Novelty Journals

ISSN 2394-7322

International Journal of Novel Research in Marketing Management and Economics
Vol. 13, Issue 2, pp: (40-49), Month: May - August 2026, Available at: www.noveltyjournals.com

Improving Hospital Supply Chain Efficiency through Inventory Optimization: A Study of U.S. Hospital Systems

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DOI: https://doi.org/10.5281/zenodo.21158699

Published Date: 02-July-2026

Abstract: **Hospital supply chain efficiency is essential to reduce drug shortages, high costs, and lack of efficiency in inventory management which directly impact patient care and service delivery. To mitigate these challenges, optimal inventory management becomes crucial to ensure that medical supplies are provided and that the amount of stock kept is kept to a minimum and any losses minimized. The aim is to understand how inventory optimisation (IO) and healthcare logistics management (HLT) can affect hospital systems' performance and cost. A mixed-method research approach is used—qualitative using information gained from the interviews and quantitative using the quantitative data obtained from questionnaires that were used to interview 250 professionals in the hospital supply chain. Relationships among key variables are assessed for using statistical techniques like correlation and regression analysis. The results showed there is a positive correlation between Inventory Optimization Practices and SC Operational efficiency and a moderate but significant correlation between Healthcare Logistic Management and Cost reduction. The benefits of digital systems for inventory and real-time monitoring are emphasized. The sample size and the cross-sectional design are some of the limitations, and thus a longer time perspective with more advanced incorporation of technologies would be preferable.**

Keywords: **Inventory optimization, healthcare supply chain, hospital efficiency, logistics management, cost reduction.**

1. INTRODUCTION

In healthcare industry, inventory management associated to drugs is a big amount of costs, particularly in hospital supply chain to manage easily and meet the requirements for their consumption. The current healthcare system has the challenge to become more effective and eliminate waste, however. The first thing to be noted is that the scope of drug shortages seems to be limited and it really goes to any healthcare organization no matter of its size. Most hospitals have been impacted or have been a victim of drug shortages. There are a host of reasons behind a drug shortage, and this forced healthcare organisations to have to buy a more expensive alternative to make functioning their systems sustainable. Secondly, one of the solutions is used in the hospital, which is called over-provisioning, generally with the safety stock (Abu Zwaida, et al., 2021). The safety stock is a value that is calculated considering the variability of demand during the lead time, as well as the variability of delays in getting the ordered goods. Yes, doing this can ease the dilemma of scarcity in a hospital but it also raises hospital's cost of purchasing and storing medicines without any regard to the high cost of medicines in the system. Namely, if the quantity of drugs is high without considering the need of users, it may also be expensive to store and prevent damage. Certain medications need special storage procedures, and the majority have expiration dates which cannot be taken after (Mišić, & Perakis, 2020).

Managing inventory efficiently seems to be a way of enhancing the quality of customer service and the organisation in “the Hospital Supply Chain (HSC)”. In a previous study on the drug shortage issue, Qiu, et al., (2019) noted that there may still

be a nationwide drug shortage. The risk of a drug shortage is not only the case in one part of the health system; it could also have a domino effect in other parts, even if are in different localities. But this negative effect can be overcome with a local optimal system. Establishing open communication channels, obtaining transparency regarding the reasons for shortages, and consistently evaluating in-stock and cost-effective alternatives are the most effective strategies for achieving a balanced inventory. To mitigate drug shortages, Food and Drug Administration (FDA) has come out with an Innovation Act and Strategic Plan. Drug shortage has been identified as a worldwide issue by WHO (World Health Organization). The term "supply chain management (SCM)" is defined by the integration of manufacturers, suppliers, wholesalers and stores to ensure the proper distribution of proper amount of drugs at proper places, at proper time, in proper qualities and quantity to meet the given level of service and reduce the cost at system level (Ivanov, & Dolgui, 2020).

Optimization is, therefore, required; it goes alongside the inventory supply chain management aspect which considers the supply, management, and utilization of medicines and drugs. The paramount factor for any hospital or health system to comprehend in order to mitigate these impacts is the comprehension of the underlying causes of medicine shortages. This facilitates the formulation of proactive strategies utilising the existing resources. Determining the precise source of medicine shortages presents a significant difficulty, generally categorised into three groups: manufacturing complications, discrepancies between demand and supply, and issues with raw materials (Abu Zwaida, et al., 2021).

