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Research paper

Impact of Supply Chain Management on Operational Efficiency: A Study of Kerala's E-Commerce Landscape

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Abstract

Supply Chain Management (SCM) plays an important part in enhancing operational efficiency, especially in the dynamic and customer-driven e-commerce sector. In Kerala, the growing e-commerce landscape faces notable challenges such as fragmented supply networks, poor coordination, and limited real-time information sharing. These inefficiencies often result in increased costs, delayed deliveries, and diminished service quality. This empirical study proposes a structured SCM framework focusing on three key dimensions, such as information flow, supply chain integration, and coordination mechanisms, and examines their influence on four operational performance indicators, like cost-efficiency, delivery speed, product quality, and operational flexibility. Primary data were collected from 426 respondents working in Kerala's e-commerce sector using a structured questionnaire. Statistical analysis using multiple linear regression revealed that all three SCM practices significantly influence operational performance, with information flow showing the strongest impact ($\beta = 0.338$), followed by supply chain integration ($\beta = 0.297$) and coordination mechanisms ($\beta = 0.259$). The overall framework described 47.9% of the variance in operational performance ($R^2 = 0.479$). Additionally, the Kruskal-Wallis test confirmed significant differences in performance across varying levels of SCM practice implementation ($p < 0.01$). The results affirm that efficient SCM practices directly enhance operational-al outcomes in Kerala's e-commerce retail sector.

Keywords: *Supply Chain Management; E-Commerce Retail; Operational Performance; Kerala; SCM Practices.*

1. Introduction

E-commerce, or electronic commerce, refers to the buying and selling of goods and services through online platforms using the internet. It encompasses a wide range of activities such as online retail shopping, digital payments, electronic supply chains, internet banking, and even online marketing campaigns that directly engage consumers. Unlike traditional brick-and-mortar retail, e-commerce provides customers with the convenience of shopping anytime and anywhere, supported by features such as product comparisons, customer reviews, digital wallets, and door-to-door delivery services. With the integration of technologies like artificial intelligence, big data analytics, and cloud computing, e-commerce platforms are increasingly able to personalize customer experiences, recommend products based on browsing history, and optimize logistics for faster delivery. The sector has become one of the most dynamic drivers of global economic growth, significantly reshaping how businesses and consumers interact. It eliminates geographical barriers, enabling even small-scale enterprises to reach global markets. Consumers benefit from a wider variety of products, competitive pricing, and improved accessibility, while businesses gain opportunities to expand customer bases, reduce overhead costs, and leverage data-driven insights for strategic decision-making. Moreover, e-commerce has been instrumental in accelerating the growth of allied sectors such as logistics, digital payments, and information technology services. In recent years, innovations such as mobile commerce (m-commerce), social commerce, and omni-channel retailing have further broadened the scope of e-commerce. Platforms now integrate social media, live-streaming, and influencer-driven marketing, creating more interactive and engaging customer experiences. Additionally, the rise of secure payment gateways, government support for digitalization, and consumer trust in online transactions have strengthened the foundation for sustainable e-commerce growth. The e-commerce retail sector, particularly in Kerala, has emerged as a vital contributor to economic innovation, digital transformation, and entrepreneurial development. The state's increasing digital literacy, rapid adoption of online platforms, and government support for digital infrastructure have collectively positioned Kerala as a promising hub for e-commerce expansion. Platforms ranging from national giants to local online retailers are redefining how goods and services are distributed, creating new opportunities while also introducing complex operational demands (Shah, M. V., 2024). Ensuring smooth and efficient logistics, timely delivery, consistent product quality, and optimized operational costs has become a top priority in this rapidly evolving ecosystem. At the core of successful e-commerce operations lies

SCM a strategic process that ensures the efficient coordination of procurement, inventory, distribution, and customer service. SCM encompasses critical elements such as information flow, supply chain integration, and coordination mechanisms, all of which facilitate the seamless movement of goods from origin to consumer (Czinkota et al., 2021). Figure 1 illustrates the typical SCM flow, representing key stages from procurement to final consumer delivery, which collectively form the operational backbone of e-commerce businesses. In Kerala's context, where regional logistical challenges and service delivery disparities exist, efficient SCM practices are crucial in minimizing delays, reducing costs, and improving customer satisfaction. High-performing SCM systems empower e-commerce retailers to respond quickly to dynamic market conditions, support last-mile delivery networks, and scale operations in a cost-effective manner.

Fig. 1: SCM Flow in E-Commerce

Operational performance in the e-commerce sector is typically assessed using four key indicators: cost-efficiency, delivery speed, product quality, and operational flexibility. These metrics reflect an organization's ability to manage internal processes and external service quality while adapting to changes in customer expectations. Any weakness in supply chain performance can lead to delayed shipments, increased operational costs, and reduced customer satisfaction factors that directly impact brand loyalty and profitability (Negi, S., 2021). As competition in the digital marketplace intensifies, understanding how supply chain practices influence these performance indicators is essential for maintaining a competitive edge. Kerala's e-commerce ecosystem, though expanding, faces notable challenges such as fragmented supplier networks, infrastructure bottlenecks, and varying levels of digital adoption across regions. Inconsistent logistics integration and poor real-time coordination among supply chain actors often hinder seamless operations (Shekhar, S., 2023). Additionally, the COVID-19 pandemic has accelerated online shopping trends, placing further pressure on supply chains to become more responsive, adaptive, and resilient. Addressing these concerns requires data-driven insights into SCM practices and their measurable effect on business performance (Sharma et al., 2021).

This research focused on investigating the role of SCM in enhancing operational performance among e-commerce retailers in Kerala. Specifically, it focuses on three key SCM practices: information flow, supply chain integration, and coordination mechanisms, and investigates their influence on the four critical performance indicators. The study is conceptually grounded in Transaction Cost Economics (TCE), which posits that efficient governance structures minimize the costs of transactions between economic actors. In the context of e-commerce SCM, coordination mechanisms, information flow, and supply chain integration can be interpreted as means to reduce transaction costs, mitigate uncertainties, and optimize resource allocation. Additionally, drawing from the Resource-Based View (RBV), firms that develop robust SCM capabilities possess valuable, rare, and inimitable resources that can serve as a basis for sustained competitive advantage and improved operational performance.

