

Article

# Enhancing Competitive Capabilities of Healthcare SCM through the Blockchain: Big Data Business Model's Viewpoint

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**Abstract:** The reasons why supply chain management (SCM) needs blockchain technology include simplification of transaction procedures, time and cost reductions, and reliability improvement. This study emphasizes the necessity of introducing a blockchain-based joint logistics system to strengthen the competency of medical SCM and proposes a healthcare supply chain management (HSCM) competency measurement item through an analytic hierarchy process. The variables needed for using blockchain-based joint logistics are the performance expectations, effort expectations, promotion conditions, and social impact of the unified theory of acceptance and use of technology (UTAUT) model, as well as the HSCM competency results in increased reliability and transparency, enhanced SCM, and enhanced scalability. By analyzing the importance of securing reliability based on blockchain technology in the establishment of a supply chain network for HSCM competency, we reveal that joint logistics can be achieved, and synergistic effects can be created by implementing the integrated database to secure HSCM competency. Strengthening partnerships, such as joint logistics, will eventually lead to HSCM competency. In particular, HSCM should seek ways to upgrade its competitive capabilities through big data analysis based on the establishment of a joint logistics system.



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**Keywords:** blockchain; healthcare supply chain management; logistics cooperation; big data

## 1. Introduction

Supply chain management (SCM) involves connecting the entire logistics pipeline with an integrated solution from raw material suppliers to product production, distribution processes, and end-users, and it is applied in various fields. This study focuses on the integration of supply chain management in the medical industry. Since all costs associated with the healthcare sector's supply chain are rising rapidly, alternatives are needed that can reduce these costs. Naturally, healthcare-related companies are in demand to reduce supply chain management and maintenance costs [1].

Implementing healthcare supply chain management (HSCM) to properly regulate and control uncertainties and variables arising from highly complex medical health market conditions would further enhance the efficiency of health services and help prepare measures to protect consumers, including patients, and their rights and interests [2]. Therefore, this study recognizes the importance of supply chain management throughout the relevant agencies in the medical industry and emphasizes the need for active adoption. However, to successfully introduce supply chain management in the medical sector, it is essential to establish a system where the various stakeholders, including medical device manufacturers, distributors, customer departments, and logistics service providers, can share data. In particular, SCM in the healthcare sector has emerged as an unexpected challenge because of the significant and complex differences between countries, regions, and healthcare-related agencies, especially in the production and distribution stages, due to the large cost-increasing factors for inventory burdens. In addition, the medical sector is difficult to access because it is directly related to human health, and also because the interests of doctors, patients, and the government are complicated in making purchasing

decisions. Therefore, the purpose of this study is to identify the importance of HSCM and enhance the efficiency of supply chain management to derive implications and contribute to the development of HSCM.

Blockchain technology has recently emerged as a subject of social interest due to the secure reliability that it provides. This technology is receiving considerable attention as there is increased interest from many fields, including the medical industry [3]. A blockchain provides a secure distributed database that can operate without centralization, using a distributed P2P (peer-to-peer) network to continuously encrypt a list of sorted records, referred to as blocks, that make up an expanded digital distributed ledger, increasing the validity of each transaction by automatically validating them on the network itself. A blockchain is also attracting attention as a platform for improving the reliability and transparency of medical data through various utilization cases, ranging from maintaining the right to use electronic health records (EHRs) to streamlining claim processing.

The interest and drive to use a blockchain have now expanded to medical information technology. Realizing the potential validity and importance of blockchain technology in healthcare, the National Health Information Technology Coordination Office in the United States laid out an ideal challenge, in 2016, which required a white paper on the potential use of a blockchain in the healthcare field. In response, several medical applications were proposed for a blockchain. While storing entire health records within a blockchain can be regarded as a utilization case for healthcare, some potential barriers for implementation include most short-term proposals, including technical barriers related to privacy, compliance with regulatory requirements, and data storage and distribution focus on data validation, auditing, and certification.

Measures to reduce logistics costs include expanding facilities by increasing investment in social overhead capital, building and securing the logistics facilities, and introducing new logistics management techniques that companies must perform on their own. Among them, the best way to reduce logistics costs, in which companies are the main participants, is to introduce logistics cooperation. Logistics projects that have limitations at the individual level require companies to form a joint organization seeking corporate profits.

Therefore, measures that rationalize logistics need to be taken to secure big data through the reliability of blockchain technology, as well as to expand the overall social overhead facilities in the medical industry. In the case of social overhead facilities, there is a limit to individual companies' performances, which allow them to introduce and utilize logistics cooperation with management techniques that firms can perform independently.

The necessity of the abovementioned research may be summarized as follows: First, data reliability can be retained if the huge volume of big data accumulated in the medical fields through logistics collaboration is combined with a blockchain, securing reliable data flows to coincide with the corporate goals of creating mutual benefits through cooperation. Therefore, customer value could be created in reality by implementing new business models from the perspective of sustainable management of the medical industry. In particular, this research has distinguished itself from previous studies by deriving the SCM competitive capability variables of the healthcare institutions through an analytic hierarchy process (AHP) analysis model and by presenting implications through a word cloud analysis using R in order to increase work efficiency among suppliers participating in the medical industry.

Based on the background of the above research and problem posing, this study seeks to empirically analyze the following research objectives: First, to derive medical SCM competitive competency variables with an AHP analysis. Second, to identify the causal relationship between the intention to introduce and utilize a blockchain and medical SCM. Third, to examine the relevance of the unified theory of acceptance and use of technology (UTAUT) variables regarding logistics cooperation. Fourth, to emphasize the need for logistics cooperation from the perspective of big data business models.

## 2. Theoretical Background

### 2.1. Relationship between Logistics Cooperation and HSCM

There have been continuous efforts to enhance SCM performances among companies, and therefore, the importance of efficiently managing SCM has been emphasized. However, there are only a few studies that have identified inefficient waste factors that arise from the absence of a central logistics cooperation by medical institutions. The key point in supply chain management is the visualization of the whole process in one system. By doing so, companies participating in the supply chain can operate efficiently by eliminating redundancy and inefficiency even among partner companies [4]. Therefore, the integration of big data is imperative.

