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Perceived Usefulness and Intention to Use Blockchain Technology Combined with AI in Monitoring and Managing Warehouse Capacity of Logistics Enterprises in Ho Chi Minh City, Vietnam

Pham Ngoc KHANH[1], Vo Thanh PHU[2], Bui Thi Thuy HANG[3], Ngo Anh CUONG[4]

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Abstract

Purpose: This study aims to explore "Factors affecting the intention to use Blockchain technology integrated with artificial intelligence (AI) in warehouse management and monitoring". **Research design, data, and methodology:** The research model is built on the combination of the unified theory of acceptance and use of technology, the theory of planned behavior, and the theory of technological innovation. By employing a mixed-methods approach comprising expert interviews and a quantitative survey of 303 individuals working in the logistics sector; the data were processed using SPSS 27.0 and AMOS 20.0 through several steps: reliability testing, Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and Structural Equation Modeling (SEM). **Results:** The results reveal that four factors: performance expectancy (HS), facilitating conditions (DK), social influence (AH), and technology readiness (SS) positively affect perceived usefulness (NT). Meanwhile, effort expectancy (NL) and facilitating conditions (DK) have a direct impact on the intention to use technology (YD). Notably, perceived usefulness (NT) plays an important mediating role and strongly influences the intention to use Blockchain technology combined with AI. These findings confirm the suitability of the TAM model in explaining the behavior of using Blockchain technology combined with AI. **Conclusions:** The study provides managerial implications for logistics business leaders in the development and deployment of technology. These results contribute to guiding technological development and management innovation in the logistics sector in Vietnam.

Keywords: Blockchain, AI, SCM, Logistics, Supply Chain Management, Awareness, Intention to Use, Technology Acceptance, Blockchain Combined with AI

JELClassification Code: M00, M10, M11, M21, L91

1. Introduction

In the context of a booming international trade, the demand for buying and distributing goods is increasingly growing, making the logistics and supply chain management sector an indispensable and extremely important factor in online retail in particular, and wholesale and retail in general. In addition, businesses in the import-export industry often

1 First author and corresponding. Department of Logistics and Supply Chain Management, Faculty of Business Administration, Industrial University of Ho Chi Minh City, Vietnam. Email: phamngockhanh@iuh.edu.vn
2 Second author. Faculty of Business Administration, Industrial University of Ho Chi Minh City, Vietnam. Email: thanhphu01456@gmail.com
3 Third author. Faculty of Business Administration, Industrial University of Ho Chi Minh City, Vietnam. Email: buithithuyhang2604@gmail.com
4 Fourth author. Faculty of General Education, University of Labour and Social Affairs, Hanoi City, Vietnam. Email: ngoanhcuong.nac@gmail.com

choose to use external logistics services to reduce costs, optimize market access time, and minimize the necessary workforce. Efficient management of transportation and inventory processes is a key factor in ensuring that goods and services are delivered to customers at the right time and place (Pečený et al., 2020). This not only helps enhance customer satisfaction but also optimizes supply chain management, strengthens brand reputation, and develops sustainable relationships.

Ho Chi Minh City (HCMC) is the leading economic center and an important trading gateway of Vietnam with a strong development of the logistics and supply chain management industry, contributing 8.9% to the gross regional domestic product. HCMC has about 9,600 enterprises operating in the logistics sector, accounting for 36.7% of the total number of logistics enterprises nationwide. In particular, there are about 2,700 enterprises, equivalent to 54% of the number of professional logistics service providers operating in Vietnam (Ministry of Industry and Trade, 2022).

As the world moves towards a digital age, the combination of Blockchain and AI technology is opening up revolutionary opportunities in the logistics and supply chain management (L&SCM) industry. Blockchain, with its ability to create decentralized ledgers, provides a transparent and secure platform for managing transactions and information in the supply chain. This technology not only helps digitize processes but also reduces costs and risks, while eliminating unnecessary intermediaries, thereby increasing efficiency for businesses (Schuetz & Venkatesh, 2020). Meanwhile, AI is emerging as a powerful tool to automate and optimize complex operations in the L&SCM industry, from robotic process automation to machine learning and natural language processing. The combination of AI with supply chain management systems enables fast, accurate data-driven decision making while developing agile capabilities that help organizations reengineer and improve processes efficiently (Pessot et al., 2023; Richey et al., 2022). As technology vendors continue to enter the market, AI is expected to become increasingly sophisticated and effective, expanding not only its applications but also its potential risks in the modern business environment (Heater, 2023). The combination of Blockchain and AI has the potential to bring about breakthrough improvements, while also posing new challenges in integrating and managing the technology.

According to the World Bank (2022), although the quality of logistics services in Vietnam has improved, ranking third in the ASEAN region, after Singapore and Thailand, there is still much to be done to further improve the quality of logistics services. This is demonstrated by the WB's Logistics Performance Index (LPI), when Vietnam is ranked at an average level compared to countries globally in terms of logistics performance (Ministry of Industry and Trade, 2022).

Foreign studies related to the application of Blockchain in Logistics and supply chain management include: research by (Queiroz & Wamba, 2019; Abat, 2020; Kapnissis et al., 2022; Kabir et al., 2021; Zhang et al., 2023; Queiroz et al., 2021; Chatterjee et al., 2023), and (Jain et al., 2022). These studies mainly focus on analyzing and evaluating the factors influencing the behavioral intention to use Blockchain or AI, but they have not analyzed the factors affecting the perceived usefulness and, in particular, the mediating role of perceived usefulness on the intention to use Blockchain combined with AI in monitoring and managing warehouse capacity of Logistics enterprises. On the other hand, domestic studies such as: research by (Hung, 2021) on technological innovation of logistics enterprises in HCMC have identified factors affecting technological innovation, such as social influence, voluntariness, management experience, gender, and age... However, research on the application of Blockchain combined with AI in the logistics industry in Vietnam is still quite limited, mainly focusing on theory without specific empirical data. Although this integration point has great potential in increasing transparency and security, current research is not deep enough to evaluate practical effectiveness. Therefore, the proposed model that the group has put forward has inherited elements from the research model on Blockchain combined with AI in the logistics industry in HCMC, helping the group to research more deeply and find new features in this topic. Therefore, the group's research topic has become increasingly meaningful and practical in the context of strong development of the digital age.

