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RESEARCH PAPER

Investigating the impact of smart supply chain technologies on operational efficiency of the fast-moving consumer goods manufacturing industry

Olufemi A. Oroye[1], Bolaji S. Hamzat[1], Peters F. Sokenu[1]

[1]Bells University of Technology Ota, Ogun State, Nigeria.

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ABSTRACT

Background: This study investigated the impact of smart supply chain and smart technology on the operational efficiency of the fast-moving consumer goods (FMCG) manufacturing industry.

Methods: A quantitative research approach was employed, and data were collected from 18 fast-moving consumer goods (FMCG) companies listed on the Nigerian Stock Exchange as of March 2024, located in Lagos and Ogun states, using a purposive sampling technique. The extent to which smart supply chain has been adopted by FMCG companies in the study area was assessed via descriptive statistics, while Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to test the proposed hypotheses.

Results: The descriptive analysis indicates that ninety-four percent (94%) of the respondents' companies have adopted the use of a smart supply chain. The PLS-SEM result indicates that all eleven proposed hypotheses were accepted. This study reveals a statistically significant positive relationship between the direct and indirect effects of smart supply chain indicators (such as intelligent supply chain and interconnected supply chain) and smart technology on firm operational performance.

Limitations of the investigation: The major limitation of this study is the small sample size; only the FMCG companies listed on the Nigerian Stock Exchange that are located in Lagos and Ogun state were considered.

Practical implications: The study provides insight into the significant influence that the adoption of smart technology and supply chain has on operational performance of FMCG companies.

Originality / Value: The study contributes to the limited literature on smart supply chain practices in emerging economies, offering empirical evidence of their influence on operational performance.

Keywords: Smart supply chain; Smart technology; Firm operational performances; Fast-moving consumer goods industry; Partial least squares structural equation model.

1 INTRODUCTION

There has been a growing interest in how information and communication technologies (ICTs) are transforming supply chain operations. This transformation can be attributed to the application of advanced technology such as Industry 4.0 (Id4.0) and Internet of Things (IoT) (Abiodun et al., 2023; Almulhim, 2021). According to Saryatmo & Sukhotu, (2021) and Zhang et al., (2023) the transformation process has made supply chain operations more resilient, adaptable, and enhanced on-spot data, which has aided operation predictability.

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This is evidence in manufacturing organisations such as the Fast-Moving Consumer Goods (FMCG) industry, where Ivanov et al., (2018) and Oyeyemi et al., (2024) argued that, in order for them to remain competitive, the introduction of agile methodology is required in their operation to ensure products align with the dynamic nature of consumers' expectations. Thus, implementation of Id4.0 and IoT-enabled technologies in manufacturing industries has led to improvement of their supply chain operational activities, resulting in product quality and market resilience (Makgabo et al., 2025; Shakur et al., 2024).

The FMCG manufacturing industry is characterized by low-cost products, short product life, fragile customer demands, and fierce competition. For such organisation, competition implies improvement in operational efficiency driven by agile and optimises supply chain operations. The deployment of smart supply chain technologies in this orgainsation and other manufacturing firms has created an edge over the conventional supply chain operations, which are characterized by weak visibility, reactive decision making, and fragmented systems. Smart supply chain (SSC) has the name implies utilised advance technologies that have reinvented supply chain operations via automation. For instance, according to Maqueira et al., (2019) the deployment of cloud-based technologies improves supply chain operations. Also, in the study of Omar et al., (2020) it was found that implementation of blockchain technologies reduces discrepancies and fraud in supply chain operations of manufacturing firms, thus improving transparency and inventory management. Scholarly discussion regarding the connection between SSC technologies and FMCG-specific issues is still limited despite the increase in the deployment of SSC technologies in the manufacturing industries (Neboh & Mbhele, 2021; Saryatmo & Sukhotu, 2021). For instance, Saryatmo & Sukhotu, (2021) observed that there are limited studies assessing the relationship between SSC technologies and FMCG performance. Also, according to Nozari et al., (2022) there is a limitation in accessing the adoption rate of SSC among the food and beverage FMCG firms. Thus, since the FMCG industry requires an agile, responsive and resilient supply chain system, there is need for an explicit knowledge of the impact of SSC technologies on their operation (Attaran, 2020; Tibokbe & Shankar, 2025).

Thus, this study examines these gaps by analysing the effect of SSC technologies on the operational efficiency of FMCG Manufacturing. The study contributes to the extant literature on Supply Chain Management (SCM) in three important ways. Firstly, we review and critically analyse fragmented studies of SSC technologies linking them with FMCG's operational efficiency. Secondly, we develop hypotheses to analyse and test how SSC technologies impact the operational efficiency of FMCGs. Thirdly; we offer important practical insights into how FMCG manufacturers can leverage emerging technologies for operational efficiency, aligning with Yang et al. (2022). The rest of this article is structured as follows: Section 2 reviews theories underpinning this study, while Section 3 discusses the empirical studies of SSC technologies and the operational efficiency of FMCGs. In Section 4, we outline the study methodology, while in Sections 5 and 6, we present the study findings and discussion, respectively, and in Section 7, we conclude this study with the implications and future research direction.

