

EXPLORING THE MODERATING ROLE OF GREEN INFORMATION SYSTEMS IN ENHANCING THE EFFECTS OF SUPPLIER INTEGRATION AND CUSTOMER ORIENTATION ON GREEN INNOVATION

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ABSTRACT:

This study investigates the moderating influence of Green Information Systems (GIS) on the relationship between supplier integration and customer orientation and their subsequent impact on green innovation. By applying information processing theory, the study demonstrates the critical role of GIS in facilitating communication and knowledge sharing within the supply chain, thereby amplifying the positive effects of supplier integration and customer orientation on green innovation. The findings offer valuable insights into the strategic importance of investing in GIS as a catalyst for sustainable business practices. This study contributes to the existing literature by providing empirical evidence on how GIS can enhance the benefits of supply chain integration in driving green innovation.

Keywords: green information systems, customer orientation, green product innovation, green process innovation.

1. Introduction

The increasing environmental concerns have pressured companies to adopt models prioritizing sustainability over traditional profit-focused approaches, necessitating a balance between environmental management and economic performance (Zhang et al., 2019). Green innovation, seen as a strategic tool, aims to achieve sustainable development and competitive advantages through product differentiation, new-market strategies, cost-saving techniques, and advanced management capabilities (Junaid et al., 2022). While green innovation can improve

resource productivity and offset environmental costs, research on its drivers is limited, often focusing on external factors like government regulations and stakeholder pressures (Novitasari and Agustia, 2023).

Innovation, requiring the acquisition, management, and application of diverse knowledge, faces high complexity and uncertainty in green contexts (Setyaningrum et al., 2023). Information-processing theory suggests enhancing information-processing capacity to manage these uncertainties (Galbraith, 1973). Sustainable supply chain management and green

supply chain integration are crucial for aligning profitability with sustainability, requiring green information systems (Singh and Trivedi, 2016).

The role of green information systems in supporting sustainable operations and promoting green innovation capabilities is increasingly recognized (Yang et al., 2020). While many studies have examined supply chain management and information systems' impacts on performance, there is a need to explore their alignment with green innovations, particularly in process and product innovations (Dong et al., 2019).

This research proposes a conceptual framework to empirically study the fit between green supply chain integration (supplier integration and customer orientation) and green information systems, examining their combined effects on green processes and product innovations. By leveraging information processing theory, this study aims to fill existing gaps and provide managerial insights, contributing to the literature on green supply chain integration and innovation through theoretical and empirical validation. The paper is structured to discuss literature reviews, research methodology, results, and conclusions.

2. Literature reviews

2.1. Information Processing Theory

Information Processing Theory (IPT), initially developed to describe cognitive processes in human learning (Shiffrin and Schneider, 1977), was later applied to organizational learning, viewing organizations as information-processing systems with specific capacities (Galbraith, 1973; Nadler and Tushman, 1990). Effective performance requires organizations to align their information-processing capacity with the volume and intensity of information they face, enabling efficient information collection, storage, and transformation (Egelhoff, 1991; Galbraith, 1977). Complex tasks necessitate higher information-processing capacities to manage associated risks and uncertainties.

The need for substantial information-processing capacity is critical in green innovations,

characterized by high complexity and uncertainty. These innovations involve large volumes of knowledge and information, market dynamics, and intense competition (Corrocher and Zirulia, 2010; Gilbert and Cvsa, 2003). IPT suggests that expanding information-processing capacities helps companies manage these complexities and uncertainties, enhancing green innovation without incurring additional costs.

2.2. Green innovation

Green product innovation focuses on creating new, sustainable products that reduce environmental harm through energy-saving designs, pollution prevention, and improved recycling (Chen et al., 2006), using a “cradle to grave” life cycle approach. Green process innovation involves modifying existing products or processes to minimize environmental impacts by reducing energy use, waste, and emissions, and enhancing recycling and efficiency (Tseng et al., 2013).

2.3. Hypothesis development

2.3.1. Supplier integration

Green innovations demand extensive information processing and involve significant uncertainties. Companies need robust systems to manage both operational and non-operational information. To support suppliers' environmental practices, companies should provide guidance, share expertise, and foster direct interactions at various organizational levels to enhance information processing and reduce uncertainties (Egelhoff, 1991; Galbraith, 1973). IPT suggests that close integration with key suppliers boosts a company's information-processing capacity and efficiency, incorporating external expertise and preventing information overload (Bonaccorsi and Lipparini, 1994). High-level supplier integration thus facilitates the effective management of information required for green innovations, ensuring successful implementation.

