The Role of Artificial Intelligence in Collaborative Green Supply Chain Management: Impact on Company Performance and Moderation of Top Management Commitment

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ABSTRACT

This study explores the growing interest in big data and Artificial Intelligence (AI) while addressing the gap in research on AI's role in Collaboration within Green Supply Chain Management (CGSCM) and its impact on Firm Performance (FP). Integrating AI and assessing Top Management Commitment (TMC) as a moderating factor, a moderated mediation model was constructed using data from 152 Indonesian manufacturing firms. The results show that AI positively influences CGSCM and FP, with CGSCM acting as a mediator between AI and FP. Additionally, TMC enhances the positive relationship between AI and CGSCM, strengthening this connection at higher TMC levels. Conversely, TMC moderates the link between AI and FP, reducing its strength at lower TMC levels. These findings provide valuable insights for supply chain and logistics managers, offering guidance on implementing AI to promote collaboration in sustainable supply chains and improve firm performance.

1. INTRODUCTION

The rapid evolution of digital technologies in recent years has significantly reshaped how modern organizations manage their operations, especially within supply chains. One of the most transformative technologies is Big Data Analytics (BDA), which has become increasingly relevant in both theoretical and practical domains [1]. Papadopoulos and Gunasekaran [2] note that BDA has emerged as a vital organizational capability due to the explosion of data volume, velocity, and variety stemming from increasingly digital business processes. Particularly in supply chain management (SCM), where data is generated across multiple stakeholders and processes—from suppliers to end customers—BDA offers the ability to extract insights that improve forecasting, inventory control, logistics efficiency, and risk management [3], [4].

The strategic value of BDA lies not only in its ability to enhance operational efficiency but also in its potential to support sustainability and environmental performance within Green Supply Chain Management (GSCM). However, despite its promise, the application of BDA in environmental dimensions of SCM remains under-researched [5]. Existing empirical studies that examine the influence of BDA on green collaboration, sustainability practices, and firm performance (FP) are still limited [6], [7], [8]. Yet, in the current era marked by climate change, increasing regulatory pressure, and stakeholder demands for corporate responsibility, integrating green objectives into supply chain processes is no longer optional but essential.

This issue is particularly critical for the manufacturing sector, which is both a key driver of economic growth and a major source of environmental degradation. In Indonesia, the manufacturing industry contributes significantly to national GDP, accounting for 19.80% of total economic output in

2023 according to Statistics Indonesia (BPS) [9]. The sector also provides substantial employment, absorbing nearly 18% of the national workforce [10]. However, its environmental footprint is equally notable. According to the Ministry of Environment and Forestry (KLHK), the manufacturing sector is responsible for approximately 23.4% of Indonesia's total greenhouse gas (GHG) emissions, making it one of the highest-emitting sectors after energy [11].

Various environmental challenges afflict Indonesian manufacturers. Many rely on resource-intensive production systems, utilize outdated technologies, and often lack structured environmental management systems. A World Bank report in 2022 revealed that over 65% of manufacturing firms in Indonesia do not comply with national environmental standards or monitoring frameworks [12]. Furthermore, the implementation of green innovations and eco-efficiency practices remains slow due to limited awareness, weak regulatory enforcement, and fragmented coordination across supply chain actors [13]. These problems suggest that a shift toward more sustainable and collaborative supply chain models is urgently needed.

A central obstacle in achieving green supply chain outcomes is the difficulty of coordinating diverse actors across the supply chain, each with different interests, capabilities, and levels of commitment. Green supply chain collaboration (GSCC) requires shared goals, real-time communication, data integration, and mutual accountability between buyers, suppliers, and other stakeholders [14]. This is where Artificial Intelligence-enhanced Big Data Analytics (BDAI) can play a pivotal role. By leveraging AI algorithms, machine learning, and predictive modeling, BDAI can improve visibility, enable advanced analytics, and support decision-making processes that promote environmental objectives across the supply chain [15], [16].

