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Impact of adoption challenges on sustainability outcomes in FMCG green supply chains : The role of smart technologies

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Abstract

The Fast-Moving Consumer Goods (FMCG) business in India is expanding due to government initiatives, legislation, a youthful demographic, and rising demand from rural areas driven by increased technology penetration. This study aimed to understand the challenges in adopting green supply chain management technology (GSCMT), encompassing technologies such as Blockchain, Internet of Things (IoT), Artificial Intelligence (AI), and automation for sustainable outcomes. It examined the elements influencing the adoption of GSCMT while also emphasizing the essential sustainable outcomes. To achieve the research aims, a meticulously designed questionnaire utilizing a Likert scale from 1 to 5 was developed. The questionnaire was constructed with the assistance of experts possessing practical knowledge in utilizing smart technology. Ten big corporations' HR departments were approached to gather data via stratified sample and snowball sampling methods. Descriptive analysis, factor analysis, and structural equation modelling were conducted to evaluate the determinants influencing technology uptake and sustainable outcomes. Factor analysis identified four variables accounting for 69.32% of the variation. The challenges identified were financial barrier (23.46%), technological barrier (21.03%), organizational resistance (18.89%), and regulatory barrier (5.93%).

The sustainability outcome was further analyzed. The primary discovered criteria were carbon footprint (29.21%), waste reduction (27.50%), and energy efficiency (16.30%), contributing 73.02% of total variance. The impact of adopting GSCMT on carbon footprint, waste reduction, and energy efficiency was analyzed using SEM analysis. The SEM analysis indicated that the adoption of GSCMT significantly decreases carbon footprint (β=-0.55, p=0.001), so validating hypothesis H1, facilitates waste reduction (β=-0.43, p=0.001), thereby validating hypothesis H2, and enhances energy efficiency (β=0.37, p=0.002), thereby rejecting hypothesis H3.

The managerial implication indicates that the use of GSCMT in fast-moving consumer goods (FMCG) will enhance energy efficiency while contributing to the reduction of carbon footprint and waste. Nonetheless, the current analysis is confined to businesses and technologies, which do not provide a comprehensive view of GSCMT across other sectors.

Subject Classification: *36J99.*

Keywords: *Green supply chain management technology, Energy efficiency, Waste reduction, Carbon footprint, Financial barrier.*

1. Introduction

The Fast-Moving Consumer Goods (FMCG) industry constitutes one of the largest and most dynamic areas of global trade, marked by high-volume production, swift inventory turnover, and intricate supply chain networks. In recent years, this industry has experienced rising pressure to change its operations toward more sustainable practices while retaining operational efficiency and market competitiveness. Recently, the notion of the green supply chain has arisen in response to increasing customer

demand for environmentally sustainable products. The green supply chain encompasses environmental awareness in business and ensures the sustainable growth of industries. Consequently, several initiatives have been implemented by governments and organizations to tackle this issue [1]. This include the enforcement of environmental regulations, the utilization of sustainable raw materials, the reduction of fossil fuel and petroleum consumption, the recycling of paper, and the repurposing of trash inside businesses. The successful integration and realization of sustainable concepts in supply chain operations render their potential rather obscure. Consequently, the actions and outputs of the green supply chain are subject to varying levels of risk [2]. For this reason, precise management and knowledge of the green supply chain is of fundamental significance and it will be required to focus on defining relevant duties and strategies that are beneficial in effectively implementing the green supply chain.

Enhancing energy efficiency across the product life cycle has emerged as a critical concern for enterprises [3]. Given the significance of the topic and the necessity to enhance knowledge of technologies utilized in the manufacture and distribution of goods, alongside the critical role of products in the FMCG sector, it is essential to implement sustainable practices within the supply chain. The FMCG sector is universally acknowledged as a crucial business that fulfill a substantial volume of everyday human need, engaging consumers regardless of age, gender, or geographical borders. The FMCG sector primarily include processed foods, prepared meals, drinks, fresh or frozen and dry foods, pharmaceuticals, cosmetic items, and other perishable goods. The industry's scale allows for a more sustainable supply chain, facilitating sustainable development and compliance with environmental regulations. Consequently, green supply chain managers at prominent firms in the FMCG sector endeavor to implement green logistics by utilizing technologies to enhance their environmental performance across the supply chain as a strategic tool for achieving competitive advantage [4].

