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ORIGINAL RESEARCH

Technology in Hospital Supply Chain Management

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Abstract

The healthcare industry is rapidly advancing, making it essential to integrate the various technologies adopted by hospitals. These technologies encompass data collection, data management, and information presentation. However, in the current state of hospital supply chain technology, integration remains limited, indicating the need for further research. This study examines hospital supply chain technologies, including Blockchain, the Internet of Things (IoT), Radio Frequency Identification (RFID), Artificial Intelligence (AI), Telemedicine, and Hospital Information Systems (HIS). To ensure optimal functionality, these technologies must be integrated across hospital systems. Several variables influence technology integration and must be carefully considered, such as the level of integration, accuracy, data security, stakeholder trust, information quality, system quality, efficiency, perceived ease of use, perceived usefulness, reliability, and real-time capability. This research employs a Causal Loop Diagram (CLD) to visualize the relationships among these variables and their impact on the degree of technological integration. By achieving integrated technology, hospital supply chain processes can operate more efficiently while enhancing trust among stakeholders in adopting and utilizing these systems. Furthermore, this study acknowledges its limitations and proposes directions for future research, particularly the application of the Stock Flow Diagram (SFD) method to further analyze hospital supply chain technologies.

KEYWORDS:

Causal Loop Diagram; Efficient; Hospital Supply Chain Management; Integration; Technology; Trust.

1 | INTRODUCTION

Every nation's economy is impacted by a variety of industries in this world, including the health sector. Because it is a necessity for every nation, healthcare is one of the most significant industries. There is a need to lower costs while maintaining high-quality services in this complex and costly industry (Srivastava et al., 2020; Rakovska dan Stratieva, 2017; Mathew et al., 2013). The country's health and quality of life can be enhanced by this industry.

Here, the supply chain's role is to cope with these demands by managing medical supplies and integrating stakeholders or processes in hospital services effectively. Patient satisfaction with reasonably priced and decently quality health products and services can be achieved with efficient supply chain procedures. Supply chain management is difficult when it comes to the pharmaceutical and healthcare industries. The vulnerability of supply chains to disruption is a result of their complexity, which may have an impact on patient safety (bin Megat Adnan and bin Sahroni, 2020;[1]; Srivastava et al., 2020). However, the truth is that the supply chain is still incredibly dispersed, ineffective, and unable to fully utilize its benefits. This may occur as a result of the supply chain's fragmented structure, which emphasizes internal operations over external coordination and solitary worker behavior.

Technology that can combine automation and digitization to achieve maximum productivity, accuracy, quality, and speed with less resources and improved processes is also needed to support the supply chain process (Ilangakoon et al., 2018). By enhancing service and financial performance, digitalization can enhance supply chain integration and add value to the healthcare supply chain. A number of businesses have stated that in order to promote agility in the face of unforeseen circumstances and enhance transparency, Indonesia needs to establish a digital healthcare ecosystem (Deloitte, 2019, 2020; Kearney, 2020). However, there is a lack of transparency and integration in Indonesia's industrial supply chain operations. In contrast, Australia has one of the best-organized and most globally regulated healthcare systems (Deloitte, 2019). Australia has come a long way in developing an intelligent healthcare supply chain.

The policy in the hospital is stated in PMK (Minister of Health regulations) no 269 of 2008 concerning electronic medical records (RME). RME must be held by all existing health service facilities (FASYANKES) such as hospitals, health centers, clinics, etc. FASYANKES requires a separate work unit that takes care of medical records from the time the patient enters until the patient is discharged, referred, or dies. The government, in this case through the Indonesian Ministry of Health, not only obliges health facilities through existing regulations but will also continue to facilitate the implementation of RME by providing electronic systems, facilities, infrastructure, and equipment needed. RME in health facilities must be integrated with the Ministry of Health. Data and system standards refer to those set by the Ministry of Health (KEMENKES). Data processing and access to medical records by KEMENKES, the context of health data processing for health policy purposes. Patients or families receive RME after treatment in various forms.

PMK Number 20 of 2019 and KMK 4829 of 2021 regarding Guidelines for Health Services through Telemedicine during the COVID-19 pandemic specify how Health Service Facilities are to implement Telemedicine Services. Telemedicine has many advantages for enhancing the standard of care provided in hospitals, including removing barriers to specialist-physician communication, strengthening the referral system, decreasing referral rates, boosting productivity, avoiding patient travel, serving as a platform for medical education, overcoming diagnostic delays, and enabling patient monitoring.

The management of technological interfaces between patients and healthcare providers and the incorporation of new technologies into practice present the largest challenges for nurses. In addition, there are various ethical and risk issues that raise concerns over the implementation of technology and its impact on patients. (Thimbleby, 2013). Nurses find it difficult to integrate technology and are reluctant to change the way they work in clinical practice (Kurki et al., 2018). The result of this study is that the application of technology in hospitals needs training and socialization as an introduction and to improve skills in operating technology for nurses to be able to work effectively.

With the facts of the problem that is happening, the aim of this research is to find out what variables in technology affect the integration between information and between technologies in the hospital supply chain process. The integration process is very important because it can connect all information between stakeholders so as to make the

TABLE 1 Statement related to Blockchain.