1.1. Research questions

1) How does information flow within the supply chain influence the operational performance of e-commerce retailers in Kerala, particularly in terms of cost-efficiency, delivery speed, product quality, and operational flexibility?
2) To what extent does supply chain integration impact the operational performance of Kerala's e-commerce retail sector across various performance indicators?
3) What is the effect of coordination mechanisms among e-commerce supply chain stakeholders on improving operational performance in Kerala's e-commerce retail environment?
4) Which of the three independent variables, information flow, supply chain integration, or coordination mechanisms, has the most significant influence on specific dimensions of operational performance?

1.2. Research objectives

To understand the strategic role of SCM in enhancing operational efficiency within Kerala's e-commerce retail sector, this study has been structured around the following key objectives:

1) To comprehensively examine the current landscape of Kerala's e-commerce retail sector, with emphasis on major players, market dynamics, regional growth patterns, and the role of SCM.
2) To investigate the key factors influencing information flow, supply chain integration, and coordination mechanisms among stakeholders within Kerala's e-commerce retail ecosystem.
3) To evaluate the operational performance of e-commerce retailers in Kerala by analyzing cost-efficiency, delivery speed, product quality, and operational flexibility, thereby identifying potential areas for improvement.

1.3. Proposed hypothesis

To examine the effect of key SCM components on the operational performance of Kerala's e-commerce retail sector, the following hypotheses were formulated:

H_{11}: Information flow significantly influences operational performance in the Kerala e-commerce retail sector.

H_{01}: Information flow does not significantly influence operational performance in the Kerala e-commerce retail sector.
H_{12}: Supply chain integration significantly improves operational performance in the Kerala e-commerce retail sector.
H_{02}: Supply chain integration does not have a significant impact on operational performance in the Kerala e-commerce retail sector.
H_{13}: Coordination mechanisms among e-commerce retail stakeholders significantly affect operational performance in the Kerala e-commerce retail sector.
H_{03}: Coordination mechanisms among e-commerce retail stakeholders do not significantly affect operational performance in the Kerala e-commerce retail sector.
H_{14}: SCM practices significantly influence key performance indicators (cost, delivery speed, quality, and flexibility) in the Kerala e-commerce retail sector
H_{04}: SCM practices do not significantly influence key performance indicators (cost, delivery speed, quality, and flexibility) in the Kerala e-commerce retail sector.

2. Literature Review

Several studies have situated supply chain effectiveness within the framework of Transaction Cost Economics (Williamson, 1981), emphasizing how integration and coordination reduce transactional inefficiencies. Furthermore, the Resource-Based View (Barney, 1991) suggests that strategic supply chain practices, such as information flow and integration, constitute intangible assets that enhance firm performance. A recent meta-analysis by Xu et al. (2025) synthesizes findings from over 70 studies and highlights how technologies such as AI, predictive analytics, and digital twins play differentiated roles at various supply chain stages. Information flow quality and data-driven coordination were found to have the most significant effects on resilience and responsiveness, especially in digitally transforming supply chains. These insights support the current paper's emphasis on information flow as a determinant of operational agility. Raj et al. (2025) proposed an empirically validated model linking digital infrastructure, logistics integration, and platform coordination to regional e-commerce performance. The framework emphasizes how uneven logistics development and weak coordination among stakeholders act as structural constraints in emerging markets—insights that closely mirror challenges observed in Kerala's e-commerce ecosystem.
Naveen Kumar et al. (2025) explored the impact of reverse logistics practices on circular economy integration within e-commerce using the Five R's model. The research aimed to assess the efficiency of these approaches and offer practical insights for sustainable operations. Data were collected from 208 respondents across southern India using a structured questionnaire and a non-probabilistic sampling method. Structural Equation Modeling (SEM) validated the relationships between the key variables. The findings revealed that circular economy principles, reverse logistics, information systems, and supply chain design significantly influenced productivity (38%) and sustainability (27%), explaining 36% of performance variance. Factor analysis identified four critical dimensions. The study acknowledged limitations, including its specific regional focus, dependence on self-reported data, and cross-sectional design. Mauki et al. (2025) investigated the relationship between electronic ordering and supply chain performance in large retail chains in Kenya, emphasizing the moderating influence of top management assistance. The analysis implemented a descriptive research design under a positivist paradigm and was guided by Dynamic Capability Theory and Power Theory. Data were collected using structured questionnaires from heads of procurement, logistics, finance, and ICT departments across 12 retail chains, involving 240 respondents. Quantitative analysis was conducted using SPSS, with multiple regression and Pearson correlation employed to examine relationships. The findings confirmed a positive and substantial impact of electronic ordering on supply chain performance. Additionally, top management support significantly moderated this relationship, emphasizing the role of organizational leadership in performance outcomes.
Musibon et al. (2024) examined the effect of e-commerce on the supply network of small-scale horticultural farmers in South Africa. The study focused on how online transactions influence market access, supply chain efficiency, and cost reduction. Using a quantitative research approach, data were collected from 100 randomly selected farmers out of a targeted 200. The findings indicated that e-commerce improved access to timely information, lowered supply chain costs, and enhanced the delivery efficacy of freshly produced products. Also, at the same time, the research did not enable farmers to set competitive prices for their goods. The study emphasized the existing challenges faced by small-scale farmers in leveraging e-commerce fully, particularly in terms of connectivity, infrastructure, and commercial capacity within the agricultural value chain. Research by Brown et al. (2024) examined how e-commerce technology affected SCM in the retail industry. Using thematic analysis of literature and findings of a qualitative study, the research examined the roles of predictive analytics, real-time monitoring, blockchain, IoT, and Artificial Intelligence (AI) in transforming customer service, procurement, logistics, and inventory management. The study identified substantial developments in decision-making, customer experience, and operational efficiency through the strategic use of these technologies. However, the study also acknowledged key challenges, including cybersecurity risks, regulatory compliance problems, and system integration complexities. The analysis highlighted the importance of technological combination in enhancing supply chain resilience, sustainability, and competitiveness.
Islam et al. (2024) examined the role of AI in addressing last-mile delivery challenges within the e-commerce sector, concentrating on enhancing customer experience and operational efficiency. Using a cross-sectional survey approach, the study gathered information from 42 online shoppers. The research explored correlations between AI adoption, customer satisfaction, AI awareness, and environmental impact awareness. Results showed a weak negative correlation between AI adoption and customer satisfaction, while AI awareness and environmental concern demonstrated a positive relationship with the intent to adopt AI-driven delivery solutions. The findings emphasized operational factors over customer satisfaction in influencing adoption. The study acknowledged a limitation related to the use of convenience sampling, which introduces bias and affects the generalizability of the results. Guo et al. (2024) investigated how supply chain finance (SCF) platforms enabled through e-commerce influence the financing efficiency of small and medium-sized enterprises (SMEs) in China. Research employed a panel dataset of 423 examinations from technology-driven SMEs spanning the years 2011 to 2020. Using correlation analysis, descriptive statistics, and regression modeling, the analysis revealed that SCF coverage breadth exerted a significant beneficial effect on SME financing efficiency in comparison to usage depth. Additionally, green innovation was recognized as a positive mediating element in this research. The findings highlighted the role of SCF platforms in expanding financial access for SMEs. A noted limitation was the variation in SCF outcomes based on firm characteristics and regional development approaches, limiting generalizability across contexts.
Gopal et al. (2024) assessed the impact of big data analytics (BDA) on the retail supply chain by identifying as well as ranking nine analytics practices based on seven performance criteria. The study applied the TODIM technique, a multi-criteria decision-making (MCDM) technique, to evaluate practices such as data mining, machine learning, RFID, IoT, and blockchain in relation to supply chain metrics like supplier integration, cost, flexibility, and demand management. The findings revealed a conflict between customer loyalty and cost during implementation decisions, with certain practices showing dominance based on specific performance priorities. The study

