INFLUENCE OF SUPPLY CHAIN PRACTICES ON HEALTHCARE SUPPLY CHAIN PERFORMANCE: A DECISION-MAKING TRIAL AND EVALUATION LABORATORY APPROACH

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Abstract

In Nigeria, as in the global space, the 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. In the bid to proffer solutions to the aforementioned challenges, this study examined the influence of supply chain practices on healthcare supply chain performance. To achieve this, the study employed a quantitative research design with the aid of Decision Making Trial and Evaluation Laboratory. Using the Lagos University Teaching Hospital (LUTH) and Lagos State University Teaching Hospital (LASUTH) as the units of analysis, the findings revealed that to improve healthcare supply chain performance, compared to other supply chain practices, the total supply chain visibility is of upmost importance followed by the flexibility sourcing which is a confirmation of the prominence of resilient practices denoted at the supply chain paradigm level.

Keywords: DEMATEL, Healthcare, Supply Chain Practices, Supply chain performance

1. INTRODUCTION

The healthcare system is a fundamental component of any nation's economy, crucial for ensuring the well-being of its citizens and economic growth (Medic West Africa, 2023). In tune with this, in Nigeria, various overlapping supply chain strategies, health insurance schemes and substantial government investments such as segmentation of supply chain network, end-to-end data visibility and analysis, and the #1.17 trillion federal government allocations in the healthcare sector in the 2023 proposed budget have been implemented to ensure universal healthcare coverage and even distribution of essential health products to the appropriate end-users, at the right place, at the right time, and the most efficient cost (Nsikan, Okon, and Uduak, 2019; Medic West Africa, 2023).

Despite this development, similarly to what is obtainable across the global south, the Nigeria healthcare supply chain has been faced with increasing risks, cost pressure, and complex governing regulations on the basis of its products' uniqueness, complexity, and cost (Rakovska & Stratieva, 2017). Hence, the system has continually experienced stock out and longer delivery times of essential medications, medical supplies, and equipment with associated supply chain risks and increased healthcare service delivery costs, among other supply chain issues (Aigbavboa & Mbohwa, 2020). Consequently, this has resulted in inefficiencies in healthcare service delivery and a significant outflow of funds on medical tourism, amounting to $1.3 billion annually (Balogun, 2020).

Thus, considering the need to balance better healthcare, lower costs, and improved care with the attainment of the United Nations (UN) Sustainable Development Goals (SDG's) of good health and wellbeing for everyone by 2030, the continuous improvement of healthcare supply chain performance by stakeholders have become more than ever before imperative and inevitable.As such, the principles and practices of supply chain management are crucial for an industry with these characteristics, as they drive operational and economic efficiency and overall sustainability (Hove-Sibanda & Pooe, 2018).

Supply chain management is the process of managing the movement of supply material, money and related information within all the involved organisationsto promote the reduction in service cost and lead time while enhancing the quality of service rendered to end-users and promoting improved workflow of stakeholders within the healthcare setting (Nsikan, Ekiens, Tarela, & Affiah, 2018). Hence, a strategically coordinated supply chain system tends to achieve efficiency such as 25% inventory cost reduction, 30% increase in on-time delivery, and nine-fold reduction in stock-out rate, in different operational areas (Nsikan, *et al.*, 2018). In view of the associated benefits ascribed to the implementation of supply chain practices, this study focused on examining supply chain practices as they influence supply chain performance within the healthcare system with the aid of Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach. Thus, the research questions are as follows:

i. How are the supply chain practices related to each other within the healthcare supply chain of Lagos University Teaching Hospital (LUTH) and Lagos State University Teaching Hospital (LASUTH)?

ii. To what extent do the supply chain practices influence healthcare supply chain performance?

2. LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Supply Chain Paradigms

Mathur, Gupta, Meena, and Dangayach (2018) defined a supply chain as a network that includes healthcare supply chain stakeholders involved in various activities and processes to ensure the efficient flow of essential medications, pharmaceutical materials, vaccines, and medical information to consumers. It is a network of functions connected by products and services rendered and delivered to end-users (Adebiyi, Adeniran, Shodiya, and Olushola, 2021). Supply chain and logistics operations are the most crucial activities within an organisation as it helps in cost minimisation, inventory reduction, and increased demand and supply visibility (Sahraeian, Bashiri, and Moghadam, 2013). Moreover, in the words of Azevedo *et al.*, (2011), organisational competitive edge is based on supply chain efficiency. Hence, as the second largest expenditure for healthcare providers, its effectiveness and efficiency are paramount to the institution's performance (Abdulsalam & Schneller, 2019).

Supply chain paradigms are a set of practices implemented along with the value system of the supply chain to improve performance and meet end-users ever-changing demands (Amole, Adebiyi, & Oyenuga, 2021). They are activities and principles implemented within the healthcare supply chains to improve the chain's and the organisation's performance (Mathur *et al.*, 2018). To this end, scholarly research has assessed various metrics, both one-dimensional and multi-dimensional, to evaluate their importance in enhancing supply chain performance (Adebanjo et al., 2016; Mathur et al., 2018; Nsikan et al., 2019; Adebiyi et al., 2021). Multi-dimensional practices are increasingly emphasized due to the uncertainties in modern business environments (Chakraborty et al., 2022). Therefore, this study focuses on determining the relative importance of integrating lean, agile, resilient, and green (LARG) supply chain practices to improve healthcare supply chain performance while balancing better services and cost efficiency.

2.1.2 Supply Chain Performance

Supply chain performance refers to the overall effectiveness (doing the right things) and efficiency (doing things right) of the supply chain (Gunasekaran, Patel, & McGaughey, 2004). Healthcare supply chain performance is the ability to efficiently deliver essential medications and equipment at the right price, source, time, and conditions to the appropriate recipients (Aryatwijuka, Kamukama, Frederick, & Rukundo, 2020). Thus, as the supply chain competes with other supply chains, supply chain and organisation performance at different levels, such as strategic, tactical, and operational organisational levels, depends on the decisions made in the business (Akbarzadeh *et al.,* 2019). Thus, a lack of performance assessment means no clue to the missing gap or organisational weakness (Gunasekaran *et al.,* 2004). The literature review highlights various metrics for evaluating supply chain performance. Adebanjo et al. (2016) assessed it through operational and financial benefits and organizational image in lean supply chain initiatives. Mathur et al. (2018) focused on effectiveness metrics such as flexibility, delivery, customer responsiveness, and time to market in Indian hospital supply chains. Nsikan et al. (2019) evaluated hospital operational efficiency in Nigeria using cost efficiency, delivery efficiency, and service level efficiency.

2.1.3 Decision-Making Trial and Evaluation Laboratory

The Decision Making Trial and Evaluation Laboratory (DEMATEL) was developed in 1972 by the Battelle Memorial Institute of Geneva Research Center as a multi-criteria decision analysis model for comparing the interaction within varying measurable attributes of a more complex decision problem (Ramesh *et al.,* 2020). Generally, its base of graph theory and matrix operation helps generate an impact relation map (IMP), which provides a clear visual influential relationship of sub-attributes (Tang, 2018). Moreover, it helps determine the degree of interrelation and interaction amid varying sub-features of observed variables (Huang *et al.,* 2022)**.** Given this, DEMATEL has been applied in addressing several highly complicated societal and business decision problems, such as the assessment of inbound supply risk, leadership competencies, and supplier quality performance, among others (Ramesh *et al.*, 2020; Tang, 2018; Hu, Chiu, Yen, & Cheng, 2015), in examining the causal relationship among measuring variables for optimal decision making.