Supply chain management focuses on the importance of supply chain efficiency. However, to understand the significance of the long-term interaction between logistics cooperation and HSCM [5], it is necessary to understand the competency of HSCM. Therefore, this study also serves as a measurement question by obtaining HSCM competency that reflects the views of experts through the AHP model. It is based on the rationale that HSCM's competition capability can be secured by utilizing the big data generated through the realization of logistics cooperation based on blockchain technology.

### 2.2. Blockchain Features and Logistics Association

Blockchain is a distributed ledger consisting of blocks and chains.

The characteristics of the blockchain are summarized in Table 1, regarding decentralization, efficiency, scalability, security, transparency, and immutability.

**Table 1.** Features of Blockchain.

Characteristics	Content
Decentralization	Distributed public transaction books through networks between individuals breaking away from centralized methods
Efficiency	Reduces investment capital and infrastructure costs by eliminating the need for trusted, authorized third parties
Scalability	Pursues openness to enhance scalability by constructing blocks easily and adopting easily through connection network
Security	Free from malicious attacks such as hacking due to the fact that ledgers open to all nodes and lack the concept of central server
Transparency	Disclose all transaction records for high transparency and reduces regulatory compliance costs from easy transaction tracking
Immutability	Cryptographic hash of previous blocks ensures reliability as records are not modified upon completion

If you load data generated during the distribution process on the blockchain, the reliability of products is increased as you may be able to track sequentially various information such as the source, delivery process, or storage status of products. Currently, the monitoring system for drug supply chains is incomplete. As drugs directly affect the human body, it is critical to deliver authentic drugs without forgery or modulation in the distribution process. Some statistics show that global losses incurred by counterfeit drugs amount to USD 200 billion a year. Applying blockchain technology to drug distribution may prevent forgery and modulation of information which may occur in the process of delivering to consumers from the production site. Smart contracts may automate some processes of distribution which could lead to lower costs and better efficiency [6].

In 2021, blockchain technology was applied to the distribution of the COVID-19 vaccine. Pfizer and Moderna's vaccines should be stored and distributed at ultra-low temperatures below  $-70$  degrees Celsius. In Korea, as of March 2021, 800 dosages had been disposed of due to failure to observe the proper storage temperature since commencement

of vaccination. The reasons for this include broken refrigerators, broken thermometers, and carelessness of the staff. Therefore, if any problem occurs during the distribution process, it may be clearly identified who is responsible [6].

The consensus algorithm is used by many participants to make unified decisions, which was designed to store the same data in a distributed system. The three representative consensus algorithms are PoW (proof of work), PoS (proof of stake), and DPoS (delegated proof of stake) [7].

In the PoW method, a miner who solves the problem first among several miners creates a block and connects the new one to the existing blockchain. This is the way that a node participating in a network creates a block by finding a hash value of a specific difficulty through a mathematical operation. The PoS method is to create a new block by granting decision-making authority according to the stake owned, and when a voted block is registered as an official one, a new block is compensated in parallel with the stake voted for. The DPoS method does not allow all participants in the network to create blocks, but is a method in which a small number of representatives, selected through participants' votes, create blocks on behalf of the entire ones. While PoW has advantages in security and decentralization instead of having a lower processing speed than PoS or DPoS, PoS has a higher processing speed and high security and decentralization as compared with PoW. Though DPoS has the fastest processing speed, it is of low security and decentralization [8]. Since the characteristics, strengths and weaknesses of each consensus algorithm, are different, it is important to select a suitable one for the purpose of the blockchain to be built.

Blockchain technologies that make convenient sharing mechanisms possible and procurable for electronic health data can play an important role for improving interaction and collaboration with the health care industry [9]. This is deemed to be one of the most important contributions of blockchain-based medicine. A blockchain is a distributed ledger that records medical data generation and data sharing events. Blockchain can prevent forgery based on the high reliability of stored data without trusting third parties, and its consensus mechanism. The medical data sharing solution, MediChain uses a distributed network separated into the blockchain network and P2P storage network, and is constructed based on a distributed network that connects all medical service providers including hospitals, insurance companies, and medicine-related companies, and it aims not at replacing the existing electronic medical records systems of hospitals, but to serve as a supplementary solution specified for sharing data among organizations.

As shown above, by using blockchain technologies in healthcare SCM, it is possible to protect personal information, and all companies participating in the supply chain can utilize necessary data to use as various business models. Thus, the need to implement blockchain technologies as a platform technology for strengthening SCM competition capacities, which is the goal of this study, is adequate, and it is possible to create synergy effects with logistics collaboration using big data analysis accumulated here.

Supply chain management is designed to include industry best practices to streamline the whole delivery process from order to supply. Therefore, the security of such digital information is given utmost priority, and currently, is used for safe and secure data [10]. In HSCM, the blockchain technology transactions are especially a key monitoring technology for tapping into the entire process of drugs and medical product movement [11]. Maintaining the value of data, and reducing storage cost for data management in HSCM blockchain technology plays a significant role. Blockchain technology is the only answer to digital information security, due to its unique capability, and it continues to play a crucial role in the future of enterprise data management [12].

The following is an examination of the methods to integrate and apply a blockchain in the distribution industry and SCM. Blockchain's key point is maximizing the safety of information security and transaction management. Therefore, data created in the logistics field, formed over several stages with diverse interested parties, will be utilized in various

areas since the blockchain can share bit data created between contracting parties, shippers, and logistics companies in related organizations, to double its synergy effect.

The reasons why SCM needs blockchain technology are simplification of transaction procedures, time and cost reduction, and reliability improvement [13]. The blockchain is the support of optimization for overall SCM, including connection between information and process, strengthening of reliability and transparency, maximizing utilization of existing legacy systems, material supply, quality management, and maintenance fields. As the blockchain digitalizes and connects whole distribution processes from country or origin, the data can be permanently preserved as unchangeable data and utilized in various forms [14].