A study by [5], found that the FMCG firms are able to able to enhance their supply chain with the help of breakthrough technologies particularly the blockchain, bigdata, IOT and digital twins, making them more sustainable and performance driven. [6] in the context of sustainable performance found that an advancing framework is needed for monitoring and evaluating sustainable performance, & to balance social, economical and environmental goals.

The adoption and implementation of a swift supply chain in FMCG is intricate due to industry specific consideration and resource constraints [7]. Further, the legislative mandate is diverse across region affecting adoption and implementation [8]. In addition, they also found that environmental repercussion alongside sustainability sustainability accomplishment becomes difficult to accomplish. Hence, the research is aimed to comprehend the challenges associated with the adoption of technology & its impact on sustainable outcomes.

2. Literature Review

A detailed literature review is being done to comprehend each component of FMCG.

2.1 *FMCG Industry*

FMCG refers to all those commodites which are generally non-durable and are sold to consumer at a low-cost, low-profit margin [9]. India's FMCG sector is growing as a result of consumer-driven growth, advantageous government policies, a young population, and a growing rural market [10]. According to the [11], the FMCG business is projected to increase between 4.5% and 6%, with the market size anticipated to reach US $470 billion by 2028. The Indian FMCG sector is primarily led by HUL, ITC, P&G, and Patanjali, with substantial backing from e-commerce enterprises. A [12] survey indicated that 60% of FMCG firms see e-commerce as their paramount sales platform [13]. As many individuals purchase FMCG products through technology, there is escalating demand on retailers to manage costs and enhance service [14]. Currently, e-retailers are persistently striving to enhance customer service by minimizing environmental effect and employing GSCM tools and strategies to ensure items reach their destinations. Consequently, the FMCG business has selected GSCMT as an alternative transportation option, utilizing IoT, BCT, and Big Data to enhance customer experience and save operational costs [15]. Therefore, GSCMT is especially pertinent to FMCG, and comprehending its limitations may provide sustained advantages.

2.2 *GSCM & Technology*

In the 21st century, Green Supply Chain Management Technology (GSCMT) is progressively acquiring importance due to environmental concerns and regulatory pressures [16]. Integrating environmental

management techniques throughout the whole supply chain is essential for achieving a sustainable supply chain and sustaining competitive advantage [17].

Multiple definitions of Green Supply Chain Management (GSCM) are present in the literature.[18] describe Green Supply Chain Management (GSCM) as encompassing green buying and integrated supply chains that extend from suppliers to manufacturers to customers, including reverse logistics, therefore "closing the loop." [19] defines Green Supply Chain Management (GSCM) as the incorporation of environmental considerations into supply chain management, encompassing product design, material sourcing and selection, manufacturing processes, delivery of the final product to consumers, and end-of-life management of the product post-utilization.

GSCMT incorporates digital solutions such as IoT, Blockchain, AI, and Big Data to enhance supply chain processes through real-time monitoring, tracking, predictive analysis, and trend analysis, hence improving resource usage and minimizing environmental effect [20]. The function of BCT is to assist FMCG firms in expanding, tracking, lowering carbon emissions, and mitigating counterfeit risk [21]. Likewise, the function of AI in GSCMT is to assist firms with demand forecasting, minimizing waste, managing inventory, and enhancing sustainability [22-23]. A comparable research by [24] revealed that IoT in GSCMT facilitates real-time monitoring, tracking of commodities, enhances operational efficiency, and reduces environmental effect [25].

2.3 *Challenges in adoption of GSCMT*

Several studies have been conducted to better understand the challenges of using GSCMT in the FMCG industry. [26] discovered that cost is the most important element in the adoption of GSCMT, whereas [27] discovered regulatory hurdles. Other studies [28-29], discovered that differing organizational needs influence the adoption of supply chain integration. [26] and [34] investigated how the deployment of Green Supply Chain Management (GSCM) often requires a significant investment, discouraging many organizations from adopting. As a result, they struggle to reconcile costs with sustainability objectives, leading to a reluctance to use GSCM tactics in their businesses.