Statement	Reference
Through authentication, blockchain controls IoT device accuracy and prevents malicious behavior.	Chen et al., 2020; Wang et al., 2018
Blockchain transparency strengthens product safety by increasing supply chain visibility.	Abeyratne & Monfared, 2016; Francisco & Swanson, 2018; Korpela et al., 2017
Concerns about trust between stakeholders are frequent in health and safety supply chains.	Betcheva et al., 2021; Hobbs, 2020
Efficient handling of pharmaceutical processes and supply chain management is necessary to minimize bottlenecks and potential errors during these testing intervals.	Tahlil et al., 2023

supply chain process in the hospital more efficient and effective. And also have a positive impact on both the hospital, suppliers, and patients.

2 | LITERATURE STUDY

Technology literature on hospital supply chain management includes the Internet of Things (IoT), Radio Frequency Identification (RFID), Blockchain, and Artificial Intelligence (AI) to improve supply chain visibility, digital control, accuracy, trustworthiness, and readability (Al et al., 2019; Kumar dan Pundir, 2020;[2], 2013; Queiroz et al., 2020). There are also Hospital Information Systems (HIS) and Telemedicine technologies (Ministry of Health of the Republic of Indonesia, (2021)). Firstly, the author summarizes the relevant hospital supply chain management technology literature. Then the author creates a variable mind map for each technology (can be seen in Figure 1). The next step each variable is explained more fully and including the definition, advantages, disadvantages, similarities, and differences between these variables. A brief explanation of these technologies includes blockchain is used to track and overcome drug counterfeiting, in this study using two journals; RFID is used to improve product traceability, in this study using two journals; Telemedicine is used to serve patient complaints remotely, in this study using two journals; IoT is used to help improve operational efficiency and security in hospitals, in this study using two journals; AI is used to help plan hospital needs, in this study using two journals; and HIS is used to help patient medical records technologically, in this study using two journals. Each of these technologies will be explained in the following subchapters.

2.1 | Blockchain

As shown in Table 1 , blockchain, as a technology for hospital supply chain management, has the potential to address uncertainties related to drug authenticity, enhance drug traceability, and facilitate secure communication across supply chain components[1]. Within the blockchain context, four key variables are identified: accuracy, security, trust, and efficiency. Accuracy[3] (Wang et al., 2018) refers to the correctness and reliability of data stored on the blockchain, such as drug inventory records. Real-time monitoring of drug location and quality reflects the level of data accuracy. Security (Abeyratne and Monfared, 2016; Francisco and Swanson, 2018; Korpela et al., 2017) represents the extent to which stored data are protected from cyberattacks and unauthorized access, thereby preventing data breaches.

TABLE 2 Statement related to IoT.

Statement	Reference
IoT sensors are still required to monitor vaccine temperatures in order to ensure vaccine potency and data accuracy, even though blockchain offers a platform for vaccine traceability and real-time vaccination consumption data.	Hasan et al., 2019; Singh et al., 2020
Potential hazards have an impact on the overall vaccine supply chain (VSC) efficiency at every node and along every channel.	Ellis et al., 2015
The security and privacy of Internet of Things systems are improved by blockchain's decentralized structure.	Banerjee et al., 2018; Kouzinopoulos et al., 2018

Security failures may lead to drug counterfeiting, drug unavailability due to manipulated information, and potential threats to patient safety when altered data no longer correspond to patients' medical conditions. Trust [4, 5] among stakeholders—including hospitals, pharmaceutical suppliers, and logistics providers—is fostered through data accessibility and transparency, enabling all participating parties to monitor supply chain activities. Finally, efficiency [6] is reflected in the extent to which transaction processes can be executed seamlessly and automatically.

Based on these four variables, each has advantages and disadvantages. The data entered at the beginning must be accurate to be trusted. All data that has been validated and confirmed cannot be changed/manipulated, and any unauthorized changes will be quickly detected. The data that is displayed transparently, can create trust Between stakeholders so that all parties and the same data can see any changes are presented to each other so as to minimize disruptions that only occur in one stakeholder. It should also be noted that differences in understanding of how blockchain works can reduce the level of trust between stakeholders. Smart contracts increase efficiency because they automate various goods transactions (reorder goods when the stock has reached a certain point automatically), validate transactions (medicine, supplier identity, price, quality), inventory tracking, and payments.

The four variables are interrelated because they have the blockchain criteria in common: data transparency, data integrity, data resilience, and data validation and confirmation. Multiple parties can verify data stored on the blockchain thus increasing accuracy and trust between stakeholders, and security because it can detect and monitor suspicious transactions or sudden attacks and increase efficiency in terms of monitoring and validating data. Besides the similarities, there are also differences between these four variables. First, accuracy refers to the extent to which data on stocks, shipments, receipts, and other transactions match the actual conditions in the hospital. Second, security refers to the protection against theft, manipulation, or vulnerability to attacks on hospital data and supplies. Third, blockchain helps in building trust between various parties by providing better visibility and confirmation of transactions. Fourth, efficiency refers to the ability to manage inventory and flow of goods in an automated and well-documented manner.