### 2.3. Big Data and Joint Logistics

There is a strong need to derive critical success factors by expanding the existing research on medical institutions' joint logistics systems and strengthen the medical SCM competitive capacity from the perspective of big data. In response, this study attempts to combine medical SCM competitive capacity from the perspective of practitioners in medical institutions and apply the R analysis method to identify operational implications. The Cyber Physical System (CPS) is one of the keywords for the 4th industrial revolution, together with artificial intelligence (AI), big data, internet of things (IOT), augmented reality (AR), virtual reality (VR), and Bio. CPS represents creating new value through hyper-connective and hyper-intelligent big data created based on th4 IoT.

Big data are explained through 4V components (volume, velocity, variety, and value) and data complexity [15]. It refers to a technology that extracts value and analyzes results from a large amount of structured or non-structured data sets by a circle course of extracting, storing, analyzing, visualizing, predicting, and applying it to the existing database management tool [16].

While the concept of existing big data simply means a large volume of data, the recent concept illustrates the collection of structured or non-structured data that are difficult to collect, store, search, analyze, and visualize in commonly used methods or tools because of being too large as compared with existing data. The value of utilizing big data started from the process of creating customer-centered value and is applied to joint logistics to understand a company's situation more clearly.

The fundamental goal of big data also emphasizes the importance of sharing the value, necessary for the era of the sharing economy. Various distributed data are gathered in a certain platform based on high relevance, before being applied with the innovational multiplier effect to create new value. During an era where the value of sharing is emphasized by the concept of possession, opening and sharing of tangible and intangible assets and data owned by individuals, companies, and governments create more value. This creates a sharing society beyond the level of the sharing economy, which may realize this economy by creating a control tower where big data is shared for medical SCM as a new economy model. Therefore, the development of a business model for constructing reliable medical industry-related big data is expected to secure transparency by utilizing blockchain technologies.

In the current business field of medical institutes, there is a need to clearly suggest the fields where decisions can be made through big data analysis. With overflowing data, efficient delivery systems for enhancing the synergy effect in related industries through joint logistics are needed. In order to pursue efficiency in joint logistics management through big data's connections with medical institutes, the prior task is to assess the opinions of on-site specialists on the various issues faced by related industries in order to derive core insights.

The strategy of constructing a collaboration system through joint logistics can be accomplished by including all fields, regardless of the industry, or the presence of hostile companies, and by performing joint transportation/delivery and loading/unloading, such as, for example, the campaign of "Business Competition and Joint Logistics." Joint logistics

would reduce their costs, provide stable logistics supply, and maintain/improve the current level of service.

In detail, joint logistics contribute by reducing costs and also enhance productivity by improving the loading rate in trucks, reducing the empty car rate, and preventing excessive transportation fees for holding unnecessary vehicles. In addition, joint logistics are greatly effective for reducing delivery time, reducing driving distance, reducing the number of personnel, making shipping work into the system, helping loading and unloading work, simplifying inspection, maintaining vehicle and facilities, preventing inspection accidents, and reducing facility investment [17]. Furthermore, they contribute to relieving traffic jams by eliminating the need for drivers' direct labor, clarifying fare systems, simplifying fare payments, and preventing overlapping cross delivery. They also provide tangible and intangible effects by reducing the daily driving in crowded city centers, reducing the risk of loss, rationalizing work handling, and reducing the harmful influence on the environment. Constructing mutual trust between partner companies is the prior task for creating this joint logistics system in medical SCM. Therefore, to accomplish a sharing economy and analyze big data, it is necessary to construct a trust network by introducing a blockchain.

### 3. Research Model and Hypotheses Establishment

#### 3.1. Research Model

As shown in Figure 1, this study's research model has been derived, based on the theoretical background of the AHP analysis model and the UTAUT model. The research goal is to examine the need for introducing joint logistics to strengthen HSCM competitive capacity. This study conducted an empirical analysis on the effects of UTAUT's components, performance expectancy, effort expectancy, facilitating conditions, and social influence, with the intention to use and introduce a blockchain. Thus, this study tried to deduce the implications for accessing the big data sharing economy's perspective for realizing joint logistics.

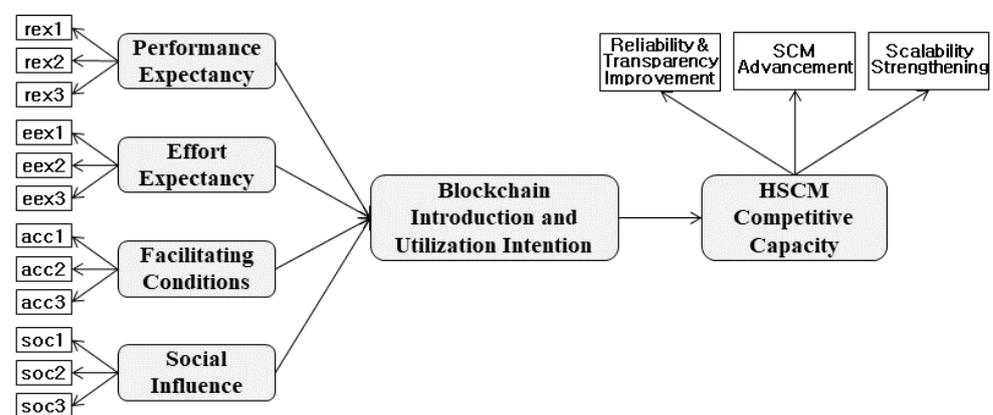


Figure 1. Research model.

#### 3.2. Hypothesis Establishment

Performance expectancy is the degree to which an individual believes that using the system is influenced by the system and will help him or her to attain gains in job performance [18]. Performance expectancy refers to the degree of belief in improving work performance by using new technology, or in other words, the degree of belief in the benefits of introducing and using blockchain technology. The intention of introducing blockchain technology can be enhanced by expecting that utilizing the blockchain technology would help improve work efficiency by securing reliability without inconvenience. Venkatesh et al., (2003) [19] insisted that among the variables in the UTAUT model, performance expectation had the most influence on individual behavioral intentions.