For example, BDAI can help firms identify emissions hotspots, simulate the environmental impacts of supply chain decisions, optimize transport routes to reduce fuel use, and monitor supplier compliance with environmental standards [17]. It also facilitates large-scale group decision-making essential in circular economy models, where end-of-life product recovery, waste minimization, and recycling must be integrated into supply chain design [18]. Thus, GSCC may act as a critical mediating mechanism between BDAI adoption and improved firm performance, especially in sectors like manufacturing where environmental risks are high.

Despite the growing recognition of BDAI's potential, its actual use in driving green practices in the Indonesian manufacturing sector remains underexplored. Most research on BDAI focuses on cost reduction, production efficiency, or product innovation [19], [20], [21], with limited emphasis on its role in facilitating green supply chain initiatives. Moreover, studies that examine its effect on firm performance through green collaboration, particularly in developing country contexts, are scarce. Given Indonesia's unique institutional, environmental, and cultural challenges, this represents a critical research gap.

Another underexamined factor in the BDAI- GSCM-FP nexus is the role of top management commitment. Leadership plays a central role in setting strategic priorities, allocating resources, and fostering a culture of innovation and sustainability. As noted by previous studies, successful digital transformation and sustainability initiatives require strong leadership support [22], [23]. In the context of green supply chains, top management commitment is essential to build trust with partners, ensure compliance with environmental standards, and integrate BDAI technologies into existing workflows. However, few empirical studies have rigorously tested the moderating effect of top management commitment on the impact of BDAI on firm performance through green collaboration [6].

This lack of research is especially pronounced in Indonesia, where organizational structures tend to be hierarchical and managerial decisions are centralized. The influence of top executives on strategic outcomes is likely to be stronger in such contexts compared to decentralized corporate cultures. Despite this, little is known about how executive support affects the success of digital and environmental initiatives in Indonesian manufacturing.

Jurnal Logistik Indonesia Vol. 9, No. 2, Oktober 2025, pp. 136-149

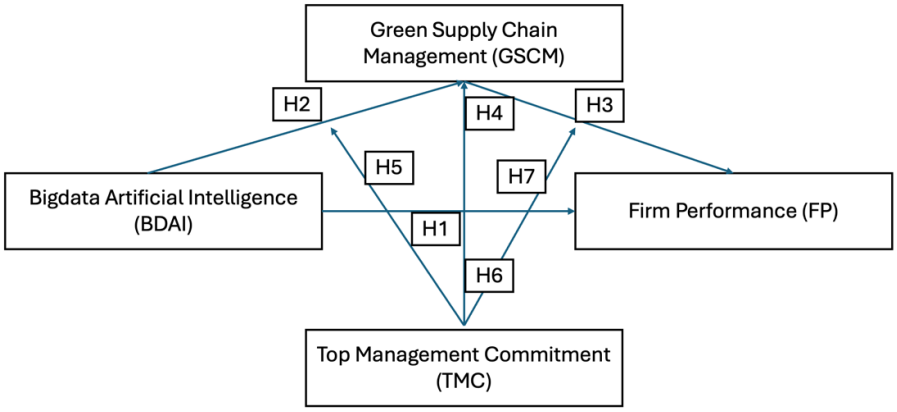

Fig. 1. Research Framework

2. THE PROPOSED METHOD

2.1. Big Data Artificial Artificial Intelligence (BDAI)

[24] assert that a new generation of technologies and architectures enables rapid data capture, identification, and analysis to get value from extensive and diverse data sets cheaply. These technologies employ advanced computational techniques that allow firms to evaluate and comprehend essential business data, enhancing their understanding of operations and markets [3]. Consequently, these technologies facilitate the acquisition of competitive advantages. One of these advantages is supply chain and logistics management [3]. Therefore, it is unsurprising that scholars in management science and supply chain and logistics management have begun to focus on big data analytics (BDA). Brynjolfsson et al. [1] ascribe this to their capacity to employ methodologies that facilitate decision-makers in achieving superior conclusions grounded in data rather than relying on human intuition or judgment. This necessitates the creation of suitable technologies to manage the anticipated data volume and, consequently, identify trends and reveal patterns to achieve lucrative results [16]. [24], [25] identify three categories of data processing schemes: batch processing, real-time stream processing, and interactive processing. BDA-related systems are applicable in multiple analytical domains, encompassing descriptive, predictive, and normative analysis [26]. By employing various approaches, tools, and processes, BDA assists firms in making informed decisions about green efforts within their supply chains [27]. The influence of BDA on GSCC and FP decision-making processes needs to be more adequately comprehended and documented in the literature.