2.2 | Internet of Things (IoT)

The Internet of Things (IoT) is one of the technologies applied in hospital supply chain management to enhance the quality of healthcare services. Within the IoT framework, three key variables are identified: data accuracy, decision efficiency, and security. Data accuracy [7] (Singh et al., 2020) refers to the reliability and precision of data used to support decision-making. Decision efficiency [8] represents the ability to improve operational efficiency through timely and informed decisions. Security (Banerjee et al., 2018; Kouzinopoulos et al., 2018) measures the extent to which data are securely stored and protected from unauthorized access. The statements related to IoT and its associated variables are summarized in Table 2 . Data accuracy enabled by real-time monitoring allows data to be collected and observed across multiple aspects of the hospital supply chain, thereby reducing human error and optimizing data collection processes. Furthermore, improved decision efficiency through the analysis of historical and real-time data provides more actionable information and supports the optimization of various supply chain operations.

TABLE 3 Statement related to RFID.

Statement	Reference
The majority of healthcare organizations considering RFID implementation are concerned about costs and return on investment (ROI), according to recent journals and articles on supply chain management and healthcare.	Murphy, 2006
As part of RFID technology, a product's or piece of equipment's usage history can be preserved, and potential issues can be identified much more quickly with accurate records.	Chopra and Sodhi, 2007
The appropriate application of this technology could significantly reduce time, costs, effort, and patient mortality.	Bowersox et al., 2007
Utilizing RFID facilitates easier access to material movement, resulting in more precise data regarding inventory and material flow throughout hospitals.	Erick et al., 2015

The disadvantage of IoT security is that if other parties hack it, there can be huge losses. Each variable of the internet of Things has similarities, and the following are the similarities. The variables of data accuracy, efficiency of decision, and security both make the best/right decision. All variables also contribute to improving service quality. Variables become a reference for technology to try to increase productivity and cost savings. The similarity of all variables is that both will further improve hospital supply chain technology. Data accuracy leads to the extent to which the data collected and used is representative of the actual situation. From these differences, it can be seen that each variable has its own importance.

2.3 | Radio Frequency Identification (RFID)

RFID is the third technology adopted by hospitals to support supply chain management. It enhances medical product traceability, thereby reducing inventory loss, minimizing non-recurring inventory costs, and improving logistics efficiency (Bendavid and Boeck, 2011). Four key variables are associated with RFID implementation: return on investment, reliable data, search time, and data accuracy. The statements related to RFID are summarized in Table 3 . Return on investment (Murphy, 2006) reflects the effectiveness of RFID investment, reliable data (Chopra and Sodhi, 2007) indicates the consistency of stored data with actual and historical conditions, search time [9] measures the reduction in time required to locate items, and data accuracy [10] represents the precision of real-time tracking of medical products.

The advantages and disadvantages possessed by the four variables. High ROI shows added value and is profitable for hospitals when implementing RFID, but ROI only focuses on finance. Furthermore, reliable data shows that decision-making is appropriate and efficient because no errors occur during the inventory management process. Fast search times also improve service to patients, but this must be driven by the ability of hospital staff to remember where the items are located to be efficient. Then, the accuracy of the data can help reduce the risk of medication errors and inventory problems that impact patient safety and patient satisfaction with the services provided. Therefore, RFID tags should not be damaged because data will be lost.

These four variables are related to each other. The first relationship, namely high ROI, proves that the data is reliable in the process of managing inventory, thereby increasing efficiency. The second relationship is that data reliability helps ensure that the data reflects the actual situation that occurs, thereby increasing data accuracy. The third relationship is when the data stored in the RFID system is always consistent, the time needed to find goods can be short. Finally, ROI will be higher when operational costs can be minimized due to high data accuracy in inventory management and better decision-making.

The differences in focus and impact on these four variables include the following. ROI has an impact on developing or improving the RFID system if its implementation results in a high ROI value. Reliable data has an impact if the data can have an influence on operational efficiency and effectiveness. Search time impacts the level of service and

TABLE 4 Statement related to AI.

Statement	Reference
Demand forecasting is one area where supply chains have shown benefits from artificial intelligence applications.	Bala and Feng, 2019
Applications of artificial intelligence (AI) in supply chains have proven advantageous in areas such as inventory replenishment.	Sinha et al., 2012
As the benefits of AI become more widely recognized, supply chains may use it to reduce fraud and delivery delays.	Rodriguez-Espindola et al., 2020
Operational problems, such as lead time, can be addressed through the application of artificial intelligence.	Xu et al., 2020
In this sector, disruptive technological innovations and integrations such as artificial intelligence (AI), machine learning (ML), blockchain technology (BT), and the Internet of Things (IoT) have the potential to generate value-added services.	A. Kamar et al., 2022

responsibility to patients in the speed of meeting the patient's medical needs. Accurate variables have an impact on minimizing errors in the service process at the hospital.