Effort expectancy is defined as the degree of perceiving that a work can be performed easily by using new technology. In addition, effort expectancy is known to have a moderat-

ing effect based on the experience between intent and use. While such effort expectancy is an important factor in the early stage of use, its influence declines after continuous use. In the research on factors related to intention to adopt blockchain technology conducted by [19], it has been empirically analyzed that performance expectancy, social influence, and facilitating conditions influence that intention. Regarding the reasons why effort expectancy has been rejected as the availability of technology utilization and technology introduction, the analysis shows that the desperate acceptance intention for system security strengthening and securing reliability through decentralization of the blockchain technology was weak due to lacking awareness caused by an approach different from the existing concept.

Facilitating conditions refer to the degree of an individual's belief in an organizational or structural base when using a new technology. Therefore, this study set a research model on how trust in blockchain technology and organizations will have a moderating effect on blockchain introduction and utilization intention.

Accordingly, it is explained that the more positive promotion conditions are perceived, the less fear or reluctance to new technologies is felt, which results in the user's intention to use them. It is acknowledged that these promotion conditions may have a greater impact on the user's intention to use when new information technology is just introduced [20].

Social influence refers to the degree of belief in adopting and utilizing a new technology based on the view of other people influencing oneself [18]. Humans as social animals are bound to be influenced by others' behaviors [20].

It can be inferred that it is related to acceptance intention since blockchain-based joint logistics between partner companies need cooperation in the overall supply chain rather than individual companies. The acceptance intention will eventually be enhanced by securing organized support from suppliers and partner companies to construct an infrastructure for introducing the blockchain technology.

Intent to use refers to a user's intention to use the system continuously or recommend it to others. Previous studies, such as the one conducted by Davis [21], proved that this intention to use influenced the actual usage. For the UTAUT components, including performance expectancy, effort expectancy, facilitating conditions, and social influence, having a positive influence on blockchain introduction and utilization intention, this study employs the prediction of HSCM competitive capacity, blockchain introduction, and utilization intention [12]. Thus, this study set the following hypotheses regarding the relationship between blockchain introduction and utilization intention for UTAUT components:

**Hypothesis 1 (H1).** *Performance expectancy will have a positive influence on the intent to introduce and utilize blockchain.*

**Hypothesis 2 (H2).** *Effort expectancy will have a positive influence on the intent to introduce and utilize blockchain.*

**Hypothesis 3 (H3).** *Facilitating conditions will have a positive influence on the intent to introduce and utilize blockchain.*

**Hypothesis 4 (H4).** *Social influence will have a positive influence on intent to introduce and utilize blockchain.*

### 3.3. Design and Empirical Analysis of AHP Models

Currently, it is difficult to select variables due to a lack of theoretical discussion on HSCM competency. Therefore, it is necessary to derive the key performance indicator (KPI) required for HSCM's connection to the blockchain for management information systems (MIS), blockchain, and medical professionals, based on the order of priority. To this end, the analytic hierarchy process (AHP) was applied. The AHP is an analysis tool that deals with multi-criteria decision making, reflecting the views of many decision makers, before taking advantage of the strength to easily handle not only quantitative, but also qualitative information reflecting long experience and intuition that must be considered [22].

The reason why the AHP model is needed in this study is to develop variables for HSCM competitive capabilities. As there was not enough development of measurement items to advance blockchain-based HSCM in the existing literature, it was intended to be used as a variable by reflecting the opinions of experts.

Based on prior research reviews and interviews with practitioners in the medical industry, big data, and blockchain experts, this study conducted measurements using a 9-point scale for a total of 12 determinants. In a preliminary investigation on the order of priority for medical SCM advancement, it was found that increased reliability and transparency, enhanced SCM, and enhanced scalability were recognized as important factors. These results prove that increasing the level of trust and collaboration through IT infrastructure needed for the blockchain-based joint logistics is the key to overcoming the difficulties of medical SCM.

It also shows that enhanced scalability through the expansion of legal systems from a long-term perspective is another factor in strengthening HSCM capabilities. The above three factors were placed in the higher criteria. In addition, lower criteria for enhancing reliability and transparency, guarantee of uniqueness, signing and certification, prevention of redundancy, and securing traceability were derived. Subbasics of strengthening scalability were derived from the expansion of the legal system, improvement of composing performance, support for network optimization, and establishment of an integrated dB network.

Based on these preliminary investigation results, the hierarchical structure of the blockchain-based medical SCM enhancement priority was set up as a three-step structural model, as shown in Figure 2, with the extracted and measurement factors at the center.

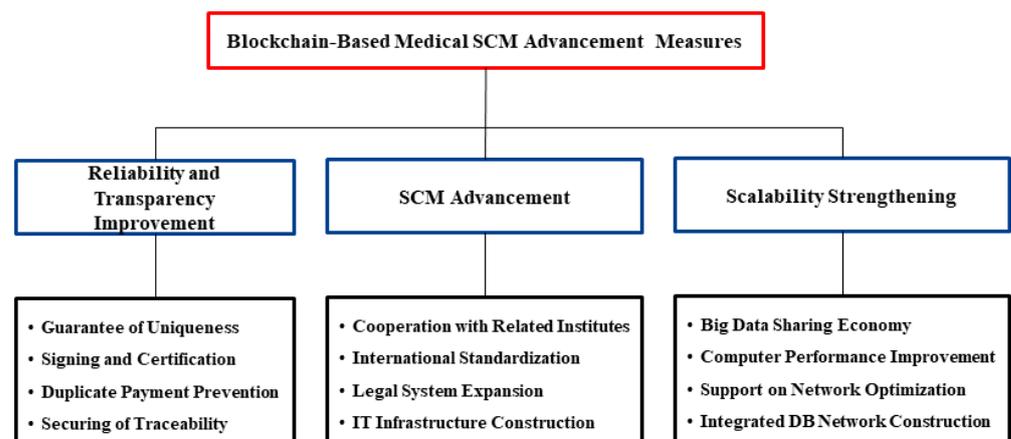


Figure 2. AHP research model.

