Research Article

Investigating the Role of Cloud-Based Information Sharing on Hospital Supply Chain Performance Using System Dynamics Approach

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Abstract: Globally, increasing speed and quality and reducing expenses in the supply chain have been mentioned as companies` considered issues and important actions have been applied accordingly. Due to the rapid distribution, traditional approaches less respond to the chain expectations appropriately. Modern companies seek to find ways for optimizing their supply chains. As a profitable technology, cloud computing helps this optimization by providing substructures and software solutions for the overall supply chain. On the other hand, considering the recent years increase of services in the health management system, improving the supply chain has a high importance. Therefore, the current study evaluated the use of cloud-based information sharing and presented a dynamic model of the hospital supply chain based on the system dynamic approach as well as the analysis of related behaviors. The results of the investigation indicated that cloud-based information sharing model could improve the performance of supply chain components significantly.

Keywords: hospital supply chain; dynamic system; cloud-based information sharing; supply chain improvement

1. Introduction

Nowadays, customer expectations are growing and changing through creating competition in various parts of production and serving. Therefore, the need for faster distribution and better serving is felt more than before. Organizations are also trying to find methods that can improve the customers` flexibility and response to their needs. One of these methods is supply chain management, which is responsible for appropriately managing the flow of materials, information, and finance among a network of organizations. Coordination is one of the most important criteria of evaluation in the supply chain performance showing how a supply chain can perform in a concentrated way. Increasing the number of decision-makers in a supply chain as well as their various information and motivation would increase the coordination risk among them; this would make the supply chain face more problems and get out of its optimal form. Therefore, supply chain management seeks to integrate the organization through managing suppliers and customers as a universal and asks for the coordination of the existing flows such as information, products, and money; this helps to the production and distribution of the proper product in a suitable size and amount at the right time and place. The supply chain aims to coordinate the flow of information, finance, and materials in a way that customers can receive the required services in the highest possible confidence level, with the highest speed and quality and the least expense.

On the other hand, among serving parts, health and medical education, as one of the greatest domains in the serving part, has a proper opportunity for affecting sustainable performance. This part has one of the most complicated supply chains in the world; its main reason is its high-risk index. The Health system is a high-risk system due to dealing with human beings and their health; thus, providing medicine and medical facilities in the least possible time is one of the most important challenges of this supply chain. Therefore, providing or lacking material or tools for surgery or medical purposes can lead to the death of a human being (Lee, 2016).

Considering the necessity of rapid distribution, and more customer-orientation, traditional approaches can less respond to the expectations of the supply chain, so a novel technology should help the managers of this chain. The created signs of progress in technology have identified the role of Information Technology in the supply chain more than ever. Cloud computing of technology is rapidly changing, which can be used by companies for more productivity. This study evaluated the effect of cloud-based information sharing`s role on the supply chain performance using a system dynamic approach in hospitals and not only identified the effect and relationship between supply chain performance model variables, but also presented a dynamic model of hospital supply chain.

1.1. Literature Review

Recently, presenting health and care services with high quality and optimal cost has been one of the main aims of hospital supply chain management (Wernz et al., 2014). A united supply chain includes interaction and cooperation among companies, customers, and suppliers and highly depends on the information transformation, mutual dependence, and common actions among supply chain members (Huang et al., 2019). Since the past, traditional information sharing in hospitals has faced problems. Insufficiency of traditional information sharing is highly significant especially in intensive-care units of the hospital. Moreover, the weak demands have led to the asymmetry of offers and demands of health care products so that they may have unpleasant economic implications for patient care (Kochan et al., 2018).

Considering the systematic relationship between suppliers, producers, distributors, retailers, and customers that relate financial information and participants` information from any side, information sharing of the supply chain system is an important subject for coordinating unit actions; therefore, cloud-based information sharing is a new solution for information technology services. Its flexibility and speed can help in improving the performance of supply chain processes of hospital services rapidly, which is the largest organization among health and care service organizations and needs testing and measurements. Online information sharing and cloud processing mean that all units of the supply chain share the key and vital data of the demands with a certain platform (Kochan et al., 2018). Chang et al. (2016) presented an investigation regarding cloud computing due to the advantages of returning to cloud computing as a new business model; this is mostly related to the industry and university and most of the organizations are assessing, accepting, or using the new technology of cloud computing. They also stated that any organization focusing on the business model may have factors like popularity, entrepreneurship, capital, evaluation, innovation, and customers. Other organizations concentrating on information technology services may also include factors such as performance, portability, confidence capability, security, scalability, and usability. They concluded that accepting cloud computing would lead to organizational challenges in which, three challenges could be identified:

- Organizational sustainability
- Portability: Cloud portability
- Connection: Connecting various activities and different cloud services.