1.1. Role of Inventory in Hospital Supply Chain

"According to American Production and Inventory Control Society (APICS), inventory management is the area of business management that focuses on planning and controlling inventories". The Study of the inventory in Hospital and Healthcare supply chain are to decrease Health Care costs without compromising Health Care Services quality level to patients by increasing hospital management systems efficiency and productivity levels (James F. et al., 1998).

Inventory Management is important in the Supply Chain. In relation to all the issues that could arise in SCM, the issue related to inventory is more relevant to the entirety of the supply chain. There is no doubt that the inventory management function is one that has been coming under the spotlight of inventory management and has a huge impact on their overall performance. Supply chain inventory management is driven by end-customer demand and targeted towards enhancing customers service while reducing relevant cost (Dias, 2025).

1.2. Supply chain challenges within the healthcare industry

The complexity of inventory is also felt because of the uncertainty of patient demand, fluctuation in treatment volumes, supplier lead times, and multiple locations of inventory monitoring. Major health care units lack real-time monitoring of supplies, and do not have accurate forecasting systems that can predict future needs. The consequence of this is usually the reactive purchasing decisions which may impact on clinical performance. When the necessary drugs or equipment are not available due to wrong medication or wrong medical equipment, it affects the quality and safety of care for patients (Dias, 2025).

The study is important due to its examination of the effects that inventory optimization has on the efficiency of the hospital supply chain in order to minimize operational costs, avoid the loss of needed medical supplies and ultimately improve patient care. It also offers ideas for good resource management practices which could lead to prompt healthcare delivery, optimise the performance of hospital organisations and increase the sustainability and resilience of hospital systems in the context of complex healthcare systems in the United States.

The study is organized into several different sections, starting with an introduction that provides background on the challenges facing supply chains and on inventory issues. The methodology provides details of the data collection and analysis, results report findings, the discussion explains results, and the conclusion summarizes implications, limitations, and fields for further studies.

2. LITERATURE REVIEW

- **Challenges in Healthcare Supply Chains**

"Healthcare supply chains (HSCs)" are complex in themselves and have unique challenges that make them distinct from other sectors. Demand for critical medicines, diagnostic devices, and life-support equipment varies randomly and results in stock-outs or overstocks, sometimes leading to shortages of the necessary supplies (Kumar et al., 2021). Now compared to consumer goods supply chain, the level of uncertainty in healthcare logistics is high, and responsibility for patients' safety

comes first, rather than focus on minimizing costs (Chopra & Meindl, 2019). The pandemic COVID-19 also revealed the fragility of health care supply chains, including during the pandemic, as shortages of essential products as ventilators and vaccines showed. Lack of essential products like ventilators and vaccines during the COVID-19 pandemic demonstrated the fragility of these supply chains, (Ivanov & Dolgui, 2020). A common issue is issues with demand uncertainty (Frichi, Y., et al., 2020). The forecast accuracy of the business's data is particularly challenging in the healthcare sector because of the seasonal fluctuation and sudden increase in health emergencies as well as outbreaks (Govindan et al., 2020). Many healthcare providers are still using some of the old, reactive procurement processes that do not provide up-to-the-minute information. This means sub-optimal inventory management, especially for perishables such as blood, vaccines and some pharmaceutical products (Chamberlain, et al., 2021).

Delays in procurement and dependency with suppliers are also important challenges. A limited number of global suppliers are key to the system of hospitals with regard to critical drugs, and their dependency leaves hospitals vulnerable to transportation issues, accompanied by regulatory concerns and raw material shortages (Shih, 2020). A lot of products—like generic pharmaceuticals in India and China—are concentrated in certain geographic areas which further intensifies the risks of global shocks (Boselie, P., et al., 2021). Furthermore, as there are no visibility and coordination among a multi-level healthcare network, the efficiency is adversely affected. Not only it is known that a hospital can have thousands of suppliers and distributors but also do not have visibility of the levels of stock in their suppliers, often a major problem (Ruíz Orjuela, et al., 2023). This opacity increases the risks for counterfeit products to be introduced on the supply chain, thereby compromising patient safety (Mišić, & Perakis, 2020).