Similarly, weak legislative frameworks and regulatory backing have a significant impact on the implementation of GSCM systems in any country [27] [29], discovered that the lack of defined norms and governmental

incentives impedes the transition to environmentally sustainable supply chains. [28] found that firms struggle to adopt GSCMT due to limited workforce knowledge and competency, which complicates the transition, as well as internal resistance to change and a lack of management support and policies [27].

Despite the numerous challenges associated with the adoption of Green Supply Chain Management Technology (GSCMT), certain organizations and sectors are beginning to recognize its potential advantages, including sustainable outcomes related to brand reputation [30], customer loyalty [29], cost reduction [31], waste minimization [32], and enhanced energy efficiency [33].

2.4 *Sustainable Outcome*

Several sectors recognize GSCMT's significant benefits in cost reduction, energy efficiency, and waste minimization. The combination of technology, notably AI, blockchain technology, and big data, improves supply chain transparency [34] by optimizing routing and inventory management using data analytics and machine learning. Additionally, using electric vehicles and renewable energy reduces carbon emissions and operational expenses [35-36]. According to [37] research, technology integration in Green Supply Chain Management (GSCM) enables Fast-Moving Consumer Goods (FMCG) companies to maintain strong vendor connections while saving up to 3.59% over traditional techniques [38].

[39] investigated waste reduction by GSCMT and discovered that AI, BCT, Big Data, and machine learning improve resource management among supply chain stakeholders, which has the potential to minimize waste output. Another study by [32] and [40] looked at how technology adoption helps firms improve data-driven decision-making, hence minimizing overproduction and aligning with a circular economy. Nonetheless, the biggest impediment is the significant upfront cost [41]. Furthermore, waste reduction activities conserve resources and reduce energy consumption throughout production and disposal processes [42]. These measures improve sustainability while also providing cost savings and operational efficiency, highlighting the importance of GSCM in promoting energy conservation in the FMCG industry.

Furthermore, [43] energy efficiency research showed that sustainable sourcing reduces the production and transportation of energy-intensive

commodities, and optimized logistics reduce fuel consumption and carbon emissions [44].

As a result, firms that apply GSCM strategies achieve a balance between economic performance and environmental sustainability, ensuring long-term competitiveness and regulatory compliance [45]. Figure 1 shows a conceptual framework for testing the hypothesis.

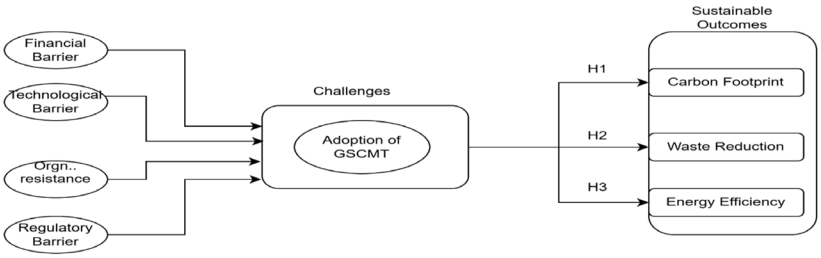


Figure 1

Conceptual Framework

Objectives

- To analyse the role of smart technologies (IoT, AI, blockchain, automation) in optimizing sustainability practices within the FMCG supply chain.
- To evaluate the challenges associated with adopting smart technologies for green supply chain management in FMCG companies.
- To assess the direct impact of adoption challenges on sustainability outcomes (carbon footprint reduction, waste reduction, energy efficiency.

Hypothesis:

H_1: Adoption of GSCMT negatively impact Carbon Footprint Reduction.

H_2: Adoption of GSCMT negatively impact Waste Reduction.