combined qualitative and quantitative factors in a unified model. A noted limitation was the variation in dominance values across industries, making the findings specific to the Indian retail supply chain context. Tambuskar et al. (2024) explored the challenges faced by India's industrial sector in integrating BDA into sustainable supply chain management (SSCM). The research applied the PESTEL model to identify 10 influencing elements and 31 sub-elements, which were validated and analyzed using structural equation modeling. Eight out of eleven hypotheses were supported. The findings emphasized the role of government IT policies, data quality, and regulatory compliance. The study was geographically limited to India's manufacturing sector and acknowledged a low survey response rate due to limited awareness of BDA, which constrained the generalizability of the results.

Jain et al. (2024) explored the application of BDA in SSCM within the background of emerging economies. Using the PESTEL framework and expert opinions, the study identified 13 critical factors from an initial pool of 18. A structural model was developed and further analyzed with MICMAC analysis. The results indicated that policy support, data-based decision-making culture, BDA technology selection, and data privacy laws had the highest driving power. Environmental vision and resource optimization also played a key role in sustainability outcomes. The study highlighted interrelationships among these factors and offered a hierarchical structure. Using a single-case design based on data from fieldwork, interviews, and secondary sources, Li et al. (2023) explored how rural e-commerce platforms contribute to enhancing and reshaping the agricultural supply chain. Results revealed that Tudouec functioned as a versatile platform providing technological assistance, logistics, SCF, insurance, and warehousing. It improved supply chain performance by combining the data, material flows, and capital, thereby reducing risk and enhancing product quality. The platform also strengthened collaboration between the farmers, consumers, and distributors. The study concluded that rural e-commerce contributes to rural revitalization and poverty reduction. Limitations included the research's single-case focus and a short observation period.

In the context of Jordan's manufacturing industry, Hijjawi et al. (2023) examined the intermediating part of digital SCM in the connection between supply chain operations and lean management practices. The study collected data from 445 managers across various industries, including garments, electronics, and automobiles. SEM utilizing Smart PLS was applied to examine the relationships. Findings showed that technology, as well as communicative and structural dimensions, had a substantial positive effect on supply chain operations. The analysis also confirmed partial mediation of digital SCM among supply chain operations and lean management. All latent variables met the reliability and validity criteria. Gangwar et al. (2023) developed a sustainability valuation framework tailored to the e-commerce sector and investigated the main enablers of BDA practices within supply chains. The study used a mixed-method approach. In Phase I, BDA drivers in the e-commerce sector were identified using PLS-SEM. A fuzzy AHP was applied within a case study of the Indian fashion e-commerce industry to calculate sustainability scores in Phase II. The results showed economic sustainability had the highest index (0.220), followed by environmental (0.182) and social sustainability (0.142), indicating a skewed benefit distribution. The findings suggested that BDA practices favour economic performance over social and environmental dimensions.

Qi et al. (2023) observed the role of platform supplier integration in improving supply chain resilience through the COVID-19 pandemic, using information from a Chinese e-commerce platform. The study developed a framework to assess the effect of integration elements like joint planning, information sharing, and logistics cooperation on resilience, and evaluated the mediating role of product adaptability. The analysis based on operational indicators revealed that sharing data, logistics cooperation, and planning positively influenced dependence, whereas the automated procurement process negatively affected it. Flexibility of the product strengthened the positive effects of combined measures. The study emphasized that resilience outcomes depend on contextual factors. A key limitation was the focus on domestic consumer product suppliers, restricting the generalizability of findings to global or industrial product supply chains. Abtahi et al. (2023) explored the effect of the adoption of e-commerce on supply chain efficiency between SMEs in Bangladesh. The research applied a qualitative strategy by making use of semi-structured interviews with owners and managers of SME engaged in e-commerce-integrated supply chain operations. Key findings revealed that e-commerce improved efficiency, reduced costs, and enhanced customer experiences. Factors influencing adoption included infrastructure, organizational culture, technological readiness, and external pressure. Respondents emphasized the importance of skill development, market research, and stakeholder engagement to enhance decision-making. The study confirmed a positive perception of e-commerce among supply chain partners. Thomas et al. (2023) examined the influence of e-commerce on SCM within the retail and consumer goods sector in Lusaka Province, an emerging economy context. Data were collected from merchants in the region and analysed using a regression model, which showed a high positive correlation between performance expectancy and e-commerce adoption intentions. The findings highlighted the critical role of digital infrastructure and governmental support in overcoming market fragmentation. The study provided valuable insights into strategic and behavioral determinants of e-commerce adoption.

