LEAN PRACTICES AND HEALTHCARE SUPPLY CHAIN PERFORMANCE: AN INTEGRATED DEMATEL-ANP APPROACH

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Abstract
Similar to what is obtainable across the globe, the Nigeria healthcare supply chain system has been faced with increasing risks, cost pressure, and complex governing regulations on the basis of its products' uniqueness, complexity, and cost. Thus, this has continuously made medications to fail in meeting the needs of the right end-user at the right time, right cost, and right quality. To address the challenges identified, this study assessed the influence of lean practices on healthcare supply chain performance. To achieve this, the study employed a quantitative and survey-based research design with the aid of Decision Making Trial and Evaluation Laboratory and Analytical Network Process (DANP). Using the Lagos University Teaching Hospital (LUTH) as the unit of analysis, the supply chain practitioners which totalled forty-two were engaged as the unit of observation. The findings revealed that to improve healthcare supply chain performance, compared to other lean practice, the value stream mapping is of upmost importance followed by the standardization of supply chain processes. Moreover, at the performance metric, the cost factor within the healthcare supply chain system is positioned most important by experts for aiding improved supply chain performance on both sides of the analytical procedure followed by service level. Among the key performance indicators, waste reduction is positioned most important as against inventory cost. However, the indicator inventory cost needs not to be negated in decision making, as DEMATEL analysis of expert opinion ascribe it as the most important and influential within the key performance indicators.

Key words: *Healthcare, Supply chain, Performance, Lean practices, Dematel-ANP*

Introduction

Healthcare is a vital sector for a nation's well-being, and its optimal functioning relies on its effective supply chain system (Hossain et al., 2023). The healthcare supply chain (HSC) involves the flow of medications, money, pharmaceutical material, and information among stakeholders to meet end-user needs. It is a complex network of agents engaged in various activities to ensure the right flow of value-added products at the right time and cost. Effective management of healthcare supplies and supply chain processes is crucial for continuous improvement in the healthcare sector (Khorasani et al., 2020). The healthcare system in Nigeria faces increasing risks, cost pressure, and complex regulations due to its unique, complex, and expensive products (Balogun, 2021). The system is fragmented, uncoordinated, and inflexible, leading to stock shortages, delays in disbursement due to bureaucratic bottlenecks, and resource wastage (Nsikan et al., 2019). To meet customer demands and reduce service costs and waste, an efficient supply chain performance-enhancing strategy like lean thinking is needed, such as lean thinking, to improve efficiency and reduce waste (Borges & Tortorella, 2019).

Lean thinking is a process improvement approach (Kelendar et al., 2020), that focuses on identifying and eliminating waste, creating customer value, and mitigating non-value-adding activities in supply chains like healthcare. It involves strategically applying practices like value stream mapping, standardized work, automation, total productive maintenance, vendor-managed inventory, pull system, and just-in-time (Cabral et al., 2012). Lean thinking promotes efficiency, competitiveness, and lower costs by eliminating non-value-added activities within the healthcare supply value chain (Quadras et al., 2024). This study examined the impact of lean practices on healthcare supply chain performance using the Decision Making Trial and Evaluation Laboratory (DEMATEL) method and the Analytical Network Process (ANP). DANP (DEMATEL and ANP) is an integrated Multi-Criteria Decision-Making (MCDM) technique that evaluates and prioritizes attributes within a decision-making system (Buyukozkan & Guleryuz, 2016). It helps explore causal relationships, dependencies, feedback relationships, and relative weights of decision-making criteria. DANP has been applied to various decision-making problems, such as customer retention strategies (Jeng & Bailey, 2012), renewable energy resource selection (Buyukozkan & Guleryuz, 2016), supply chain risk quantification (Tarei et al., 2018), and the evaluation internal hospital supply chain performance (Supeekit et al., 2016).

Literature Review

Lean Practices

Lean thinking is a systemic approach to waste minimization and cost reduction, focusing on meeting end users' increasing demands with fewer resources (Douglas et al., 2015). It involves a set of interlinked operational practices to mitigate non-value-added activities within a product/service value stream. Lean thinking is attributed to zero inventories and a just-in-time productive approach, aiming to meet customer requirements at the lowest possible cost of production (Borges & Tortorella, 2019). High lean practices adopters show better performance on lead times, inventory, and turnover metrics than quality and on-time delivery. In healthcare, Matt et al. (2018)

opined that lean thinking involves the optimal utilization of constraint resources and extensive waste mitigation within its value stream.