2.2. Green Supply Chain Management (GSCM)

Green supply chain management (GSCM) integrates green management with supply chain management to tackle environmental challenges inside enterprises and their supply chains. Organizations encounter daily pressure from the media, local communities, non-governmental organizations, and legal obligations dictated by ecological legislation [28]. Moreover, consumers insist on enhanced responsibility and openness concerning the conditions of production and delivery of their products. They are also advocating for enhanced environmental awareness. Consequently, firms must exert considerable effort to establish more sustainable supply chains and reassess their business practices as they recognize their responsibilities to guarantee humanity's long-term survival [29], [30].

Consequently, for effective green management, firms must prioritize the supply chain rather than the company itself [13]. This is particularly significant in the manufacturing sector, where pollution substantially affects the environment. In the circular economy, GSCM focuses on the extent to which an organization and its suppliers enhance environmentally conscious decision-making and performance, including aspects such as sustainable product design, material production and recycling,

waste management, and material reuse throughout the lifecycle of a flow [31]. In the manufacturing sector, GSCM necessitates the coordination and cooperation of several entities [19]. The probability of realizing green initiatives in the supply chain escalates with the extent of consultation and collaborative ties among supply chain partners [32]. A prior study by [33] recommended collaboration among supply chain participants to facilitate knowledge sharing, optimize fundamental business processes, and enhance inter-organizational operations. Corso et al. (Mariano et al. 2010) highlighted that certain firms still need more comprehension of the essential components that facilitate the implementation of collaborative green supply chain initiatives. This study posits that implementing advanced technologies (BDAI) can enhance the management of flows, processes, and inter-organizational connections within manufacturing supply chains to achieve superior firm performance.

2.3. Analysis of Big Data and Artificial Intelligence in the Manufacturing Sector.

Green supply chain management (GSCM) integrates green management with supply chain management to tackle environmental challenges inside enterprises and their supply chains. Organizations encounter daily pressure from the media, local communities, non-governmental organizations, and legal obligations dictated by ecological legislation [28]. Moreover, consumers insist on enhanced responsibility and openness concerning the conditions of production and delivery of their products. They are also advocating for enhanced environmental awareness. Consequently, firms must exert considerable effort to establish more sustainable supply chains and reassess their business practices as they recognize their responsibilities to guarantee humanity's long-term survival [29], [30].

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2.4. BDAI and Ecological Performance.

Wu and Pagell [36] assert that artificial intelligence-driven big data analytics is essential in green supply chain management since it mitigates information asynchrony and processes intricate environmental data. Consequently, it provides insights into the decision-making process to enhance green supply chain management and firm performance [8]. [NO_PRINTED_FORM] [37] qualitative study revealed that AI and analytics are crucial for data analysis, pattern recognition, environmental effect prediction, and energy consumption reduction, enhancing firm performance.

Numerous academics have proposed that using BDAI is crucial for incorporating environmental measures into various supply chain operations. [38] contend that big data analytics (BDAI) can significantly enhance production, storage, and waste management, thus boosting firm performance (FP). Utilizing BDAI in green supply chain management via eco-design and supplier selection has been documented to enhance firm performance [39]. [19], [24] and [39] asserted that BDAI enhances internal green operations and supplier collaboration, diminishing waste, emissions, and environmental concerns.

Most studies above provide only theoretical elucidations of the correlation between BDAI and FP, with few undertaken beyond the manufacturing sector. Consequently, drawing on the current research, we propose the hypothesis:

H1: BDA-AI-enhanced decisions positively influence FP.