2.2 Theoretical Review

The study was underpinned by resource-based theory owing to its extensive importance to the study:

2.2.1 Resource-Based Theory

The resource-based view (RBV) theory, introduced by Barney in 1991, is a management philosophy that organizations have employed over the past three decades. It emphasizes maximizing the utilization of an institution's inherent capabilities and resources to achieve its stated goals and objectives. Thus, as supply chains compete based on their unique strategic capabilities (Azevedo et al., 2011; Chakraborty et al., 2022). Lean, agile, resilient, and green (LARG) supply chain practices are regarded as intangible strategic capabilities that organizations leverage to enhance both supply chain and organizational performance. As intangible capabilities, these practices are valuable, rare, inimitable, and non-substitutable, enabling organizations whether in manufacturing or services to achieve a sustainable competitive advantage and improve overall performance.

2.3 Empirical Review

Adebanjo, Laosirihongthong, and Samaranayake (2016) examined the perceptions of healthcare experts on the prioritisation of healthcare performance measures and their relationship with lean supply chain management (LSCM) practices. Using Fuzzy Q-sort method and analytical hierarchy process at the proposed two phases of research design, the findings of the study revealed that the LSCM continuous improvement dimension possessed the highest dominating influence on healthcare operational and financial performance while, organisational image and operational performance can be simultaneously enhanced by enterprise alignment/integration. However, to encourage LSCM implementation in healthcare management, customer needs and the influence of competitors' actions need to be highly examined.

Mathur, Gupta, Meena, and Dangayach (2018) assessed the relationship between supply chain practices and supply chain performance and organisational performance among Indian healthcare industry. The study using structured questionnaires and SPSS analysis found a significant positive relationship between supply chain practices and performance, which impacts the organizational performance of India's healthcare industry. Additionally, supplier integration, mediated by supply chain performance, plays a crucial role in enhancing organizational performance.

Nsikan, Okon, and Uduak (2019) conducted a study on supply chain functions in Nigerian public hospitals, aiming to enhance efficiency through various supply chain management (SCM) practices. The research employed a survey design to define the study population, selecting 293 participants from 18 public hospitals in Nigeria's southern geopolitical zone using a multistage sampling method. The study's findings revealed that operational efficiency is significantly and positively impacted by three key practices: strategic supplier partnerships, supplier selection decisions, and the integration of information and communication technologies among supply chain partners. In conclusion, pursuing operational efficiency through effective supply chain management is recognized as a strategic path that all organizations should adopt.

Adebiyi, Adediran, Shodiya, and Olusola (2021) conducted a study examining the impact of supply chain management (SCM) activities on the performance of manufacturing firms. Data were collected using a well-structured questionnaire administered to 227 professionals from five selected manufacturing firms in Lagos. The data were analyzed using structural equation modeling

(SEM), revealing that strategic partnerships significantly and positively affect consumer satisfaction in manufacturing firms. Additionally, the findings indicate that greater adoption, application, and improvement of SCM practices directly enhance the performance of manufacturing companies.

Chakraborty, Sashikala, and Roy (2022) explored the relationship between green and agile supply chain practices and patient satisfaction in India's healthcare sector, with service care delivery as a mediating variable. Using a survey-based research design and structural equation modeling, the study found a significant relationship between integrated green and agile supply chain practices and patient satisfaction, strongly mediated by the quality of healthcare service delivery. Additionally, a positive relationship was observed between care service delivery and patient satisfaction. The study concludes that patient care service delivery serves as a mediator between supply chain practices and outcomes, emphasizing the importance of implementing upstream practices.

3. Methods

The study employed a quantitative and survey-based research approach grounded in positivism theory. A cross-sectional survey, utilizing DEMATEL-structured questionnaires, was conducted to address the research question (Huang et al., 2022; Ramesh *et al.,* 2020). Seventy-five out of 92 supply chain experts responsible for administering essential medical supplies and equipment within two teaching hospitals in Lagos State (LUTH and LASUTH) were selected through a multi-stage sampling technique. This technique combined quota sampling and proportional allocation to ensure representative generalization across expert designations.

Data collection was facilitated using measurement variables adapted from established literature, with two items for each LARG practice (Akbarzadeh et al., 2019; Borges et al., 2019; Farias et al., 2019; Al-Refaie et al., 2020). Structured DEMATEL questionnaires employed pairwise comparisons based on a 5-point Likert scale (0–4, denoting "no influence" to "very high influence") to identify cause-effect relationships among elements and criteria.