THEORETICAL FRAMEWORK

The FMCG industry is dominated by high-volume, low-margin products that often require an efficient supply chain to remain profitable and competitive. In recent years, integrating smart technologies into the supply chain system has transformed the supply chain operations, allowing for reduced cost, improved operational efficiency, and increased customer satisfaction. Importantly, the theoretical foundations of SSC and its impact on operational efficiency are grounded in different concepts such as Industry 4.0 (Zheng et al., 2018), the IoT (De Vass et al., 2018), and digital SCM (Büyükozkan & Goçer, 2018). More recently, a major theoretical foundation upon which SSC technologies have been grounded is the Industry 4.0 (Shakur et al, 2024). Industry 4.0 is premised on the integration of multiple ICT resources and systems (smart technologies) to digitalised and optimized supply chain operations (Zheng et al., 2018). The assumption is that the integration of these smart technologies (IoT, AI, blockchain, cloud-based, big data analytic) enables optimisation, visibility, agility, resilience, responsive and seamless (Büyükozkan & Goçer, 2018; De Vass et al., 2018). Industry 4.0 combines the cyber-physical and human-machine interface to transform the conventional supply chain into an SSC - driven by big data and automation, creating more robust and efficient supply chain operations ((Shakur et al., 2024).

A more conventional understanding of the theoretical foundation of SSC technologies is the Resource-Based View (RBV) (Barney, 1991). The RBV assumption is that the source of a firm's sustainable competitive advantage is its Valuable, Rare, Inimitable and Non-Substitutable (VRIN) resources (Barney, 1991). For FMCG, SSC technologies represent exploitable VRIN resources to gain and sustain a competitive edge. Compared to traditional supply chain operations, FMCG adoption and deployment of SSC technologies (VRIN) enhance resilience and efficiency, creating a sustainable competitive advantage (Lee et al., 2023). In linking supply chain theory with digital transformation, Carter et al. (2015) describe supply chain theory as the configuration of processes and technologies to optimise value. Based on this assumption, Büyükozkan and Goçer (2018) proposed a digital supply chain system whose focus is mainly on the exchange of real-time data that aids prediction and decentralized decision-making. In line with Büyükozkan and Goçer's (2018) work, Yang et al. (2021) argued that manufacturing industries' drive to adopt digital technologies in their supply chain systems is due to the thirst for resource optimization, flexibility, transparency, and responsiveness.

Despite the inherent benefits associated with smart technology adoption in the supply chain process, several impediments affect FMCGs' adoption of SSC. For example, Attaran (2020) raises interoperability issues as many legacy technologies lack compatibility with emerging technologies, thereby leading to data silos. Moreover, a robust encryption protocol is required for the deployment of SSC technologies (Neboh & Mbhele, 2021). The absence of this protocol can compromise firm data security. Similarly, operational changes in firms often encounter resistance from employees. For example, in the implementation of SSC, 60% of firms experience pushback from employees as they feel threatened by potential job displacement or skill gaps (Nasiri et al., 2020). The acquisition cost of SSC technologies can be a challenge, especially for FMCGs in developing countries, as many of these FMCGs are small and medium-sized enterprises (Ramakrishna et al., 2023). Though some of these FMCGs may be able to deploy smart technologies in their operations, a reluctant relationship between supply chain parties and the potential returns on investment in SSC technologies may impede the deployment.

Empirical and conceptual review

The nature of relationships between SSC technologies and the operational efficiency of firms has been examined empirically in prior studies. In a most recent study of FMCG, Tibokhe and Shankar (2025) reveal that FMCG that deployed SSC technologies experienced improved ability to forecast demands, optimise the management of their inventory and efficient supply chain operations. Similarly, an empirical study of FMCG by Sun et al. (2020) found that IoT-enabled supply chain resulted in improved cost savings and operational efficiency for FMCG firms through enhanced visibility and immediate monitoring. It facilitates enhanced supply chain partners' collaboration and coordination, leading to improved data process time and quick and better decision-making for FMCG (De-Vass et al., 2018). In the manufacturing sector, manufacturers who deploy SSC technologies experience enhanced operational performance with increased production efficiency and reduction in lead times (Lee et al., 2024). Also, Zheng et al (2018) found that the deployment of Industry 4.0 improves a firm's capabilities to predict and respond to market demands effectively, and enhances the management of inventory, leading to improved operational efficiency and customer satisfaction. The deployment of a digitalised supply chain in food and beverage industry- is associated positively with the visibility of supply chain operations, thereby reducing lead times and improving overall operational efficiency (Saryatmo & Sukhotu, 2021). These findings show the efficacy of SSC technologies in the operational performance of firms.