2.4 | Artificial Intelligence

In artificial intelligence (AI) technology, four key variables are identified: inventory replenishment [11], lead time (Xu et al., 2020), delivery delay (Rodríguez-Espíndola et al., 2020), and demand forecasting (Bala and Feng, 2019). The statements related to AI and its associated variables are presented in Table 4 . Inventory Replenishment is the process of managing the re-procurement or replenishment of inventory. The second variable, lead time is the amount of time required from the time the order is placed until the product is received at the hospital. Third, delivery delay detects delays in the delivery of hospital products by suppliers or delivery service providers from the expected date. Fourth, demand forecasting is the process of predicting how many items the hospital will request in a certain period of time. The last is the integration of technology, with integration can help achieve high service.

The advantages of using AI with variable Inventory Replenishment are the optimization of refill inventory with the demand cost efficiency that avoids high replenishment costs. Demand, cost efficiency that avoids excessive replenishment costs. The lead time variable has the advantage of helping better quality control and planning so that order fulfilment time can be better automatically. Delivery delay is one of the variables with AI-detected delay notifications and can react quickly to respond quickly to delivery delays. According to the data-dependent inventory replenishment variable, inventory replenishment requires accurate and continuous data. The cost of implementing an AI system also requires a significant initial investment. Deficiencies in lead time have control limitations that constitute hospitals, such as disruptions in logistics. The last variable also has a reliable effect on the change, which is demand forecasting, where the sudden demand of the health world can bear fruit quickly, especially since the pandemic situation has rapidly changed and there is a lack of data analysis skills.

The similarities of these variables are to help improve efficiency and accuracy in inventory management, forecast demand, manage lead time, reduce delivery delays, and integration of technology that can synchronize each technology used by the hospital. The method used is also a statistical analysis method to manage all variables. The difference between inventory replenishment, lead time, delivery delay, and demand forecasting variables has its own focus and role in hospital supply chain management.

2.5 | Telemedicine

In hospital supply chain technology, several variables are associated with telemedicine, including contamination avoidance (CA) [12], safety (SF) (Koch, 2006; Gore et al., 2009; Hsieh et al., 2015), professionalism (PRO) (Epstein, 2002), perceived ease of use (PEU) (Adams et al., 1992), perceived usefulness (PU) [13], information quality (IQ) [13],

TABLE 5 Statement related to Telemedicine

Statement	Reference
The degree to which customers tend to avoid other people or places due to concerns about potential contamination is referred to as contamination avoidance.	Kamal et al., 2020
The level of safety of a hospital's infrastructure, personnel, and medical services is referred to as the safety factor.	Koch, 2006; Gore et al., 2009; Hsieh et al., 2015
Health workers are considered professional when they possess fundamental knowledge, engage in lifelong learning, demonstrate interpersonal skills, and apply their expertise in delivering healthcare services.	Epstein, 2002
Perceived ease of use refers to the degree to which using a system does not require additional effort.	Adams et al., 1992
Patients perceive benefits from telemedicine when it enables faster access to care, lower costs for medical examinations, improved record management, and reduced waiting times.	Kamal et al., 2020
Information quality is a critical factor in assessing the competitiveness of a telehealth system.	Zhou et al., 2019
Reliability refers to the degree of trust patients place in telemedicine technology, healthcare professionals, and service quality.	Saigi-Rubio et al., 2016
A system that possesses features desired by patients and telemedicine users, such as usability, responsiveness, flexibility, dependability, and ease of use, is referred to as system quality.	Oppong et al., 2018

reliability (RA) [14], and system quality (SQ) [15]. The statements related to telemedicine and its associated variables are presented in Table 5 . Telemedicine technology can improve patient service and safety. The CA variable is a benchmark to determine how consumers avoid contaminated contact with the surrounding. SF measures how secure medical services, staff, and hospital infrastructure are. PRO measures knowledge of health service capabilities. PEU measures the perception of how the system can be understood by users. PU measures the perceived impact of the technology on users. IQ measures the quality of information in determining competitiveness. RA measures the level of patient trust in technology. SQ measures flexibility, responsiveness, usability of the system for users.

These variables have the following advantages and disadvantages. Avoidance of contamination can be done with remote services, but there are limitations of physical interaction so that doctors cannot detect the patient's illness in more detail if they have to take roentgen, etc. Patient safety/security is obtained from the doctor's response, which will be faster when the patient is in an emergency condition but not a severe illness. The professionalism of the doctor is assessed from the identity and qualifications; if it is good, then the patient is likely to choose the doctor to be served, and vice versa. In addition, telemedicine is often cheaper than hospital consultations. For its use, it can be accessed via an application, making it easier for patients to consult, but it is not suitable for elderly patients and patients who live in areas that have not been reached by this technology. The application is also equipped with information such as complete medical records, and this data needs to be safeguarded against hacking.

The similarities and differences between variables are that PEU and PU both discuss the perceived usefulness of technology, but PEU discusses ease of use and PU discusses whether technology can have an impact on users. CA, SF, PRO discuss safety for patients, in this case CA discusses avoiding contact with other people by choosing remote health services, SF discusses the safety of hospital elements, and PRO discusses the quality of doctors. IQ, SQ, RA discuss the quality offered. IQ discusses how quality information can be provided to users and satisfy users, SQ

TABLE 6 Statement related to HIS.