The analysis was conducted using Microsoft Excel Solver, following the DEMATEL procedure, to achieve the study's objectives.

Step 1: Define the objective, criteria, sub-criteria, and alternatives of the evaluation model: Based on the evaluated supply chain practices, the selected practices were used to form the alternatives for the DEMATEL model.

Step 2: Construction of direct-relation matrix using DEMATEL: Following the development of the DEMATEL model, decision-makers were tasked with conducting pairwise comparisons of the criteria based on their influence and direction. A 5-point Likert scale, ranging from no influence (0) to very high influence (4), was used for comparisons (Huang et al., 2022). These evaluations were used to construct an n × n direct-relation matrix P, where p_{ij} represents the degree to which criterion i affects criterion j.

$$p_{ij} = \frac{1}{h}\left(E_1 + E_2 + E_3 + \cdots \cdots + E_n\right) \tag{1}$$

Where h is the total number of experts and $E_{1\ldots n}$ are supply chain experts

$$P = \begin{bmatrix} 0 & \cdots & p_{n1} \\ \vdots & \ddots & \vdots \\ p_{1n} & \ldots & 0 \end{bmatrix}$$

Step 3: Normalize the direct-relation matrix: Once the unified direct-relation matrix P was derived, the newly obtained matrix was used to calculate the normalized direct relation matrix Q, using the formulae (2) and (3).

$$Q = \frac{1}{s} * P \tag{2}$$

$$s = max\left\{max \sum_{j=1}^{n} p_{ij}, \sum_{i=1}^{n} p_{ij}\right\} \tag{3}$$

Step 4: Calculate the total-relation matrix: Once Q, the normalized direct-relation matrix, was obtained, the following formula (5) was used to compute the total-relation matrix T, in which I is the identity matrix.

$$T = Q \times (I - Q)^{-1} \tag{4}$$

Step 5: Calculate the centrality degree and the cause and effect degree: Based on matrix T, the sum of the row values and column values are computed as indicated in the formulae (5) – (6) and denoted by U and V respectively. Afterward, the value of $U+V$ and $U-V$ depicting the centrality degree and cause and effect degree is computed.

$$U = \sum_{j=1}^{n} T_{ij} \tag{5}$$

$$V = \sum_{i=1}^{n} T_{ij} \tag{6}$$

Step 6: Set a threshold value and construct the impact digraph map: To create an appropriate diagram, decision-makers must establish a threshold value, 'g', for influence levels. When the influence level in matrix T exceeds this threshold, it is used to create an impact-digraph map. This map is derived by plotting data points based on ($U+V$, $U-V$), where the horizontal axis represents $U+V$ and the vertical axis represents $U-V$.

4. Results

Seventy-five questionnaires were distributed to supply chain practitioners with expertise in operations, procurement, storage, and distribution of medical supplies within Lagos University Teaching Hospital (LUTH) and Lagos State University Teaching Hospital (LASUTH) in Nigeria. Of these, 50 were returned (66.7% response rate), with 40 (53.3% of the total) properly completed and valid for analysis.

Table 1: Expert Profile

	Expert Designation		Industrial Experience			Professional Body Membership	
	Procurement	Store	Below 10	11-20	21 and above	Yes	No
Freq	12	28	13	20	7	21	19
PCT (%)	30	70	32.5	50	17.5	52.5	47.5

Source: Field, 2023

Following the analytical procedure of DEMATEL methodology, the study results are discussed.

Data analysis by DEMATEL process

Step 1: Identify supply chain practices as related to the study: The evaluation model contains 4 supply chain paradigms namely; lean, agile, resilient, and green. The lean paradigm comprised of vendor managed inventory (SP1) and 5S (SP2); the agile paradigms were proxied by rapid response to special demands (SP3), use of information technology in integrating activities within the hospital (SP4), while, the resilient paradigm was measured by flexible sourcing (SP5) and total supply chain visibility (SP6). Whereas, the green paradigm comprised of environmental emission control (SP7) and prequalification of suppliers (SP8).