Although Vietnam is facing many opportunities to integrate advanced technology into the transportation industry, supply chain management, domestic logistics companies, especially in big cities like HCMC, have not yet fully exploited these potentials. Currently, businesses mainly use basic technologies such as electronic customs declaration software, vehicle positioning systems and the internet. The application of Blockchain technology combined with AI in the logistics sector in Vietnam is still quite new and faces many barriers. This has motivated the research team to conduct the topic “Perceived usefulness and intention to use Blockchain technology combined with AI in monitoring and managing warehouse capacity of logistics enterprises in HCMC, Vietnam”.

2. Literature Review

2.1. Blockchain Technology

Blockchain is a distributed ledger technology platform

(Walport, 2016) and plays an important role in revolutionizing the process of managing, transacting and storing data in many fields, from finance to supply chains and public administration. This technology eliminates the dependence on traditional intermediaries by establishing a decentralized data distribution system where transactions are authenticated and recorded in a secure and transparent manner (Schatsky & Muraskin, 2015).

2.2. Blockchain in Logistics

With the immutable nature of data on blockchain, no one can edit information about the origin of products, as well as production and distribution processes without consent. Currently, many industries such as food, diamonds and pharmaceuticals have successfully applied Blockchain technology, not only to ensure the quality and authenticity of products but also to enhance the ability to quickly recall when necessary (Lim et al., 2018).

Blockchain solutions in the maritime shipping and port operations sector can bring significant improvements in digitizing cross-border operations, while increasing efficiency and reducing costs. The application of this technology allows for accurate tracking of every movement of shipments, documents, and financial transactions without the need for verification by intermediary financial institutions or manual updating of information from various sources (Sengupta, 2021).

The mechanism of blockchain makes it almost impossible to update or delete transactions without authorization. The original data, once authenticated, can be accessed from multiple sources within the Blockchain, thereby minimizing the risks associated with relying on a single source of information. Thanks to this mechanism, authorized parties can also access confidential trade data when required by business rules or national and international laws. These anti-fraud features not only enhance trust in the supply chain but also enhance the confidence of business partners and end consumers (Sengupta, 2021).

2.3. Artificial Intelligence in Logistics

Artificial Intelligence (AI) is increasingly asserting its pivotal role in modern society, with widespread applications in many fields to improve efficiency, cut costs and maximize profits. Currently, AI has become an indispensable tool in business activities in many industries, from healthcare, legal, finance, accounting, tax and auditing, to architecture, consulting, customer service, manufacturing and transportation (Dash et al., 2019).

Estimated time of arrival prediction: using data from control towers and real-time tracking of transport vehicles, combined with transport plans, predictive models can be built to determine the exact time a vehicle will arrive at its destination, including factors such as weather and traffic (Kolner, 2019).

Multi-sourcing and multi-modal transportation: when a business has access to multiple sources of inventory, reinforcement learning can help optimize decisions about what proportion of goods to source from low-cost foreign suppliers, versus sourcing from higher-cost domestic sources. Similarly, this technique can also be applied to coordinating different modes of transportation, allowing a business to ship a portion of its goods via cost-effective or environmentally friendly means such as rail or water, while the remainder can be shipped via faster modes such as road or air (Gijsbrechts et al., 2019).

Collaboration in replenishment and transportation: to optimize the replenishment cycle between different products or companies, reinforcement learning can be applied in real-time supply chain operating systems, supporting transportation cooperation between stakeholders, thereby minimizing costs and processing times (Vanvuchelen et al., 2020).

Inventory management of perishable products: inventory management of products with short shelf lives requires taking into account not only the quantity of inventory but also the age of the products in the warehouse. Reinforcement learning can help develop inventory optimization methods that accurately predict the demand and condition of products, thereby ensuring that waste is avoided and the risk of spoilage is minimized (De Moor et al., 2022).

2.4. Intention to Use and Perceived Usefulness

Behavioral intention reflects an individual's willingness to perform a particular action, which is considered the most important predictor of behavior (Ajzen & Fishbein, 1975). In contrast to this view, the Technology Acceptance Model (TAM) argues that an individual's attitude toward a technology strongly influences their use of that technology. Together with pressure from the social environment, it forms the intention to adopt a technology (Ajzen, 1991; Venkatesh et al., 2003). Subsequent studies have integrated these models into the UTAUT model, which analyzes how individuals adopt and adopt new technology at work, based on factors such as performance expectancy, effort expectancy, social influence, and facilitating conditions.

According to the TAM, the two main factors that determine the level of acceptance of a new technology are perceived usefulness and perceived ease of use. Users' attitudes toward adopting a technology are formed when they perceive that the technology will improve work efficiency and is easy to use. When the new technology brings clear benefits and is easily accessible, users will have more confidence in it, thereby promoting the intention to use;

perceived usefulness defined as "the degree to which a person believes that using a particular system would enhance their job performance" (Davis, 1989).

3. Hypotheses and Research Model

3.1. Performance Expectancy

Venkatesh et al. (2003) proposed that performance expectancy is the extent to which a user believes that using a technology will help them overcome difficulties and achieve desired goals in their work. If the technology brings clear benefits, this will promote acceptance and use of the service (Tojib & Tsarenko, 2012). Performance expectancy is defined as the extent to which an individual believes that using a system will help them achieve their job goals (Venkatesh et al., 2003). This concept has been validated in many previous studies, confirming that performance expectancy has a significant impact on technology implementation in various contexts.

In particular, in studies related to Blockchain technology and artificial intelligence (AI), performance expectancy are considered to be a determinant of the intention to use the technology, including in the field of cryptocurrency (Jung et al., 2019) and supply chain (Francisco & Swanson, 2018; Zailani et al., 2015). This is also consistent with other literature (Gurtner et al., 2014; Venkatesh et al., 2012). In the context of supply chains using Blockchain technology combined with AI, performance expectancy are predicted to influence behavioral intentions when implementing this technology. In this study, performance expectancy are directly related to the readiness of employees in the enterprise, the application of Blockchain in the supply chain will improve the operational efficiency of the entire supply chain.

H1a: Performance expectancy has a positive impact on perceived usefulness of Blockchain technology combined with AI in warehouse capacity monitoring and management.

H1b: Performance expectancy has a positive impact on intention to use Blockchain technology combined with AI in warehouse capacity monitoring and management.