Lean Implementation in Healthcare Supply Chain

Different industries have adopted lean practices, including healthcare, to improve performance and reduce risks and cost pressures. The healthcare supply chain, which accounts for 30%- 40% of total healthcare expenditures, requires increased attention to adopting supply chain management principles like lean thinking. Effective implementation of lean principles can mitigate approximately 50% of total healthcare expenditures related to the supply chain, according to studies by Schwartzing et al. (2011) and Chen et al. (2013).

Lean healthcare supply chain management is a process improvement approach that focuses on waste elimination, customer value creation, and mitigating non-value-adding activities. It goes beyond waste and cost implications, involving organizational and employee motivation (Khorasani, et al, 2020). Lean thinking practices include value stream mapping, kaizen, automated systems, kanban, 5S, and visual management (Borges & Tortorella, 2019). These practices have been implemented in the healthcare supply chain to achieve sustainable results.

Healthcare Supply Chain Performance

The literature reviews various metrics used to evaluate healthcare supply chain performance. These include operational, financial benefits, organizational image, supply lead time, inventory level, cost, quality, and delivery service level (Adebanjo et al., 2016; Chorfi et al., 2018; Moons et al., 2019; Pal et al., 2022). Chakraborty et al. (2020) explored various perspectives on financial, customer, operational, information, and innovation and learning. Shahzad et al. (2020) evaluated internal supply chain performance based on patient safety, clinical care process efficiency, and supporting process efficiency using DANP. This study focuses on cost, service level, and product quality based on system and product uniqueness and complexity. The study also considers increasing risks and cost implications associated with the healthcare supply chain.

Decision-Making Trial and Evaluation Laboratory-Analytic Network Process

Decision-Making Trial and Evaluation Laboratory-Analytic Network Process (DANP) is an integrated multi-criteria decision-making approach used in operations research to solve business and societal decision problems. According to Chen et al. (2018), DANP is a decision-making model utilized to explore dependencies and feedback relationships, and relative weights of decision criteria within a decision-making context. The DANP model helps to project real-world interdependency situations within a decision-making context against the sole application of ANP. To this effect, DANP has been applied in the evaluation of carbon system (Liou, 2014), internal hospital supply chain performance (Supeekit et al., 2016); and assessment of customer retention strategies (Jeng and Bailey, 2012), project risk (Chen et al.,2018), critical success factors towards a successful transition to a circular economy (Khan et al., 2020), inbound supply risks (Ramesh et al., 2020), among others. The DANP model can be subdivided into two decision-making phases: (1) the usage of DEMATEL in building an Impact Relation Map (IRM), and (2) the determination of decision dimensions and criteria relative weights using ANP for exploring causal relationships, dependencies, and feedback relationships, and relative weights of decision criteria within a decision-making context.

Theoretical Framework

The study is underpinned by lean theory.

Lean Theory

Lean, originating from the manufacturing industry, has gained popularity in the service industry due to Bowen and Youngdahl's (1998) contributions. Lean is applied in sectors like telecommunication and hospitality to achieve zero defects in operational processes. Scholars view lean as a basis for attaining quality at strategic and operational levels. Lean focuses on continuous process improvement, increasing customer value or reducing non-value-added activities, process variations, and poor work conditions (Pranata, 2024). Lean is also known as a just-in-time (JIT) system, requiring a highly specified process to coordinate activities and deliver goods (Stevenson, 2012). Lean helps prevent excessive work-in-process (WIP) and ensures unproductive processes.

The overall objective of lean is to achieve “zero waste” in production and service, for resource optimization, and to achieve the highest quality of services (Afum et al., 2022). This study uses lean theory to underpin how the theory helps stakeholders and policy-makers understand that achieving optimal quality output and service in the healthcare supply chain system is not solely about employees working harder but also smarter within streamlined processes.

Methodology

The study employed a quantitative and analytical approach aligned with positivism. It utilized a cross-sectional survey and DANP-structured questionnaires to address research questions, systematically modelling cause-effect relationships and dependencies within conflicting criteria (Saaty, 2008; Cabral et al., 2012, Lin et al., 2020).

The study involved 47 supply chain practitioners at Lagos University Teaching Hospital (LUTH), who were involved in the procurement, administration, storage, and distribution of medical supplies and equipment. LUTH was chosen due to its high involvement in complex supply chain activities, ensuring quality healthcare service delivery to its large end users. To achieve the study's objectives, a sample size of five experts was selected, adhering to DEMATEL and ANP guidelines, which recommend a smaller sample for consistency and practical applicability (Lin et al., 2020). This practice is also supported by scholars such as Saaty (2004), Shao et al., (2016) among others, as reduced sample size helps to facilitate consistency of judgements, time saving, and improve and robust overall outcome. Therefore, these experts, chosen through purposive sampling and guided by the Head of the Store Department, possess extensive knowledge and experience in supply chain operations, procurement, and practices. The study evaluates the impact of lean practices on healthcare supply chain performance using established measurement variables from the literature. Data collection for lean practices utilized three items adapted from Cabral et al. (2012) and Farias et al. (2019). Supply chain performance was assessed based on cost, service level, and product quality, as operationalized by Cabral et al. (2012) and Tortoella et al. (2018).

