this success is attributed to the platform's marketing strategies, such as free shipment services, product discounts, premier service quality, convenience, rapid delivery, and efficient smart warehousing and logistics. Despite ranking second in the operational efficiency of AI-powered intelligent warehouses, D1 excels in offering online shoppers convenience, superior service quality, and discounts, thus securing its top position in sales efficiency. Conversely, the lowest efficiency of AI-powered intelligent warehouses and less appealing product discounts and service quality of D7 indirectly affect the sales market efficiency of the online shopping platform.

According to the above mathematical equations, the weighted average total efficiency values of the online shopping platforms between 2021 and 2023 are calculated in Table 4. The weight assigned to the AI-powered intelligent warehouse phase is observed to exceed that of the market sales phase for each online shopping platform, surpassing 0.5. This indicates that the overall operational efficiency of online shopping platforms is primarily influenced by the efficiency during the AI-powered intelligent warehouse phase, which is a pivotal factor behind the success of online shopping platforms. Furthermore, the outputs and shipment volume of AI-powered intelligent warehouses indirectly impact the orders and overall operational efficiency during the market sales phase.

According to the table, D1 has the highest average number of orders and popularity per year among online shopping platforms. However, its overall operational efficiency ranks second, primarily due to D1's lower weight and efficiency in the AI-powered intelligent warehouse phase compared to D3. Hence, it can be inferred that the operational efficiency

Table 3. Analysis of the operational efficiency of online shopping platforms during the online sales phase between 2021 and 2023

DMU	2021	2022	2023	Efficiency value	Ranking
D1	1.000	1.000	1.000	1.000	1
D2	0.986	1.000	0.978	0.962	3
D3	1.000	1.000	0.968	0.992	2
D4	0.852	0.882	0.932	0.886	4
D5	0.631	0.728	0.812	0.756	6
D6	0.587	0.802	0.822	0.761	5
D7	0.460	0.608	0.708	0.629	7
Average value	0.733	0.846	0.881	0.802	NA
Maximum value	1.000	1.000	1.000	1.000	NA
Minimum value	0.460	0.608	0.708	0.629	NA
Standard deviation	0.013	0.018	0.011	0.015	NA

of AI-powered intelligent warehouses is crucial in determining the overall efficiency of online shopping platforms.

Table 4. Weighted average overall efficiency of the online shopping platforms between 2021 and 2023

DMU	Efficiency of the AI-powered intelligent warehouse	Market sales efficiency	Weight for the AI-powered intelligent warehouse phase	Weight for the market sales phase	Overall efficiency	Ranking
D1	0.986	1.000	0.652	0.348	0.991	2
D2	0.852	0.962	0.621	0.379	0.894	3
D3	1.000	0.992	0.702	0.298	0.998	1
D4	0.826	0.886	0.616	0.384	0.849	4
D5	0.702	0.756	0.562	0.438	0.726	6
D6	0.738	0.761	0.526	0.474	0.749	5
D7	0.638	0.629	0.508	0.492	0.634	7
Average value	0.815	0.802	0.598	0.402	0.809	NA
Maximum value	1.000	1.000	0.702	0.492	0.998	NA
Minimum value	0.638	0.629	0.508	0.298	0.634	NA
Standard deviation	0.015	0.020	0.008	0.010	0.015	NA

5. Conclusions

Consumer habits, coupled with modern AI technology, IoT, and big data technology, have ushered in an innovative and intelligent high-tech business system. This system offers consumers convenient, secure, and rapid shopping experiences while enhancing operational efficiency and reducing the operating costs of online shopping platforms.

Since customers of modern online malls focus on transaction convenience and shortened delivery time, the empirical analysis results of this study show that online malls that incorporate AI-Powered intelligent warehouse management will have higher overall operating efficiency. The operation and management of AI-Powered intelligent warehousing increases the speed of picking, packaging, and shipping of traded goods, which not only saves delivery time, but also saves a lot of labor costs to improve online mall operating profits and overall operating efficiency.

In recent years, with the development of high technology, artificial intelligence (AI) and machine learning (ML) have grown rapidly, which has had a huge impact on industries such as online shopping platforms and retail. Industries that can combine the development of AI-Powered intelligent technology will be the key to competitiveness.

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