2.1. Research gap

Although substantial studies have examined the function of SCM in enhancing operational efficiency across various industries and regions, a significant void exists in comprehending this relationship within the specific background of Kerala's e-commerce retail sector. Reverse logistics and circular economy practices were explored in southern India, while electronic ordering and top management support influenced retail supply chain performance in Kenya (Naveen Kumar, R et al., 2025; Mauki et al., 2025). Technologies like AI, IoT, and blockchain enhanced SCM in retail, and last-mile delivery efficiency was associated with operational factors in e-commerce (Brown et al., 2024; Islam et al., 2024). Financing access through supply chain finance platforms among Chinese SMEs was positively influenced by green innovation (Guo et al., 2024). In India, big data practices were ranked using TODIM, while PESTEL-based frameworks and TISM models were used to examine analytics-driven sustainability in SCM (Gopal et al., 2024; Tambuskar et al., 2024). Additional studies investigated rural agricultural platforms, digital SCM mediation, and supply chain resilience during COVID-19 (Li et al., 2023; Qi et al., 2023). Despite these varied insights, a clear research gap exists regarding the specific role of SCM in enhancing operational performance within Kerala's e-commerce retail sector. Kerala presents a distinct retail landscape shaped by high digital adoption, local logistics dynamics, and region-specific operational constraints. This study intends to fill that gap by examining how SCM practices directly influence operational performance in Kerala's e-commerce retail environment.

3. Methods

3.1. Conceptual framework

The conceptual framework is structured to examine the relationship among important SCM practices and operational performance indicators in Kerala's e-commerce retail sector. It is based on empirical findings and theoretical insights from supply chain literature, which posit that well-executed SCM functions lead to enhanced efficiency, responsiveness, and service quality across e-commerce operations. The independent variables in the framework include three critical SCM constructs: information flow, supply chain integration, and coordination mechanisms. These constructs were chosen on the basis of their importance to digital commerce ecosystems and their documented impact on business agility and resilience. The framework integrates elements from TCE and the RBV. From a TCE perspective, coordination and information flow minimize transaction costs by improving predictability and trust among supply chain actors. From an RBV lens, these SCM practices represent strategic organizational resources that contribute to competitive advantage by enhancing cost-efficiency, operational flexibility, and service quality. The dependent variable is Operational Performance, conceptualized as a multi-dimensional construct encompassing cost-efficiency, delivery speed, product quality, and operational flexibility. These dimensions reflect both internal efficiency and customer-facing outcomes that are critical in a competitive e-commerce environment. The framework assumes that higher levels of SCM maturity and adoption contribute to improved operational outcomes by streamlining processes, reducing redundancies, and enabling real-time decision-making. Additionally, demographic and organizational factors are considered as control variables to explore their moderating effect on the SCM-performance relationship. Figure 2 represents the proposed conceptual framework.

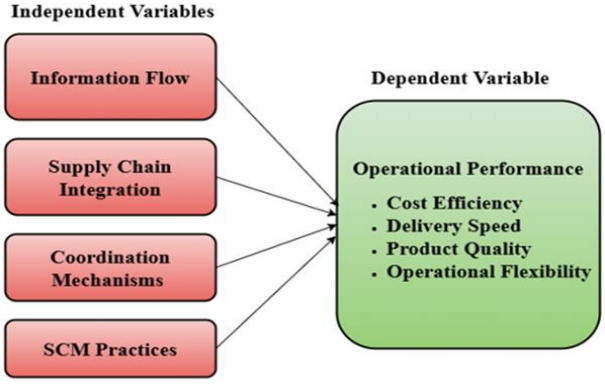

Fig. 2: Conceptual Framework.

3.2. Research design

This research adopts a quantitative, cross-sectional, and descriptive research design to study the effect of SCM practices on operational performance in Kerala's e-commerce retail sector. The design was selected to enable a structured and statistical assessment of the relationships among variables such as information flow, supply chain integration, and coordination mechanisms, and their impact on cost-efficiency, delivery speed, product quality, and operational flexibility. A cross-sectional method was employed to gather information at a single point in time, providing an overview of SCM practices across a wide range of firms. The design supports hypothesis testing and allows for generalization of findings across the sector. The research was conducted within the positivist paradigm, emphasizing objectivity, replicability, and measurement through empirical data. This design ensures the findings are not only statistically robust but also practically relevant for decision-makers in logistics, operations, and strategic planning within Kerala's growing e-commerce ecosystem.

3.3. Data collection

This research applied a thorough data collection approach to obtain significant information on SCM practices and operational performance. The primary data were collected utilizing a structured, self-administered questionnaire, carefully designed to capture measurable insights across key SCM dimensions. The questionnaire also assessed operational performance in terms of cost-efficiency, delivery speed, product quality, and operational flexibility. The data collection was disseminated through a combination of digital platforms and offline channels to maximize outreach and ensure a representative sample. Respondents were professionals actively engaged in supply chain and operational roles, such as executives, managers, and team leads across various e-commerce organizations in Kerala. A five-point Likert scale was applied to quantify responses, enhancing the ease of analysis. Ethical standards, consisting of participant confidentiality, informed consent, and voluntary participation, were rigorously upheld. Additionally, secondary data sources, including scholarly articles, government publications, and industry reports, were consulted to enrich the context and support triangulation of primary findings.

3.4. Designing of questionnaire

The questionnaire used in this study was designed to capture the multidimensional nature of SCM practices and their influence on operational performance in Kerala's e-commerce retail sector. The items were developed by adapting measurement scales from established literature on SCM and operations management. Four main constructs were assessed: Information Flow, Supply Chain Integration, Coordination Mechanisms, and Operational Performance, each represented by 4–5 items. A five-point Likert scale that varies from "Strongly Disagree" (1) to "Strongly Agree" (5) was used to confirm consistency and quantifiability of responses. The questionnaire also included demographic data like gender, age, organizational role, educational qualification, years of experience, and business type. Before full-scale administration, a pilot test was performed with the participants to assess clarity, readability, and reliability. Based on the feedback, minor revisions were made. Internal consistency was verified utilizing Cronbach's Alpha, with all constructs exceeding the 0.80 threshold, confirming high reliability.

3.5. Sampling area and population

The study was geographically confined to Kerala, a state in southern India known for its high digital literacy and rapidly evolving e-commerce ecosystem. The target population comprised individuals working in supply chain, logistics, operations, procurement, and strategic planning roles within e-commerce businesses operating in the state. Kerala's unique logistics infrastructure, consumer behavior, and entrepreneurial culture make it an ideal small-scale version for studying SCM dynamics in India. The sampling frame included a variety of business formats such as B2C, B2B, and C2C models, covering both startups and established firms across urban and semi-urban regions. This enabled the inclusion of perspectives from a cross-section of the industry, including private limited companies, MSMEs, government/PSU entities, and hybrid business models. The demographic scope of the study ensured that respondents possessed both operational familiarity and strategic insight, enriching the data quality and applicability of findings across Kerala's e-commerce landscape.