Agarwal et al. (2006) utilized the dynamic system method for assessing the effectiveness of various methods of information technology on the supply chain of cars. Through analyzing the casual and effect relationships between different variables of the supply chain, they showed that using Data Accuracy (DA), Delivery Speed (DS), Usage of IT (UIT), and Process Integration (PI), the effect of information systems on the performance of supply chain was relatively important.

Chen et al. (2013) investigated the factors affecting hospital supply chain performance. To this end, they used the information of 117 supply chain managers of USA hospitals and indicated that confidence, knowledge interchanging, and the integrity of information technology among hospitals and suppliers were of utmost importance and those hospitals having more integrity with their suppliers in terms of logistics were in a better status regarding supply chain performance; moreover, the integration of information technology and knowledge interchange among hospitals and suppliers had more logistic integrities.

Kembro and Selviaridis (2015) presented the practical consequences of information sharing management considering the kind and intensity of mutual dependencies in a multi-level supply chain and suggested preventing information sharing in a multi-level supply chain due to common and weak mutual dependencies that are not directly related to each other. They also identified three main obstacles for developing information sharing:

- Separating information
- The risk of a false understanding of the demanding information
- Making decisions regarding the distribution and production based on incomplete information

Avram (2014) investigated factors that should be considered while using cloud computing in an organization. Some of the organizations use cloud computing only for the reason that it is the last information technology. Accordingly, this study assessed the positive and negative aspects, their integration with IT substructures and the existing software, costs, capital, performance, and security; it showed that one of the advantages of using cloud computing was its cost-effectiveness. Each organization has to define its economic purposes in four parts including finance, customer, internal, and learning development to find a way for preserving the purposes by cloud computing.

Fiala (2005) in a study that had been allocated to dynamic modeling of the supply chain, indicated that integration of network structure modeling and dynamic behavior simulation in the supply chain can be a powerful tool for analyzing the supply chain performance. Multivariate analysis of the supply chain performance includes criteria like amount, time, cost, and profit. Using a simulation approach by STELLA software, he proposed a proper tool for predicting the real status of the supply chain and showed that the main components of the supply chain can enjoy common decisions. He also indicated that integration of non-participatory and participatory behaviors of the network components seems more real.

Pheng et al. (2014) investigated the effect of determining factors on the supply chain performance of services. To this end, they used a questionnaire and showed that three determining factors (people, process, and technology) had a positive effect on the supply chain performance of services regarding costs and quality and the kind of hospital, the size of the hospital, and owner of the hospital had no significant effects on the studied variables. They also showed that proper comprehension of the main factors of the improvement of supply chain services would increase the productivity of the supply chain.

Chong et al. (2015) predicted the RFID acceptance by doctors and nurses in the health care supply chain using the information of 252 doctors and nurses as well as the analysis of the neural network and showed that individual differences and personalities were the most important problem of accepting RFID solutions such as controlling and following the entity and identifying and recording patients.

Wu et al. (20113) utilized the regression analysis method to investigate the conditions affecting the purpose of the organization for using cloud technology to support the supply chain and showed that the complexities of business processes, entrepreneurship culture, and adaptability, as well as information systems` capabilities, significantly affected the tendency of the organization toward using cloud technology.

Roshan et al. (2019) presented a multi-purpose model in the uncertainty form for the crisis management of medicine supply chain with the aim of reducing total costs of the network and minimizing unmet demands and increasing social satisfaction; they showed that the amount of objective function of the model deteriorated as the demands and store capacity increased, which meant that costs increased, as well.