Besides, many FMCGs operational performance is hinged on integrated supply chain (Almulhim, 2021; Masa'deh et al., 2022). The problems associated with demand variability and potential disruption of the supply chain of FMCGs can be eased with the deployment of SSC technologies. For example, a high level of SSC technology integration is associated with improved operational efficiency, reduced supply chain-related costs and enhanced customer satisfaction (Masa'deh et al., 2022). Similarly, the ability of FMCGs to effectively respond to changing conditions of markets and demands is associated with the level of SSC technology integration (Liu et al., 2022), enabling improved operational performance. Critically, evidence from these empirical studies shows that deploying SSC technologies can facilitate improved operational performance of FMCGs.

In recognition of the mediating role of smart technologies (ST) and interconnected supply chain (ICSC) in the relationship between intelligent supply chain (ISC) and firm operational performance (FOP), this study conceptualised framework is as shown in Figure 1:

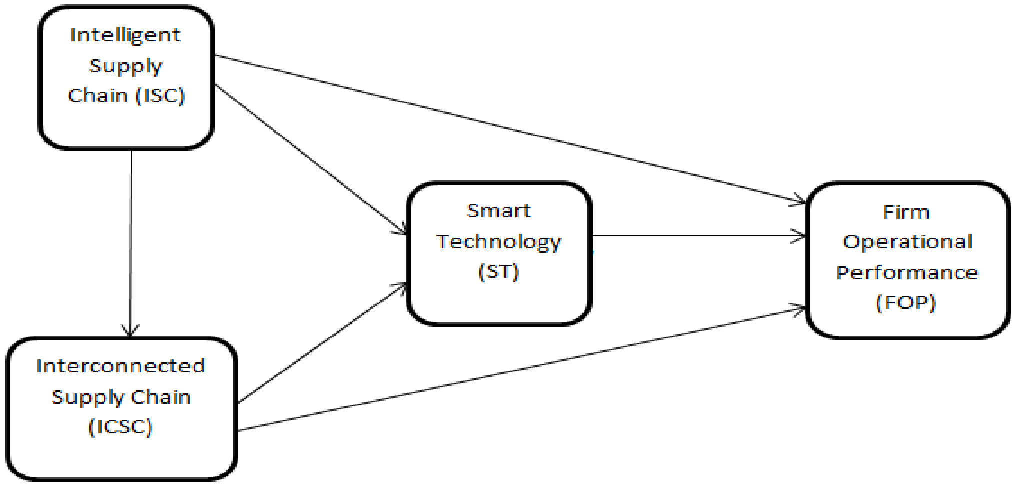

Figure 1 - Conceptual Framework

From Figure 1, ISC encapsulates the integration of smart technologies (ST) like IoT, blockchain, AI and Big data analytic into supply chain operations. These technologies, as evidence (Abiodun et al., 2023; de Vass et al., 2018), enable real-time data sharing, predictive analytics, and automated decision-making, leading to resilience and efficient supply chain. The mediating role of ST and ICSC is critical in transforming potentials ISC into tangible operational improvements. Smart Technology and ICSC do not just enhance visibility and control within the supply chain, more importantly; they foster better collaboration and coordination among supply chain partners, resulting in improved FOP (Liu et al., 2021; Nasiri et al., 2020). Based on these, the following hypotheses were developed to assess if the proposed relationships are statistically significant in the case of FMCGs industry in an emerging economy like Nigeria.

H1: There is a positive significant relationship between ISC and FOP

H2: There is a positive significant relationship between ICSC and FOP

H3: There is a positive significant relationship between ISC and ST

H4: There is a positive significant relationship between ICSC and ST.

H5: There is a positive significant relationship between ST and FOP

H6: There is a positive significant relationship between ISC and FOP with the mediating effect of ST.

H7: There is a positive significant relationship between ICSC and FOP with the mediating effect of ST.

H8: There is a positive significant relationship between ISC and ICSC

H9: There is a positive significant relationship between ISC and ST with the mediating effect of ICSC

H10: There is a positive significant relationship between ISC and FOP with the mediating effect of ICSC.

H11: There is a positive significant relationship between ISC and FOP with the mediating effect of both ICSC and ST

Using the quantitative approach, we use these hypotheses to empirically validate the mediating role of ST and ICSC in the relationship between ISC and FOP, thereby contributing to the extant body of knowledge of SSC technologies and operational performance.

METHODOLOGY

In this study, a quantitative research approach was employed. This approach ensures that data for the study is gathered through a closed-ended questionnaire. The data collection was centered on solicited perception-based insights that draw participation from key decision-makers within the FMCG manufacturing industry. The decision-makers include managers, unit heads, and supervisors collectively. This represents a robust cohort drawn from seventy-two (72) management respondents of eighteen (18) FMCGs listed on the Nigerian Stock Exchange with their headquarters or manufacturing plants situated in either/both Lagos State or Ogun State. The questionnaire is made up of three (3) sections, with section A addressing the respondents' demographic information. In Section B, the statements elicit information on the level of implementation of SSC technologies in the firms, while those in Section C elicit information on the influence of smart supply chain and smart technology factors on FMCG operational performance. The questionnaire was designed based on a Likert scale – 1 (Strongly Disagree) to 5 (Strongly Agree).To ensure the reliability and validity of the questionnaire before its administration to respondents in the study area; a pre-test was conducted with 2 academics and an industry expert to validate the content. Table 1 presents each construct's measurement statements to support the proposed conceptualised framework. The data analysis was carried out with the aid of descriptive and partial least squares structural equation model (PLS-SEM) analysis. Although the proposed SEM presents an insight into the relationships among the study variables as conceptualized in figure 1, the findings are interpreted with respect to the relatively small sample size. A small sample size can lead to parameter estimation sensitivity as well as minor variation in the data overfitting and standard error inflation (Kline 2016 and Hair et al., 2022). A common method bias was also tested by conducting Harman's single-factor test.