Statement	Reference
Perceived usefulness (PU) and the level of satisfaction with technology adoption influence a system's behavioral intention to use (BITU).	Ho et al., 2019
Perceived ease of use (PEOU) and the level of satisfaction with technology adoption influence a system's behavioral intention to use (BITU).	Ho et al., 2019
Research indicates a positive correlation between computer self-efficacy (CSE) and computer usage, suggesting that higher levels of CSE lead to increased computer usage.	Achim and Kassim, 2015

discusses whether the system works according to its usefulness, RA discusses how the technology can be trusted by users. These variables are interconnected with each other and play a role in the successful use of technology.

2.6 | Hospital Information Systems (HIS)

The Hospital Information System (HIS) is the most common computerized system designed to support healthcare services, primarily for communication and the storage of medical and administrative information (Farzandipour, Sadoughi, and Meidani, 2011, p. 147). The statements related to the Hospital Information System and its associated variables are presented in Table 6 . In HIS, there are 3 important variables, namely perceived usefulness (PU), perceived ease of use (PEOU), and computer self-efficacy (CSE). PU (Ho et al., 2019) is the degree to which a person is able to accept that the system will help them perform better. This can also increase satisfaction with the technology used. PEOU (Ho et al., 2019) is the perception of users regarding the ease of use of the system. If it is easy to use, it is proven that the system is useful and has an effect on users. CSE (Achim dan Kassim, 2015) is the extent to which users believe in their ability to use computers / technology. The higher the CSE, it will increase computer usage.

The advantage is that measuring the perception of users can help measure users' perceptions and attitudes towards the technology used in the supply chain. Taking into account PEOU can identify barriers that users may face when using technology. CSE can measure the level of user confidence to use technology. By calculating the level of user confidence, it can increase the user's ability to use technology. Understanding these three variables can help the system to be more accepted by users so that hospitals can pay attention to user perceptions regarding benefits, user convenience, and confidence in technology in the hospital. Each variable has similarities in several aspects, namely in terms of measuring user perceptions. They are also the same for designing hospital technology strategies. The variables are combined to give a more thorough understanding of hospital supply chain technology. The main focus of Perceived Usefulness is to measure the extent to which users believe in technology that will provide benefits for implementation in hospitals.

3 | METHODOLOGY

3.1 | System Thinking

System Thinking (ST) consists of two systems, namely System Analysis (SA) and System Dynamics (SD). Finding the system's organizational structure and gaining an understanding of cause-and-effect relationships are the primary goals of system analysis. It involves disassembling and reassembling a problem in order to comprehend its constituent parts and feedback loops. A causal loop diagram is used in systems analysis to illustrate the problem. At MIT, Jay Forrester first used the term "System Dynamics" in the 1960s (Forrester, 1961). The term "system dynamics" describes the process of restructuring our understanding of a system and its feedback loops. Its goal is to investigate how the system responds dynamically to changes that occur either inside or outside the system. System dynamics is concerned with the numerical analysis and understanding of uncertainty in the mathematical models constructed to represent real-world systems. A model is considered successful when its underlying reasoning is effectively communicated from the modeller to the observer (Haraldsson and Sverdrup, 2003). The relationship between System Thinking, System