3.2. Facilitating Conditions

Facilitating conditions are defined as "the extent to which an individual believes that the structural and practical infrastructure exists to support the use of a system" (Venkatesh et al., 2003). In previous studies, facilitating conditions have been shown to have a significant positive impact on the intention to use and adopt a technology. Facilitating conditions reflect users' perceptions of the availability of resources and support needed to adopt a technology, which directly affects users' usage behavior (Venkatesh et al., 2012).

The role of "facilitating conditions" in the intention to use Blockchain in supply chains can be understood through factors such as the availability of technical support, hardware/software, and knowledge of the system (Lallmahomed et al., 2013). Empirical studies have shown that this support has a positive impact on supply chain coordination activities (Akhtar et al., 2012) and exposure to new technology (Hew et al., 2015).

For Blockchain and AI technology, organizational support, IT infrastructure, cloud storage, and internet speed are important factors in facilitating (Chatterjee et al., 2021; Francisco & Swanson, 2018). Facilitating conditions are considered to be an important predictor of adoption of Blockchain technology combined with AI.

Thompson (1991) study initially did not find a clear relationship between "facilitating conditions" and "behavioral intention". However, when further analyzed by factors such as age and gender, the results showed that "facilitating conditions" had a significant influence on technology use behavior. This effect was especially evident among older and more experienced employees, as they often valued supporting factors and appropriate infrastructure in adopting new technology. This demonstrates that the favorable environment in an organization can strongly influence employees' decisions to adopt technology. According to (Teo, 2011) study, user behavior can be directly affected by favorable conditions, because when the technological environment is favorable, users tend to choose to use more advanced technologies. Similarly, Im et al. (2011) study also confirmed that support and favorable conditions from the environment will help people adopt new technologies more easily.

H2a: Facilitating conditions have a positive impact on perceived usefulness of Blockchain technology combined with AI in monitoring and managing warehouse capacity.

H2b: Facilitating conditions have a positive impact on intention to use Blockchain technology combined with AI in monitoring and managing warehouse capacity.

3.3. Social Influence

Social influence is the extent to which people important to an individual believe that they should use a new system (Venkatesh et al., 2003). For example, colleagues, friends, and family members can significantly influence the decision to adopt a technology (Aneke & Wang, 2016). In this study, social influence includes employees' understanding of recommendations related to Blockchain and AI from people they trust. In fact, at the individual level, many studies have shown that users are often strongly influenced by the opinions and experiences of friends, colleagues, and family (Irani et al., 2017).

H3a: Social influence has a positive impact on perceived usefulness of Blockchain technology combined with AI in warehouse capacity monitoring and management.

H3b: Social influence has a positive impact on intention to use Blockchain technology combined with AI in warehouse capacity monitoring and management.

3.4. Effort Expectancy

Effort expectancy is the ease associated with the use of a technology by users (Venkatesh et al., 2003), meaning that the easier a technology is to learn and use, the more likely users are to accept and decide to use it (Wong et al., 2015). Many studies have confirmed the pivotal role of expected effort in technology acceptance (Martin et al., 2014; Mutahar et al., 2018). (Davis, 1989) also supports this view, stating that users often weigh the effort expended against the benefits gained when using technology.

In the logistics industry, if the use of Blockchain becomes simple and does not require too much time or effort to learn, users will be willing to adopt this technology. It has been proven that Blockchain is not too difficult to understand and implement for experts in this field. Therefore, it can be predicted that the intention to use Blockchain will increase as this technology becomes easier to use (Alalwan et al., 2017). Similarly, AI-integrated tools, such as CRM systems in organizations, if designed to be easy to use, will facilitate users and increase their intention to use (Chatterjee et al., 2021; Dwivedi et al., 2019). Overall, effort expectancy is an important factor influencing users' attitudes and behaviors when approaching new technologies. Technologies that reduce the effort required to complete tasks are more likely to be widely used.

H4a: Effort expectancy has a positive impact on perceived usefulness of Blockchain technology combined with AI in warehouse capacity monitoring and management.

H4b: Effort expectancy has a positive impact on intention to use Blockchain technology combined with AI in warehouse capacity monitoring and management.

3.5. Technology Readiness

Technology readiness is the tendency of an individual to adopt and use modern technology to achieve goals in personal or professional life (Parasuraman, 2000). In this study, technology readiness refers to the organization and reliability required to complete work in the supply chain. This concept has been extensively studied in various fields, from the airline industry to online retailing (Vize et al., 2013), the internet movement (Borrero et al., 2014), and technology adoption (Chang, 2011).

Technology readiness is closely related to the ability to understand and apply technology to improve work efficiency; positive perceptions can increase consumers' intention to use technology (Wong et al., 2016). Technology readiness is also related to the level of perception of the usefulness of technology in improving performance; positive perceptions promote intention to use, as users tend to be more willing to adopt technology (Wong et al., 2016).

Many studies have combined the concept of technological readiness with various technology adoption models, consistently demonstrating a positive and encouraging relationship. Technical expertise and readiness are considered to be important factors in building sustainable supply chains (Kusi-Sarpong et al., 2019). For companies that want to adopt Blockchain combined with AI in their supply chains, the challenge of integrating multiple stakeholders with different capabilities needs to be overcome. Results from various studies have consistently demonstrated a positive relationship between technological readiness and technology adoption models in sustainable supply chains, where technological excellence and flexibility are important factors (Kusi-Sarpong et al., 2019).

H5a: Technological readiness has a positive impact on perceived usefulness of Blockchain technology combined with AI in warehouse capacity monitoring and management.

H5b: Technological readiness has a positive impact on intention to use Blockchain technology combined with AI in warehouse capacity monitoring and management.

3.6. Perceived Usefulness

According to (Jaspers & Pearson, 2022) argue that the intention to adopt technology is closely linked to the expected outcomes from the business side. Specifically, the factors of perceived control and transparency have a strong influence on the behavior of organizations. Therefore, when businesses in the logistics industry perceive that Blockchain technology combined with AI can improve warehouse management and monitoring processes, they are more likely to adopt these technologies. The motivations for adoption include the benefits of safety and efficiency that the technology brings, which directly affect the behavior and intention of the business to use.

Lee (2009) combined the technology acceptance model (TAM) and the theory of planned behavior (TPB) to show that positive cognitive factors have a great influence on the intention to adopt Blockchain technology combined with AI in online warehouse monitoring and management at logistics enterprises.

H6: Perceived usefulness has a positive impact on the intention to use Blockchain technology combined with AI in warehouse capacity monitoring and management.