This study conducted a survey with experts from Busan and Gyeongnam of Korea and used a total of 12 questionnaires for the final analysis. The applicational AHP techniques recommend having 10 to 15 individuals with working knowledge and professional experience [23]. To review the reliability of the survey data, this study utilized the consistency ratio (CR) of the AHP method for measuring the consistency of respondents in a double-contrast bridge. In general, double-contrast bridges can be reasonably assessed when the CR is less than 0.1 [24]. In this study, the CR is 0.04–0.08, which indicates that reliability has been secured. As illustrated in Table 2, analysis of the questionnaire on the first stage evaluation items showed a preference to improve reliability and transparency (0.644), upgrading SCM (0.253), and strengthening scalability (0.103), indicating that experts consider securing reliability that reflects the characteristics of the blockchain to be the most important of the primary factors. In addition, the assessment of subcategories, shown in Table 3, demonstrated that the single-state guarantee was the most important factor in enhancing reliability and transparency. It was analyzed that the most important factors for upgrading SCM were collaboration with related agencies and expansion of legal systems.

**Table 2.** Results of pairwise comparison in Level 1.

Type	Valuation Criteria		
	Reliability and Transparency Improvement	SCM Advancement	Scalability Strengthening
Importance Rank	0.644 1	0.253 2	0.103 3
C.R.	0.08		

**Table 3.** Results of AHP on subfactor.

Representative	Detail Element	Itemized		Relevance of Evaluation Criteria					
		Importance	Rank	Effectiveness		Technology Securing		Urgency	
				Average	Rank	Average	Rank	Average	Rank
Enhancing Reliability and Transparency (C.R. = 0.07)	Guarantee of Uniqueness	0.464	1	4.50	1	4.58	1	4.33	2
	Signing and Certification	0.336	2	4.08	5	4.08	5	4.08	6
	Duplicate Payment Prevention	0.137	3	3.83	8	3.66	9	3.58	10
	Securing of Traceability	0.062	4	3.75	9	4.33	4	3.41	12
Advancing SCM (C.R. = 0.04)	Cooperation with Related Institute	0.428	1	3.91	7	3.25	11	3.83	9
	International Standardization	0.226	3	3.58	10	3.58	10	3.50	11
	Bigdata Information Sharing	0.254	2	4.08	5	4.41	3	4.25	4
	IT Infrastructure Construction	0.092	4	4.25	3	4.50	2	4.58	1
Strengthening Scalability (C.R. = 0.06)	Securing of Legal System	0.477	1	4.16	4	2.91	12	4.16	5
	Improvement on Computing Performance	0.224	2	3.50	12	3.83	8	4.00	7
	Support on Network Optimization	0.143	4	3.58	10	4.00	6	3.917	8
	Integrated DB Network Construction	0.155	3	4.33	2	3.91	7	4.33	2

In addition, the results of compiling the relative importance of the decision items to derive the overall ranking of the detailed indicators are, from the perspective of effectiveness of final ranking: ① uniqueness guarantee; ② integrated DB network establishment; ③ high IT infrastructure establishment. In terms of technology security, it was ranked high in the order of: ① uniqueness guarantee; ② IT infrastructure establishment; ③ sharing big data information. In terms of urgency, ① IT infrastructure establishment; ② uniqueness guarantee and integrated DB network construction was high on the same average. Following the AHP analysis, both CR and lower criteria were surveyed, consisting of the structural equation model measurement items, including improved reliability and transparency, enhanced SCM, and enhanced scalability as HSCM competency measurement items.

For HSCM's competitive capacity of achieving joint logistics by introducing blockchain, this study used the AHP analysis and derived three items, including enhancing reliability and transparency, advancing SCM, and strengthening scalability. To reach a sharing economy by introducing blockchain technology, the top priority is to secure trust between partner companies. It is necessary to pursue advancement of medical SCM through the construction of an IT infrastructure. In addition, a big data sharing economy can be created by constructing an integrated DB network.

Accomplishing the goal of joint logistics through the supply chain [25], the ability to construct a goods delivery system within the shortest time [26], and securing flexibility to respond to unexpected situations are possible and have the capacity to adjust and revise the supply chain operating process that quickly responds to rapidly changing corporate environment changes [25]. From the perspective of SCM, introducing the blockchain technology can track the history of goods during the whole process, from production to moving, storage, distribution, and consumption. Realization of joint logistics by introducing a

blockchain refers to the process of real-time collection and analysis of data from all processes, from production to distribution [27]. Thus, real-time information-based competitive capacity will contribute to the advancement and scalability of the medical supply chain [28]. In response, this study established the following hypothesis regarding the relationship between the intent to introduce and utilize blockchain and HSCM's competitive capacity.

**Hypothesis 5 (H5).** *Intent to introduce and utilize blockchain will have a positive influence on HSCM's competitive capacity.*

#### 4. Research Model and Analysis

##### 4.1. Survey Composition and Features of Sample

In this research model, all variables were applied using a Likert Scale, and the sample targeted the Busan, Gyeongnam, Seoul, and Gyeonggi-do regions of Korea. The mobile survey was conducted on pharmaceutical, manufacturing, and logistics businesses by focusing on medical institutes. Among 270 questionnaires, 261 were used after excluding those with biased distribution. For statistical analysis, SPSS 25 and Smart PLS 2.0 software were used.

For hypothesis testing, this research model adopted a partial least square (PLS) structural equation analysis because it uses the least squares method to reduce the measuring and prediction errors, enhancing verifiability for path coefficients [29].

The features of the research model are shown in Table 4. The business type was distributed in the order of hospital and medical institutes (46.3%), pharmaceutical distribution, manufacturing businesses, service businesses, and medical device manufacturing businesses. However, since the companies are representative related industries in HSCM-related industries, it is judged that there will be no problem with the overall research progress.