Jurnal Logistik Indonesia Vol. 9, No. 2, Oktober 2025, pp. 136-149

2.5. BDAI and GSCM.

In recent years, there has been a notable rise in applying Big Data Analytics (BDA) within green supply chains across multiple sectors [1], [40]. Fernando et al. (Fernando, Zainul Abideen, and Shaharudin 2020) indicated that efficient data synchronization in supply chain management has emerged as a challenge. Supply chain partners consistently seek to connect and coordinate business activities to attain corporate objectives. Nonetheless, difficulties in information dissemination throughout the supply chain have persistently occurred, including information delays, distortions, and losses [41]. From this viewpoint, [42] proposed that utilizing big data analytics enhances the visibility and integration of sustainability in supply chain management, along with the accessibility of critical information.

BDAI facilitates efficient data gathering, integration, and reporting [43], enhancing product design sustainability [8]. [24], [37] integrated big data analytics, cloud computing, and operations research methodologies (AHP, TOPSIS, and DEMATEL) to develop a novel decision-making instrument to assess carbon footprint and greenhouse gas emissions during supplier selection. Furthermore, in the healthcare industry, [6]. [44] indicated that BDAI enhanced decisions were favorably correlated with GSCM.

Consistent with the rationale above and empirical evidence, we endorse the proposition that implementing novel BDAI technologies can assist the manufacturing sector in processing data from intra and cross-organizational sources while facilitating collaboration with suppliers in the environmental decision-making process. Therefore, we propose the hypothesis:

H2: Decisions enhanced by BDAI positively influence GSCM.

2.6. Collaboration in Green Supply Chain Management and Firm Performance.

Prior research [45], [46] has demonstrated the correlation between environmental integration and supplier partnership to guarantee sustained ecological performance. Nevertheless, despite its increasing significance in recent years, research has yet to examine this link inside the Indonesian manufacturing sector.

Supplier collaboration is a mutual comprehension encompassing resource sharing and joint decision-making to mitigate environmental consequences during product development [32]. [47] proposed that enterprises should commit additional resources to research and development and collaborate with suppliers to enhance firm performance. Supplier collaboration, as demonstrated by several research [31], [32], is critical for organizations aiming to include low-carbon emission resources and operations while reducing their energy and environmental impacts. [48] asserted that cross-collaboration tactics can assist organizations in minimizing waste, enhancing firm performance, and establishing an eco-friendly reputation.

GSCM enhances the monitoring of suppliers that commit to supplying and utilizing ecologically sustainable equipment and raw materials [20]. Moreover, embracing a collaborative strategy among suppliers in the manufacturing sector appears essential for advancing green purchasing and supply methods and managing prospective demand and transportation. This technique can enhance inventory management, optimize warehouse storage, and streamline transportation while reducing production waste disposal. Consequently, we propose the hypothesis that

H3: Green Supply Chain Management (GSCM) positively influences Firm Performance (FP).

2.7. The Mediating Function of GSCM.

Manufacturing businesses must consider green supply chain methods to enhance their firm performance, driven by escalating pressures and obstacles and the necessity to address evolving customer demands. [49] show that the design stage is the important phase of the product life cycle, as it is the point at which environmental concerns can be mitigated. Creating reusable and recyclable products via low-energy methods can enhance waste management and reduce hazardous substances and toxic emissions [47], thus enhancing firm performance. Organizations can engage with suppliers to align environmental needs with product design, manufacturing processes, and transportation for green operations [46]. [6] demonstrated that BDAI facilitates sustainable decision-making and serves as a crucial instrument for addressing environmental challenges within and between companies. Prior

research [39], [44] showed that BDAI facilitates intra-organizational green initiatives and supplier engagement, reducing waste, carbon emissions, and environmental challenges.

In conclusion, it is plausible to assert that BDAI can activate GSCM and that green supply chain management will enhance firm performance. GSCM can facilitate the connection between BDAI-supported decisions and FP. No prior studies have examined the mediating function of GSCM in the link between BDA-AI-supported decisions and FP. Consistent with theoretical and empirical evidence, we propose that

H4: Green supply chain management mediates the relationship between BDAI-supported decisions and firm performance.