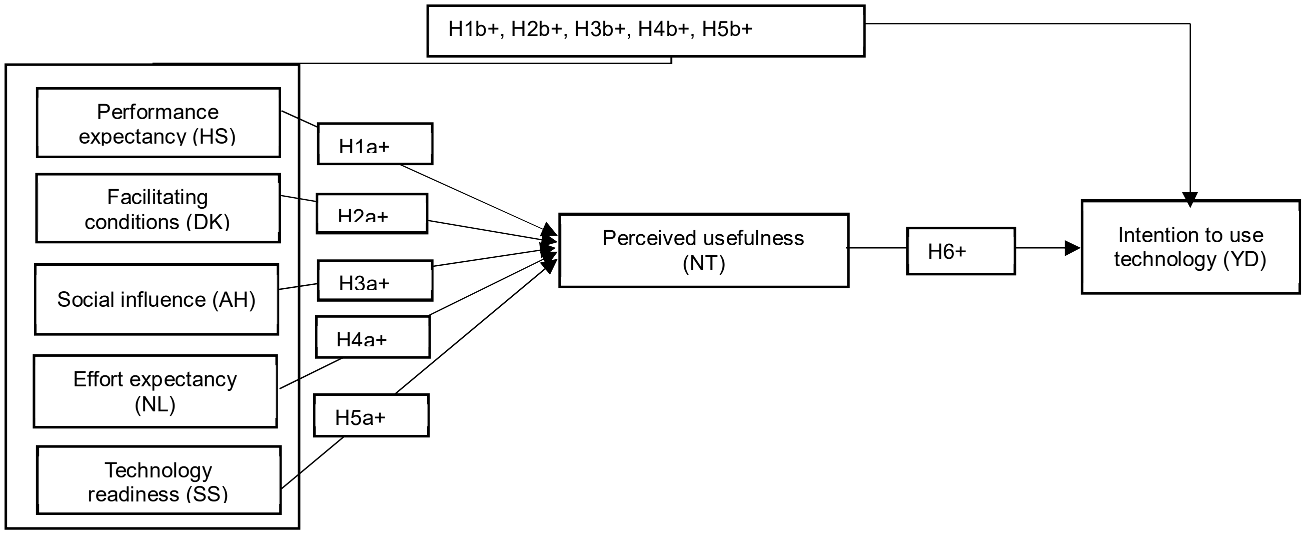

Figure 1: Proposed Research Model

4. Research Method

4.1. Qualitative and Quantitative Research Methods

4.1.1. Qualitative Research Methods

The author conducted in-depth interviews and focus group discussions with 8 experts in the logistics field of HCMC to explore the perception of usefulness and intention to use Blockchain technology combined with AI in monitoring and managing warehouse capacity of logistics enterprises; and recalibrate the scale of the factors in the research model to suit the practical context in HCMC. Before collecting information, the research team conducted a pilot survey of 5 questionnaires for logistics enterprises to check the logic of the questionnaire and will adjust and supplement it to suit the research purpose. After that, the author conducted direct interviews with 320 logistics enterprises to collect data for quantitative analysis.

4.1.2. Quantitative Research Method

The information was collected and processed through SPSS 27.0 and AMOS 20.0 software. The preliminary research was conducted by sending survey questionnaires to 55 logistics enterprises. After collecting 50 valid responses, the author coded and analyzed the data using SPSS 27.0 software through Cronbach's Alpha (CA) reliability testing. After that, the author began to conduct official quantitative research. The author analyzed descriptive statistics of the survey sample, variables and tested Cronbach's Alpha to assess the reliability of the scale; analyzed the EFA exploratory factor with Bartlett and KMO tests; used AMOS software to analyze the CFA confirmatory factor, analyzed the SEM linear structure model, tested Bootstrap, tested the influence of factors and assessed the impact of perceived usefulness and intention to use Blockchain technology combined with AI in monitoring and managing warehouse capacity of logistics enterprises. On that basis, the author draws conclusions and proposes managerial implications.

4.2. Survey Sample

According to (Hair et al., 1998), to be able to conduct exploratory factor analysis, it is necessary to collect data with a sample size of 5:1 observation ratio for each measurement variable, which means that for every 1 measurement variable, there are at least 5 observations. In the research model, there are a total of 27 observed variables, so the minimum sample size required is 135 observations (n=5*27=135). To increase the reliability of the study, the author plans to survey 320 people. The survey sampling method was convenient but based on characteristics such as: gender, work experience, business operation time, business size, and business type to ensure that the selected survey sample is the most representative. The results obtained 303 valid survey questionnaires after data screening and were used for analysis and official assessment of the perception of usefulness and intention to use Blockchain technology combined with AI in monitoring and managing warehouse capacity of logistics enterprises.

4.3. Build a Scale

The study used a Likert scale with 5 levels: (1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, and (5) Strongly agree to measure the impact of perceived usefulness and intention to use Blockchain technology combined with AI in monitoring and managing warehouse capacity of logistics enterprises.

5. Results

5.1. Descriptive Statistics of the Survey Sample

Table 1 shows that, in terms of gender, the proportion of men accounts for 60.4% and women 39.6%, with the level of interest in new technology, especially Blockchain combined with AI, being quite even between the two genders, reflecting the general interest in advanced technology and women's initiative in researching and applying technology. In terms of enterprise size, 39.6% of large enterprises, 33.3% of medium enterprises, and 27.1% of small enterprises show awareness and intention to apply technology, showing a strong transformation trend in the logistics industry, with large and medium enterprises taking the lead in optimizing costs and improving operational efficiency. Regarding business types, limited liability companies accounted for the highest proportion (39.9%), followed by partnerships (32.3%), and joint stock companies (27.7%). The majority of surveyed businesses have been in business for over 10 years (40.9%), indicating the proactive application of advanced monitoring and management methods in long-standing businesses. Furthermore, 62.7% of respondents had more than 5 years of work experience, indicating that experienced people are interested in applying new management methods to improve business performance.