The study utilized structured questionnaires aligned with a two-phase research design. The first phase involved DEMATEL-based questionnaires administered to five experts, featuring close-ended questions with a 0–4 scale ("no influence" to "very high influence") to identify cause-effect relationships among elements and criteria. The results were used to develop a network relationship map (NRM) of criteria and elements and determine inner dependencies for ANP operationalization.

The second questionnaire, based on the ANP model, used close-ended questions with Saaty's (2008) fundamental ratio scale to capture expert preferences on elements (key performance indicators) and criteria (performance metrics) concerning the goal (healthcare supply chain performance improvement) and the alternative (lean practices). Questions were structured from the criteria cluster to the alternative cluster to clarify factor relationships and simplify the response process.

Methods of Data Analysis

In a bid to achieve the aim of the study, the analysis of collected data with the aid of Excel Solver (Microsoft Excel), MATRIXCAL, online output software (DEMATEL solver), and Super Decision Software (Analytic Network Process Model Solver) was actualized following the procedure of DANP as operationalized by Büyüközkan and Öztürkcan, (2010).

Results

Five questionnaires were distributed to experienced supply chain practitioners at Lagos University Teaching Hospital (LUTH), Lagos, Nigeria. Four were returned, achieving an 80% response rate, but only three (60% of the total) were properly completed and deemed valid for analysis.

Table 2: *Expert Profile*

	Designation	Qualification	Industrial Experience (years)	Professional Qualification
Expert 1	Deputy Director of Procurement	Masters	21 and above	Chartered Institute of Purchasing and Supply Management
Expert 2	Assistant Chief Store Officer	Degree	21 and above	Chartered Institute of Purchasing and Supply Management
Expert 3	Store Officer	Degree	21 and above	Chartered Institute of Purchasing and Supply Management

Following the analytical procedure of DEMATEL and ANP methodology, the study results is discussed.

Step 1: Define the objective, criteria, sub-criteria, and alternatives of the evaluation model: In view of this, the evaluation model (see Figure 1) contains 4 clusters (goal cluster, criteria cluster, sub-criteria cluster, and the alternative cluster), nodes/elements, and links. The goal cluster contains improving healthcare supply chain performance as the goal; the criteria cluster embodies constructs such as the cost, quality of product, and service level; while the sub-criteria cluster comprises inventory cost (KPI1), out of stock ratio (KPI2), and waste reduction (KPI3). Whereas, the alternative cluster comprises value stream mapping (P1), standardized work (P2), and automated system (P3).

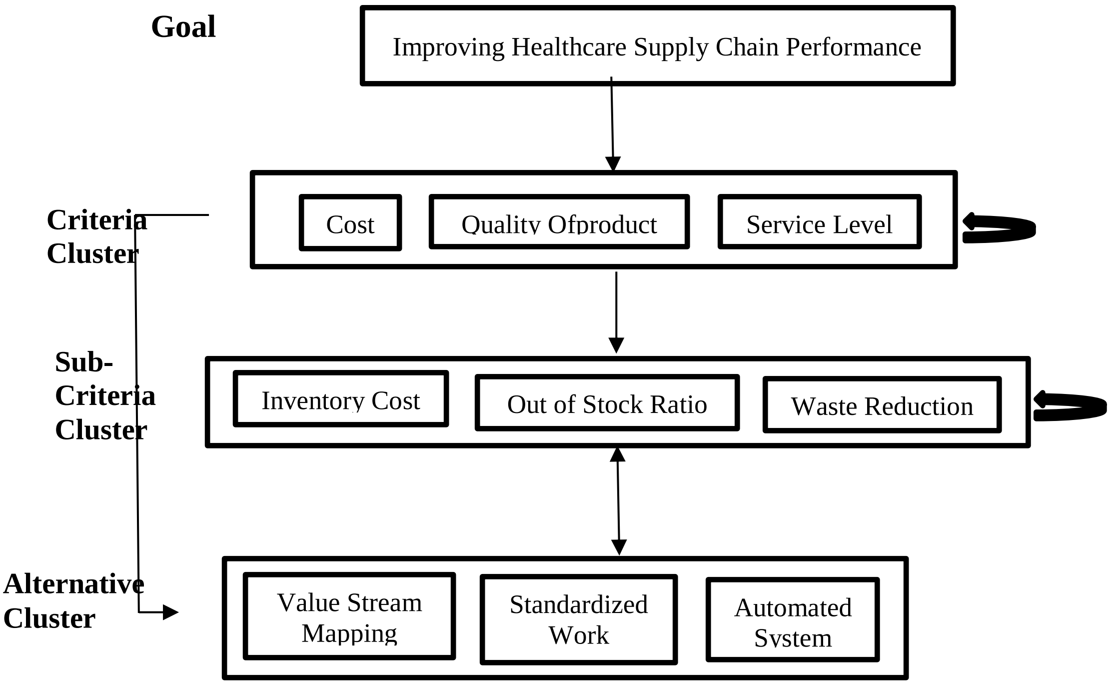

Figure 1: General framework for assessing lean practices and healthcare supply chain performance