**Table 4.** Profiles of companies and respondents.

	Classification	Frequency	Percentage (%)
Type of business	Pharmaceutical	48	18.4
	Medical device manufacturing	6	2.3
	Medical institute	121	46.3
	Logistics	73	28.0
	Service	13	5.0
Gender	Male	98	37.5
	Female	163	62.6
Age	Less than 20 s	22	8.4
	30 s	127	48.7
	40 s	55	21.1
	50 s	40	15.3
	More than 60 s	17	6.5
Position	Assistant manager	159	64.8
	Department manager	57	21.8
	Executive	35	13.4
No. of Employee	Less than 10	108	41.3
	11–50	49	18.8
	51–100	19	7.3
	101–300	53	20.3
	301–500	13	5.0
	Over 500	19	7.3
Region	Busan	128	49.0
	Gyeongnam	127	48.7
	Seoul and Gyeonggi-do	6	2.3
Medical records program	EMR	140	53.7
	ERP	121	46.3
Total		261	

The respondents included 62.6% females and 37.5% male, and their positions were in the order of highest percentage, assistant manager, department manager, and executive. The age of respondents was high in their 30s (48.7%) and 40s (21.1%). Regarding the number of employees at an institute, 41.3% of institutes had fewer than 10 employees, 25.1% had fewer than 100 employees, 25.3% had less than 500 employees, and 7.3% had over 500 employees. The survey region was divided across Busan (49.0%), Gyeongnam (48.7%), and other Seoul and Gyeonggi-do regions (2.3%). The medical record programs in use were identified as EMR (electronic medical record) 53.7% and ERP (enterprise resource planning) 46.3%.

#### 4.2. Empirical Analysis and Result

A confirmatory factor analysis (CFA) was conducted to test the discriminant validity of these structures. Table 5 shows the result. The result shows that Cronbach's  $\alpha$  for each construct is above the recommended threshold of 0.6, indicating higher measurement reliability. If the construct reliability (CR) and all factor loadings are greater than 0.7 and average variance extracted (AVE) is greater than 0.5, it means that convergence validity is good. In this study, the AVE range of values of the variables in this study is between 0.588 and 0.890. The results show that the convergence validity is good.

**Table 5.** Analysis on reliability and convergent validity of the measuring model.

Latent Variable	Measurement Variable	Factor Loading	t-Value	AVE	C.R.	Cronbach's $\alpha$
Performance expectancy	rex1	0.941	99.106 ***	0.833	0.937	0.900
	rex2	0.905	64.171 ***			
	rex3	0.892	69.491 ***			
Effort expectancy	eex1	0.914	5.494 ***	0.683	0.864	0.825
	eex2	0.684	3.434 ***			
	eex3	0.865	5.592 ***			
Facilitating conditions	acc1	0.940	133.850 ***	0.890	0.961	0.938
	acc2	0.943	123.789 ***			
	acc3	0.948	189.350 ***			
Social influence	soc1	0.873	29.894 ***	0.588	0.808	0.660
	soc2	0.788	16.908 ***			
	soc3	0.617	7.420 ***			
Intent to use	bin1	0.880	67.693 ***	0.804	0.943	0.919
	bin2	0.902	79.466 ***			
	bin3	0.915	94.288 ***			
	bin4	0.889	62.882 ***			
Competitive capacity	abi1	0.837	51.648 ***	0.622	0.734	0.750
	abi2	0.816	40.482 ***			
	abi3	0.788	30.961 ***			

\*\*\*  $p < 0.01$ .

For the factor loading value of the constructs, the value was over the reference value of 0.5. In measuring items that did not belong to each construct (Table 6), the confirmatory factor analysis results showed that all items, except one value, satisfied a reference value below 0.4, and six factors were bound together with a minimum value over 0.585. In the convergent validity evaluation, the factor loading for all constructs was over the reference value of 0.7, as shown in Table 7. In addition, as the square root for the average variance extracted was higher than the correlation coefficient of other variables, it was proven that the measuring tool of this study had discriminant validity.

**Table 6.** Results of confirmatory analysis.

Classification		1	2	3	4	5	6
Intent to use	bin3	0.916	0.070	0.046	−0.033	0.059	0.021
	bin1	0.865	0.118	0.091	0.031	0.068	0.039
	bin4	0.865	0.077	0.191	0.062	0.057	0.017
	bin2	0.859	0.140	0.136	0.031	0.052	0.094
Performance expectancy	rex1	0.148	0.860	0.251	0.054	0.047	0.042
	rex2	0.139	0.843	0.163	−0.032	0.166	0.082
	rex3	0.161	0.795	0.215	0.041	0.041	0.075
Facilitating conditions	acc2	0.194	0.208	0.845	0.061	0.198	0.044
	acc3	0.187	0.280	0.820	−0.005	0.160	0.061
	acc1	0.230	0.271	0.799	0.111	0.073	0.055
Effort expectancy	eex3	0.041	0.031	0.098	0.887	0.106	0.009
	eex2	−0.038	−0.052	0.007	0.850	0.130	0.009
	eex1	0.065	0.062	−0.024	0.751	0.034	0.326
Competitive capacity	exp2	0.066	0.139	0.043	0.125	0.849	0.102
	exp1	0.107	−0.010	0.036	0.220	0.813	−0.015
	exp3	0.082	0.113	0.329	−0.004	0.789	0.039
Social influence	soc2	0.088	0.003	0.063	0.126	−0.006	0.820
	soc3	0.009	0.253	−0.025	0.045	0.187	0.605
	soc1	0.127	0.163	0.157	0.498	0.102	0.585

**Table 7.** Analysis on discriminant validity of measuring model.

	Performance Expectancy	Effort Expectancy	Facilitating Conditions	Social Influence	Intent to Use	Competitive Capacity
Performance expectancy	<b>0.913</b>					
Effort expectancy	0.097	<b>0.826</b>				
Facilitating conditions	0.558	0.157	<b>0.943</b>			
Social influence	0.304	0.428	0.281	<b>0.767</b>		
Intent to use	0.316	0.076	0.380	0.194	<b>0.897</b>	
Competitive capacity	0.284	0.265	0.410	0.362	0.126	<b>0.789</b>

Bold item in diagonal line, AVE square root.