Table 1: Survey Sample Characteristics

Details	Categories	Frequency	Percent (%)
Gender	Male	183	60.4
	Female	120	39.6
	Total	303	100
Size of the business	Small scale	82	27.1
	Medium scale	101	33.3
	Large scale	120	39.6
	Total	303	100
Type of business	Joint stock companies	84	27.7
	Partnership company	98	32.3
	Limited liability companies	121	39.9
	Total	303	100
Business operating time	Under 5 years	83	27.4
	5 - 10 years	96	31.7
	Over 10 years	124	40.9
	Total	303	100
Work experience	Under 3 years	25	8.3
	3 - 5 years	88	29.0
	Over 5 years	190	62.7
	Total	303	100

5.2. Evaluate the Reliability of the Scale

The results of Table 2 show that the Cronbach's Alpha (CA) coefficient of the remaining observed variables is > 0.6 and the total variable correlation coefficient > 0.3, so the remaining observed variables are all reliable and tested in the next step.

Table 2: Results of Reliability Assessment

Variables	Cronbach's Alpha	Corrected item-total Correlation
Performance expectancy (HS)	0.848	0.761 – 0.808
Facilitating conditions (DK)	0.946	0.741 – 0.819
Social influence (AH)	0.844	0.659 – 0.793
Effort expectancy (NL)	0.895	0.751 – 0.805
Technology readiness (SS)	0.923	0.786 – 0.884
Perceived usefulness (NT)	0.764	0.788 – 0.848
Intention to use technology (YD)	0.799	0.825 – 0.862

5.3. Exploratory Factor Analysis (EFA)

In Table 3, KMO = 0.838 > 0.5 shows that the factors in the study are reliable. Sig = 0.000 < 0.05 on Bartlett's test, the independent factors are statistically significant. The total variance extracted = 67.612% shows that independent factors explain 67.612% of the variability of the data. The 5th factor gives the Eigenvalues = 1.265 > 1 indicates the convergence of 5 independent factors and stops at the 5th factor. The observed variables representing the 5 independent factors that all give a load factor of > 0.5, so the observed variables are meaningful and represent the factor they represent. After EFA testing, there are 21 observed variables of 5 independent factors retained.

Table 3: Results of Exploratory Factor Analysis of Independent Variables

KMO and Bartlett's test	
Kaiser-Meyer-Olkin (KMO)	0.838
Bartlett's test	0.000
Eigenvalues	1.265
% of total variance	67.612%

In Table 4, KMO = 0.688 > 0.5 shows that the factors in the study are reliable. Sig = 0.000 < 0.05 when Bartlett's test shows statistically significant intermediate variables. The total variance extracted = 68.353% shows that 1 intermediate factor explain 68.353% of the variability of the data. The 1st factor for Eigenvalues = 2.051 > 1 indicates the convergence of 1 intermediate factor and stops at the 1st factor. The observed variables representing the intermediate factor all have loading factors > 0.7, so the observed variables are all significant and represent the factor they represent. After EFA testing, there are 3 observed variables of the intermediate factor that are retained.

Table 4: Results of Exploratory Factor a Analysis of Intermediate Variables

KMO and Bartlett's test	
Kaiser-Meyer-Olkin (KMO)	0.688
Bartlett's test	0.000
Eigenvalues	2.051
% of total variance	68.353%

In Table 5, KMO = 0.707 > 0.5 shows that the factors in the study are reliable. Sig = 0.000 < 0.05 when Bartlett's test shows statistically significant dependencies. The total variance extracted = 71.380% shows that dependent factors explain 71.380% of the variability of the data. The 1st factor for Eigenvalues = 2.141 > 1 indicates the convergence of 1 dependent factor and stops at the 1st factor. The observed variables representing the dependent factors all have loading factors > 0.8, so the observed variables are all significant and represent the factor they represent. After EFA testing, there are 3 observed variables of the dependent factor that are retained.

Table 5: Results of Exploratory Factor Analysis of Dependent Variables

KMO and Bartlett's test	
Kaiser-Meyer-Olkin (KMO)	0.707
Bartlett's test	0.000
Eigenvalues	2.141
% of total variance	71.380%

5.4. Confirmatory Factor Analysis (CFA)

The results of the CFA analysis in Table 6 indicate that all model fit indices meet the necessary criteria, reinforcing the validity of the model in this study. Specifically, the CMIN/df value is 1.174, which is below the threshold of 5, indicating a good model fit without excessive complexity. The GFI is 0.887, exceeding of 0.8, suggesting a good fit (Baumgartner & Homburg, 1996); (Doll et al., 1994). The TLI and CFI values are 0.923 and 0.933, respectively, both surpassing the minimum threshold of 0.9, demonstrating excellent model fit. The RMSEA is 0.051, well below the cutoff of 0.08, further confirming the very high fit of the CFA model. These indices collectively demonstrate that the model fits the research data well, ensuring the reliability of the CFA results. Key fit indices such as Chi-square/df, GFI, TLI, CFI, and RMSEA all meet the standard thresholds, confirming that the model exhibits excellent fit and can be confidently used for further analysis in this study.

Table 6: Fit Indices for Confirmatory Factor Analysis

Indicator	CMIN/df	GFI	TLI	CFI	RMSEA
Value	1.774	0.887	0.923	0.933	0.051
Benchmark value	< 5	> 0.8	> 0.9	> 0.9	< 0.08
Conclusion	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied

5.5. Structural Equation Modeling (SEM) Analysis

5.5.1. Assessment of SEM Model Fit

The results of the SEM analysis, as presented in the Figure 2, indicate that the model exhibits a good fit with the collected data. All model fit indices meet the required standards, reinforcing the model's validity in this study. Specifically, the Chi-square/df ratio is 1.774, which is below the threshold of 5, indicating a good fit without excessive complexity. Other fit indices, including RMSEA = 0.051 (below the 0.08 threshold), GFI = 0.887, CFI = 0.933, and TLI = 0.923, all reach excellent values, surpassing the minimum acceptable criteria (GFI > 0.8, CFI and TLI > 0.9, RMSEA < 0.08). Regarding the relationships within the model, most path coefficients between latent constructs and observed variables are statistically significant, demonstrating strong associations among the factors.