3.6. Sample size

To determine the sample size for the research, the Cochran formula for population sampling was applied, incorporating adjustments for the expected response rate and finite population correction. Ensuring a 95% confidence level and a 5% margin of error, the sample size required was calculated using Cochran's formula, as shown in Equation (1).

$$n = \frac{Z^2 \cdot p(1-p)}{E^2} \tag{1}$$

In this formula, n represents the sample size, p denotes the estimated population proportion (set at 0.5 to reflect maximum variability), Z indicates the Z-score conforming to the chosen confidence level (1.96), and E refers to the margin of error (0.05).

$$n = \frac{(1.96)^2 \cdot 0.5(1-0.5)}{(0.05)^2}$$

$$n = \frac{3.8416 \cdot 0.25}{0.0025}$$

$$n = 384.16$$

After applying the Cochran formula, the initial sample size was computed to be approximately 384 participants. However, since the formula assumes perfect response validity, it does not account for potential issues such as incomplete or inconsistent responses that commonly occur in actual field data. To address this, a buffer of 10–12% was added to the computed sample size, providing a safeguard against data loss and ensuring the integrity of the final dataset. While 384 represents the minimum threshold necessary for generalizability, the final number of valid responses was increased to 426 to ensure robustness. Since the study involves comparisons across multiple demographic and organizational categories, a larger sample size was selected to enhance the reliability of non-parametric tests and multivariate models, which require sufficient representation across diverse subgroups.

3.7. Statistical tool for analysis

The data gathered from the questionnaire were examined utilizing a combination of descriptive and inferential statistical techniques with the support of IBM SPSS software version 26. The collected data underwent descriptive analysis to summarize the demographic distribution of respondents using measures such as frequency and percentage analysis. For hypothesis testing, various inferential tools were employed on the basis of the nature of the variables and research questions. Simple linear regression (SLR) was applied to test the impact of individual SCM variables on operational performance. Multiple linear regression assessed the combined effect of all SCM factors. Pearson correlation tested the strength of relationships between paired variables, and the Kruskal-Wallis test was employed to examine median differences across multiple groups. Reliability was verified through Cronbach's Alpha for each construct, confirming internal consistency. These tools were chosen to ensure methodological rigor and to derive valid and reliable conclusions about the influence of SCM practices on operational performance in Kerala's e-commerce retail sector.

4. Results

4.1. Demographic distribution

Demographic distribution denotes the statistical analysis of the features of the respondents involved in a study, like age, gender, years of experience, educational qualification, organizational role, and business type. It provides insight into the composition and diversity of the sample, which is necessary for understanding the background and relevance of the study. Table 1 indicates the demographic distribution of the 426 respondents, while Figure 3 depicts a visual illustration of the same data for better interpretation.

Table 1: Demographic Distribution of Respondents

Variables		Frequency	Percentage (%)
Gender	Male	248	58.2%
	Female	178	41.8%
Age Group	21–30 years	96	22.5%
	31–40 years	182	42.7%
	41–50 years	101	23.7%
	Above 50 years	47	11.0%
Educational Qualification	Graduate	153	35.9%
	Postgraduate	201	47.2%
	Doctorate	28	6.6%
	Diploma/Other	44	10.3%
Years of Experience	Less than 5 years	102	23.9%

Position in Organization	5–10 years	164	38.5%
	11–15 years	91	21.4%
	More than 15 years	69	16.2%
	Executive	124	29.1%
	Manager	169	39.7%
	Senior Team Lead	81	19.0%
	Director	52	12.2%
Type of E-commerce Business	B2C (Business to Consumer)	247	58.0%
	B2B (Business to Business)	96	22.5%
	C2C or Hybrid Models	83	19.5%
	Government/PSU	38	8.9%
Type of Organization	Private Ltd.	201	47.2%
	Startup	97	22.8%
	MSME	64	15.0%
	Others	26	6.1%
Annual Revenue of the Organization	Below ₹10 Lakhs	87	20.4%
	₹10–50 Lakhs	143	33.6%
	₹50 Lakhs–1 Crore	112	26.3%
	Above ₹1 Crore	84	19.7%
Number of Employees in Organization	Less than 50	103	24.2%
	50–100	137	32.2%
	101–500	109	25.6%
	More than 500	77	18.1%

The demographic distribution of the 426 participants reveals a diverse representation across multiple categories relevant to the Kerala e-commerce retail sector. A majority of participants were male (58.2%), and most fell within the 31–40 years age group (42.7%), indicating a relatively young and professionally active population. Postgraduates formed the largest educational category (47.2%), and a significant proportion had 5–10 years of experience (38.5%), suggesting a workforce with considerable industry exposure. Managers constituted the largest professional group (39.7%), reflecting mid-level decision-making perspectives. Most respondents worked in B2C businesses (58.0%) and private limited companies (47.2%), pointing to the dominant models in Kerala's e-commerce sector. In terms of business scale, nearly one-third of the organizations reported annual revenue between ₹10–50 Lakhs, and 32.2% had 50–100 employees, indicating a strong presence of medium-sized enterprises. Overall, the demographic composition supports the study's objective of analyzing operational performance across a well-distributed and professionally relevant sample.