Table 1 - Constructs and Measurement Scale

Construct	Item Code	Item
Smart Technologies	ST1	Our communication protocols are standardized.
	ST2	We make use of every gadget that has messaging capabilities.
	ST3	We utilize gadgets that can be linked to other gadgets, identify locations, and humans.
	ST4	We make use of any gadget that has a distinct identity.
	ST5	We employ every applicable instrument/equipment that can be programmed.
Intelligent Supply Chain	ISC1	Systems are used to deliver more precise data so that decisions can be made effectively.
	ISC2	We have implemented clever procedures for organizing, locating, and shipping products.
	ISC3	We actively employ gadgets to check that goods are being handled properly.
	ISC4	We use Automated Quality Control (AQC) system.
	ISC5	We use Warehouse Management Systems (WMS)
Interconnected Supply Chain	ICSC1	We prioritize managing, integrating, and coordinating important/critical business operations throughout our supply chain.
	ICSC2	We are able to monitor businesses in real time.
	ICSC3	Standardized communication protocols are what we employ.
	ICSC4	We use Geo-coded technologies
	ICSC5	We use Electronic Commerce Technologies.
Firm Operation Performances	FOP1	In order to shorten production lead times, we employ intelligent technologies and a clever supply network.
	FOP2	We employ intelligent technologies, and intelligent supply chains to optimize resource allocation.
	FOP3	To forecast accurately, we leverage intelligent supply networks and technology.
	FOP4	We employ intelligent technology and intelligent supply chains in which both function more effectively.
	FOP5	To achieve more precise costing, we employ smart supply chain management and smart technologies.
	FOP6	To lower inventory levels, we employ smart supply chain management and smart technologies
	FOP7	In order to reduce expenses, we employ smart supply chains and smart technology.

RESULTS

Table 2 represents the survey sample socio-demographics analysis results.

Table 2 - Respondents' Demography

	Count	Percentage (N=72)
Company Ownership		
Local	8	11%
Foreign	60	83%
Joint Venture	4	6%

Company Size		
Small	0	0%
Medium	2	3%
Large	70	97%
Years of Experience		
1-5 Years	0	0%
6-10 Years	10	14%
10 Years Above	62	86%
Company Year of Operation		
1-5 Years	0	0%
6-10 Years	17	24%
10 Year Above	55	71%
Respondents Job Position		
Manager	26	37%
Unit Head	29	40%
Supervisor	16	23%

As shown in Table 2, the majority of the FMCG companies consulted are owned by foreigners, with most being large-sized and having been in operation for more than 10 years. Also, the years of experience by majority of the respondents imply that the respondents are knowledgeable in matters related to FMCG manufacturing company operation, this is collaborate by the respective job position statistic of the respondents which further qualify them as part of decision makers of their organizations.

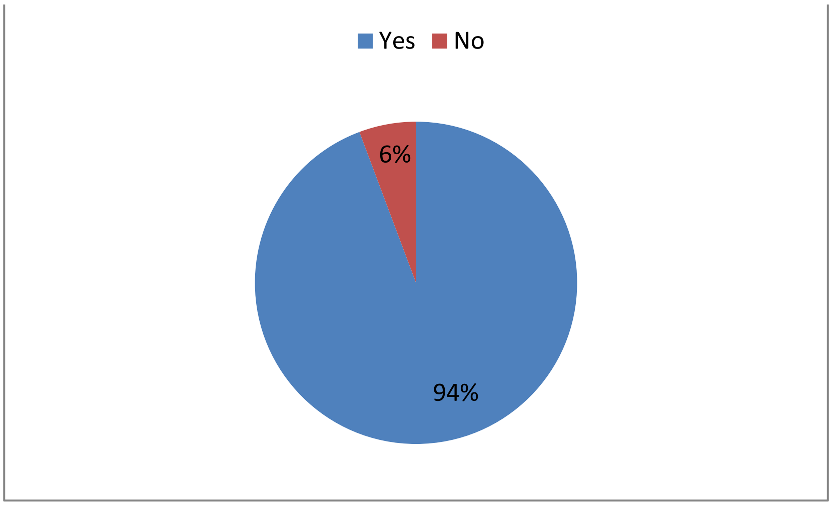

Figure 2 - Implementation of SSC technologies

Figure 2 shows the implementation rate of smart supply chain technologies. With ninety-four percent (94%) of the FMCGs in this study implementing SSC technologies in their operations, this implies that majority of the study respondents have a clear understanding of SSC technologies. Thus, the respondents are better positioned to provide reliable information on statements in Section C of the research instrument.