Healthcare supply chain complexity is exacerbated by regulatory pressures. Handling of a controlled substance, medical devices and biologics are subject to strict compliance requirements, which impose constraints on procurement and distribution (Chowdhury, R. & Sultana, R.). 2023). These requirements, along with environmental laws and sustainability requirements, call for an integrated approach to supply chain management – complying with environmental legislation and meeting the sustainable demands of stakeholders in an economically viable way (Jahid, M. S. R 2021). The study indicates that Health care supply chains face a very particular set of constraints: uncertainty, regulations and ethical requirements. This presents unprecedented (for logistics) challenges that require innovative optimizing approaches that go beyond the traditional logistics approaches (Rasel, et al., 2022).

- **Healthcare Logistics and Resource Management**

Healthcare organisations encounter numerous problems as transition from fee-for-service reimbursement models to value-based payment systems (Heydari, M., et al., 2020). Healthcare organizations are incentivized under current and future reimbursement policies to adopt a strategy of care management at each stage of the patient's care journey, ultimately to lessen patients' reliance on an inpatient stay. 2023). These are the problems driving the need for OM to boost the efficiency and effectiveness of care by populations throughout all parts of the supply chain; both from the provider and patient viewpoints and at the same time, through both views of throughput and outcomes. 2023). As mentioned above, OM efforts aimed at advancing the chronic care management could serve as examples of work that needs to be accomplished within OM in terms of new models of care design and evaluation (Frichi, Y., et al., 2020).

Emergency logistics is the identification of logistics actions that are initiated in response to an emergency, which involve limiting the emergency logistics demand and/or emergency logistics supply activities to perform the logistic needs, in order to get the greatest value from the time and minimize losses caused by the disasters (Beaulieu, M. & Bentahar, O.). 2021). When managing emergency logistics, the positioning of emergency facilities and distribution of rescue materials are important factors in making emergency decisions and emergency operations (Boselie, P., et al., 2021). The theory of emergency logistics is first suggested in 2004, which describes as 'logistics activities to provide resources for responding to natural disasters, public health problems, catastrophic accidents and other emergencies' (Damali, U., et al., 2021). Humanitarian logistics involves the efficient and effective movement of humanitarian goods and quality-related information from the source to the target (using the language of the point of origin to the point of destination) site. (Mamun, A., & Raj, M. W. Z.) 2023). These include the preparation, planning and procurement, shipping, tracking and monitoring in a truck, and customs clearance procedures (Heydari, M., et al., 2022).

The previous study on the healthcare supply chain mainly discusses the uncertainty in demand, emergency logistics planning, procurement problems and healthcare regulations constraining the performance of operations in the healthcare

industry (Govindan et al., 2020; Shih, 2020). Some previous study also pointed out the operational management and logistics coordination needed to enhance the efficiency of healthcare delivery services (Heydari et al., 2020). A few studies, however, have conducted limited study on how resource utilization, operational cost reductions, and the optimization of supply chain can be addressed with an integrated real-time inventory management and predictive logistical management framework in U.S. hospital systems.

3. RESEARCH METHODOLOGY

The research methodology used is mixed-methods approach to analyzing the effect of inventory optimization on supply chain efficiency within hospital systems in the United States. The study combines the qualitative aspects of insights with quantitative aspects of the evaluation to comprehensively understand the inefficiencies in procurement, logistics coordination aspects, inventory management practices and the effect brings in the operational performance. The descriptive and analytical research design enables a systematic evaluation of the relationship between the inventory optimization practices and a hospital's operations (healthcare logistics management), operational efficiency and cost reduction. The methodological framework provides for a thorough assessment of the practices in the healthcare supply chain and ensures analytical depth and relevance.

The collection of the study is done across hospitals in the United States, aiming at U.S. hospital procurement/purchasing, warehousing and logistics coordination, and inventory decision-making task forces. The sample size is 250 respondents with stratified random sampling design to represent balanced responses from different (date) categories of hospitals and operational departments of hospitals. Primary data collected through structured questions, Secondary data enhance the knowledge of theory and practical aspects. Mean, standard deviation is used in statistical analysis to assess the format of responses, correlation to understand the relationship between variables and regression analysis to assess the influence of HCLM on hospital cost reduction in MS excel and SPSS 27.