H1. High-level supplier integration can help improve green product innovation.

H2. High-level supplier integration can help improve green process innovation.

2.3.2. Customer orientation

Customer orientation, a crucial aspect of market orientation, requires companies to monitor and satisfy customer's needs (Deshpande and Farley, 1998; Kohli and Jaworski, 1990). To achieve high-level customer orientation, companies must gather extensive customer-related information and respond promptly to dynamic customer requirements, enhancing customer satisfaction. This orientation is vital for new product success and aligning innovations with customer environmental concerns (Banerjee et al., 2003). Close customer connections can alleviate information asymmetry and processing burdens. High-level customer orientation ensures an accurate understanding of customers' environmental preferences, which is increasingly important as consumers become more environmentally conscious. Thus, customer-oriented companies must prioritize communication and efficient information processing to implement green innovations.

H3. High-level customer orientation can help improve green product innovation.

H4. High-level customer orientation can help improve green process innovation

2.3.3. Green Information System

A Green Information System (GIS) helps organizations manage sustainable operations and interactions with supply chain partners (Siegler and Gaughan, 2008). An effective GIS monitors and reduces environmental impacts, optimizing supply chains and supporting activities like carbon footprint analysis and emission reduction (Carberry et al., 2019). GIS enhances sustainable activities, communication, and operational efficiency. It underpins environmental management across supply chains, aiding eco-product design and production (Le Quế et al., 2018).), a well-developed GIS increases information-processing capacity, facilitating knowledge sharing and communication within the company and with partners. This improves supplier integration and customer orientation, enabling companies to manage green innovations

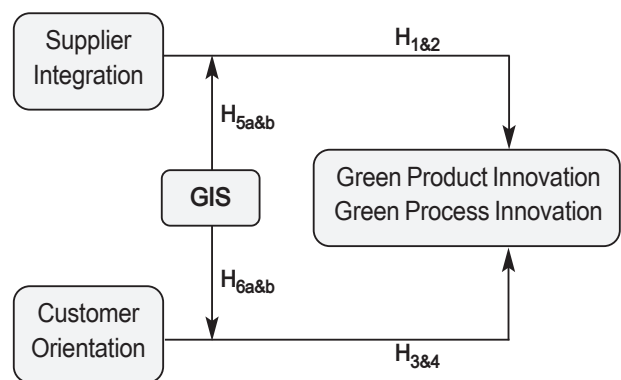
effectively and efficiently, and enhancing the impact on green products and process innovation.

H5. GIS positively moderates the impacts of supplier integration on (a) green product innovation and (b) green process innovation.

H6. GIS positively moderates the impacts of customer orientation on (a) green product innovation and (b) green process innovation.

In Fig. 1, we graphically illustrate the conceptual model

Figure 1: Conceptual model



Source: Analysis by authors

3. Methodology

3.1. Survey design

We collected data by surveying corporate managers in Ho Chi Minh City, Dong Nai, and Binh Duong Province. The questionnaire, developed by Hinkin (1998) was reviewed and pre-tested by top managers and several CEOs. Based on their feedback, the questionnaire was revised to ensure clarity and specificity.

3.2. Data collection

We sent questionnaires to 450 companies, recommended by the Ho Chi Minh City Institute for Development Studies (HIDS) with prepaid return envelopes to these companies, ensuring anonymity and confidentiality to mitigate privacy concerns and bias. After four months, we received 360 responses, with 240 usable after excluding 20 incomplete ones.

To address common method variance (CMV), each questionnaire was completed by a director or senior manager, whose understanding of CMV

risk (Miller and Roth, 1994). We interspersed dependent variables among independent variables in the questionnaire to minimize cues for respondents. Harman's single-factor test was also employed, yielding fit indices of RMSEA = 0.206, $\chi^2 = 1547.69$ (df. = 648), CFI = 0.401, and SRMR = 0.247, which were less favorable than those from the Confirmatory Factor Analysis (CFA) model.

3.3. Measurement validation

A five-point Likert scale was used for all measurement items, CFA indicated good unidimensionality for the constructs, with RMSEA at 0.041 and $\chi^2 = 657.8$ (df = 543) within acceptable thresholds. Additional fit indices (CFI = 0.971, TLI = 0.962) further supported a good model fit.