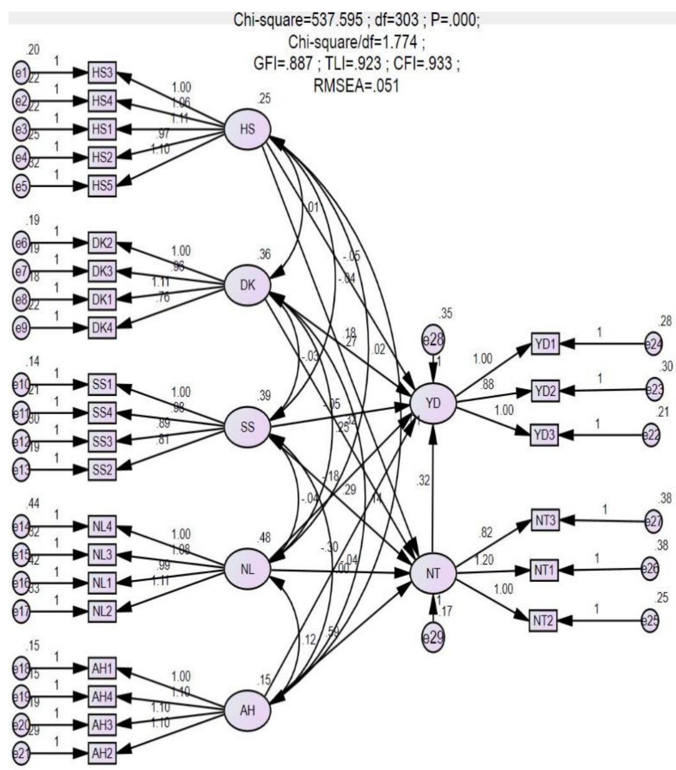

Figure 2: Results of the SEM Model Analysis

Table 7: Bootstrap Analysis Results

Hypothesis	Relationship	Sig.	β	C.R.	Result
H1a	HS --> NT	0.000	0.076	2.500	Supported
H2a	DK --> NT	0.003	0.111	0.275	Supported
H3a	AH --> NT	0.000	0.176	3.500	Supported
H4a	NL --> NT	0.853	0.066	-3.500	Not supported
H5a	SS --> NT	0.000	0.075	-1.500	Supported
H6	YD --> NT	0.012	0.07	-1.500	Supported
H1b	HS --> YD	0.666	0.094	3.330	Not supported
H2b	DK --> YD	0.011	0.146	3.600	Supported
H3b	AH --> YD	0.471	0.185	-1.670	Not supported
H4b	NL --> YD	0.022	0.091	-0.670	Supported
H5b	SS --> YD	0.000	0.076	2.500	Supported

With a 95% confidence level, the bootstrap test results in Table 7 show that, except for the three hypotheses H4a (Sig. = 0.853), H1b (Sig. = 0.666), and H3b (Sig. = 0.471) all have Sig. values greater than 0.05, indicating that these relationships are not statistically significant and are rejected, the remaining hypotheses are accepted. This proves that performance expectancy, facilitating conditions, social influence and technological readiness all have positive effects on perceived usefulness. At the same time, facilitating conditions, effort expectancy and technological readiness all have positive effects on the intention to use technology.

5.5.2. Testing the Mediating Role of the Factor "Perceived Usefulness"

In Table 8, it can be seen that the Sig. values are all less than 0.05, so the factor "facilitating conditions" not only has a direct impact on the intention to use technology and perceived usefulness, but also indirectly affects the intention to use technology through perceived usefulness. Therefore, the factor "perceived usefulness" plays an additional mediating role between the factor "facilitating conditions" and "intention to use technology"; moreover, "effort expectancy" not only directly affects the intention to use technology and perceived usefulness, but also indirectly affects the intention to use technology through perceived usefulness. Therefore, the factor "perceived usefulness" is also a partial mediator variable in the relationship between the factor "effort expectancy" and "intention to use technology".

Based on the analysis results, the total impact of the factor "facilitating conditions" on "intention to use technology" reached 0.284, while "effort expectancy" had a total impact on "intention to use technology" at 0.088. This shows that these findings clarify the important mediating role of the factor "perceived usefulness" in the research model.

Table 8: Results of the Mediation Analysis for "Perceived Usefulness"

Impact	Relationship	β	Sig.
Direct	DK ---> YD	0.146	0.011
	NL ---> YD	0.091	0.022
Indirect	DK ---> NT ---> YD	0.138	0.029
	NL ---> NT ----> YD	- 0.003	0.027
Total impactlevel	DK ---> YD	0.284	
	NL ---> YD	0.088	

6. Discussion

The research results show that the factor "facilitating conditions" has a positive impact on both "perceived usefulness" (β2a = 0.111, Sig. = 0.003) and "intention to use technology" (β3b = 0.145, Sig. = 0.011). Thus, hypotheses H2a and H2b are both accepted. This is consistent with previous studies related to perceived usefulness and intention to use Blockchain technology combined with AI (Chehade et al., 2020; Lim et al., 2018; Yadav & Singh, 2020). Specifically, when leaders and administrators receive support from facilitating conditions, their perception of the usefulness of the technology is improved, thereby strongly promoting the intention to use Blockchain technology combined with AI.

The results of the study showed significant relationships between the factors. Although "performance expectancy" had no direct impact on "intention to use technology" (β1b = 0.094, Sig. = 0.666), it had a positive impact on "perceived usefulness" (β1a = 0.076, Sig. = 0.000), leading to the acceptance of H1a, while H1b was rejected. Similarly, "social influence" had no direct impact on "intention to use technology" (β3b = 0.185, Sig. = 0.471) but had a significant impact on "perceived usefulness" (β3a = 0.176, Sig. = 0.000), so the acceptance of H3a was confirmed, while H3b was rejected. For "technology readiness", this factor has no impact on "intention to use technology" (β5b = 0.06, Sig. = 0.542) but has a positive impact on "perceived usefulness" (β5a = 0.075, Sig. = 0.000), so hypothesis H5a is accepted, while H5b is rejected.

In contrast, "effort expectancy" did not affect "perceived usefulness" (β4a = 0.066, Sig. = 0.853) but had a direct impact on "technology usage intention" (β4b = 0.091, Sig. = 0.022), leading to H4a being rejected and H4b being accepted.

Thus, the analysis results show that although "performance expectancy", "social influence" and "technology readiness" do not have a direct impact on the intention to use technology, they have a significant impact on perceived usefulness. This highlights the importance of enhancing the perception of the value and benefits of technology as a key factor driving the intention to use technology. Meanwhile, "effort expectancy" had a direct impact on "intention to use technology," although it did not change "perceived usefulness." This reflects a trend that for leaders, the level of effort expectancy can impact the intention to use technology, regardless of perceived benefits.

The results of the study indicate that not all factors directly influence the intention to use technology, but there are factors that indirectly influence through improving perceived usefulness. This provides important insights for developing technology implementation strategies, encouraging increased user awareness and minimizing barriers related to readiness or expectations in the process of technology adoption.