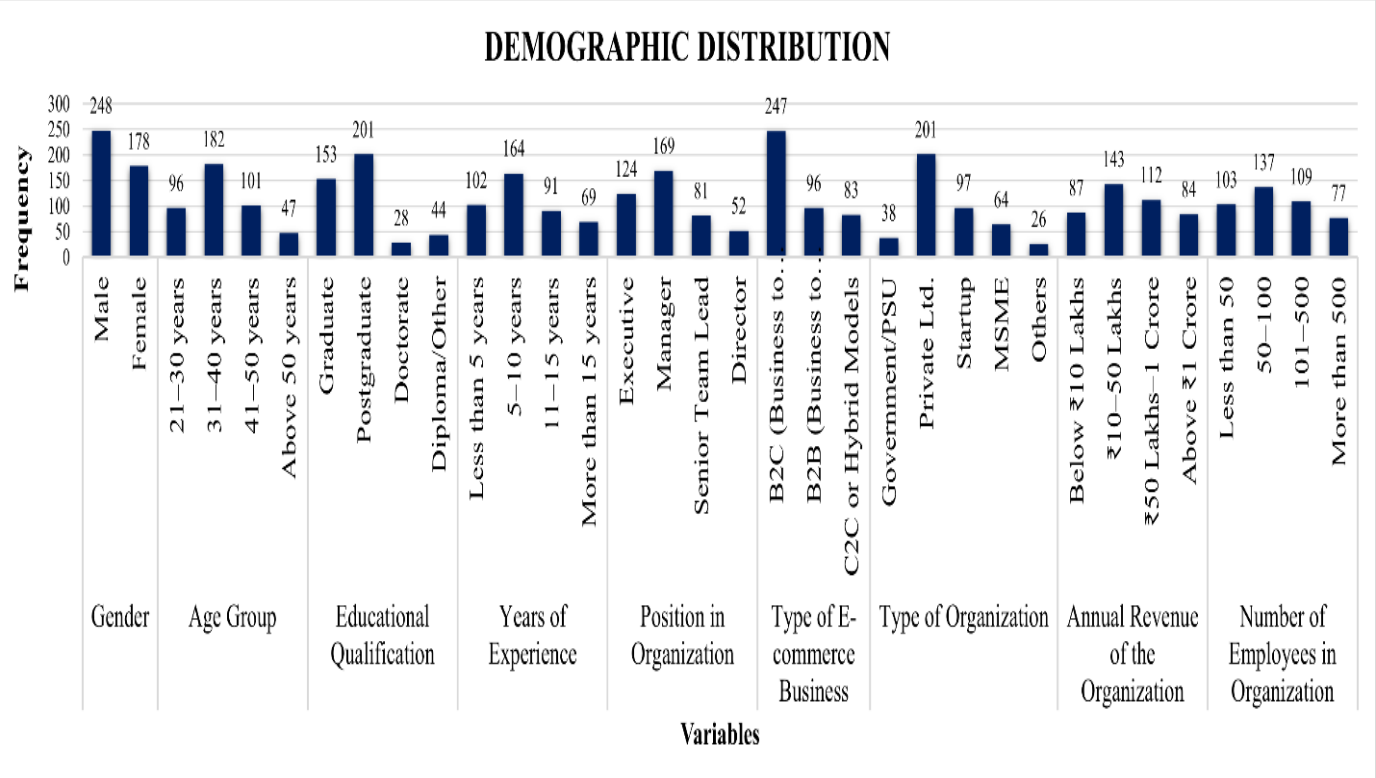

Fig. 3: Demographic Distribution of the Respondents.

4.2. Reliability analysis of research constructs

Cronbach's Alpha was computed for each concept to evaluate the internal reliability and dependability of the questionnaire. It is a statistical metric utilised to assess the reliability of a collection of items in measuring a singular underlying construct, such as a particular talent or attitude. An alpha value (α) greater than 0.70 is often regarded as appropriate, although values over 0.80 signify good reliability. This analysis showed that the items in the questionnaire were coherent and dependable for evaluating the targeted aspects of English language proficiency and student self-efficacy. The Cronbach's Alpha values are illustrated in Table 2, which also contains the reliability coefficients for each construct.

Table 2: Reliability Statistics of Research Constructs

Construct	Number of Items	Cronbach's Alpha (α)	Reliability Level
Information Flow	5	0.845	High Reliability
Supply Chain Integration	5	0.872	High Reliability
Coordination Mechanisms	4	0.811	Acceptable to High Reliability
Operational Performance	4	0.879	High Reliability

The reliability statistics indicate that all four research constructs used in this research demonstrate a better degree of internal consistency. The alpha values for Information Flow (0.845), Supply Chain Integration (0.872), Coordination Mechanisms (0.811), and Operational Performance (0.879) all exceed the threshold of 0.70, which is considered the minimum acceptable value for scale reliability. These results confirm that the Likert-scale items grouped under each construct are consistent and suitable for further statistical analysis. The strong reliability further supports the validity of the instrument in capturing the intended dimensions of SCM and operational performance within Kerala's e-commerce retail sector. Figure 4 indicates the Cronbach's alpha values of each research construct.

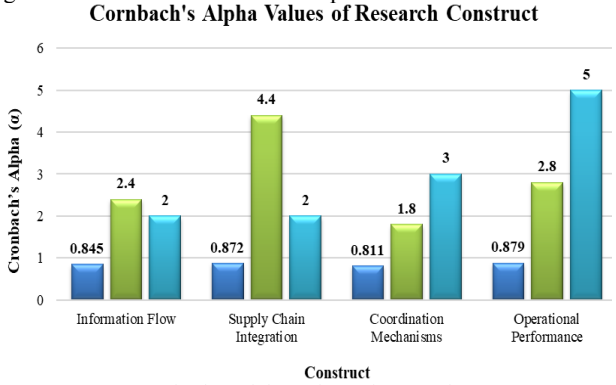

Fig. 4: Cronbach's Alpha Values of Research Construct.

4.3. Information flow and operational performance

Simple linear regression is a predictive statistical method employed to examine the relationship between a single independent variable and a single dependent variable. It determines the extent to which variations in the independent variable correlate with variations in the dependent variable.

Table 3: Model Summary – Simple Linear Regression

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.546	0.298	0.296	0.488

Table 4: ANOVA – Regression Significance

Model	Sum of Squares	df	Mean Square	F-value	p-value
Regression	38.812	1	38.812	162.67	0.000
Residual	91.234	424	0.215		
Total	130.046	425			

Table 5: Impact of Information Flow

Model	Unstandardized B	Std. Error	Standardized Beta (β)	t	p-value)
(Constant)	2.081	0.112	—	18.58	0.000
Information Flow	0.524	0.041	0.546	12.75	0.000

The model summary, shown in Table 3, indicates a moderate correlation between information flow and operational performance ($R = 0.546$), accompanied by an R^2 value of 0.298. This implies that about 29.8% of the variance in operational performance is assigned to changes in information flow alone, signifying a substantial predictive capability of the framework. The statistical significance of the framework was further confirmed through an ANOVA test. Table 4 indicates an F-value of 162.67 and a p-value of 0.000 ($p < 0.01$), confirming the statistical significance of the regression framework. This supports the hypothesis that the regression equation accurately predicts the dependent variable. The regression coefficients are shown in Table 5, which offers insights into the strength and direction of the relationship. The unstandardized coefficient ($B = 0.524$) suggests that for every single-unit increase in information flow, there is an associated 0.524 unit rise in operational performance, holding all else constant. The standardized beta value ($\beta = 0.546$) signifies a moderately significant positive influence. The t-value (12.75) and the p-value (0.000) determine that the relationship is statistically significant at the 1% threshold level. Thus, the null hypothesis (H_{01}) is rejected, showing that information flow significantly enhances operational performance in the Kerala e-commerce retail sector.