Reliability, assessed by Cronbach's Alpha, confirmed internal consistency for each construct. Convergent validity was confirmed with average variance extracted (AVE) values exceeding the 0.5 threshold for all constructs. Discriminant validity was established by comparing the square root of the AVE for each construct with its correlations with other constructs, with each construct showing greater variance with its indicators than others (Table 1).

the conceptual framework, as depicted in Fig. 1. SEM, integrating factor and path analysis, examines relationships among latent constructs indicated by multiple measures and accounts for measurement errors. It enables the modeling of complex relationships and simultaneously testing numerous hypotheses. Mplus 8 was employed to estimate the SEM. A hierarchical estimation process first assesses the direct effects of supplier integration (SI) and customer orientation (CO) on green product innovation (GPDI) and green process innovation (GPCI) in model 1. Then, we assess the moderation effect of the green information system (GIS) in model 2. This hierarchical approach mitigates collinearity risks and confirms relationships step-by-step. Fit indices indicate a good model fit with RMSEA below 0.08 and CFI above 0.945, supporting the proposed relationships in the conceptual model and showing significant improvement over the null model.

4.1. Main effects

In model 1 (Table 2), the study confirms the significant positive effects of SI and CO on GPDI and GPCI, supporting hypotheses H1 to H4. Specifically, SI positively impacts GPDI (0.205, $p < 0.01$) and GPCI (0.232, $p < 0.01$), while CO

Table 1: Correlations & Reliability

	Supplier Integration (SI)	Customer Orientation (CO)	Green Information System (GIS)	Green Product Innovation (GPDI)	Green Process Innovation (GPCI)
SI	0.768				
CO	0.105	0.766			
GIS	0.117	0.138	0.801		
GPDI	0.342	0.302	0.205	0.705	
GPCI	0.313	0.302	0.134	0.347	0.742
Reliability	0.855	0.855	0.914	0.843	0.867

Source: Analysis by authors

4. Results and analyses

This study utilizes a structural equation model (SEM) to analyze the proposed relationships within

positively impacts GPDI (0.173, $p < 0.05$) and GPCI (0.269, $p < 0.01$). These findings underscore the importance of SI and CO in enhancing green

innovations, suggesting that high-level integration with suppliers and a strong focus on customer environmental preferences bolster a firm's green initiatives. The results advocate for seamless integration and collaboration across the supply chain to improve environmental performance and competitive advantage. Companies should invest in training suppliers and understanding customer environmental concerns to drive green innovations and address environmental challenges.

4.2. Moderation effects of GIS

Model 2 (Table 2) examines the moderation effect of green information systems (GIS) on supplier integration (SI) and customer orientation (CO) regarding green innovations. GIS significantly enhances the positive impact of SI on both green products (0.178, $p < 0.05$) and process innovations (0.189, $p < 0.05$), supporting hypotheses H5a and H5b. Additionally, GIS positively moderates the relationship between CO and green process innovation (0.197, $p < 0.01$), confirming hypothesis H6b, though its effect on green product innovation (0.132, $p < 0.1$) is not significant. These findings highlight GIS's role in improving supply chain communication and facilitating green innovation. The insignificant

moderation effect of GIS on the CO-green product innovation link may stem from customers' limited expertise or dataset limitations. Control variables reveal that larger companies and those with highly educated employees exhibit higher levels of green innovation, likely due to economies of scale and superior learning capabilities. The results of the hierarchical estimation of models 1 and model 2 are shown in Table 2.

5. Discussion

This study highlights the crucial role of GIS in enhancing green innovations within green supply chain management (SCM). Although the individual impacts of green SCM and GIS on organizational green innovations and environmental performance are well-documented, their combined influence has been understudied. Based on information-processing theory, the research suggests that aligning GIS with supplier integration and customer orientation is essential for improving green innovations. This alignment addresses the increased information-processing demands of green innovations by enhancing supply chain integration and enabling efficient information sharing. The findings offer theoretical and managerial insights into optimizing green innovations through the strategic alignment of GIS and green SCM in inter-organizational contexts

5.1. Theoretical implications

This study highlights the critical alignment of GIS with green supply chain integration (SCI) to enhance organizational green innovations, addressing a gap in SCM research. It proposes a conceptual framework to identify GIS's moderating effect on the relationship between supply chain integration - supplier integration and customer orientation-and green performance in product and process innovation. The findings suggest that SCI's impact is context-dependent and should consider contingent factors to achieve desired benefits. Applying information-processing theory, the study emphasizes the need for enhanced information-processing capacity to manage the complexity and uncertainty of green innovations efficiently. The insights offer valuable references for future