Step 2: Construction of direct-relation matrix using DEMATEL: Using a standard comparison scale of 0 - 4 indicating no influence (0), low influence (1), medium influence (2), high influence (3), and very high influence (4), the unified direct relation matrix (see Table 3) for healthcare supply chain performance metric was derived.

Step 2.1: Normalize the direct-relation matrix: Using formulae (1) and (2), the normalized direct-influence matrix Q for healthcare supply chain performance metrics is shown in Table 3.

$$Q = \frac{1}{s} * P \quad (1)$$

$$s = max\{max \sum_{j=1}^{n} p_{ij}, \sum_{i=1}^{n} p_{ij}\} \quad (2)$$

Step 2.2: Calculate the total-relation matrix: The total-relation matrix R is computed following the actualization of the normalized direct-relation matrix Q using formula (3). Given this, Tables 3 and 4 displayed the total-influence matrix (R) on healthcare supply chain performance metrics and key performance indicators respectively.

$$R = Q \times (I - Q)^{-1} \quad (3)$$

Table 3:

DEMATEL analysis of Healthcare Supply Chain Performance (HSCP) metrics

	Direct Relation Matrix (*P*)			**Normalized Direct Relation Matrix (*Q*)**			**Total Relation Matrix (*R*)**		
HSCP metrics	**C**	**QOP**	**SL**	**C**	**QOP**	**SL**	**C**	**QOP**	**SL**
Cost (c)	0	3	3	0	0.5	0.5	0.544	1.123	1.053
Quality of Product (QOP)	1.5	0	1.5	0.25	0	0.25	0.526	0.474	0.632
Service Level (SL)	1.5	2	0	0.25	0.333	0	0.561	0.772	0.474

Table 4: *Total Relation Matrix (R) for Key Performance Indicators (KPIs)*

Key Performance Indicators	**IC**	**OSR**	**WR**
Inventory Cost (IC)	1.333	1.911	1.756
Out of Stock Ratio (OSR)	1.333	1.244	1.422
Waste Reduction (WR)	1.333	1.511	1.156

From Table 3, the result depicts the direct relationship influence the measuring variables have over each other. For instance, the direct relative influence of cost when compare to quality of product is 3 which implies that cost highly influence quality of product. The result was further normalized and the total relationship matrix derived. Likewise, Table 4 follows the same procedure.

Step 2.3: Calculate the centrality degree and the cause and effect degree: With respect to formulae (4) – (5) X and Y values were computed respectively. Afterward, the value of $X+Y$ and X-Y depicting the centrality degree and the cause and effect degree are derived (see Table 5).

$$X = \sum_{j=1}^{n} R_{ij} \quad (4)$$

$$Y = \sum_{i=1}^{n} R_{ij} \quad (5)$$

Table 5: *Row-sum, Column-sum, Centrality degrees, and Cause degrees of Healthcare Supply Chain Performance (HSCP) metrics and key performance indicators*

Healthcare Supply Chain Performance (HSCP) metrics	X_i	Y_j	**Centrality Degree**	**Cause Degree**
Cost (C)	2.719	1.632	4.351	1.088(+)
Quality of Product (QOP)	1.632	2.368	4	-0.737
Service Level (SL)	1.807	2.158	3.965	-0.351
Key Performance Indicators				
Inventory Cost (IC)	5	4	9	1
Out of Stock Ratio (OSR)	4	4.667	8.667	-0.667

Waste Reduction (WR)	4	4.333	8.333	-0.333

The results of the centrality degree analysis at the HSCP metrics level depicted in Table 5 revealed that Cost (C) has the largest centrality degree of 4.351 followed by Quality of Product (QOP), which explains that they have relatively stronger connections with the other metric. That is, they are more important as metrics of healthcare supply chain performance compare to service level. While, with regards to the causal relationship, Cost (C), possessing the highest cause degree (1,088), represents the most influential healthcare supply chain performance metric casting two output connections with other metrics (see Figure 2). Quality of Product (QOP), with the lowest cause degree (-0.737), is identified as the most influenced metric.