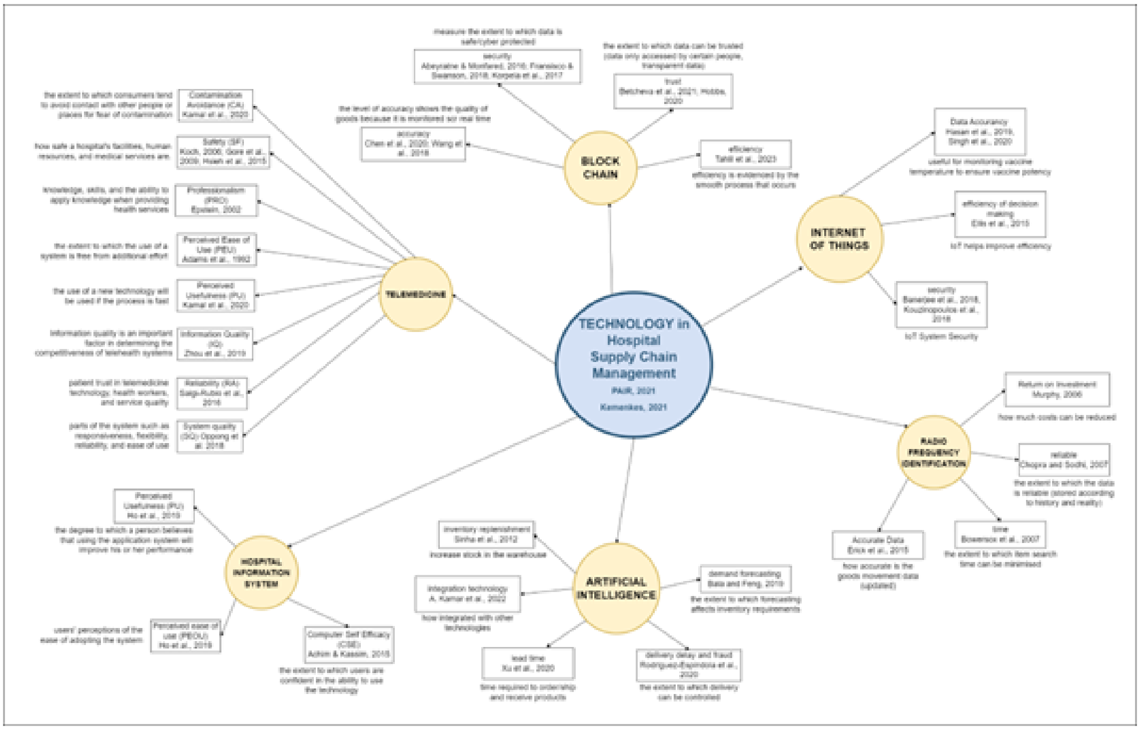

FIGURE 1 Testing of rotor rotation with wind velocities of 3 and 4 m/s.

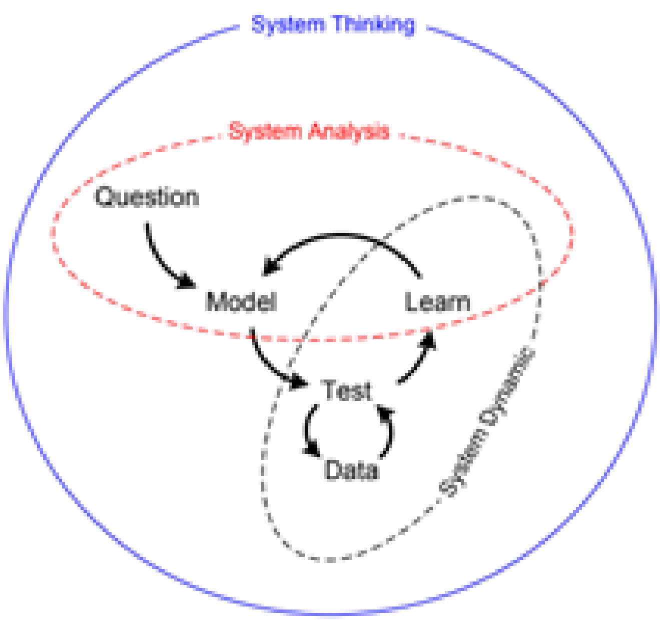

FIGURE 2 Testing of rotor rotation with wind velocities of 3 and 4 m/s.

Analysis, and System Dynamics, illustrating how SA and SD function as complementary components within the ST framework, is presented in Figure 2 .

System thinking is the art and science of creating the most comprehensive understanding feasible, according to Barry Richmond. According to Linda Sweeney and John Sterman, system thinking is understanding how the elements

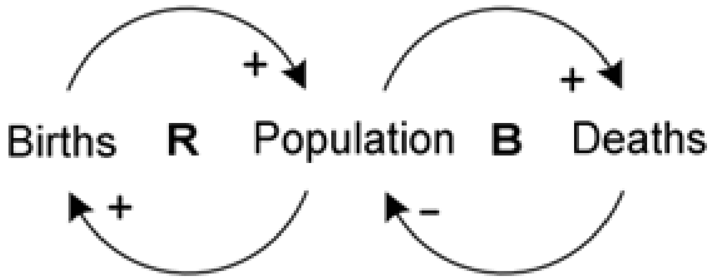

FIGURE 3 Testing of rotor rotation with wind velocities of 3 and 4 m/s.

interact and provide feedback to each other. System thinking is an analytical skill that works together as a system to improve the ability to identify and understand complex non-linear relationships and conceptually design models to produce the desired effect. The important things in system thinking are:

1. Identifying interconnections
2. Recognize and comprehend feedback
3. Understand the system's structure
4. Differentiating between variables, stocks, and flows
5. Identify and understand non-linear linkages
6. Understand dynamic action
7. Reduce complexity by conceptually modeling the system
8. Understand systems at various scales

3.2 | System Dynamic

According to Forrester and Sterman, the dynamic interplay of information flows, physical processes, and managerial approaches to enhance system performance over time is explained structurally by system dynamics (SD). At MIT, Jay Forester first used the phrase "System Dynamics" in the 1960s (Rimbawan, 1961). The goal of SD is to investigate dynamic reactions to systemic changes as well as external ones. Here, we design in order to forecast the future and explain the past. Furthermore, mathematical representation is an issue of system dynamics. System Dynamics is also concerned with analyzing and numerically understanding the uncertainties of practical representations in the developed mathematical models.

3.3 | Causal Loop Diagram

The CLD (Causal Loop Diagram) model shows the interaction between variables. According to Sherdood (2002) CLD are very important to understand because they provide important clues in understanding and for a problem. Knowing the boundaries and scope of the problem from the variables of interest. In the causal loop diagram there is an arrow as a sign of relationship and accompanied by a negative or positive sign.