In the convergence validity of the structural model, the communality value was over 0.5, as shown in Table 8, satisfying the suitability of the measuring model. For R Square ( $R^2$ ), an average suitability measurement for the structural model, it is classified as high (over 0.26), medium (0.13~0.26), and low (0.02~0.13), as a path model evaluation for each endogenous variable [30]. In addition, the overall suitability of the PLS path model is the root square root value calculated by multiplying the mean value of the endogenous variable  $R^2$  and communality. The suitability value should be at least 0.1, and it is classified as high (over 0.36), medium (0.25~0.36), and low (0.01~0.25), depending on the size. As shown in Table 8, the overall PLS path model's suitability was 0.284, representing a medium level.

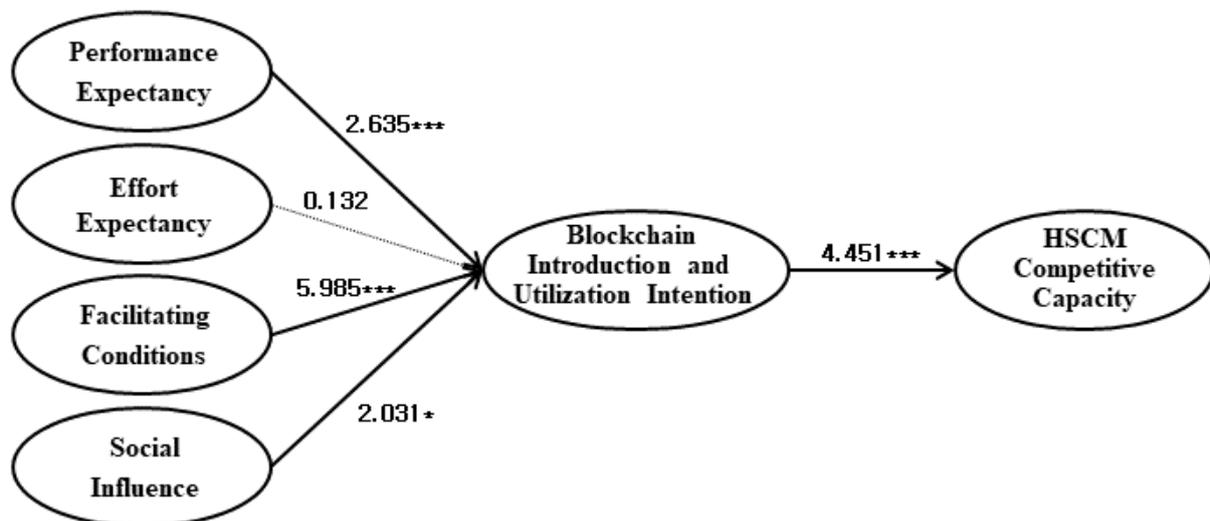
#### 4.3. Hypothesis Testing

As illustrated in Figure 3, hypothesis H1 ( $\beta = 0.128$  and  $t = 2.635$ ), regarding how performance expectancy will have a positive influence on the intent to introduce and utilize the blockchain, showed statistical significance at a significance level of  $p < 0.001$ . Hypothesis H2 ( $\beta = 0.006$  and  $t = 0.132$ ), analyzing how effort expectancy will have a positive influence on the intent to introduce and utilize the blockchain, did not show statistical significance. Hypothesis H3 ( $\beta = 0.285$  and  $t = 5.985$ ) which examined how facilitating conditions will have a positive influence on the intent to introduce and utilize the blockchain showed statistical significance at a significance level of  $p < 0.001$ . Hypothesis H4 ( $\beta = 0.099$  and  $t = 2.031$ ), regarding the way social influence will have a positive impact

on the intent to introduce and utilize the blockchain, showed statistical significance at a significance level of  $p < 0.05$ . Hypothesis H5 ( $\beta = 0.197$  and  $t = 4.451$ ) which focused on how the intent to use will have a positive influence on HSCM’s competitive capacity showed statistical significance at a significance level of  $p < 0.001$ .

**Table 8.** Analysis on fitness of structural model.

Constructs	R Square	Communality	Redundancy
Performance expectancy		0.833	
Effort expectancy		0.683	
Facilitating conditions		0.890	
Social influence		0.588	
Intent to use	0.171	0.804	0.052
Competitive capacity	0.048	0.622	0.010
Overall model fitness		$\sqrt{0.110 \times 0.737} = 0.284$	



Significance level: \*:  $p < 0.05$ , \*\*\*:  $p < 0.001$

**Figure 3.** Hypothesis testing results.

Figure 4 shows the results of the word cloud analysis regarding the utilization of R to deduce major implications for achieving work efficiency between cooperative companies in medical institutes. In word cloud, words and phrases, such as unexpected situations, delivery, trust in technology, sharing, information, effectiveness, and emergency, were often mentioned. This result implies the necessity of constructing a system for immediate delivery in unexpected situations on weekends and holidays. The results also highlight the necessity of smooth communication and information sharing through a mutual-trust system. In addition, the results demonstrate the need for efficient inventory management. Therefore, the field needs to pursue a HSCM business model that analyzes big data mutually between related institutes, achieving real-time SCM to enhance visibility in information sharing.



Figure 4. Word cloud analysis results.

## 5. Conclusions

To advance medical institutes' competitive capacities, it is necessary to introduce joint logistics through big data information sharing. This study applied medical SCM competitive capacity toward the intent to introduce blockchain technology and the need for joint logistics from the perspective of big data. There are various fields where big data can be utilized by medical institutes, such as improvement of internal business handling, better targeting of products and services provided to customers, and change of all business models for utilizing real-time information and feedback. In the medical SCM field, joint logistics is likely to be applied to reduce the investment risk by reducing the required time for each process, enhancing the rate of on-time delivery, and increasing the logistics center and vehicles in the short and long term. Therefore, this study examined the perspective of big data to analyze the close relationship between partner companies, such as matching supply with demand between them, reducing inventory level, enhancing logistics delivery, and creating an opportunity to shorten the new product release period.