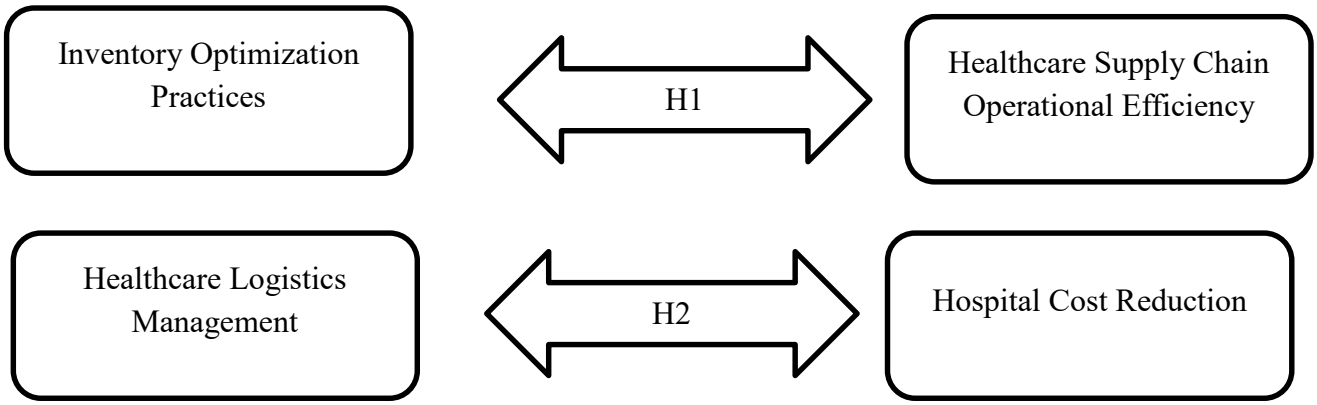

Figure 1: Conceptual framework

Source: Authors own compilation

4. DATA ANALYSIS AND INTERPRETATION

Table 1: demographic profile of the respondents

S.NO	Demographic variable		N	%
1	Gender	Female	117	46.8
		Male	133	53.2
2	Age	25-35 years	67	26.8
		36-45 years	54	21.6
		46-55 years	69	27.6
		Above 55 years	60	24
3	Educational qualification	Bachelor's degree	60	24
		Doctorate	65	26

		Healthcare management	56	22.4
		Master's degree	69	27.6
4	Job position	Inventory manager	77	30.8
		Logistics coordinator	62	24.8
		Procurement officer	62	24.8
		Supply chain manager	49	19.6
5	Work experience	Less than 5 years	63	25.2
		5-10 years	55	22
		11-15 years	61	24.4
		Above 15 years	71	28.4
6	Hospital size	Small	57	22.8
		Medium	61	24.4
		Large	66	26.4
		Multi-speciality network hospital	66	26.4
7	Use of digital inventory systems	Planning stage	59	23.6
		Partially implemented	70	28
		Fully implemented	62	24.8
		Not implemented	59	23.6

The demographic profile of the respondents participating in the study is presented in table 1. There are 53.2% male respondents and 46.8% female respondents. Most participants are in their 40s (27.6%) and middle aged (27.6%) are also majority, with master's degree as majority among these subjects (27.6%). The top job in inventory is 30.8% for inventory managers. Most of the respondents have over 15 years work experience (28.4%). 26.4% of hospital responses are from large and multi-speciality network hospitals. Further, 28% of hospitals report that their digital inventory systems are partly implemented, representing that some level of technological integration in various healthcare supply chain activities.

H1: Inventory optimization practices have a significant relationship with healthcare supply chain operational efficiency in hospitals.

Table 2: descriptive statistics

Descriptive Statistics			
	Mean	Std. Deviation	N
Inventory Optimization Practices	15.7600	3.97563	250
Healthcare Supply Chain Operational Efficiency	17.5680	3.83251	250

The descriptive statistics are shown for inventory optimization practices and operational efficiency of the healthcare supply chain at the U.S. hospital system level, as summarized in Table 2 below. The mean of inventory optimisation practices is 15.7600 and the SD is 3.97563, suggesting that there is moderate variation in the inventory optimisation practices (in terms of respondent's perception) attained. However, the operational efficiency performance in the healthcare supply chain responds comparatively well in the mean value 17.5680 with a relatively low standard deviation of 3.83251, which suggests that operational efficiency performance is strong among the 250 participants involved in the study, and the responses were relatively consistent.

Table 3: Correlations

Correlations			
		Inventory Optimization Practices	Healthcare Supply Chain Operational Efficiency
Inventory Optimization Practices	Pearson Correlation	1	.428**
	Sig. (2-tailed)		.000
	N	250	250
Healthcare Supply Chain Operational Efficiency	Pearson Correlation	.428**	1
	Sig. (2-tailed)	.000	
	N	250	250
**. "Correlation is significant at the 0.01 level (2-tailed)".			