Qing et al. utilized structural equations model and investigated the effect of cloud computing on information sharing among supply chain partners and showed that information sharing through cloud computing had a positive effect on the supply chain performance; they also indicated that inter-organizational confidence is of utmost importance in facilitating the use of cloud computing for information sharing.

2. Methodology

System Dynamics (SD) was firstly proposed by J.W.Forrester to analyze the feedback of complex dynamic systems. System Dynamics integrates the qualitative and quantitative analysis and uses system construction reasoning for describing undefined behavioral features. Accordingly, SD is a better choice while facing linear time-variant complex systems. Based on computer simulation technology, this tool can analyze the relationship between various factors, simulate the quantitative data, and present information regarding feedback structure and system behavior, which helps in understating the total system and different relationships related to the control policies of the dynamic system performance (Akbari et al., 2020).

The main art of modeling through the system dynamics method is discovering and identifying feedback processes that determine system dynamics through flow structures, time intervals, and nonlinearities. Feedback is a process through which, one variable of a cause and effect relationship hierarchy affects other variables in a way that eventually affects itself and leads to its increase or decrease (Sterman, 2000).

2.1. Modeling

The dynamic model of the current study refers to the relationships between three sub-systems considered for the supply chain model based on hospital clouding. This model includes three sub-systems of hospital, distributors, and producers. Figure 1 identified the existing sub-systems and the kind of their relationships. The hospital sub-system was related to the 2 other sub-systems that have been shown in the figure. Patients` demands and hospitals` orders were the output variable of the hospital sub-system and the input of producers and distributors. Besides, distributors` orders as the output of the distributor sub-system were the input of the producer sub-system.

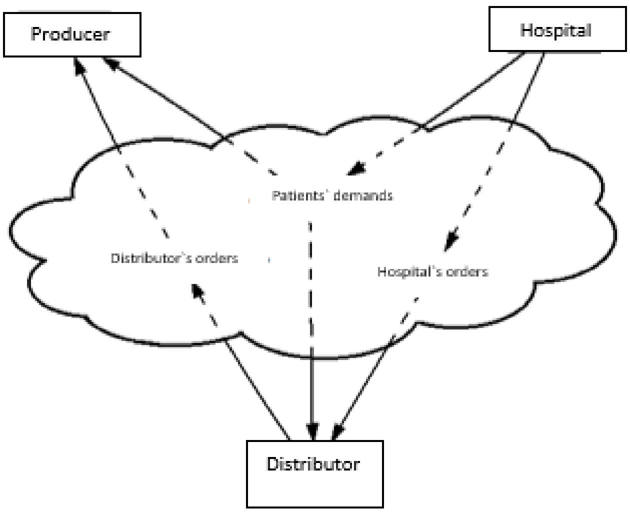


Figure 1. Subsystem diagram.

2.2. Cause and Effect Diagrams

Various schematic tools are utilized in the dynamic system or Dynamics Systems (DS) to comprehend system structures. Cause and effect schemas are important tools for showing the feedback structure of systems. Drawing circles and conceptual relations among variables are among the most important phases of creating SD models (Sterman, 2000). Cause and effect schemas of hospital supply chain have been presented in Figure 2;

Patients` medicine demands are sent to the orders part of the hospital, the increase of demands, increases hospital orders, as well. The demands are met considering the amount of stock storage of the hospital which has been provided by the distributor. Administering orders reduced their volume in a circle. On the other hand, the time of receiving orders and their completion would cause delays in delivering medicine to the patients. The difference between stock storage of the hospital and patients` demands would increase medicine demand for the hospital, which would increase distributors` orders. The volume of the orders depends on the amount of stock storage of the distributor, the cost of medicine delivery by the producer, and the number of hospital demands, which reduces the volume of the distributor`s orders. It`s well clear that there would also be a time delay in this circle since completing the received orders from the hospital. Those hospital orders that are not responded by the distributor, would create medicine demands by the distributor whose orders would be delivered to the producer. The producer, also, considers orders` amounts and increases production, and balances its stocks for providing distributors` demands; this process would have time delays for processing and completing orders.