Notably, this study particularly highlighted the important role of "perceived usefulness" as a mediating factor. Specifically, "perceived usefulness" not only directly affects the intention to use the technology ($\beta 6 = 0.07$, Sig. = 0.012), with hypothesis H6 being accepted, but also plays a mediating role in the relationship between factors affecting the intention to use Blockchain technology combined with AI. The results indicate that perceived usefulness fully mediates the effect between performance expectancy and intention to use Blockchain technology combined with AI. Furthermore, "perceived usefulness" also plays an additional mediating role in the relationship between facilitating conditions and intention to use technology, as well as between expected effort and intention to use for this group of subjects. These findings indicate that perceived usefulness not only plays an important role but also contributes to enhancing the effectiveness of factors such as "facilitating conditions" and "expected effort". When perceived usefulness is enhanced, it not only clarifies and strengthens the impact of supporting factors but also strongly promotes the intention to use Blockchain technology combined with AI.

7. Conclusion and Implications

7.1. Conclusion

Through the application of mixed research methods, the study achieved its objectives, exploring the factors affecting the perceived usefulness and intention to use Blockchain technology combined with AI in monitoring and managing warehouse capacity of logistics enterprises.

Firstly, the analysis results show that although factors such as "performance expectation", "social influence", and "technology readiness" do not have a direct impact on the intention to use the technology, they have a significant impact on the perceived usefulness. This highlights the importance of raising awareness of the value and benefits of technology, considering it a key factor promoting the acceptance and use of technology; and enhance online trading capabilities and promote the most efficient goods distribution.

Secondly, "effort expectancy" has a direct impact on the intention to use the technology, even though it does not change the perceived usefulness. This suggests that, for leaders, the level of effort expectancy may be a decisive factor in the use of the technology, regardless of the perceived benefits. More importantly, the study also shows that perceived usefulness is an important mediator, playing a full and additional mediating role in the relationship between the influencing factors and the intention to use Blockchain technology combined with AI.

Thirdly, the results of the study not only expand the theoretical foundation of the application of Blockchain technology combined with AI in the logistics sector, but also highlight the role of perceived usefulness in promoting the intention to use technology. The study is based on the combination of the acceptance and use model of technology, the theoretical frameworks of technology risk management, and provides a comprehensive view of how perceptual factors can influence technology usage behavior in practical contexts.

Fourthly, in addition to theoretical contributions, the study also provides recommendations to help logistics enterprises raise awareness of the usefulness of Blockchain technology combined with AI; enterprises should focus on optimizing user experience and enhancing perceived value through effective integrated solutions. At the same time, it is necessary to build trust by ensuring transparency and safety when applying technology. These solutions not only promote the intention to use technology but also create a solid foundation for logistics and supply chain management businesses to improve the efficiency of optimal goods distribution operations and enhance competitiveness in the digital transformation era.

7.2. Implications

(i) For the group of factors "expected performance" that have a positive impact on "perceived usefulness". In the field of logistics, to optimize the impact of 'expected performance' on perceived usefulness, the use of Blockchain combined with AI helps ensure absolute transparency and security in tracking and recording all transactions related to goods in the warehouse, from receiving and storing to distributing them, creating strong customer trust in the accuracy and immutability of the data. With this technology, it is possible to automatically optimize warehouse space allocation, forecast storage demand, distribute goods in a timely manner, and propose strategies to optimize capacity based on intelligent predictive models Businesses can publish impressive figures, such as warehouse costs thanks to optimized capacity and increased shipping speed to demonstrate the effectiveness of technology application. In addition, by using Blockchain combined with AI, businesses can create an immutable warehouse tracking system, the status of goods is stored and shared securely among stakeholders, minimizing the risk of fraud or errors. It can assist in analyzing storage and shipping behavior patterns to forecast warehouse space needs during peak periods, thereby helping to optimize warehouses without having to increase storage space. Next, sharing success stories from major customers using this technology will help increase trust, while demonstrating the usefulness and clear competitive advantage that the technology brings in optimizing the supply chain. Finally, businesses should regularly organize seminars or develop in-depth articles on the application of Blockchain combined with AI in logistics, which will reinforce the company's position as a pioneering and reliable partner in addressing complex problems related to warehouse management and optimal goods distribution.

(ii) For the group of factors “favorable conditions” that have a positive impact on “perceived usefulness” and “intention to use technology”, logistics enterprises need to create a fully supportive and favorable environment for the implementation of Blockchain technology combined with AI. This includes investing in technology infrastructure, ensuring that software and hardware systems operate stably, and are easily integrated into current processes without causing disruption. Enterprises need to build a synchronized technology ecosystem where Blockchain and AI can seamlessly integrate with existing warehouse management software, helping to optimize storage space, reduce operating costs, boost sales, and enhance the efficiency of goods distribution. Furthermore, ensuring adequate support resources, including the involvement of technology experts and professional customer service, will help businesses quickly resolve problems that arise during the technology implementation process. Training programs for employees and partners should also be organized regularly, creating favorable conditions for them to quickly access and master the technology, thereby using it effectively. In addition, businesses can establish strategic partnerships with technology and service providers to receive continuous support and update the latest technology trends. When the technology deployment environment becomes favorable and fully supported, businesses will not only realize the practical value of Blockchain and AI technology but can also promote their application in warehouse management operations, contributing to improving labor productivity and competitiveness in the logistics and supply chain management industry.

(iii) The factor “expected effort” has a positive impact on the intention to use Blockchain technology combined with AI in warehouse capacity management. Logistics businesses need to focus on developing technological solutions that are both powerful and easy to access and use. The implementation of Blockchain and AI technology will bring positive effects when the application process is simplified and automated, minimizing user intervention. Businesses need to build systems with user-friendly and intuitive interfaces, enabling employees to operate and monitor storage and distribution processes effectively without requiring deep technological knowledge. For example, instead of requiring employees to manually enter data, the system can automatically recognize and update information into Blockchain combined with AI, thereby minimizing manual operations, limiting errors and saving users time. Furthermore, to enhance the usability of technology, businesses need to provide an ongoing and easily accessible training program, from online training sessions to short tutorial videos. This not only helps employees understand how the technology works but also reduces concerns about using new tools. Businesses can also deploy online help tools to answer questions instantly and provide real-time support, thereby optimizing the user experience. When the effort required to use technology is minimized, employees will perceive the adoption of Blockchain combined with AI not only as a useful tool but also as an easy and convenient solution, thereby enhancing their commitment and willingness to use technology to improve warehouse management and goods distribution efficiency.