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Vol. 13, Issue 2, pp: (40-49), Month: May - August 2026, Available at: www.noveltyjournals.com

Table 3 shows the correlation of healthcare supply chain operational efficiency with healthcare system inventory optimization practices in the U.S. hospital systems. It is evident that there is a moderate level of positive correlation (Pearson correlation coefficient = 0.428) between the two variables. Since its significance value is below the 0.01 level, it is an indication that the relationship is statistically significant. The results indicate that among the 250 respondents included in the study, good inventory control behaviour has a positive impact on the healthcare supply chain operational efficiency.

H2: Healthcare logistics management has a significant impact on hospital cost reduction.

Table 4: Model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.195[a]	.038	.034	3.57634
a. Predictors: (Constant), Healthcare Logistics Management				

Table 4 is the regression model summary for the investigations of how HCLM affects hospital cost reduction. The result of the regression model is shown in Table 4, which shows the HCLM influence on the cost reduction in hospitals. “The positive value of "r" is 0.195, which suggests that there is a weak positive correlation between the two variables”. This R square value of 0.038 indicates that the model of healthcare logistics management accounts for 3.8% of the cost reduction of hospitals. The adjusted R Square of 0.034 again shows this low of explaining variance, and the standard error estimate of 3.57634 shows this as a good prediction accuracy within the regression model.

Table 5: ANOVA

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	125.826	1	125.826	9.838	.002[b]
	Residual	3171.970	248	12.790		
	Total	3297.796	249			
a. Dependent Variable: Hospital Cost Reduction						
b. Predictors: (Constant), Healthcare Logistics Management						

Data in Table 5 shows ANOVA results for the regression model for the impact of healthcare logistics management on hospital cost reduction. “The regression model is statistically significant with an F-value of 9.838 and a significance value of 0.002 which is less than 0.05”. Results showed there is a negative association between the healthcare logistics management and reduction in hospital cost. Moreover, the regression sum of squares value is 125.826 which showed a good amount of variations explained with the help of model.

Table 6: Coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	13.488	1.019		13.238	.000
	Healthcare Logistics Management	.186	.059	.195	3.137	.002
a. Dependent Variable: Hospital Cost Reduction						

Table 6 presents the analysis of the coefficient of hospital cost reduction regarding healthcare logistics management. The coefficient analysis of healthcare logistics management on hospital cost reduction is displayed in table 6. The regression coefficient value (B = 0.186) signifying that the logistics management in healthcare sector has positive effect with regard to cost reduction in hospitals. “The standardized beta coefficient of 0.195 indicates a weak positive relationship between the variables”. Additionally, the t-value of 3.137 and significance value of 0.002 < 0.05, demonstrate the logistical management of healthcare's statistical significance in reducing hospital costs in U.S. hospital systems investigations.

5. DISCUSSION

Efficiently working the hospital supply chain is a huge concern for healthcare systems especially in the United States where the growing demand for patients is required to do more with less available resource to run operation smoothly, due to this all associated activities related to the supply chain efficiency of the hospitals became a serious concern for hospitals throughout the country (Nweje, U., & Taiwo, M.). 2025). Optimizing inventory is a key element of this change, making sure medical supplies are accessible when necessary, but not held in excess, or left to waste (Ho, G. T., et al., 2021). The use of efficient inventory can make inventory improve not only by cutting costs but also by improving patient service so that patients' treatment does not get delayed because of insufficient inventory (Hashmi, A. R., et al., 2020). For this reason, it is important that hospital systems (Eyo-Udo, N. 2024) incorporate cutting-edge practices to inventory and integrate with operational practices for clinical and financial improvement (Eyo-Udo, N. 2024).

Blood is one of the most critical services needed by hospitals in disaster situations, especially when the number of victims is very large (Khalilpourazari S, etc., 2020). According to Panda, S. K. and Satapathy, S. C. (2024), that's when the amount of blood donated following an earthquake is massive, leaving only a portion of the blood to reach the hospitals in the first few days. This scenario shows that a lack of efficiency in the blood supply chain, not a lack of blood donations, could have a great impact on service delivery (Abu Zwaida, T., et al., 2021). According to Chopra, S. et al., (2019), appropriate management of distribution, transport and coordination is crucial to ensure reaching the existing resources at the appropriate time and place in hospital systems.