Step 2: Generate the Direct Influence Matrix

To this effect, Table 2 presents the unified direct relation that a particular dimension has on the other and vice versa.

Step 3: Normalization of the direct influence matrix (NRM)

On the basis of the direct-influence matrix, represented as P, the normalized direct-relation matrix (Q) was acquired through equations (2) and (3). Thus, the NRM for supply chain paradigm is shown in Table 2.

Step 4: Creating the total-influence matrix.

After the normalization of the direct-influence matrices, the total influence matrix denoted as T was obtained based on equation (4). To this effect, Tables 2 and 3 displayed the total-influence matrix on dimensions and factors.

Table 2: DEMATEL analysis at the Supply Chain Paradigm

Supply Chain Paradigm	**Direct Relation Matrix (P)**				**Normalized Direct Relation Matrix (Q)**				**Total Relation Matrix (T_c)**			
	L	A	R	G	L	A	R	G	L	A	R	G
Lean (L)	0.44	0.34	0.35	0.34	0.00	0.04	0.04	0.04	3.44	3.53	3.68	3.61
Agile (A)	0.33	0.42	0.34	0.33	0.03	0.00	0.04	0.03	3.47	3.10	3.48	3.38
Resilient (R)	0.36	0.33	0.45	0.35	0.04	0.04	0.00	0.04	3.75	3.56	3.46	3.64
Green (G)	0.32	0.30	0.31	0.40	0.03	0.03	0.03	0.00	3.21	3.07	3.17	2.92

Table 3: The Total Relations Matrix (T_e) for Supply Chain Practices

Supply Chain Practices	**SP1**	**SP2**	**SP3**	**SP4**	**SP5**	**SP6**	**SP7**	**SP8**
Vendor Managed Inventory (SP1)	0.833	0.848	0.823	0.883	0.841	0.842	0.740	0.867
5S (SP2)	0.726	0.767	0.737	0.794	0.770	0.732	0.757	0.678
Rapid Response to Special Demands (SP3)	0.705	0.838	0.821	0.896	0.813	0.811	0.850	0.864
Usage of Information Technology (SP4)	0.746	0.664	0.733	0.800	0.762	0.765	0.768	0.792
Flexible Sourcing (SP5)	0.883	0.902	0.880	0.955	0.780	0.905	0.919	0.945
Total Supply Chain Visibility (SP6)	0.915	0.939	0.907	0.968	0.923	0.798	0.947	0.971
Environmental Emission Control (SP7)	0.739	0.750	0.634	0.787	0.739	0.747	0.749	0.770
Pre-qualification of Suppliers (SP8)	0.760	0.779	0.780	0.718	0.784	0.790	0.799	0.816

Step 5: Calculate the centrality degree and the cause and effect degree: Afterward, the sum of values in the row and column of the total-relation matrix $T_c$and $T_e$is determined (see Table 4).

Table 4: Row-sum, Column-sum, Centrality degrees, and Cause degrees of Supply Chain Paradigm and Practices

Supply Chain Paradigm and Practices	$\boldsymbol{U_i}$	$\boldsymbol{V_j}$	**Centrality Degree**	**Cause Degree**
Lean (L)	14.264	13.873	28.137	0.392
Vendor Managed Inventory (SP1)	6.677	6.530	13.207	0.148
5S (SP2)	5.962	6.486	12.666	- 0.742
Agile (A)	13.432	13.269	26.702	0.163
Rapid Response to Special Demands (SP3)	6.599	6.308	12.906	0.291
Usage of Information Technology (SP4)	6.032	6.486	12.518	- 0.455
Resilient (R)	14.405	13.795	28.201	0.610

Flexible Sourcing (SP5)	7.170	6.412	13.582	0.758
Total Supply Chain Visibility (SP6)	7.367	6.390	13.757	0.978
Green (G)	12.376	13.540	25.917	- 1.164
Environmental Emission Control (SP7)	5.914	6.316	12.230	- 0.403
Pre-qualification of Suppliers (SP8)	6.226	6.801	13.027	- 0.575