In CLD, the arrows will form a loop with an R (reinforcing) and a B (balancing). Balancing relationships describe how variables balance or limit each other. While the reinforcing relationship describes how initial changes in a variable can reinforce and magnify each other's influence. The CLD example in Figure 3 tells us that the relationship between population and births is R because the variables increase each other, while the relationship between population and

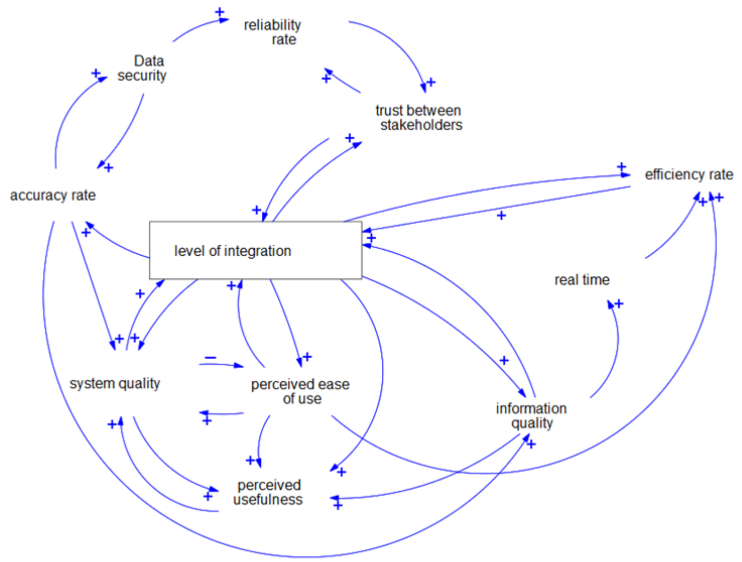

FIGURE 4 Testing of rotor rotation with wind velocities of 3 and 4 m/s.

deaths is B because when As the population grows, so does the death rate, but as the death rate rises, the population decreases.

The steps for making a Causal Loop Diagram are as follows, first determining the stock of variables in the mind map that can be used as a container to accommodate other variables. Then we select which variables from the mind map are related to stock. Then these variables are entered into an application called Vensim. In Vensim, you can create arrows equipped with + or - signs to connect between variables that have a relationship. If all the variables are connected, a CLD is formed.

System thinking will create a model in the form of a causal loop diagram where testing is done by system dynamics. This is how system thinking, system dynamics, and causal loop diagrams are related.

4 | RESULTS AND DISCUSSION

Figure 4 illustrates the visualization of relationships among variables using a causal loop diagram, where the level of integration is modeled as a stock to measure the degree of integration between information and technology across stakeholders.

In this paper, 27 variables were selected from the mindmap, then 11 variables were selected that were related to integration (as stock). Then the variables were connected so that the CLD was made. By using CLD, hospitals can understand how different factors interact in supply chain management, and how changes in one variable can affect another. This can help hospitals plan better strategies for using technology to improve their efficiency and patient care.

4.1 | Causal Loop Classification

Balancing (B)
- system quality − perceived ease of use + system quality
- accuracy rate + system quality − perceived ease of use + level of integration + accuracy rate
- accuracy rate + system quality − perceived ease of use + efficiency rate + level of integration + accuracy rate

TABLE 7 Definition of Variable used in CLD.

Variable	Definition	Reference
Level of integration (as stock)	Level of integration between all information within the technology and among HSCM technologies. Level 1 indicates a poor level of integration, while Level 5 indicates a good level of integration.	A. Kamar et al., 2022
Accuracy rate	Data are considered accurate when all changes in data (e.g., goods and patient information) are fully and precisely recorded within the technology.	Chen et al., 2020; Wang et al., 2018
Data security	Hospital systems may be severely impacted if technology is compromised; therefore, data security is crucial.	Banerjee et al., 2018; Kouzinopoulos et al., 2018
Trust between stakeholders	Trust among stakeholders enables effective use of data and technology by users.	Betcheva et al., 2021; Hobbs, 2020
System quality	The quality of technology systems that can influence users.	Oppong et al., 2018
Information quality	The quality of data and information provided that can affect users.	Zhou et al., 2019
Efficiency rate	The level of efficiency in operating hospital supply chain processes.	Tahlil et al., 2023
Perceived ease of use	The degree to which users perceive the technology as easy to use.	Adams et al., 1992
Perceived usefulness	Users' perception of how impactful and beneficial the use of technology is on performance.	Kamal et al., 2020
Reliability rate	The level of reliability of data or technology that can be accessed by users.	Saigi-Rubio et al., 2016
Real time	The extent to which the data provided are up-to-date both at the time of access and over time.	Hasan et al., 2019; Singh et al., 2020

Reinforcing (R)

- accuracy rate + data security + accuracy rate

- reliability rate + trust between stakeholders + reliability rate
- trust between stakeholders + level of integration + trust between stakeholders
- system quality + level of integration + system quality
- system quality + perceived usefulness + system quality
- perceived ease of use + level of integration + perceived ease of use
- information quality + level of integration + information quality
- efficiency rate + level of integration + efficiency rate
- accuracy rate + data security + reliability rate + trust between stakeholders + level of integration + accuracy rate
- accuracy rate + information quality + real time + efficiency rate + level of integration + accuracy rate
- accuracy rate + information quality + level of integration + accuracy rate
- accuracy rate + system quality + level of integration + accuracy rate

Description of Symbols

- + indicates a positive causal relationship
- − indicates a negative causal relationship

The balancing and reinforcing relationships among variables are described as follows. Accurate data—such as medical records and inventory information—enhance data security and reliability, which in turn fosters trust among stakeholders, including internal and external hospital actors, in the use of technology. This mutual trust supports the integration of information, technology, and hospital supply chain processes. The definitions of the variables used in the causal loop diagram (CLD) are presented in Table 7 .