H_3: Adoption of GSCMT negatively impact Energy Efficiency

3. Research Methodology

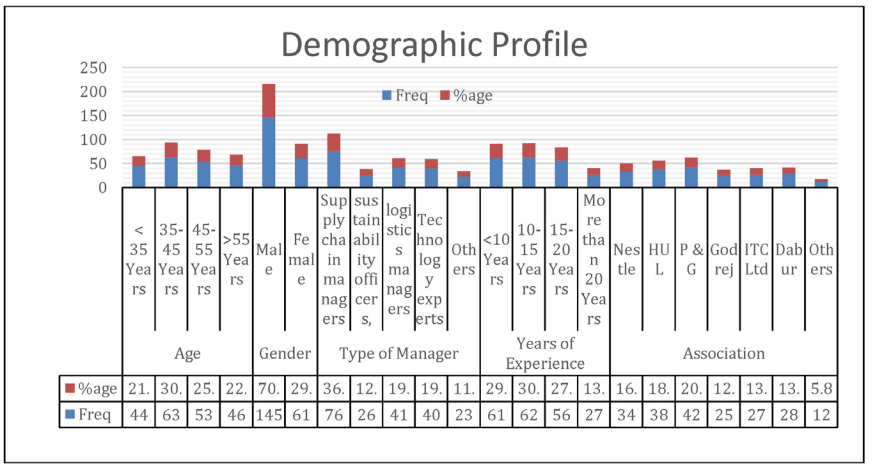
The present study used survey research to accomplish the objectives of our study. With the help of experts from industry and practitioners in the FMCG industry, data were collected from different respondents in

Delhi-NCR. For this stratified sampling & snow-ball sampling technique was used to collect data from 211 respondents in a Likert scale ranging from 1-5 [46]. All these respondents were professionals and have experienced with GSCM technologies like IOT, AI, Blockchain etc and also have clear understanding about sustainability outcome. Hence the respondents were carefully picked and fall as supply chain manager, sustainability officers, logistics manager and technology experts. Furthermore, data for sustainability outcome was also collected to understand the key role of technology on sustainable outcome. Hence to analyse the data, descriptive analysis, factor analysis and SEM was performed using SPSS-25 & AMOS to assess the factors that affect the adoption of GSCMT in FMCG industry and also to assess the sustainability outcome. Additionally, the hypothesis associated with the adoption of GSCMT on sustainable outcome was assessed.

4. Data Analysis

4.1 *Profile of the Respondents*

Figure 2 presents the demographic profile of respondents, providing insights into the professionals involved in the FMCG sector and in GSCM. The research indicated that the bulk of respondents (30.58%) belong to the 35-45 years age group, followed by 25.73% in the 45-55 years category,



Source: Authors Analysis

Figure 2

Profile of the Respondents

suggesting a sample with substantial experience. The gender breakdown indicated a predominance of male responses (70.39%), demonstrating industry patterns. Regarding job experience, 30.10% of respondents possess 10-15 years of experience, indicating a mix of mid-career and seasoned workers. The participants consist of supply chain managers (36.89%), logistics managers (19.90%), technology specialists (19.42%), and sustainability officers (12.62%), illustrating a variety of positions within supply chain operations.

Participants are affiliated with prominent FMCG businesses, such as Procter & Gamble (20.39%), HUL (18.45%), Nestlé (16.50%), and Godrej (12.14%), therefore providing a comprehensive industry viewpoint. This demographic distribution increases the study's significance by including perspectives from professionals engaged in the adoption and implementation of GSCM technology[47].

4.2 *Factor Analysis*

To understand the key factors responsible for the adoption of GSCM technology in FMCG industry, 14items for adoption and 10 items for sustainable outcome were being considered separately. Initially, the communalities test was performed to assess the relationship between the items to test whether all the items were deemed fit or not for factor analysis[48]. Further, KMO and Bartlett Test of sphericity was performed. The KMO value was found to be 0.832,0.879 & Bartlett test of sphericity was significant. Hence, the data is now deemed fit for factor analysis.

Table 1

Percentage of variance explained by factors as challenges in the adoption of GSCMT

Total Variance Explained- Challenges						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.223	23.463	23.463	4.223	23.463	23.463
2	3.786	21.033	44.496	3.786	21.033	44.496
3	3.401	18.894	63.390	3.401	18.894	63.390
4	1.069	5.936	69.326	1.069	5.936	69.326

Extraction Method: Principal Component Analysis.