4.4. Supply chain management factors and operational performance

Multiple linear regression is a statistical technique employed to determine the degree to which two or more independent variables estimate the outcome of a dependent variable. This method is particularly valuable when evaluating the combined impact of interrelated factors on a singular outcome, allowing for the identification of unique contributions from each predictor while accounting for the influence of the others. Table 6 provides the model summary, detailing the overall explanatory power of the regression model. Table 7 indicates the findings of ANOVA, confirming the statistical significance of the model. Table 8 outlines the coefficients, which signify the magnitude and orientation of the impact of each independent variable on the dependent variable.

Table 6: Model Summary – Multiple Linear Regression

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.692	0.479	0.475	0.402

Table 7: ANOVA – Significance of the Regression Model

Model	Sum of Squares	df	Mean Square	F-value	p-value
Regression	62.311	3	20.770	128.36	0.000
Residual	67.735	422	0.160		
Total	130.046	425			

Table. 8: Influence of SCM Factors on Operational Performance

Predictor	Unstandardized B	Std. Error	Standardized Beta (β)	t-value	p-value
(Constant)	1.862	0.108	—	17.24	0.000
Information Flow	0.312	0.037	0.338	8.43	0.000
Supply Chain Integration	0.281	0.041	0.297	6.85	0.000
Coordination Mechanisms	0.245	0.036	0.259	6.75	0.000

The model summary (Table 6) demonstrates that the framework clarifies 47.9% of the variance in the dependent variable, signifying substantial explanatory power. The total regression model's statistical significance (Table 7) is validated by an F-statistic of 128.36 and a p-value of 0.000, signifying that the observed results are exceedingly improbable to have evolved by chance. These findings validate the robustness of the regression model. As shown in Table 8, each of the three predictors determined shows a statistically significant effect on operational performance at the 1% level. Information Flow (β = 0.338) was the strongest predictor, followed by Supply Chain Integration (β = 0.297) and Coordination Mechanisms (β = 0.259). These results affirm that improvements in supply chain integration practices meaningfully contribute to enhanced operational performance. Based on these findings, the null hypothesis (H_{02}) is rejected, such that the supply chain integration significantly improves operational performance in Kerala's e-commerce retail sector.

4.5. Coordination mechanisms and operational performance

Pearson's correlation coefficient (r) quantifies the degree and direction of a linear relationship between two continuous variables.

Table 9: Pearson Correlation between Coordination Mechanisms and Operational Performance

Variables	Mean	SD	r	p-value
Coordination Mechanisms	3.84	0.64	0.524	0.000
Operational Performance	3.92	0.59		

Table 9 illustrates that the Pearson correlation coefficient between Coordination Mechanisms and Operational Performance is r = 0.524, with a p-value of 0.000, suggesting a statistically significant and relatively positive relationship at the 1% level. This suggests that as the quality and efficiency of coordination mechanisms among e-commerce stakeholders increase, there is a corresponding enhancement in the overall operational performance of their organizations. Given the significance level ($p < 0.01$), the null hypothesis (H_{03}) is rejected, showing that coordination mechanisms significantly affect operational performance within Kerala's e-commerce retail sector. Figure 5 shows the mean comparison between coordination mechanisms and operational performance.

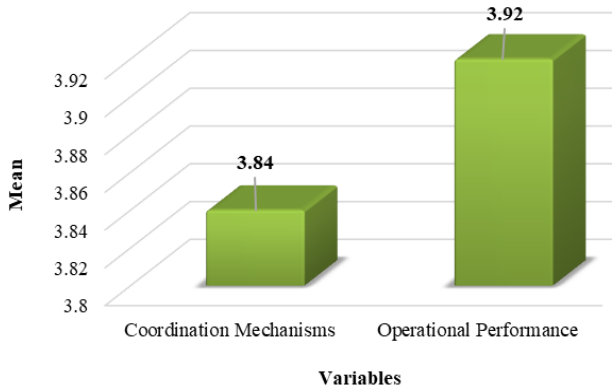

Fig. 5: Mean Comparison between Coordination Mechanisms and Operational Performance.

4.6. Influence of SCM practices on operational performance indicators

In order to investigate whether levels of SCM practice implementation led to significant differences in operational performance, specifically across cost-efficiency, delivery speed, product quality, and operational flexibility, a Multivariate Kruskal-Wallis test was employed. This is a non-parametric statistical technique employed to decide whether statistically significant changes exist among the medians of three or more independent groups regarding a continuous or ordinal variable.

Table 10: Kruskal–Wallis Test Results for Operational Performance by SCM Practice Levels

Performance Indicator	Chi-Square (H)	df	p-value
Cost-Efficiency	20.13	2	0.000
Delivery Speed	17.84	2	0.000
Product Quality	14.29	2	0.001
Operational Flexibility	11.75	2	0.003

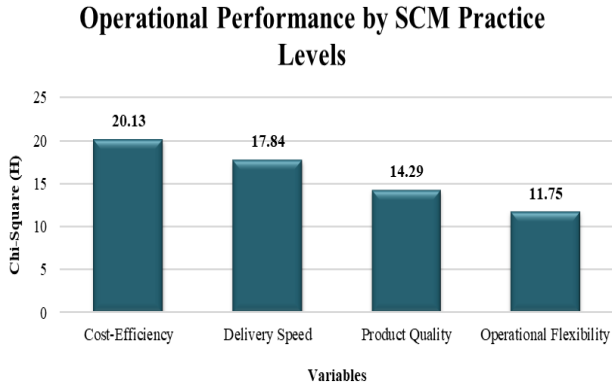

Fig. 6: Chi-Square (H) Statistics from the Kruskal-Wallis Test.