(iv) Based on the research results on the positive relationship between “perceived usefulness” and “intention to use technology”. Businesses can make the most of the benefits that technology brings, from improving warehouse management efficiency to improving productivity and competitiveness. First, to raise the “perceived usefulness” of Blockchain and AI technology, businesses need to focus on building training programs and providing information to leaders and managers about the specific benefits that this technology brings. Clarifying the ability of Blockchain and AI to optimize processes, reduce costs and improve warehouse management efficiency will help leaders realize the potential of the technology, thereby promoting the decision to apply it. At the same time, organizing seminars and conferences to share practical experiences from businesses that have successfully deployed this technology will provide leaders with in-depth and practical insights on how to apply the technology in the logistics sector. Second, businesses prioritize technology solutions that can demonstrate clear and measurable benefits. Results such as reduced operating costs, improved order fulfillment, goods distribution, and reduced inventory management errors are compelling evidence that helps increase awareness of the technology’s usefulness. Demonstrating effectiveness through specific metrics will help leaders gain confidence in implementing the technology in their business processes. Third, testing and piloting Blockchain technology combined with AI is also an effective way to increase awareness of its usefulness. Businesses can choose a specific warehouse or process to test the technology, thereby helping leaders and managers directly feel the benefits that the technology brings. Testing on a small scale will help reduce risks and facilitate leaders to make decisions to apply the technology more widely. Finally, to promote technology adoption, businesses need to create an environment that encourages innovation. Leaders should create conditions for subordinate managers to propose and test new initiatives to maximize the capabilities of Blockchain technology combined with AI. An environment that supports innovation will help employees feel more confident in applying technology to their work, while improving the competitiveness of businesses in the logistics and supply chain management industry.

7.3. Limitations and Directions for Future Research

Although the study has made certain contributions, there are still some limitations that need to be addressed. First, the research only collected data in HCMC, and therefore does not fully reflect the situation in other areas. Future studies should expand the scope and include data from other cities/regions to increase representativeness and enable comparisons between different cities/regions. Second, the study focused only on a number of factors such as expected performance, facilitating conditions, expected effort, and perceived usefulness, while there are many other factors that should also be considered, such as security perception, user trust, and the interoperability of technologies. Finally, the moderating role of demographic factors (gender, education level, business size, etc.) on usage intention also needs to be clarified in future research.

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APPENDIX

Appendix 1: Coding the Scale after Group Discussion with Experts

Encode	Scale	Source
1. Performance expectancy		
HS1	I believe that Blockchain technology combined with AI will enhance capabilities and improve online trading potential.	(Queiroz & Wamba, 2019); (Kapnissis et al., 2022); (Queiroz et al., 2021).
HS2	I believe that applying Blockchain technology combined with AI improves the quality of my work results.	(Queiroz & Wamba, 2019); (Kapnissis et al., 2022); (Kabir et al., 2021); (Queiroz et al., 2021).
HS3	I think that applying Blockchain technology combined with AI helps me reduce costs in the processing process.	
HS4	I think that applying Blockchain technology combined with AI helps me manage and track my work progress more effectively.	(Queiroz & Wamba, 2019); (Kapnissis et al., 2022).
HS5	I believe that applying Blockchain technology combined with AI helps me save time.	
2. Facilitating conditions		
DK1	I have enough resources to utilize Blockchain technology combined with AI.	(Queiroz & Wamba, 2019); (Kabir et al., 2021); (Queiroz et al., 2021).
DK2	I have enough knowledge of information technology to use Blockchain technology combined with AI.	
DK3	Blockchain technology combined with AI is fully compatible with my company's technology system and infrastructure.	(Queiroz & Wamba, 2019); (Queiroz et al., 2021).
DK4	I have the support of others when facing difficulties in using Blockchain technology combined with AI.	(Queiroz & Wamba, 2019); (Kabir et al., 2021); (Queiroz et al., 2021).
3. Social influence		
AH1	My colleagues all believe that upgrading the old system is necessary to keep up with the pace of business development and that Blockchain technology combined with AI should be applied.	(Queiroz & Wamba, 2019); (Kapnissis et al., 2022).
AH2	My colleagues all believe that Blockchain technology will bring many benefits and have a positive impact on work in the future, and that Blockchain technology should be applied in combination with AI.	
AH3	My senior leadership recognizes the usefulness of combining Blockchain technology with AI and encourages me to use it.	
AH4	My business supports and encourages the use of Blockchain technology combined with AI.	(Queiroz & Wamba, 2019); (Kapnissis et al., 2022); (Kabir et al., 2021).

Encode	Scale	Source
4. Effort expectancy		
NL1	Blockchain technology combined with AI helps carry out financial transactions more smoothly and with less effort.	(Kabir et al., 2021); (Queiroz et al., 2021).
NL2	I believe that using Blockchain technology combined with AI is very easy.	
NL3	I believe that my interaction with Blockchain technology combined with AI is very clear and easy to understand.	
NL4	I believe that my business has the ability to simplify the implementation of Blockchain technology combined with AI in business operations.	
5. Technology readiness		
SS1	Our company feels comfortable introducing the potential of Blockchain combined with AI.	(Zhang et al., 2023).
SS2	Our company has the appropriate infrastructure to integrate Blockchain technology combined with AI.	
SS3	The development of Blockchain technology combined with AI aligns with our company's information technology development roadmap.	
SS4	Our company has implemented the necessary appropriate security measures for Blockchain technology combined with AI.	
6. Perceived usefulness		
NT1	I believe that Blockchain technology combined with AI can help improve the transparency and reliability of data.	Davis (1989).
NT2	I believe that integrating blockchain combined with AI can create greater trust from consumers.	
NT3	I believe that the combination of Blockchain and AI will have a positive impact on the current logistics market.	
7. Intention to use technology		
YD1	I believe that my business will be a pioneer in exploring Blockchain technology combined with AI within the next two years.	(Queiroz & Wamba, 2019); (Kapnissis et al., 2022); (Kabir et al., 2021); (Queiroz et al., 2021).
YD2	I plan to use Blockchain technology combined with AI to support my work over the next two years.	
YD3	I believe that I should use Blockchain technology combined with AI along with other organizations to provide a reliable platform.	(Kabir et al., 2021).