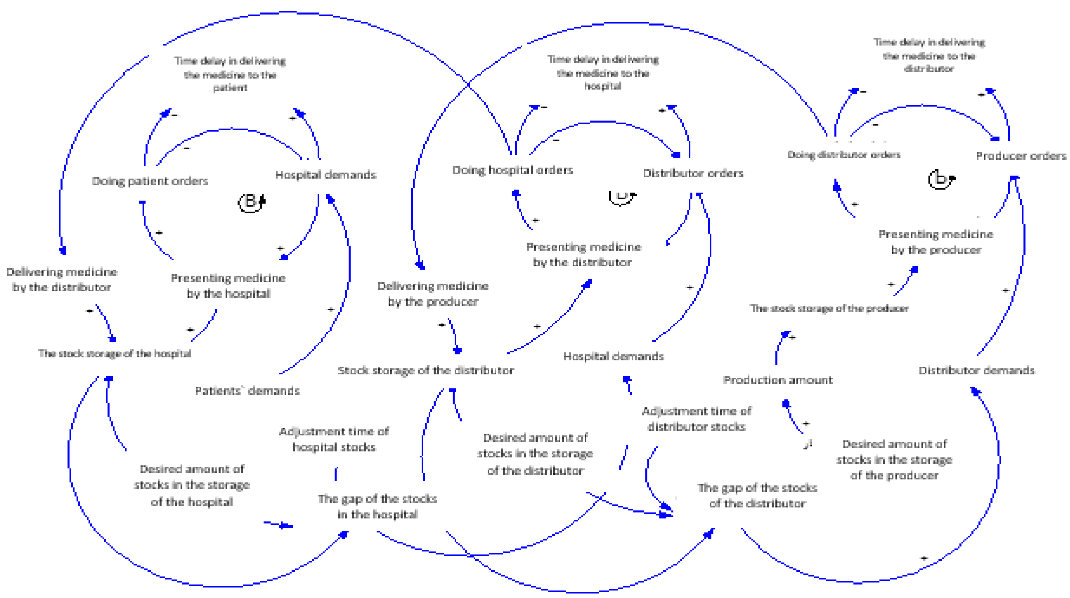


Figure 2. Cause and effect diagram of the supply chain while not using cloud-based information sharing.

Now, the effect of cloud-based information sharing is going to be evaluated. How does information sharing affect information and material transferring? How can we change the storage amount of system components?

To this end, a diagram other than the cause and effect one has been presented to investigate this subject. Unlike the previous one, this diagram predicts the number of patients` demands in the hospital for other components of the chain, based on which, the products are sent automatically to the distributor and hospital. On the other hand, the products of the producers are determined accordingly. Moreover, hospital and distributor`s demands that were sent to the distributor and producer previously, are now accessible and observable for other components. It is clear that the information is shared in a cloud space; this form of information sharing is followed through creating direct relationships between all components of the supply chain like patients and hospital, distributor and producer, patients` orders, hospital's orders, distributors orders, the number of producer`s productions as well as stocks related to each part. Medicine is produced and sent according to the number of observable demands in the cloud space so the orders are not stored and no delays take place (Figure 3).

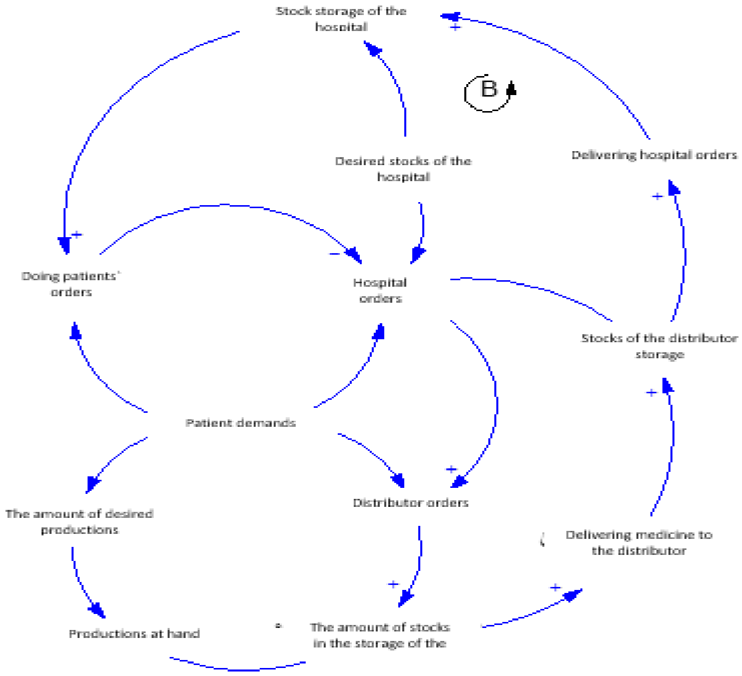


Figure 3. Cause and effect diagram of the supply chain while using cloud-based information sharing.