Convergent validity

Prior to conducting the analysis of the study, the reliability and validity of the data utilised for analysis were checked Table 3 show the result of the study convergent validity..

Table 3 - Convergent Validity

	Cronbach Alpha (α)	Rho_A	CR	AVE
FOP	0.919	0.923	0.936	0.679
ICSC	0.790	0.859	0.857	0.554
ISC	0.755	0.776	0.842	0.573
ST	0.811	0.841	0.866	0.568

In order to assess the validity and reliability of the constructs, three measures were used which are Cronbach's Alpha (α), Composite Reliability (CR) and Average Variance Extracted (AVE). Where α and CR are expected to be greater than 0.70, (Hair et al.,1998) and AVE is expected to be greater than 0.50 (Henseler et. al., 2009 and Fornell and Larcker, 1981). Both α and CR scores are higher than the recommended value as well as AVE, as indicated in Table 3, suggesting their dependability and reliability. Moreover, Rho_A is an alternative measure of internal consistency that is comparable to CR and α. In literature, such as Bonett & Wright (2015) a minimum Rho value of 0.7 is necessary to establish internal consistency of the research items/constructs. As seen in Table 3 the internal consistence is well established in this study since the entire construct variables values are all greater than the required value of 0.7.

Test for discriminant validity

To test for discriminate validity among the construct defined in the questionnaire, the following test are applied: Fornell-Lacker Criterion, and Heterotrait-Monotrait Ratio (HTMT). The results of the discriminant validity test using Fornell-Lacker Criterion that was performed on the constructs are as displayed in Table 4.

Table 4 - Fornell-Lacker Criterion

	FOP	ICSC	ISC	ST
FOP	**0.824**			
ICSC	0.773	**0.744**		
ISC	0.643	0.539	**0.757**	
ST	0.775	0.576	0.526	**0.754**

According to Hair et al. (2019), discriminant validity is proven when a construct has a higher correlation with its own measurements than with any other construct in the model. The results in Table 4 partly align with Hair et al. (2019). The following relationships, FOP and ST, as well as ISC and FOP, meet the above criterion, thus demonstrating an acceptable discriminant validity; that of ICSC and FOP, as well as ST and FOP, did not. The overlap can be attributed to the inherent interconnected nature of the constructs. In practice, activities such as information sharing, coordination, process, and strategic orientation can be jointly enacted rather than manifested individually. As such, some measurement items may capture shared underlying organizational mechanisms rather than distinct ones, making it a challenge for respondents to clearly distinguish each construct item at the measurement level. Though, the constructs are theoretically relevant, however their empirical proximity can limit the extent to which unique effects can be separated from each other. Hence, this necessitates a confirmatory test for discriminant validity using HTMT.

Table 5 - Heterotrait-Monotrait Ration (HTMT)

	FOP	ICSC	ISC	ST
FOP				
ICSC	0.861			
ISC	0.762	0.653		
ST	0.833	0.658	0.638	

The data was analyzed through the HTMT test in order to further confirm discriminatory validity; in accordance with Hensiler et al., (2015), the value of the construct association with one another should be lower than 0.90. The data in Table 5 further support the discriminating validity of the corresponding constructs.

Measurement model

According to Hair et al., (2019), factor loading between the outer models / items and their respective latent construct should be greater than 0.5. As depicted in figure 3 all the items of the respective latent construct from the independent variable SSC with indicators such as ISC and ICSC to the mediating variable ST and dependent variable FOP are in line with the recommended factor loading value as stipulated by Hair et al., (2019). Also, the result in figure 3 indicates that the coefficient of determination, R^2 for the relationship between ISC, ICSC, ST and FOP is 0.782. This implies that the effective utilization of SSC indicators (i.e. ISC and ICSC) and ST will impact predictably the FOP of the FMCGs consulted positively by 78.2%.