The centrality degree analysis at the paradigm level (Table 4) showed that the Resilient (R) paradigm has the highest centrality degree (28.201) and the strongest influence (cause degree: 0.610), with three output connections to other dimensions (see Figure 2). The Lean (L) paradigm follows with a centrality degree of 28.137. The Green (G) paradigm, with the lowest cause degree (-1.164), is the most influenced. At the factor level, the top three supply chain practices with the highest centrality degrees are total supply chain visibility (SP6) (13.757), flexible sourcing (SP5) (13.582), and vendor-managed inventory (SP1) (13.207). On the basis of cause-and-effect degree, four of the practices are cause factors (SP1, SP3, SP5, and SP6) of which SP6 was the most influential factor. Whereas, 5S (SP2) has the lowest cause degree of -0.742 making it the most influenced factor followed by Pre-qualification of Suppliers (SP8) with an influenced value of – 0.575.

Step 6: Determining a threshold value and creating the total impact-relations map.

A threshold value '*g*' is calculated as the arithmetic mean of the T matrix values, with 3.4049 at the paradigm level and 0.8117 at the factor level. Dimensions or factors exceeding the threshold are represented with arrows in a causal diagram (IRM), indicating significant influence, while those below the threshold are shown without arrows, reflecting minimal impact. The IRM visually highlights causal relationships and the extent of influence between factors, aiding decision-makers in understanding these dynamics (Tang, 2018).

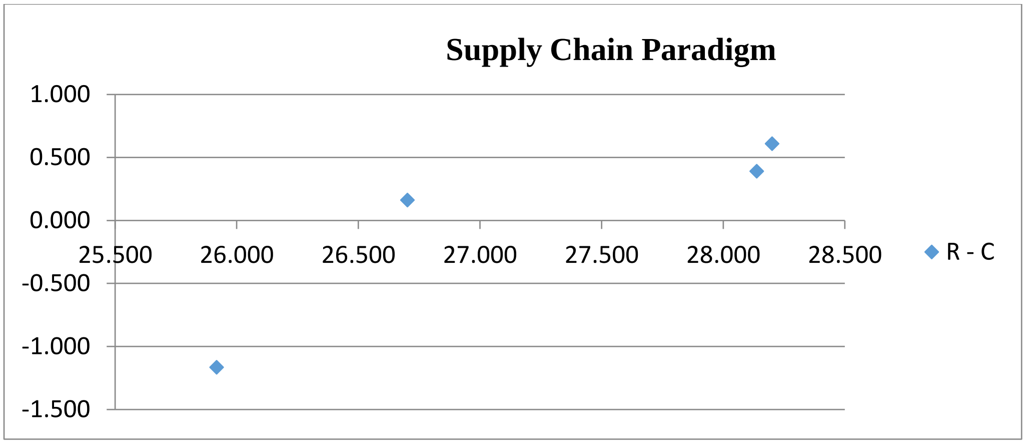

Figure 1: The Impact Relation Map for Supply Chain Paradigm

Figure 1 depicts that the resilient paradigm has 3 strong connections with other dimensions of supply chain practices followed by lean paradigm which possessed 2 strong connections with agile and green paradigms. However, there is a feedback relationship between lean paradigm and agile paradigm, and lean paradigm and resilient paradigm.