2.3. Stock and Flow Diagrams

Cause and effect diagrams are successful most of the time and have an effective role in presenting a mental model at the beginning of the modeling project. In the previous part, the mutual dependencies and feedback processes existing in the supply chain system of the hospital were shown using cause and effect model; however, due to the limitations of this diagram, one of the most important of which is its inability in showing the structure of the current-state variable of the systems (Sterman, 2000), current state diagrams have been indicated in this section.

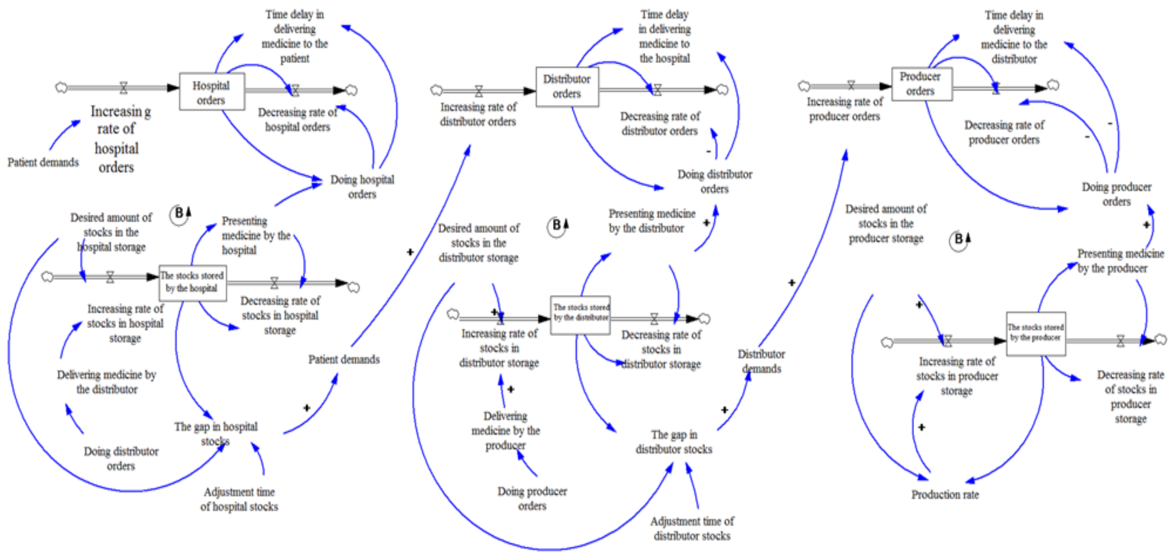


Figure 4. Current-state diagram while not sharing cloud-based information.