At the KPIs level, the centrality degree analysis results revealed that the most influential indicator with a relatively high connection with other indicators is inventory cost with a value of 9. While, on the basis of cause and effect degree, inventory cost is prescribed as the only influential indicator influencing other indicators as their values are negative. Thus, it casts two output connections with other metrics (see Figure 3).

Step 2.4: Set a threshold value and construct the impact digraph map: The threshold value ‘g’ is derived through the arithmetic mean of matrix *R* for both healthcare supply chain performance metrics and key performance indicators as 0.684 and 1.0912 respectively.

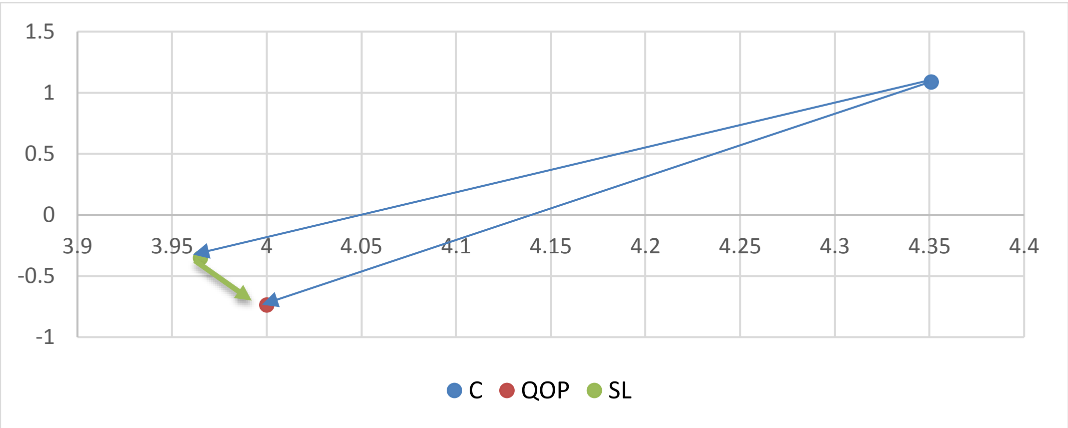

Figure 2: Healthcare Supply Chain Performance Metrics Causal Diagram

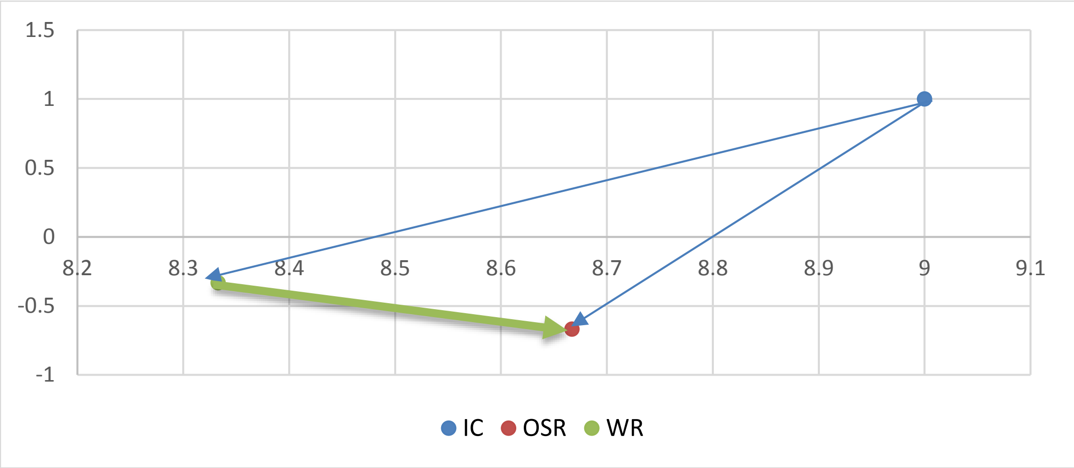

Figure 3: Key Performance Indicators Causal Diagram

Step 2.5: Obtain the inner dependence matrix: The centrality degree results show that performance metrics and indicators are strongly related, indicating significant inner dependence. To obtain the inner dependence matrix, the total relation matrix (R) is normalized by dividing individual values by the column-summed value, making the matrix stochastic, meaning the sum of each column equals 1.