Factor analysis using SPSS-25 revealed 4 factors contributing 69.32% of variance in the adoption of GSCM technology and 66.24% of variance for sustainable outcomes[49]. The result of the factor analysis of the adoption and sustainable outcome is shown in Table1 – Table 4.

Table 2

Factor Loading – challenges

Component Matrix[a]					
Items-Description	**Item Code**	**Component**			
		1	**2**	**3**	**4**
Organizations resist GSCMT implementation due to high initial investment expenses.	FB1	0.87			
Organization struggles to implement GSCM without financial incentives or government subsidies.	FB2	0.88			
Sustainable technology integration into supply chain processes is difficult to fund.	FB3	0.75			
The long payback period of GSCMT investments deters organizations from implementing IoT, Blockchain, Big data renewable energy systems, AI, RFID, etc.	FB4	0.82			
Organizations struggle to use GSCMT due to outdated technology.	TB1		0.92		
Organization struggles to integrate GSCMT with existing supply chain systems.	TB2		0.91		
Organization struggles to adopt Green Supply Chain Management Technology due to its complexity.	TB3		0.79		
Without competent staff and technical skills, organizations cannot deploy GSCMT.	TB4		0.83		
Organization's resistance to change inhibits GSCMT adoption.	OR1			0.88	
Lack of senior management support hinders GSCMT implementation in our company.	OR2			0.92	
Employees are hesitant to adopt GSCMT owing to job security and workload issues.	OR3			0.89	
Organization struggles to accept GSCMT due to unclear regulatory rules.	RB1				0.93
The lack of stringent environmental rules and enforcement prevents organization from using GSCMT.	RB2				0.92
Environmental rules raise business expenses, making GSCMT adoption difficult.	RB3				0.91
Extraction Method: Principal Component Analysis.					
a. 4 components extracted.					

Principal component analysis with SPSS-25 was conducted to evaluate the factors influencing the adoption issues of GSCMT. The research revealed four factors accounting for 69.32% of the overall variation. The identified challenges include financial consequences (23.46%), technological barriers (21.03%), organizational resistance (18.89%), and regulatory barriers (5.93%) leading to variation. All factors had Eigenvalues exceeding one, and every item demonstrated factor loadings more than 0.7 [50].

A similar approach was followed to assess the sustainable outcomes. 3 factors emerged as outcome of sustainability. These 3 contributed 73.02% of the total variance.

Table 3

Percentage of variance explained by factors as sustainable outcomes

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.629	29.212	29.212	2.629	29.212	29.212
2	2.476	27.506	56.718	2.476	27.506	56.718
3	1.468	16.308	73.026	1.468	16.308	73.026
Extraction Method: Principal Component Analysis.						

Source: Authors Analysis

Table 4

Factor Loading- Sustainable Outcome

Item Description	Component Matrix[a]			
	Item Code	Factor Loading		
		1	2	3
Supply chain carbon emissions have decreased when GSCMT was implemented.	CF_1	0.871		
GSCMT increased the organization's carbon footprint tracking and reduction.	CF_2	0.911		
Sustainable logistics and energy-efficient technology have reduced the company's carbon impact.	CF_3	0.821		

Contd...

The adoption of GSCMT has reduced waste generation in supply chain operations of your organization.	WR_1		0.923	
Implementing GSCMT has improved waste management and resource efficiency in organization.	WR_2		0.911	
Sustainable procurement and recycling initiatives enabled by GSCMT have reduced material wastage.	WR_3		0.889	
Supply chain energy efficiency has enhanced with GSCMT.	EE_1			0.932
Using energy-efficient technology through GSCMT has reduced energy use.	EE_2			0.911
GSCMT optimises logistics, manufacturing, and distribution energy use, saving money.	EE_3			0.922

Source: Authors Analysis

These factors were named as carbon footprint (29.21%), waste reduction (56.71%) and energy efficiency(16.3%) of the total 73.02% of variance**.**

4.3 *Sem Analysis and testing of hypothesis*

To evaluate the adoption problems of GSCMT on sustainability results, SEM was conducted via AMOS. The outcome demonstrated the correlation between the concept and is shown in Figure 2**.**