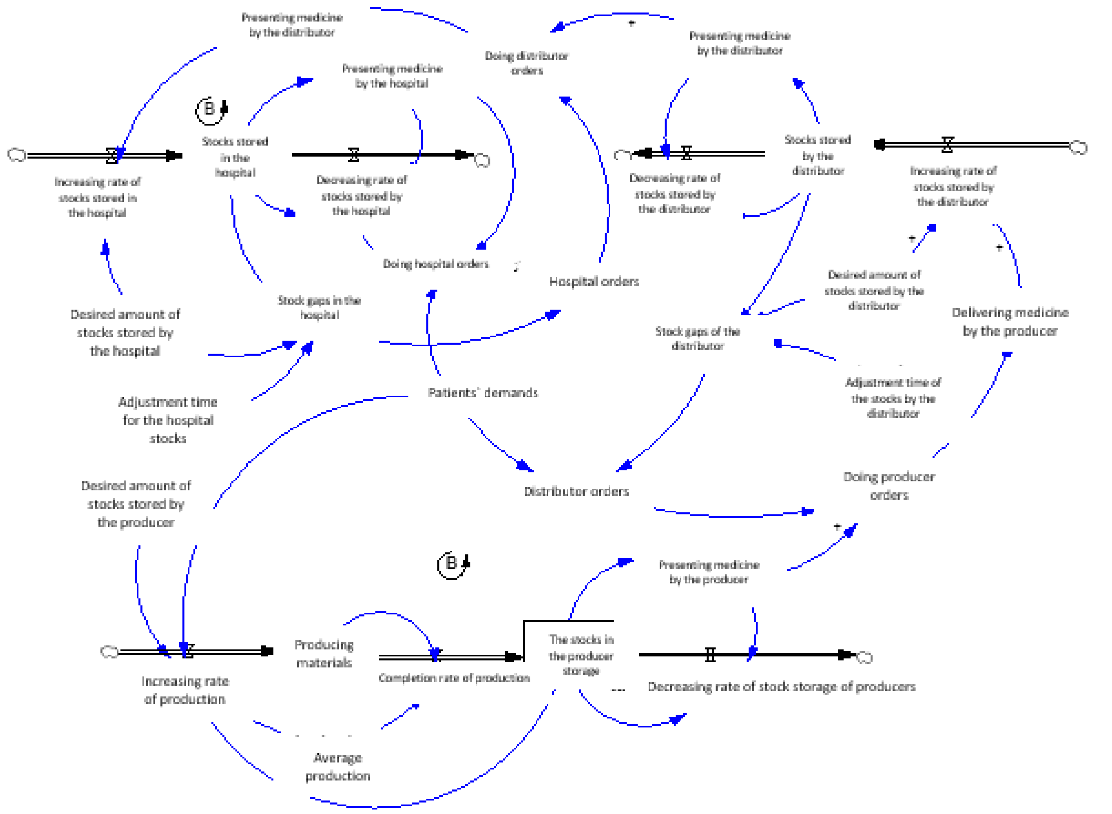


Figure 5. Current state diagram while sharing cloud-based information.

Figures 4 and 5 show respectively, not sharing cloud-based information and sharing cloud-based information forms. It is clear that in the first form since order information related to the subjects are sent to the higher-level sources by the intermediators, the volume of orders would be in the form of the stock variable so that it could be followed up in case of not being provided; others are supporting variables.

2.4. Equations Related to the Model

Equations 1 to 7 present some of the relations related to the model (proportionate to Figures 4 and 5):
1: Hospital orders= ∫ increase rate of hospital orders-decrease rate of hospital orders
2: Distributor orders= ∫ increase rate of distributor orders-decrease rate of distributor orders
3: Producer orders= ∫ increase rate of producer orders-decrease rate of producer orders
4: Hospital stock storage= ∫ increase rate of hospital stocks-decrease rate of hospital stocks
5: Distributor stock storage= ∫ increase rate of distributor stocks-decrease rate of distributor stocks
6: Still producing materials= ∫ increase rate of production-completion rate of production
7: Producer stock storage= ∫ completion rate of production-decrease rate of producer stocks

3. Sensitivity Analysis

After simulation and observing the behavior of model components in the considered time interval, different variables of the model and the analysis of their effects on the main variable have been investigated. Table 1 shows the results of sensitivity analysis for various variables.

Table 1. The results of sensitivity analysis.

Variable	Change range	The results of sensitivity analysis
Patients` demands	2000-5000 units	The amount of hospital stock storage and distributor, as well as producer stock storage, is sensitive to the patients` demand changes, and this sensitivity is not increased as time passes.
Adjustment time of hospital stock	2-10 days	The amount of hospital stock storage and distributor, as well as producer stock storage, is less sensitive to the adjustment time changes of producer stocks.
The adjustment time of distributor stocks	2-10 days	The amount of hospital stock storage and distributor, as well as producer stock storage, is less sensitive to the adjustment time changes of producer stocks.