Table 6: *Inner-dependency of Healthcare Supply Chain Performance (HSCP) metrics*

Healthcare Supply Chain Performance (HSCP) metrics	**C**	**QOP**	**SL**
Cost (C)	0.3317	0.4363	0.4322
Quality of Product (QOP)	0.3218	0.2308	0.3130
Service Level (SL)	0.3465	0.3330	0.2548

Table 7: *Inner-dependency of Key Performance Indicators*

Key Performance Indicators	IC	OSR	WR
Inventory Cost (IC)	0.3333	0.4096	0.4052
Out of Stock Ratio (OSR)	0.3333	0.2666	0.3281
Waste Reduction (WR)	0.3333	0.3238	0.2667

Step 3: Construct the network of the considered problem and evaluate the remaining nodes and alternatives using the ANP.

Based on the DEMATEL analysis, the evaluation model for ANP operations is derived and depicted in Figure 4.

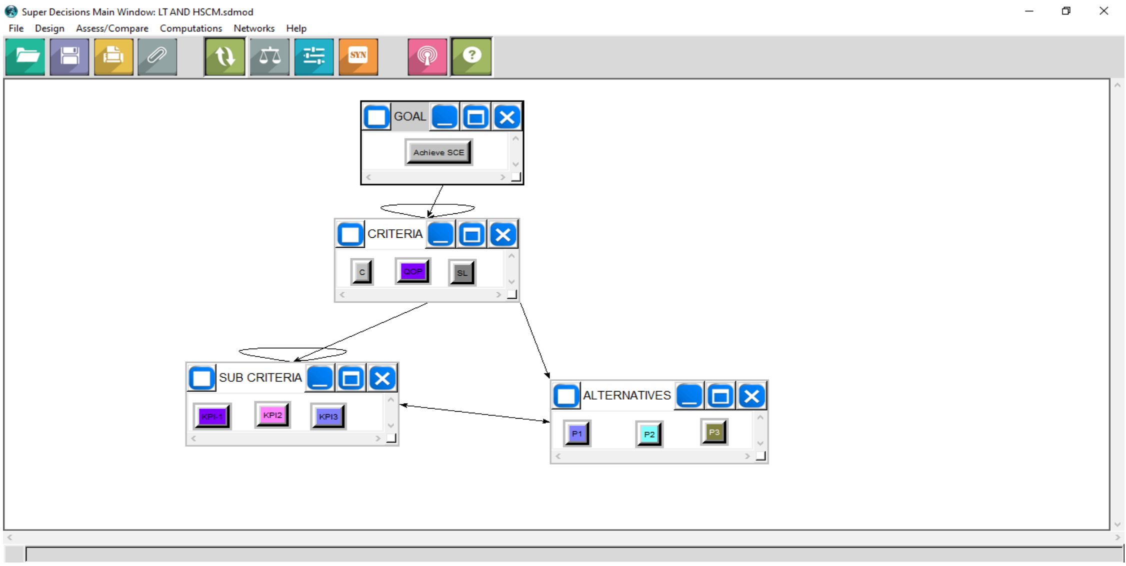

Figure 4: Network structure of the decision problem

Source: Super Decision Software, 2024

The model was built as a simple network structure that contains 4 clusters (goal cluster, criteria cluster, sub-criteria cluster, and the alternative cluster), nodes/elements, and links. The goal cluster contains the assessment of healthcare supply chain performance as the goal; the criteria cluster embodies constructs such as the cost, quality of product, and service level; while the sub-criteria cluster comprises inventory cost (KPI1), out of stock ratio (KPI2), and waste reduction (KPI3). Moreover, the alternative cluster comprises value stream mapping (P1), standardized work (P2), and automated system (P3).

Step 3.1: Generate the pair-wise comparison matrix and the Eigenvalue: The unified pair-wise comparison matrix for the sub-criteria cluster with respect to cost is exemplified in Table 8. Moreover, following the normalization of the unified pairwise comparison matrix, the Eigenvalues (see Table 8) for respective metrics and indicators are derived based on the division of the row-summed values of the normalized indicators by the total number of observed indicators.

Table 8: *Responses towards sub-criteria cluster with respect to Cost*

Key Performance Indicators	**Unified Matrix**	**Pairwise**	**Comparison**	**Normalization**				**Eigen Vector**
	IC	OSR	WR	IC	OSR	WR	TOTAL	WEIGHT
IC	1	1 4/5	1/3	0.223252	0.197475	0.227963	0.64869	0.21623
OSR	5/9	1	1/6	0.124027	0.109707	0.105539	0.339272	0.113091
WR	3	6 1/3	1	0.652722	0.692818	0.666498	2.012038	0.670679
COLSUM	4.47925	9.115227	1.50038	1	1	1		

Thus, the results depicted in Table 8 denote the relative importance of waste reduction as highly important when compare to other indicators with respect to cost at 67%.