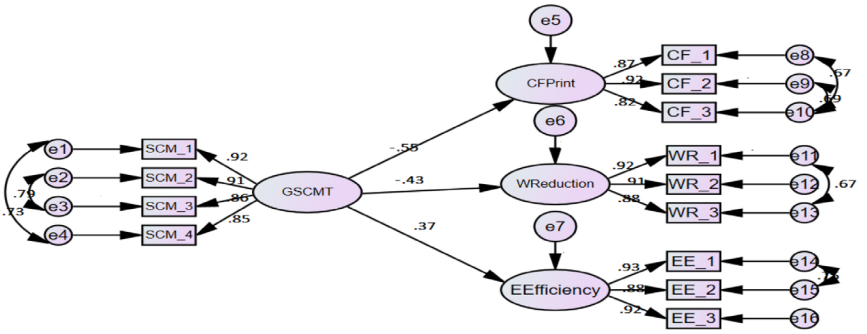
Interpretation of Results:

H_1: Adoption of GSCMT negatively impact carbon Footprint

With a coefficient of β= - 0.55 and a p-value of 0.011, the research determined that GSCMT had a negative influence on carbon footprint. The fact that the value is negative indicates that there will be a large decrease in the carbon footprint brought about by the increased adoption of technology in the fast-moving consumer goods business, which will in turn promote low-carbon logistics [31], energy-efficient transportation [34], and sustainable sourcing. Hence, we conclude that the hypothesis, H1, is reasonable and therefore accepted.

H_2: Adoption of GSCMT negatively impact waste reduction.

A negative effect on waste reduction was found to be associated with GSCMT, as indicated by the coefficient β= - 0.43 and the p-value of 0.031,



Source: Authors Analysis

Figure 3

Result of hypothesis

as established by the research results. By virtue of the fact that the value is negative, it can be deduced that the greater utilization of technology in the industry of fast-moving consumer products will result in a significant reduction in the amount of waste that is produced [32]. GSCM activities, such as resource optimization, eco-friendly packaging, and waste recycling techniques, have been shown to be beneficial in creating a circular economy and decreasing environmental impact [33]. The statistical significance ($p < 0.05$) in Figure 3 demonstrates that this association is not due to chance. This highlighted the usefulness of these initiatives. Hence, the hypothesis H_2 is accepted.

H_3: Adoption of GSCMT negatively impact energy efficiency

Based on the findings of the study, which showed that at (beta = 0.37, p = 0.022) contributes favourably to energy efficiency, the hypothesis H3 is rejected. On the other hand, the positive value indicated that as the use of technology rises, the optimal consumption of energy would improve, which will result in an improvement in the operational efficiency and effectiveness of supply chain activities. The findings of [33]and [34] are consistent with this idea.

5. Conclusion

The study examined the principal obstacles to the implementation of GSCMT in the FMCG sector. The investigation indicated that four factors greatly contributed to the adoption of GSCM technology. The challenges included financial barriers (23.46%), technological barriers (18.89% and

21.03%), and regulatory barriers (5.93%), collectively accounting for 69.32% of the variation. The study also examined the effect of GSCMT on sustainability outcomes, including energy efficiency, waste reduction, and carbon footprint. The SEM analysis demonstrated that the implementation of GSCMT markedly reduces carbon footprint (β=-0.55, p=0.001), thereby confirming hypothesis H1, promotes waste reduction (β=-0.43, p=0.001), thus validating hypothesis H2, and improves energy efficiency (β=0.37, p=0.002), consequently refuting hypothesis H3. The aforementioned findings underscored the significance of GSCMT in enhancing supply chain procedures, augmenting operational efficiency, and mitigating environmental impact.

Implications-The investigation offered insights into both theoretical and practical ramifications. Theoretically, it confirmed the beneficial impact of adopting GSCMT, while practically, it underscored the necessity for enhanced investment in low-carbon technologies, waste reduction initiatives, and energy-efficient logistics.

Constraints and Prospective Research -The study's contribution is substantial; nevertheless, it also has drawbacks. The research has been conducted solely inside the FMCG industry. Consequently, it restricts the generalizability of the findings. Secondly, alternative sustainability goals such as cost efficiency and supply chain resilience might be considered.

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