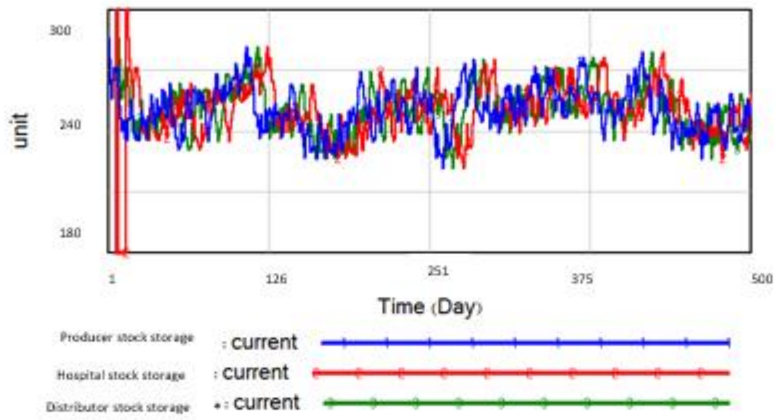
Average time of production	2-10 days	The amount of hospital stock storage and distributor, as well as producer stock storage, is sensitive to the time changes of production and this sensitivity doesn`t change as time passes.

4. Discussion and Conclusion

Figure 6 (A and B) shows the simulation results related to the stock storage by the hospital, distributor, and producer in both traditional and cloud-based supply chain models. Overall, supply chain management is concentrated on the coordination among chain components such as distributors and producers which has many advantages. Existing goods and information flow has a direct effect on the production, scheduling, and controlling stocks and any detours in this flow appear as a problem. Inequality between supply and demand in the supply chain is identified as the Bullwip effect. This effect states that any small change in the demand in lower levels of the chain could have essential changes in higher levels of the supply chain (Lee et al., 1997).

Structurally, the most important problem facing the supply chain is that any small inequality between supply and demand at the retailer level would be intensified as it reaches the producer and forms as a crisis since there may be delays in the system as information are delivered from the demanders to the suppliers and since predicting the demands in each group is done based on other parts` orders, demand vacillation would be improved in the chain.

As it is clear in Figure 6-B, in the traditional supply chain of the hospital, significant stocks and vacillations are observed in the stock level, especially in the producers` stock level. The changes of stock variable increase as the supply chain moves towards higher levels. This issue could be justified by the Bullwhip effect. False predictions of the demand amount by the distributor and producer would create surplus stocks and problems due to not observing patients` real demands and improving demand estimation can reduce these vacillations. This improvement can be created using cloud-based information-sharing technology. Figure 6-A shows the result of simulation of the stock by the producer, distributor, and hospital in case model relationships be described in a way that demanding information could be observable for all components in a cloud space. Accordingly, stock vacillations have almost similar behaviors in three levels of the supply chain, and the stocks and surplus storages have been prevented mostly. Moreover, unlike the previous form, the increase of demand changes while transferring to the higher levels (producer level) have been mostly reduced.



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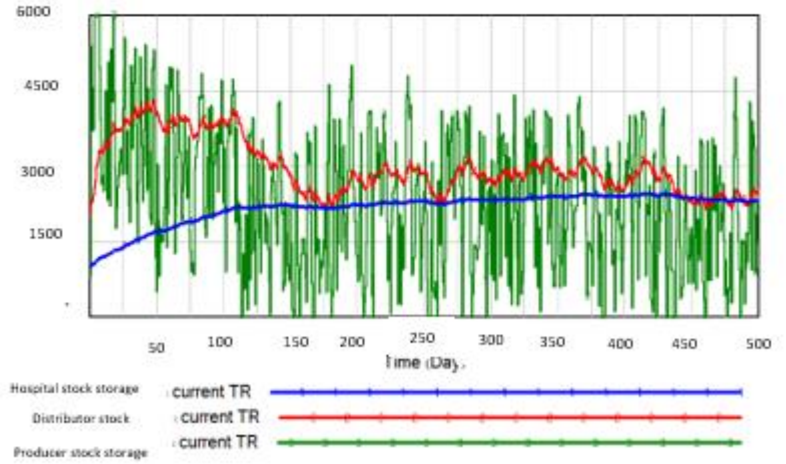

B

Figure 6. The results related to the simulation model of hospital supply chain in A) using cloud-based information sharing, B) not using cloud-based information sharing.

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