Step 3.2: Check consistency test: Based on formulas 6 and 7, using the unified pairwise comparison matrix for the sub-criteria cluster with respect to cost, the consistency ratio value was derived as 0.003186 which is less than 10%. Thus, the expert opinion is considered consistent.

$$CI = \frac{\lambda \max - n}{n-1} \quad (6)$$

$$CR = \frac{CI}{RI} \quad (7)$$

Step 3.3: Supermatrix Formulation: Following the results derived from both the

DEMATEL and ANP operations, the supermatrix is generated in form of unweighted, weighted, and limit supermatrix.

Table 9: *Unweighted Supermatrix*

		ALTERNATIVES			**CRITERIA**			**GOAL**	**SUB CRITERIA**		
		P1	P2	P3	C	QOP	SL	Improve HCSCP	KPI-1	KPI2	KPI3
ALTERNATIVES	P1	0	0	0	0.3121	0.6608	0.3274	0	0.3031	0.3284	0.5941
	P2	0	0	0	0.5131	0.1861	0.5397	0	0.1282	0.4060	0.1989
	P3	0	0	0	0.1748	0.1532	0.1329	0	0.5686	0.2656	0.2070
CRITERIA	C	0	0	0	**0.3317**	**0.4363**	**0.4322**	0.1247	0	0	0
	QOP	0	0	0	**0.3218**	**0.2308**	**0.3130**	0.3781	0	0	0
	SL	0	0	0	**0.346**	**0.333**	**0.254**	0.4972	0	0	0

					5	**0**	**8**				
GOAL	Improve HCSCP	0	0	0	0	0	0	0	0	0	0
SUB CRITERIA	KPI-1	0.2505	0.1145	0.2242	0.2160	0.1015	0.2845	0	**0.3333**	**0.4096**	**0.4052**
	KPI2	0.1514	0.3601	0.5889	0.1129	0.2392	0.5192	0	**0.3333**	**0.2666**	**0.3281**
	KPI3	0.5981	0.5254	0.1869	0.6711	0.6594	0.1963	0	**0.3333**	**0.3238**	**0.2667**

Using Super Decision software, the unweighted supermatrix (Table 9) was generated, showing local weights of measured variables after pairwise comparisons of the network structure. For example, regarding cost, standardized work (P2) accounts for 51.21% importance among alternatives. A zero value between P1 and P2 in the alternative cluster indicates no observed inner dependency between variables. Inner dependency values (bold) derived from DEMATEL operations were then integrated into the unweighted supermatrix, which was subsequently converted into a weighted supermatrix.

Table 10: *Weighted Supermatrix*

		ALTERNATIVES			**CRITERIA**			**GOAL**	**SUB CRITERIA**		
		P1	P2	P3	C	QOP	SL	Improve HCSCP	KPI-1	KPI2	KPI3
ALTERNATIVES	P1	0	0	0	0.067956	0.143891	0.071287	0	0.303112	0.328388	0.594075
	P2	0	0	0	0.111738	0.040515	0.117524	0	0.128242	0.405997	0.198942
	P3	0	0	0	0.038065	0.033353	0.028948	0	0.568646	0.265615	0.206983
CRITERIA	C	0	0	0	0.178334	0.234573	0.232374	0.124744	0	0	0
	QOP	0	0	0	0.173011	0.124077	0.168271	0.378092	0	0	0
	SL	0	0	0	0.18632	0.179016	0.13702	0.497164	0	0	0
GOAL	Improve HCSCP	0	0	0	0	0	0	0	0	0	0
SUB CRIT	KPI-1	0.2505	0.1145	0.2242	0.0528	0.0248	0.0695	0	0	0	0

ERIA		41	43	08	28	12	7				
	KPI2	0.151359	0.360062	0.588881	0.027618	0.058492	0.126985	0	0	0	0
	KPI3	0.598101	0.525394	0.186911	0.16413	0.161271	0.048021	0	0	0	0

The weighted supermatrix (Table 10) was obtained by multiplying the unweighted matrix by the cluster matrix, ensuring column stochasticity and improving measurement accuracy.

Table 11: *Limit Supermatrix*

		ALTERNATIVES			**CRITERIA**			**GOAL**	**SUB CRITERIA**		
		P1	P2	P3	C	QOP	SL	Improve HCSCP	KPI-1	KPI2	KPI3
ALTERNATIVES	P1	0	0	0	0.216	0.216	0.216	0.221	0.444	0.444	0.444
	P2	0	0	0	0.124	0.124	0.124	0.127	0.254	0.254	0.254
	P3	0	0	0	0.1	0.1	0.1	0.148	0.30	0.3	0.3