Healthcare inefficiencies cost the American hospital sector $750 billion every year due to preventable medical errors, making the implementation of optimized workflow systems a critical solution, with as much as a 28% reduction in hospital-acquired conditions and a 45% reduction in hospital preventable readmissions (Pingili, R.). 2024). Control of patient flow is a modern healthcare phenomenon that has gained increasing criticality, a lot like the elevated-busy hours of a busy restaurant kitchen (Heydari, M., et al., 2022). But the consequences in healthcare, according to extensive study conducted by the IOM, are significantly more severe, and care delivery inefficiency is responsible for around $130 billion of these losses (Govindan, K., et al., 2020). The study introduces an overview of the models used for sustainable inventory management in the supply chains and a roadmap for new study (Becerra, P., et al., 2022). It seeks to fill the knowledge gap about treating sustainability issues as a part of a quantitative inventory management model in the supply chain context (Shih, W. C. 2020).

Lugada, E., et al., (2022) identify many concerns and obstacles that impede the optimal operation of the health supply chain system at all tiers of the health system. The identified challenges are: An inadequate framework for planning, coordination, and management, insufficient funding, a lack of skilled personnel, feeble regulatory and governance structures at both national and sub-national levels, and sluggish adoption and utilisation of EIwS for the execution of Supply Chain processes and functions (Regin, R., & Rajest, S. S., 2022). Addressing these difficulties necessitates increased expenditures in policy formulation and execution, infrastructure, equipment, and supporting systems, as well as enhancing the knowledge and skills of supply chain personnel, with augmented funding and fortification of governance and accountability (Vishwakarma, A., et al., 2023). There are various problems associated with the supply chain system such as limited resources, increased complexity, deficient inventory information, unworkable organizational structures (vertical format, unwelcoming of change, inappropriate distribution to last-miles), forecasting and ordering problems, lack of innovations, etc. which affect its efficiency and effectiveness (Mamun, A., & Raj, M. W. Z. 2023).

6. CONCLUSION OF THE STUDY

The study concludes that Inventory Optimization is a key element of improving the efficiency of hospital supply chain in U.S. health care systems. The results highlight the beneficial effects of implementing better inventory management practices and their positive association with supply chain performance. Further, Healthcare logistics management has a moderate yet significant impact on cost reduction. In summary, combining inventory control with supply chain operations is valuable for hospitals to ensure medical supplies are available on time, minimize waste, and maximize the use of resources.

Structured inventory management systems and data-driven decision-making help hospitals to enhance clinical and financial performance. Overall, the statistical analysis indicates that hospitals with superior inventory optimization strategies have better supply chain coordination and operation. While the regression results show that limited further explanations are

achieved, the role of logistics control can't be neglected. Improving inventory and logistics processes, therefore, are imperative for hospitals to increase the resilience, cost-effectiveness and patient-centredness' of their healthcare supply chains.

6.1 Implication of the study

The strategic significance given to inventory optimization in healthcare operations makes for a few take-home lessons for hospitals, healthcare managers, healthcare policy makers, and CS professionals. It highlights the need for adopting digital inventory systems, real-time monitoring, and predictive analytics to improve supply chain visibility and responsiveness. The results also indicate that improved integration of procurement and logistics with inventory can make a huge difference in terms of efficiency and cost-effective operations. Furthermore, the study could contribute to the building of HCSC framework which enhances the decision makers, availability of resources, and finally, improving patient care quality and delivery.

6.2 Limitation of the study

Although the study has made contributions, it has its limitations that should be taken into consideration. The findings may not reflect a fully representative sample of all hospital systems in the U.S. and the sample size is 250. Furthermore, data from the study are also gathered from self-report, using questionnaires, so there may be response bias. The regression model is also not very precise — there may be other factors out there that affect hospital cost reduction which were not accounted for in the model. In addition, the cross-sectional feature limits the capacity to see long term effects of inventory optimization practices on supply chain performance and productivity.

6.3 Recommendation for future study

Future studies should be expanded by including more and diverse samples in different health care systems and geographic areas. Recommend Longitudinal studies to look at longer-term effects of inventory optimization on hospital performance and cost savings. Advanced technologies like artificial Intelligence, Blockchain and predictive analytics should be explored in healthcare supply chains for researchers to consider. In addition, other factors that affect the hospital supply chain could be explored in future studies to create more comprehensive models to promote supply chains' efficiency in hospital.

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