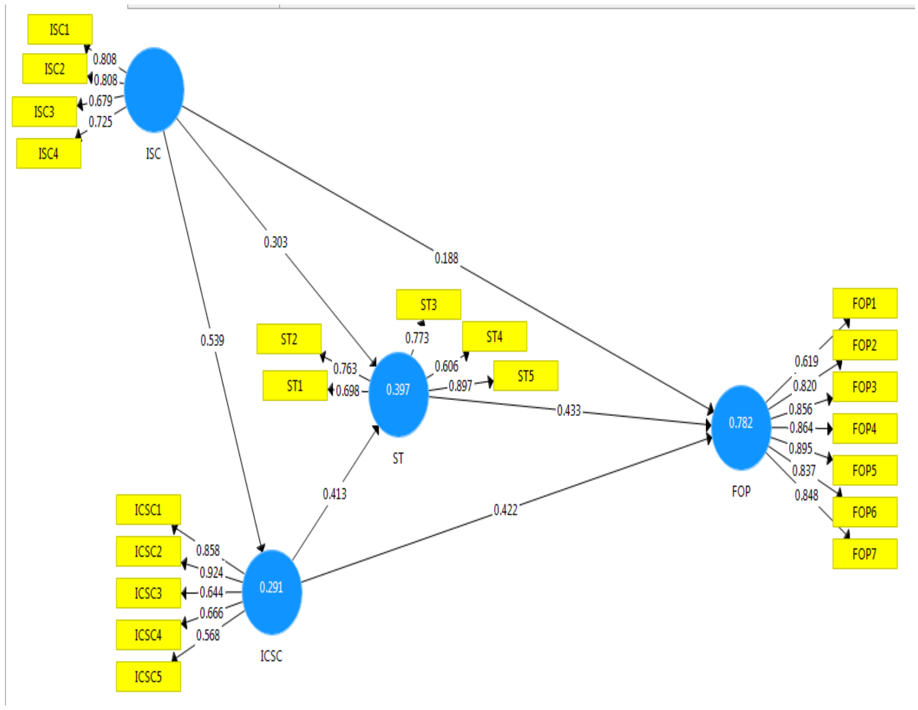

Figure 3 - Research Model with Path Coefficient and Significance

Also, the value (i.e., Stone-Geisser, also known as predictive relevance) was measured to determine the predictive power of the model. The value shows how effectively the model and its parameters can reconstruct the observed values. The blindfolding procedure was used to calculate the value in smart-pls 3; a procedure that omits a portion of the data to be analyzed and then predicts the omitted values using the model. In this study, the omission distance (D) was set to 9, within the required range of 5-12, as shown on the basic settings default page of Smart-PLS 3. Nine (9) was chosen because the dataset is small and to prevent overlapping, omission, or cyclical patterns. The results for FOP, ST, and ICSC are 0.513, 0.189, and 0.148, respectively, which fall within the recommended values by Hair et al. (2017). According to Hair et al. (2017) the required thresholds for the predictive relevance strength of value includes: $Q^2 \geq 0.02$ (i.e. a small/weak but acceptable predictive relevance), $Q^2 \geq 0.15$ (i.e., moderate predictive relevance), and $Q^2 \geq 0.35$ (i.e., large predictive relevance). Thus, it can be concluded that the study model has sufficient predictive power for the respective endogenous constructs, indicating its reliability.

Hypothesis testing

Following a thorough and methodical analysis of the respondents' responses to the research questionnaire, the hypothesis was assessed using the Smart PLS 3, Structural Equation Model. To establish the structural model (i.e. how the construct variables are related to each other), bootstrapping was carried out. Bootstrapping amplifies existing data to determine the significance of estimated path analysis. That is to determine if each of the construct variables have effect on each other.

Table 6 - Path Coefficient (Direct relationship between the constructs)

	Original Sample (O)	Sample Mean (M)	SD	T-Statistic	P-Value
ICSC → FOP	0.416	0.417	0.070	5.970	0.000
ICSC → ST	0.425	0.433	0.123	3.448	0.001
ISC → FOP	0.181	0.177	0.086	2.111	0.035
ISC → CSC	0.539	0.555	0.063	8.592	0.000
ISC → ST	0.293	0.293	0.115	2.546	0.011
ST → FOP	0.445	0.442	0.064	6.909	0.000

A t-value above 1.645 and a p-value less than 0.05 implies that the hypothesis put to test is accepted. Table 6 displays the results of the direct relationships between the variables, all of which are statistically significant, leading to acceptance of the proposed hypotheses H1, H2, H3, H4, H5, and H8.

Table 7 - Indirect Relationship of the Constructs (Mediators)

	Original Sample (O)	Sample Mean (M)	SD	T-Statistic	P-Value
ICSC → FOP	0.416	0.417	0.070	5.970	0.000
ICSC → ST	0.425	0.433	0.123	3.448	0.001
ISC → FOP	0.181	0.177	0.086	2.111	0.035
ISC → ICSC	0.539	0.555	0.063	8.592	0.000
ISC → ST	0.293	0.293	0.115	2.546	0.011
ST → FOP	0.445	0.442	0.064	6.909	0.000

Table 7 depicts the significance of the proposed hypotheses' relationship between the constructs with respect to the influence of the mediators. It was found that all the proposed hypotheses suggest a positive significant effect, thus leading to acceptance of H6, H7, H9, H10, and H11 with their respective T-values above the recommended value of 1.645 and the P-value less than 0.05.

Table 8 - Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.623	43.743	43.743	9.623	43.743	43.743
2	2.729	12.403	56.146	2.729	12.403	56.146
3	2.485	11.296	67.442	2.485	11.296	67.442
4	1.559	7.084	74.526	1.559	7.084	74.526
5	1.423	6.467	80.993	1.423	6.467	80.993
6	1.073	4.876	85.869	1.073	4.876	85.869
7	.955	4.343	90.212			
8	.567	2.577	92.789			
9	.393	1.785	94.574			
10	.320	1.456	96.030			
11	.253	1.151	97.181			
12	.171	.778	97.959			
13	.147	.670	98.629			
14	.107	.486	99.115			
15	.083	.378	99.493			
16	.050	.229	99.722			
17	.028	.128	99.850			
18	.019	.088	99.938			
19	.013	.060	99.998			
20	.000	.002	99.999			
21	.000	.001	100.000			
22	3.239E-16	1.472E-15	100.000			