2.8. The Moderating Role of TMC.

The TMC notion corresponds with the Theory of Planned conduct (TPB), which elucidates conduct based on personal motivations [50]. Behavioral performance in the Theory of Planned Behavior (TPB) transpires when individual acts possess specific aims and intentions. Individual conduct results from a rational cognitive process wherein individuals internally assess information before its use in external actions. This approach posits that the knowledge and attitudes of senior management affect the utilization of new technologies, such as big data analytics, and that managerial concerns regarding the environment impact the extent to which green innovation operations influence firm performance and competitive capability.

Organizations must present themselves as ecologically sustainable while doing their operations as usual. Nonetheless, senior management must be dedicated to their actions' economic and environmental consequences [51]. [52] assert that senior management executives must genuinely embrace sustainability to convert stakeholders' demands for environmentally friendly operations into efficient and enduring answers. Moreover, top management's robust ethical stance and environmental perspective can significantly foster a good philosophy regarding green practices inside their supplier chain and firm performance initiatives. The crucial element for the success of green practices is "top management support, leadership, and commitment to sustainability [24], [42]. Authentic leaders identify opportunities, offer a meaningful vision, and modify their ethical frameworks within their domains. [24], [45] asserted that commitment must originate from the higher echelons of management. Therefore, establishing appropriate strategy guidelines and developing sustainable operations is unequivocally unfeasible without TMC [24]. Numerous studies have indicated that certain green initiatives have significantly faltered due to insufficient backing from upper management [53], [54]. Consequently, to implement green initiatives, management must integrate sustainable practices into daily supply chain operations to promote environmental awareness. Accordingly, we propose the following hypothesis;

H5: The Commitment Of Top Management Moderates The Association Between BDAI And GSCM, Whereby The Positive Correlation Is More Pronounced At Elevated Levels Of Top Management Commitment Compared To Lower Levels.

H6: TMC Moderates The Link Between BDAI And FP, Diminishing The Intensity Of The Positive Correlation At Lower Doses Of TMC.

H7: TMC Moderates The Link Between GSCM And FP, Whereby The Intensity Of The Positive Correlation Is Amplified With Elevated Levels Of Top Management Commitment.

This work is anticipated to provide substantial contributions in multiple aspects:

This project will enhance academic literature by addressing the empirical research gap between artificial intelligence and green supply chain management, offering novel insights. The study's conclusions can serve as a reference for scholars exploring the relationship between technology and sustainability.

This study will offer managers and corporate leaders' actionable ideas on effectively integrating AI in supply chain collaboration to attain sustainable objectives. Consequently, organizations can enhance their performance while meeting their social and environmental obligations.

Jurnal Logistik Indonesia Vol. 9, No. 2, Oktober 2025, pp. 136-149

This study will elucidate the significance of management commitment by delineating its moderating impact, underscoring leadership's criticality in digital transformation and sustainability. This may prompt organizations to prioritize cultural and managerial factors in executing innovative practices.

This study's findings can serve as a foundation for subsequent research in technology, sustainability, and supply chain management. Additional analysis may be undertaken to investigate alternative influencing variables and other industry situations.

3. METHOD

Respondents in this study were selected using a purposive sampling technique to ensure that the data collected came from individuals with relevant knowledge and direct involvement in supply chain operations. The target respondents were professionals responsible for supply, logistics, procurement, or operations within manufacturing companies, particularly those listed on the Indonesia Stock Exchange (IDX), to ensure the inclusion of organizations with structured operations and access to technological resources such as big data analytics. The study focused on three key sectors—basic and chemical industries, consumer goods, and other industrial manufacturers—with companies located in prominent industrial areas, including Pulogadung (Jakarta), Jalan Raya Bogor (Depok), Tangerang (Banten), Karawang and Cikarang (West Java), and Rungkut (Surabaya). Prior to completing the full questionnaire, potential respondents were screened using a closed-ended question to assess their understanding of big data analytics (BDA) capabilities within supply chain contexts. Only individuals who demonstrated sufficient awareness or exposure to BDA were included in the final sample, ensuring the validity of the responses, particularly in relation to the study's technological focus. Furthermore, the distribution of the Google Forms survey was supported by several professionals working in the manufacturing sector, who helped identify and reach suitable participants across the targeted industrial areas.