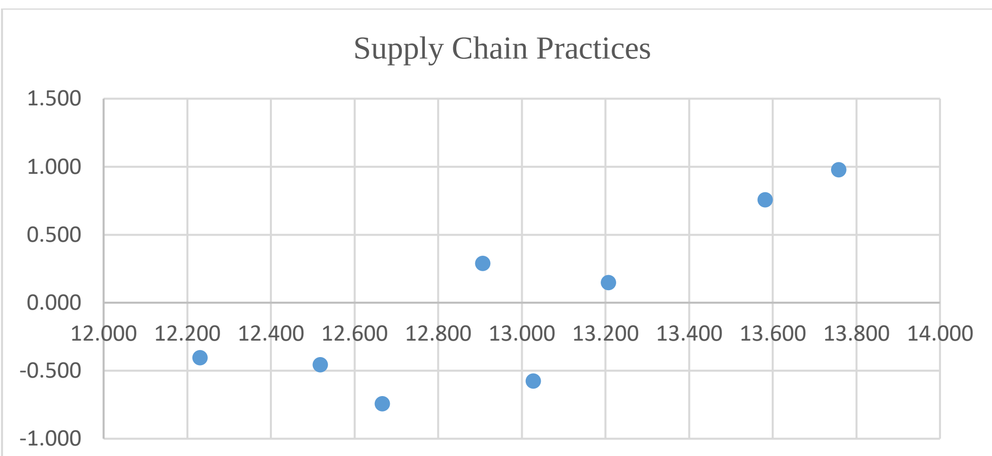

Figure 2: The Impact Relation Map for Supply Chain Practices

5. Discussion

The study employed multi-criteria decision-making model for the assessment of the influence of supply chain practices on healthcare supply chain performance using teaching hospitals in Lagos as units of analysis. In tune with the proposed research design, data analysis findings depict that supply chain experts agreed that among the supply chain paradigm, the resilient practices having flexible sourcing and total supply chain visibility practices as its practices possessed the largest centrality degree of 28.20, followed by the lean supply chain paradigm with the second largest centrality degree of 28.14. This explains that they have relatively stronger connections with the other dimensions. Thus, they are prominent, and implementing other supply chain paradigms is subject to their implementation and successful impacts. Likewise, regarding the causal relationship, the resilient supply chain paradigm, possessing the highest cause degree (0.6097), represents the most influential measured supply chain paradigm, casting three output connections with other paradigms. The Green Supply Chain paradigm, with the lowest cause degree (-1.1643), is the most influenced and the least dominant supply chain paradigm. This is consistent with the findings of Cabral *et al.* (2012) and Akbarzadeh *et al.* (2019).

At the factor level (supply chain practices), the centrality degree analysis results revealed that among the eight examined supply chain practices, four practices, which are total supply chain visibility (13.757), flexible sourcing (13.582), vendor managed inventory (13.207), and pre-qualification of suppliers (13.027), express relatively higher connections with other factors in the ranking order. Altogether, four dominant supply chain practices are prominent to the functioning of the supply chain system, while the remaining four practices are less dominant. Based on the cause-and-effect degree, SP6 has the most influential value of 0.978, followed by SP5, SP3, SP1 with an influential value of 0.758, 0.291, and 0.148 respectively. This is in consonant with Akbarzadeh *et al.*, (2019) findings where Vendor Inventory Management (SP1) was found to be a cause factor. 5S has the lowest cause degree of -0.742, making it the most influenced factor, followed by pre-qualification of suppliers (SP8), with an influenced value of -0.575. Altogether, four cause supply chain practices are influential factors, while the remaining four practices are described as effect factors, that is, influenced factors or net receivers.

6. Conclusion

The need to enhance the performance of the healthcare supply chain have become more than ever before imperative and inevitable. Thus, after the holistic implementation of the DEMATEL analytical procedure in assessing the influence of supply chain practices on the supply chain performance of the healthcare supply chain, the following conclusions are made; to aid continuous improvement in healthcare supply chain performance, among the eight (8) supply chain practices, total supply chain visibility was the most dominant and influential practice followed by flexible sourcing. Thus, it can be concluded that the resilient supply chain practices are of paramount importance to the enhancement of the healthcare supply chain. This is evident in the supply chain paradigm centrality degree and cause-and-effect relationship findings. While, green paradigm and practice of pre-qualification are perceived least dominant and influential.

The study's findings are limited in generalizability due to its focus on university teaching hospitals, a subset of the tertiary healthcare system, and the cultural diversity of Nigeria. To address these limitations, expanding the study to include other tertiary healthcare systems and private sector healthcare facilities is recommended. Additionally, broadening the range of observed supply chain practices could enhance the quality of decisions available to policymakers.

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