To further justify the hypothesis results, a common-methods bias analysis was conducted. Based on the results in Table 8, it can be observed that no single factor accounts for the majority of the variance. The first factor, with an eigenvalue of 9.623, explains only 43.743% of the dataset's total variance, which is below the general rule of thumb that common method bias is a concern if the first factor explains more than 50% of the total variance. It is also worth noting that the consistency of the uniformly significant direct and indirect effect between the respective constructs is theoretically plausible within a highly standardised operational context of firms, such as in the FMCG manufacturing industry. They are characterized by formalized procedures, shared performance objectives, and operational efficiency; this makes the constructs to tend to co-evolve, resulting in strong systematic interrelationships which are in agreement with Cherns (2020). This aligns with theories such as socio-technical systems theory, which, according to Pasmore et al. (2019), states that organizational outcomes result from the joint optimization of social and technical subsystems. Furthermore, when data are drawn from a single industry or organisation according to George et al., (2021) respondents often share common context homogeneity which reduces random variance thus, thus strengthening construct interrelationships. In this regard, the consistencies of this study hypothesis statistical significances reflex contextual alignment rather than over fitting.

DISCUSSION

This study investigated the relationship between smart supply chain indicators (i.e., ISC and ICSC), ST, and FOP of some selected FMCG firms in Nigeria. The study found a direct positive relationship between ISC and FOP (H1 accepted). This is contrary to the findings of Lee et al., (2023); however, it is supported by Lee et al., (2024) whose study concluded that the digital supply chain has a positive association with firm operational performance. Thus, a higher level of ISC tends to coexist with a strong FOP outcome. As such, in this context, the implementation of ISC can be linked to enhanced coordination and decision-making due to information availability and analytical capabilities across the supply chain process. Also, it was found that there exists a positive, direct, and significant relationship between ICSC and FOP (H2 accepted). This aligns with the finding of Masa'deh et al., (2022), though contrary to that of Lee et al., (2023). Hence, the need for FMCG firms to creatively implement technologies and strategies that promote supply chain integration, as the association between ICSC and FOP highlights the relevance in collaborative processes, information sharing and coordinated planning as key features that accompany FOP outcomes.

The study further found a positive, significant relationship between ISC and ST (H3 accepted), a result consistent with Lee et al., (2023) findings. This reflects the close alignment between ST and ISC. Previous studies revealed that firms characterised by ST utilise technologies such as autonomous data collection, blockchain, robotics, and AI-driven prediction systems to enhance ISC management. For instance, the adoption of blockchain in manufacturing firms' supply chain is linked to a reduction in the traceability period (sensos, 2024). Likewise, the utilisation of mobile robots in factories and warehouses has been linked to the mitigation of labour costs and mistakes in manual inventory (Dominguez, 2025). AI-driven predictive activities have also been linked to improved demand forecasts and to the optimisation of factory and warehouse layouts (sensos, 2024). The study likewise finds that ICSC has direct positive impact on ST (H4 accepted), which is supported by Lee et. al., (2023) and Zhao et al., (2023). This association suggests a strong collaborative integration between ICSC and ST, which, according to Lee et al., (2023) can be linked to improved visibility, traceability and coordination in any organization, factory or warehouse.

The study also found a direct positive relationship between ST and FOP (H5 accepted), though contrary to Lee et al., (2023), but supported by Lee et al.,(2024). This implies that firms with high ST utilisation tend to report better FOP. According to Guo and XU (2021) digital transformation in manufacturing firms is highly associated with operational performance. Lastly, among the constructs with a direct link, the relationship between ISC and ICSC is found to be positively significant (H8 accepted). Both (ISC and ICSC) are essential to smart supply chain management, as they complement each other in any organization where they are implemented. With the aid of Industry 4.0 technology, the Internet of Things enables ISC to collect real-time data that can be linked to improved ICSC functionality, providing end-to-end visibility in factories and warehouses. Also, Artificial Intelligence and Machine Learning are associated with predictive analysis in ISC, which contributes to dynamic risk mitigation in ICSC. Likewise, digital twins can be linked to scenario testing in ISC, which is significantly associated with ICSC in factories to develop resilience. In addition, through horizontal and vertical integration, the concept of ISC silos can be reduced, thereby improving ICSC collaboration in manufacturing firms such as FMCG factories and warehouses.

In the case of the indirect relationships shown in Table 7, a positive relationship was found between ISC, ST, and FOP. It indicates that ST effectively mediates the influence of ISCS on FOP (H1 accepted). This was supported by Büyükozkan and Goçer (2018), Nasiri et. al., (2020), AlMulhim (2021), Saryatmo and Sukhotu (2021). It highlights the value of smart technology as a bridge between the digital/intelligent supply chain and cooperation to enhance operational effectiveness in the manufacturing industry. As such it can be concluded that the interaction between the two is mutually beneficial.