Table 10 presents statistically significant changes in operational performance indicators across different levels of SCM practice implementation among e-commerce retailers in Kerala. Specifically, the Kruskal-Wallis test showed that cost-efficiency ($H = 20.13$, $p = 0.000$), delivery speed ($H = 17.84$, $p = 0.000$), product quality ($H = 14.29$, $p = 0.001$), and operational flexibility ($H = 11.75$, $p = 0.003$) vary significantly among the SCM groups. The results demonstrate that higher levels of SCM practice correlate with enhanced performance outcomes. Consequently, the null hypothesis (H_{04}) is rejected, affirming that SCM techniques significantly influence operational performance in Kerala's e-commerce retail industry. Figure 6 illustrates the Chi-Square (H) statistics obtained from the Kruskal-Wallis test.

5. Discussion

This research aimed to evaluate the effect of SCM practices on improving operational efficiency within Kerala's fast-developing e-commerce retail sector. Guided by four core objectives, the study applied rigorous statistical analyses to examine how specific SCM constructs—information flow, supply chain integration, and coordination mechanisms- affect operational performance outcomes. The results provide valuable empirical insights and extend the understanding of SCM effectiveness in the context of emerging regional e-commerce ecosystems. The descriptive analysis of the demographic profile revealed that Kerala's e-commerce sector is predominantly composed of mid-level professionals working in private limited and B2C organizations. This reflects a structurally diverse and maturing market environment that integrates both domestic and digitally enabled firms. The representation across various organizational sizes and revenue categories further ensured that the study captured a broad and relevant cross-section of the industry. Such diversity enhances the generalizability of findings and reflects the heterogeneity of operational challenges faced by e-commerce firms in Kerala.

The regression analyses demonstrated that SCM constructs exert a significant and positive influence on operational performance. Specifically, information flow exhibited the strongest effect ($\beta = 0.338$), followed by supply chain integration ($\beta = 0.297$) and coordination mechanisms ($\beta = 0.259$). The model explained 47.9% of the variance in operational performance ($R^2 = 0.479$), confirming that these three SCM dimensions collectively and independently contribute to performance enhancement. These findings validate hypotheses H1–H3 and reinforce the theoretical premise that effective information management, integrated systems, and coordinated operations are essential drivers of organizational efficiency and competitiveness in digital commerce environments. The Kruskal–Wallis analysis further revealed that firms demonstrating higher levels of SCM adoption consistently outperformed others across key operational parameters—cost efficiency, delivery speed, product quality, and operational flexibility. The statistical significance ($p < 0.01$) across all four indicators validates hypothesis H4 and confirms that SCM practices are integral to improving operational outcomes. These findings are consistent with global research trends, suggesting that supply chain sophistication directly contributes to organizational agility and resilience, particularly in high-velocity sectors such as e-commerce.

These empirical results carry important implications for industry practice, regional development, and policy formulation. For practitioners within Kerala's e-commerce sector, the dominant influence of information flow on operational performance underscores the need for robust, real-time data exchange systems. Investments in enterprise resource planning (ERP) tools, integrated logistics tracking, and AI-driven demand forecasting could substantially enhance decision-making accuracy and responsiveness. Likewise, stronger supply chain integration demands closer partnerships with logistics providers, warehousing partners, and local vendors—fostering transparency and operational synchronization. Coordination mechanisms, though slightly less dominant statistically, remain critical for mitigating uncertainty and ensuring alignment between internal departments and external stakeholders. At a broader economic level, the adoption and improvement of SCM practices have the potential to significantly advance Kerala's digital economy. Enhanced operational efficiency among e-commerce firms can reduce transaction costs, improve delivery reliability, and elevate customer satisfaction—factors that are crucial for increasing market penetration across both urban and semi-urban regions. As firms refine their operational frameworks, there is also potential for job creation in specialized domains such as logistics technology, last-mile delivery management, and data-driven operations planning. This aligns with Kerala's ongoing efforts to expand its digital infrastructure and support entrepreneurial ecosystems. Overall, the study underscores that SCM practices are not merely procedural tools but strategic enablers that enhance organizational agility and sustainable performance. The results contribute to both theory and practice by establishing empirical evidence from a regional context that is rapidly integrating into the global digital economy. Future research may extend this work by exploring longitudinal impacts, the role of digital technologies in supply chain transformation, and comparative analyses across states or national contexts.

6. Implications

This study contributes practical and policy-oriented insights for improving supply chain performance in Kerala's emerging e-commerce ecosystem. From a managerial standpoint, the findings highlight the centrality of information flow as a performance driver, suggesting the need for real-time data systems, ERP integration, and predictive analytics. E-commerce firms are encouraged to adopt advanced coordination mechanisms and enhance collaboration with logistics partners to streamline operations, reduce redundancies, and improve delivery responsiveness. Strengthening interdepartmental and interorganizational communication can also support agility and customer satisfaction. At the policy level, the results indicate that scalable improvements in digital logistics infrastructure can directly support e-commerce

efficiency in both urban and semi-urban regions. Public–private partnerships may be leveraged to promote technology adoption and supply chain integration among micro, small, and medium enterprises (MSMEs). Institutions such as the Kerala Startup Mission (KSUM) and Kerala State Industrial Development Corporation (KSIDC) can design interventions to enhance SCM training, digital literacy, and last-mile delivery systems. These strategic actions not only optimize firm-level operations but also contribute to broader regional development, employment generation, and digital economic growth.

7. Conclusion

The study on SCM practices and their influence on operational performance in Kerala's e-commerce retail sector provides crucial insights into strengthening efficiency, agility, and service quality in the regional digital marketplace. A structured quantitative approach was adopted, with responses collected from 426 e-commerce professionals across various organizational roles and business models. The research focused on the effect of three key SCM practices, such as information flow, supply chain integration, and coordination mechanisms, on four core performance indicators: cost-efficiency, delivery speed, product quality, and operational flexibility. The findings clearly indicate that these SCM practices significantly contribute to improved operational outcomes, with information flow having the most notable impact ($\beta = 0.338$). This was supported by multiple regression results ($R^2 = 0.479$) and group differences confirmed through Kruskal-Wallis analysis (Chi-square values ranging from 11.75 to 20.13, $p < 0.01$). The study emphasizes the need for e-commerce firms to adopt integrated and responsive SCM systems that align with Kerala's logistical and digital infrastructure. These practices are essential for sustaining performance and competitiveness. The findings reinforce theoretical assertions from both the Transaction Cost Economics and Resource-Based View, confirming that SCM practices serve as cost-reducing governance mechanisms and strategic resources driving performance. Future studies may explore the role of AI, automation, and real-time supply chain analytics to further enhance operational efficiency and strategic decision-making in regional e-commerce environments.

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