First, regarding the factors causing the progress of the blockchain-based medical SCM competitive capacity, this study selected enhancement of reliability and transparency, advancement of SCM, and strengthening of scalability. Securing reliability is the most crucial part in introducing the strengths of a blockchain between partner companies in the medical industry field. Therefore, securing a guarantee of uniqueness through blockchain technology is most needed. Furthermore, the AHP analysis results showed that cooperation with related institutes and the expanded legal system secure the HSCM competitive capacity the most. To store and utilize sensitive personal information, such as medical data, data can be saved with a blockchain technology's encryption, and the user can realize big data information sharing through the right to access. By utilizing decentralized blockchain technology to solve reliability, security, and sharing issues, a blockchain is expected to reach the era of a sharing economy where treatment and customized care are available.

Second, in the subfactor AHP analysis and relative importance analysis depending on effectiveness, technology securing, and urgency, the importance followed the order of guarantee of uniqueness, integrated DB network construction, and IT infrastructure construction. This represents the strong need for constructing an IT infrastructure, such as an integrated database guaranteeing uniqueness through the blockchain technology. This also implies that a synergy effect can be created by constructing an integrated database in the overall medical industry to advance HSCM's competitive capacity. This study also clarifies the prerequisite of building trust between partner companies based on the blockchain.

Third, among the UTAUT components, performance expectancy, facilitating conditions, and social influence had a significant impact on the intent to introduce and utilize the blockchain. However, effort expectancy did not influence this intent. This showed that constructing an infrastructure based on technology, such as a blockchain, would be introduced positively in terms of work efficiency and convenience. It is assumed that the importance of cooperative relationships in the overall supply chain is applied regarding blockchain-based joint logistics throughout the medical industry. Eventually, positive acceptance of the ripple effect caused by securing the blockchain technology would enhance the intent to accept it. However, another interpretation suggests that the awareness of

the need for introducing a method that is different from the existing ones, such as effort expectancy, was relatively passive.

Fourth, the intent to introduce and utilize a blockchain had a significant influence on HSCM's competitive capacity. Expected effects, such as enhancing reliability and transparency, advancing SCM, and strengthening scalability, predict new practical benefits from achieving joint HSCM logistics. It is necessary to promote the intent to use joint logistics based on expected effects, such as enhanced flexible response to demand variation, enhanced capacity for goods improvement and change, and enhanced response to market environment changes.

Fifth, while existing HSCM-related studies lacked an examination of the connection between blockchain and joint logistics, this study analyzed this connection under the aspect of big data, emphasizing the necessity to secure reliability as a blockchain's core success factor and expand its utilization regarding big data businesses in order to settle joint logistics. While some types of SCM competitive capacity that affected the related institute's performance and continuous connection eventually had direct and indirect influence on joint logistics, there were only a few studies that clarified such influence, and our research expected to provide a new framework. Therefore, by considering the need to introduce joint logistics as a practical measure for enhancing SCM performance in the medical industry field and strengthening the partnership, such as information sharing, it would be possible to establish a big data business model. In response to the rise of the 4th industrial revolution era, big data is strongly needed. Utilizing big data formed through joint logistics on medical SCM would allow the operation of a control center that would enable strategic thinking, such as cooperation and price, enhancing the synergy effect. Constructing a big data business model is expected to enhance medical institutes' capacities.

In the middle of the problem whether to survive or fall behind under the rapidly changing business environments, strategies to secure competitive capabilities are also critical for healthcare SCM. This is the right time to recognize the necessity of converting into the digital ecosystem and a company's strategy to achieve competitiveness by strengthening competitive capabilities through securing the reliability of data, which is a major feature of the blockchain. The implementation of sustainable management strategies has been sought for the innovation of business models through the grafting of big data and blockchain technology, which are the key words of the 4th industrial revolution. Therefore, the accumulation of reliable big data through the interface of logistics collaboration and blockchain in the medical industry will eventually work through to achieve the foundation for sustainable management.

This study's academic and practical implications are as follows: Since securing blockchain technology based on HSCM competitive capacity showed statistical significance in joint logistics, this study suggested a direction for establishing a strategy for related institutes in the medical field. This study also suggested the need for constructing joint logistics through the introduction of a blockchain, which would be an innovation in the comprehensive application on a supply chain network composed of numerous members. Medical SCM's competitive capacity would ultimately lead to strengthened co-operative competitive capacity, such as joint logistics. This study demonstrated the importance of the intent to use blockchain technology. The factors that reinforce joint logistics in the supply chain will be key in forming relationships with partner companies. This has been proven in numerous preceding studies, and it is important to apply blockchain technology on the basis of strong reliability. In addition, SCM's competitive capacity should be enhanced by pursuing a strategic approach between companies regarding joint logistics system to induce partnerships between them. In particular, it is necessary to pursue ways to utilize HSCM by analyzing big data for the construction of a joint logistics system.

In this research, we have derived three points that can be available as variables in the advancement of blockchain-based healthcare SCM in particular. It is expected that, by securing reliability and transparency through blockchain technology, future studies may

proceed to an AHP analysis that could help to expand the advancement and scalability of healthcare SCM.

The limitations of this study, and the directions for follow-up research are as follows: First, this study could not consider the characteristics of the scale of the medical institute. There may be differences in the intent to introduce a blockchain depending on the scale of the medical institute. Therefore, follow-up studies should take this limitation into consideration and carry out various analyses to deduce meaningful results. Second, it is necessary to enhance generalization by expanding the sample to the national level and collecting more data. Third, a more meaningful approach would include classifying companies into upstream/downstream cooperative companies focusing on medical institutes and expanding the scope of the research. Forth, the questionnaire using in this study was in the order of medical institutions (46.3%), pharmaceutical distribution (28.0%), and pharmaceutical manufacturing (18.4%). Therefore, it is necessary to increase the generality by similarly surveying the proportion of companies related to HSCM.

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