					45	45	45		2	02	02
CRITERIA	C	0	0	0	0.005	0.005	0.005	0.01	0	0	0
	QOP	0	0	0	0.004	0.004	0.004	0.007	0	0	0
	SL	0	0	0	0.004	0.004	0.004	0.008	0	0	0
GOAL	Improve HCSCP	0	0	0	0	0	0	0	0	0	0
SUB CRITERIA	KPI-1	0.208	0.208	0.208	0.104	0.104	0.104	0.1	0	0	0
	KPI2	0.337	0.336	0.336	0.168	0.168	0.168	0.16	0	0	0
	KPI3	0.45	0.45	0.456	0.2	0.2	0.2	0.22	0	0	0

	5	5		3	3	3

The limit supermatrix, calculated by raising the weighted supermatrix to the power of 15 using MATRIXCAL (based on formula 8), provides the global priority weights of measured variables. Among the alternatives, value stream mapping (P1) holds the highest priority, indicating its significant influence on improving healthcare supply chain performance.

$$\lim_{k\to\infty} w^k \qquad (8)$$

Step 4: Determine the most suitable alternative: After the convergence of the supermatrix, the alternative with the highest priority value emerges as the most influential or important lean practice to enhance healthcare supply chain performance. In view of this, value stream mapping is portrayed as the most important lean practice for improving healthcare supply chain performance. This is followed by an automated system.

Discussion of Findings

The study employed an integrated DANP model for assessing the importance of lean practices in proffering continuous improvement to healthcare supply chain performance using a public teaching hospital (Lagos University Teaching Hospital) as the unit of analysis. On the basis of the DEMATEL analysis, the result revealed the cost factor has been most influential compared to the other healthcare supply chain performance metrics. While, with regards to the key performance indicators, inventory cost was perceived most importance as other variables depict negative values. However, after integrating the procedure, the results depict that among the criteria and the sub criteria to promoting healthcare supply chain performance, cost and waste reduction were ascribed as most important followed by service level and inventory cost respectively. This supports the findings of Cabral *et al.,* (2012). Moreover, from data analysis, the findings depict that experts perceived value stream analysis has more critical to the continuous improvement of the healthcare supply chain performance on the basis that it signifies the need to face off every non-value-adding activity within the healthcare supply chain process to create room for efficiency and improved performance. Moreover, its importance can be attributed to the fact that it creates a visual opportunity for policymakers in identifying weak and non-valuable processes while streamlining the valuable processes that need necessary improvement to enhance continuous improvement of the supply chain performance. This is in corroboration with the position of Sharma *et al.,* (2016) on the importance of value stream mapping in the reduction of waste. Moreover, to aid the holistic implementation of lean initiatives in enhancing lead time, patient satisfaction, and hospital performance, there is a high need for an adequate value stream analysis in identifying the value-adding and the non-value-adding activity within the hospital supply chain processes (Matt *et al.*, 2018). While Kelender *et al.,* (2020) narrative review of lean techniques implementation in healthcare settings within developing countries discovered high implementation of value stream mapping within the supply chain process in aiding performance improvement. Surprisingly, in India, the implementation of value stream mapping is lastly prioritized among the other lean initiatives in proffering continuous improvement to the supply chain in varying manufacturing sectors (Singh *et al.*, 2016). Consequently, within the construction industry, Tezel *et al.*, (2017) study result depicted that most of the lean practices (value stream mapping inclusive at 69%) are unknown to SMEs.

Conclusions, Limits, and Future Research Directions

The study aimed at assessing the influence of lean practices on the supply chain performance of the healthcare supply chain. Thus, after the holistic implementation of the DANP analytical procedure in this study, these relevant policy implications were made; at the performance metric, the cost factor within the healthcare supply chain system is positioned most important by experts for aiding improved supply chain performance on both sides of the analytical procedure. This is followed by service level.

In addition, to aid improved supply chain performance, among the key performance indicators, waste reduction that is, elimination of every element of waste within the healthcare supply chain process is positioned most important as against inventory cost. Altogether, the indicator inventory cost needs not to be negated in decision making, as DEMATEL analysis of expert opinion ascribe it as the most important and influential within the key performance indicators. Finally, with respect to the alternatives (lean practices) in relation to improved healthcare supply chain performance, the practice value stream mapping is considered as most important and influential. Thus, the need to carefully outline the key processes within the supply chain thereby, reducing waste and optimizing cost is of paramount importance to policymakers.

However, in spite of the revealed suggestions, the findings of the study cannot be generalized on the basis that it was conducted in one of the university teaching hospitals (a subunit of the tertiary healthcare system in the country). Moreover, considering the cultural complexity of Nigeria, the findings within a sub culture might not be effective when presented with other sub culture. This also restricts its generalization. Therefore, an extension of such study to include other tertiary healthcare system is advised. Moreover, the private sector of the country's healthcare system can be observed. Likewise, the lean practices observed can be increased upon to broaden the quality of decision available to policy makers.

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