Higher data accuracy contributes to improved data security, as accurate data enable the detection of cyber threats, such as unauthorized modifications or data deletion, thereby triggering security alerts. Conversely, higher data security enhances data accuracy by reducing the risk of errors and unauthorized actions. Improved data security also increases data reliability, as protected data are more likely to be valid and trustworthy. Increased data reliability strengthens stakeholder trust, as stakeholders are more inclined to rely on information that is accurate and of high quality.

Furthermore, higher levels of trust encourage greater integration, as stakeholders collaborate more effectively in adopting and utilizing technology, thereby strengthening the integration of information and technological systems within the hospital supply chain. Increased integration, in turn, reinforces trust through faster system responsiveness and improved data accessibility. Finally, higher integration enhances data accuracy, as interconnected processes and information flows provide more comprehensive and detailed hospital data.

The relationship between accurate data has an impact on system quality, which affects the ease of use of technology and also the usefulness of the technology that can improve stakeholder performance and the quality of information provided to stakeholders, which in turn will lead to integration. The higher the data accuracy the higher the system quality as accurate information is an asset that can help improve the quality of the system. Good system quality will be more integrated because the proof of a quality system from various technologies makes it more capable of contributing to increasing integration between technologies, so that it is balanced between quality and the ability to integrate. Higher levels of integration show good / high system quality. As an integrated system is evidence of a system that has passed a trial of use and has proven to respond to each activity well. The better the quality of the system, the more difficult it is to use because there are many features that make it complex and can make the level of ease decrease so that users will be confused about using the features in the system. The easier it is to use, the better the quality of the system because it shows that all features can be accessed easily so that it shows good system quality. The easier it is to use, the technology can be integrated because if the technology is easy to use, collaboration between technologies can occur so that they will be integrated. If it is integrated, it will be easy to use because information that can be connected between internal and internal or internal and external makes it easier for users to use technology as evidenced by the availability of all data needed by all stakeholders. When it is easy to use, it is more efficient because efficient processes can occur with the support of processes that are not complicated / do not require more effort. The easier it is to use, the more impact (usefulness) its use will have on the performance of its users. The better the quality of the system, the impact (usefulness) on usability because a quality system will have an impact on improving performance on its users. If its usefulness has an impact and can be used, it shows that the system has good quality because a technology system that can run according to its function will affect the performance of stakeholders which will increase so that this proves the quality of the system is good. The higher the level of integration, the more impact (usefulness) it will have on usage because with access to processes that are connected to each other, what is needed by users is fulfilled so that it has an impact on user performance. If the quality of the information is good, it will definitely have a good impact on its use because the information that is presented is of high quality, of course, it will help stakeholders in using technology. If the quality of the information is good, it will be more integrated because quality information throughout the process makes it integrated and complementary. The more integrated, the better the quality of information because between processes or between interconnected information makes the information increase and also more detailed so as to improve the quality of the information.

The relationship between accurate data has an impact on the quality of information that can be presented in real time, with information that can be more real time, the hospital supply chain process will be more efficient. If the process is already efficient, it can certainly integrate with each other. The more accurate the information quality will be better because the more detailed data will be in line with the quality of information that will also increase. The better the quality of information, the more real time it will be because to provide data in real time, good quality information must first be required so that it can encourage mutual information from time to time. The more real time, the more efficient because with information that is always updated at that time between stakeholders, it won't interfere with hospital supply chain processes related to notification or information delivery. More efficient, the higher the level of integration because with an efficient and uncomplicated process, it enables technology to integrate with each other. If it is integrated with each other, it will definitely be efficient because information or supply chain processes that are integrated between technologies make each process automatically connected and minimize time so that it will be more efficient.

5 | CONCLUSION

This research employs Causal Loop Diagrams (CLDs) within a system dynamics model to demonstrate the importance of integrating hospital supply chain processes through technologies such as Blockchain, RFID, IoT, AI, Telemedicine, and Hospital Information Systems (HIS). CLDs illustrate the relationships among variables that influence the integration of technology and information within hospitals. The study identifies several key variables—accuracy, data security, stakeholder trust, information quality, system quality, efficiency, perceived ease of use, perceived usefulness, reliability, and real-time capability—that significantly affect integration. These variables are closely interrelated: improved data accuracy enhances security, thereby increasing reliability and fostering stakeholder trust, which in turn strengthens integration. Accurate data also improves information quality, enabling real-time communication that drives process efficiency and further supports integration. Moreover, higher accuracy contributes to better system quality, making technologies easier to use and positively impacting stakeholder performance. A system that is user-friendly enhances efficiency, which ultimately enables seamless integration. In conclusion, integrated hospital supply chain technologies not only improve efficiency but also strengthen trust among stakeholders. This is reinforced by high-quality systems that provide ease of use, positively influence performance, and deliver reliable information.

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