Table 2: Moderation Effects of GIS

	Model 1	Model 2
SI $\Rightarrow$ GPDI	0.205 (2.544) **	0.198 (2.421) **
SI $\Rightarrow$ GPCI	0.232 (2.732) **	0.229 (2.711) **
CO $\Rightarrow$ GPDI	0.173 (2.229)*	0.169 (2.116) *
CO $\Rightarrow$ GPCI	0.269 (3.376)**	0.263 (3.312) **
GIS $\Rightarrow$ GPDI		0.174 (2.216) **
GIS $\Rightarrow$ GPCI		0.162 (2.115) **
SI*GIS $\Rightarrow$ GPDI		0.178 (2.194) **
SI*GIS $\Rightarrow$ GPCI		0.189 (2.235) **
CO*GIS $\Rightarrow$ GPDI		0.132 (1.651) **
CO*GIS $\Rightarrow$ GPCI		0.197 (2.654) **

Source: Analysis by authors

research on factors enhancing green innovations within green supply chains and serve as a significant resource for scholars in green innovation, SCM, sustainability, and GIS.

5.2. Managerial implications

Green innovations serve as a strategic tool for companies to address environmental concerns and gain a competitive advantage, despite inherent risks and uncertainties. Supplier integration and customer orientation enhance a company's information-processing capacity for green innovations. An effective Green Information System (GIS) improves information sharing and collaboration across the supply chain, amplifying the impact of supplier integration on green product and process innovations and strengthening customer orientation's effect on green process innovation. The study underscores the importance of aligning GIS with green Supply Chain Integration (SCI) to meet sustainability pressures and justify top management's investment in GIS to enhance innovation capabilities and green performance.

5.3. Limits and future research

This study highlights several limitations, including the reliance on a self-reported dataset and single-region, cross-sectional data, suggesting the need for cautious interpretation and the use of longitudinal or multi-regional data in future

research. It emphasizes the focus on supplier integration and customer orientation in green innovation, recommending future studies to explore their antecedents and the factors enhancing GIS for better green supply chain integration. Additionally, it suggests investigating governance mechanisms for effective supply chain integration.

6. Conclusion

In response to stakeholder concerns about environmental impacts, companies adopt green process and production innovations through supply chain partnerships for competitive advantage. This study presents a theoretical framework exploring two benefits of Green Information Systems (GIS): enhancing suppliers' green capabilities for developing green processes and products and helping firms incorporate customer requirements into green innovations. Supplier integration and customer orientation are identified as key drivers for green product and process innovation, consistent with supply chain management literature. Implementing GIS facilitates information sharing, strengthens supplier and customer collaboration, and expands a company's information-processing capacity, thereby enhancing green innovation capabilities. Empirical results underscore the importance of developing robust GIS to improve green integration and innovation across the supply chain ■

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**KHÁM PHÁ VAI TRÒ ĐIỀU TIẾT
CỦA HỆ THỐNG THÔNG TIN XANH TRONG VIỆC
TĂNG CƯỜNG TÁC ĐỘNG CỦA SỰ HỢP TÁC
VỚI NHÀ CUNG CẤP VÀ ĐỊNH HƯỚNG KHÁCH HÀNG
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TÓM TẮT:

Nghiên cứu này dựa trên lý thuyết xử lý thông tin để khám phá vai trò điều tiết của Hệ thống Thông tin Xanh (GIS) trong việc tăng cường tác động của sự tích hợp nhà cung cấp và định hướng khách hàng đối với đổi mới xanh. Kết quả nghiên cứu nhằm nhấn mạnh tầm quan trọng của việc đầu tư vào GIS để tạo điều kiện thuận lợi cho việc giao tiếp và chia sẻ thông tin trong toàn bộ chuỗi cung ứng, từ đó thúc đẩy đổi mới xanh. Nghiên cứu đóng góp vào tài liệu nghiên cứu bằng cách cung cấp bằng chứng thực nghiệm về cách GIS có thể tăng cường các lợi ích của tích hợp chuỗi cung ứng đối với đổi mới xanh.

Từ khóa: hệ thống thông tin xanh, định hướng khách hàng, đổi mới sản phẩm xanh, và quy trình đổi mới xanh.