The specialists facilitated a pilot test of the questionnaire to assess its validity. These seasoned supply chain management and logistics manufacturing specialists participated in the initial trial we conducted. We requested these experts evaluate the survey's structure, clarity, precision, and integrity [8]. This enabled us to elucidate several inquiries concerning the measuring of the objects. The final questionnaire incorporated the advice and recommendations from the experts. Participants were supplied with a dictionary of essential terminology to mitigate comprehension challenges regarding the questions. Participants were subsequently assured that their information would remain confidential and that the acquired data would solely be utilized for academic research purposes. As per [33], the development of the Measurement Scale involved multiple measurements and the execution of a pilot test, as previously stated. As an initial step, we needed to verify the validity of the measuring scale's content. Content validity aims to assess whether the questionnaire items sufficiently represent the phenomenon under investigation.

Table 1. Respondent Characteristics

Information	Frequency	Percentage
Firm Size (Number of Employees):	152	100%
20-50	8	5%
51-100	28	18%
100-150	38	25%
Above 150	78	51%
Manufacture type:		
basic and chemical industry sector	49	32%
consumer goods industry	71	47%
various industry sector	32	21%

Quantification. BDAI was assessed using four items created by [24], [44] and [8], [55] GSCM was assessed utilizing four items created by [39]. TMC was assessed using five items formulated by [33] and [2]. FP was assessed using six items created by [56]. [39], [57]. This study employed SEM PLS PLS-SEM for data analysis. SEM PLS does not presuppose a normal distribution for the data [58].

The lack of a normal distribution in the variables may result in distortions in the results of multivariate analysis. Figure 1 below illustrates the outcomes of the normality test. What is the geographical location? Convergent validity can be assessed by comparing the factor loading values of each indicator with their respective constructs. A factor loading of 0.7 or above is considered significant in confirmatory research. Figure 2 illustrates the results obtained from the PLS-SEM technique, indicating convergent validity. The model estimates results demonstrate that all indicators possess factor loadings exceeding 0.5. Consequently, all measures are considered appropriate for the study's objectives and dependable for assessing their respective constructs.

The assessment of the measuring model (outer model) utilizes many criteria to ascertain the degree to which the concept can be precisely defined. The loading factors, Cronbach's alpha, and composite reliability are expected to approach 0.70, while the average variance extracted (AVE) is projected to surpass 0.50 (Hair and et al 2022). Table 2 presents the loading factors, Cronbach's alpha (α), composite reliability (CR), and average variance extracted (AVE). Table 2 demonstrates that all indicators possess a loading factor of 0.7, whereas two constructs exhibit a Cronbach's alpha below 0.7. According to [59], [60], a Cronbach's alpha of 0.6 is deemed acceptable, provided that the Composite Reliability (CR) and Average Variance Extracted (AVE) values adhere to the reliability norms. It may be concluded that all the evaluated constructs demonstrate robust convergent validity and reliability.

Table 3 presents the outcomes of the discriminant validity assessment employing the Heterotrait-Monotrait Ratio of Correlations (HTMT) technique as outlined by [59]. The use of HTMT arises from the assertion by [58] that the Fornell-Larcker criterion is inadequate under specific circumstances, highlighting potential deficiencies in the prevalent discriminant validity standards. The threshold values are 0.90 for conceptually comparable constructs and 0.85 for conceptually distinct constructions [58]. The discriminant validity results indicate that all constructs exhibit HTMT values below 0.90, signifying their uniqueness and distinction from other components.