In addition, ST also mediates effectively the relationship between ICSC and FOP. The association implies that collaborative integration and firm operational performance is more pronounced in FMCG firms where STs are more prominent. This emphasizes the importance of data-driven decision-making tools and workflows that are digitally enabled in strengthening performance within the supply chain network.

As depicted in Table 7, H9 was accepted because the relationship between ISC and ST was mediated by ICSC, which is possible from the context of digital transformation and physical internet. These relationships are evidenced in multiple studies' findings, such as Ballt et al., (2021), Munch et al., (2024), Peng et al., (2024), Liu et al., (2024 and Zhao et al., (2024). Likewise, in Table 7, there is a significant positive mediating effect of ICSC on the relationship between ISC and FOP of the FMCG firms studied. This is supported by Zhao et al., (2023) whose study on 210 Chinese manufacturing firms concluded that the smart supply innovation performance of the manufacturing firms was improved by ISC association with ICSC. Thus, the mediator tends to enhance ISC influence on FOP. The association further led to improved efficiency in the firms' operational performance through digital integration, real-time visibility, and resilience

Lastly, ICS and ST have a positive, significant mediating role with respect to ISC and FOP. This implies that FMCG firms with advanced collaborative integration and ST adoption tend to show a strong association with ISC and FOP. Thus, FMCG firms with a high level of ST and ICSC have the tendency of experiencing improved FOP outcomes compared with those that have a low level of ST implementation. This is consistent with the findings of Al-Tera et al., (2024).

Robustness Check of the Model

The study robustness assessment was carried out by excluding indicators with outer loading that are less than 0.60 (i.e. ICSC5 with outer loading of 0.568 was removed) and the measurement model was re-estimated. The results demonstrate a satisfactory reliability and convergent validity as revealed in Table 9.

Table 9 - Convergent Validity of the Robustness Test

	Cronbach Alpha (α)	Rho_A	CR	AVE
FOP	0.919	0.922	0.936	0.679
ICSC	0.802	0.844	0.809	0.626
ISC	0.755	0.774	0.842	0.573
ST	0.811	0.843	0.866	0.567

However, there are changes in the direction and statistical significance of some of the structural path as revealed in Table 10.

Table 10 - Path Coefficient for Direct relationship between the constructs of the Robustness Test

	Original Sample (O)	Sample Mean (M)	SD	T-Statistic	P-Value
ICSC → FOP	0.449	0.448	0.072	6.272	0.000
ICSC → ST	0.414	0.410	0.139	2.984	0.003
ISC → FOP	0.156	0.157	0.088	1.772	0.077
ISC → ICSC	0.558	0.570	0.060	9.285	0.000
ISC → ST	0.291	0.296	0.128	2.272	0.023
ST → FOP	0.444	0.441	0.065	6.836	0.000

This implies that, the hypothesized relationships between ISC and FOP as well as ISC and ST are sensitive to variation in the indicator composition. An indication that, the effects captured in the path coefficient as revealed in Table 6 and 7 can be partially driven by these respective constructs indicators.

CONCLUSION

Conclusively, this study investigated the influence of key indicators of smart supply chain (i.e. intelligent supply chain and interconnected supply chain) and smart technology on FMCG manufacturing companies listed on Nigeria stock exchange as of May 2024 and are situated in Lagos and Ogun states. All the hypotheses tested were found to be significant. These results suggest that integration of smart supply chain indicators such as intelligent supply chain and interconnected supply chain along with smart technology will enhance the FMCG manufacturing industry to improve their operational performance. Hence, implementation of smart supply chain and smart technology should be prioritized by the FMCG manufacturing industry. This study offers significant theoretical and practical implications. From a theoretical standpoint, it extends existing ideas in Supply Chain Management, technology adoption, and organizational performance while also opening the way for new models and frameworks. By investigating these links between smart supply chain, smart technology and firm's operation performance, academics may gain a better understanding of how digital transformation creates operational excellence and competitive advantage in modern businesses. The practical implication of this study is that it provides actionable insights for FMCG manufacturing companies to transform their supply chains into intelligent, data driven system that yield operational excellence and long term sustainable growth for the organization.

This study poses some limitations that should be considered when interpreting the findings. First, one limitation is that only FMCGs registered with the Nigerian Stock Exchange, all large-scale, were considered. An indication that the sample size is relatively small for the complexity of the SEM employed. Though, the post hoc power analysis carried out suggests that the model has sufficient power to detect the relationships between the variables, it does not fully address concerns about estimation stability and model generalisation. Thus, the finding can be viewed as exploratory and theory-informed. Hence, the study provides preliminary empirical support for the proposed conceptual model. As such, future research can increase the sample size and consider small and medium-sized enterprises to assess the model's robustness. Secondly, the partial support for discriminant validity from the Fornell-Larcker test can be further examined in future research, by refining the measurement items. Also, the sensitivity of certain structural paths to the re-estimated model represents a limitation of this study. Future research can validate this study's results with larger samples and a refined measurement instrument. In addition, future studies can also extend the framework of the smart supply chain by considering more of its indicators beyond Intelligent Supply Chain and Interconnected Supply Chain, along with Smart Technology, to determine their effect on organisational operational performance.

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