4. RESULTS AND DISCUSSIONS

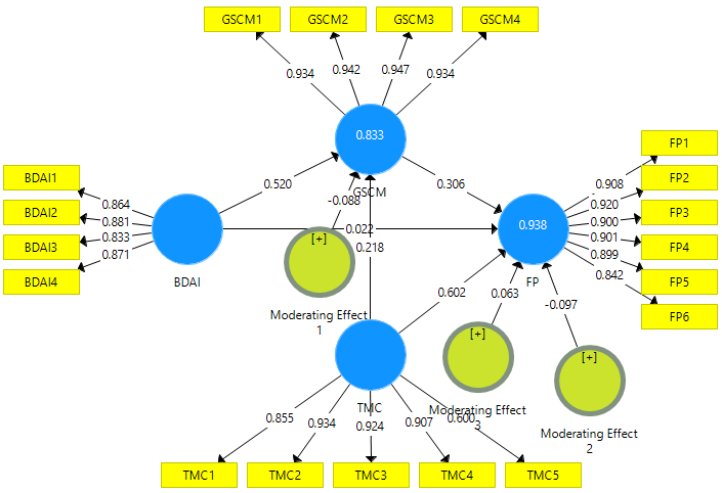

Fig. 2 Outer Model Analysis

Table 2. Reliability and Validity

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
BDAI	**0,885**	**0,890**	**0,921**	**0,744**
FP__	**0,950**	**0,951**	**0,960**	**0,802**
GSCM	**0,956**	**0,956**	**0,968**	**0,882**

Jurnal Logistik Indonesia Vol. 9, No. 2, Oktober 2025, pp. 136-149

TMC	**0,902**	**0,934**	**0,929**	**0,728**

Table 3. Discriminant Validity

	BDAI	FP__	GSCM	TMC
BDAI	0,863			
FP__	0,878	0,895		
GSCM	0,888	0,910	0,939	
TMC	0,846	0,940	0,842	0,853

Table 4. Hypothesis Testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
BDAI -> FP__	0.218	0.232	0.090	2.412	0.016
BDAI -> GSCM	0.520	0.513	0.080	6.536	0.000
GSCM -> FP__	0.306	0.301	0.058	5.283	0.000
Moderating Effect 1 -> GSCM	-0.088	-0.084	0.025	3.537	0.000
Moderating Effect 2 -> FP__	0.520	0.513	0.080	6.536	0.000
Moderating Effect 3 -> FP__	0.063	0.078	0.053	1.175	0.241
TMC -> FP__	0.306	0.301	0.058	5.283	0.000
TMC -> GSCM	0.218	0.232	0.090	2.412	0.016

This study uses an Indonesian sample to examine a moderated mediation model, elucidating the mechanisms linking BDA-AI to firm performance within the Indonesian manufacturing sector. Initially, it is disclosed that judgments augmented by BDAI exert a beneficial influence on FP. This conclusion offers empirical support for the assertions of [3], [37], [55] who contend that BDA-AI within green supply chain management can enhance firm performance (FP). The observation indicates that implementing advanced technologies like BDAI in the industrial industry can mitigate information asynchrony within the supply chain and effectively handle intricate environmental data to enhance firm performance. Secondly, it has been determined that BDAI-enhanced judgments are a factor in GSCM. This outcome aligns with the recent findings of [6] and the conclusions of [39], [61]. The identification of BDAI as a factor of GSCM indicates that this association is not confined to the Western setting. The consistency of these results suggests that the manufacturing sector must establish supporting IT infrastructure, such as BDAI, to foster collaborative partnerships for green supply chain management. Third, GSCM showed a beneficial effect on FP. This outcome corroborates the conclusions of [6], [62], who indicated that green supply chain collaboration enhances firm performance. Manufacturing companies ought to partner with their suppliers to improve firm performance. Fourth, it was determined that GSCM facilitates the direct interaction between BDAI and FP. Fifth, the commitment of top management moderates the association between BDAI and GSCM, indicating that the positive correlation is more pronounced at elevated levels of top management commitment compared to lower levels. The TMC moderates the association between BDAI and firm performance, indicating that when top management commitment is diminished, the intensity of the positive correlation is reduced. Ultimately, our findings do not substantiate the role of TMC as a moderator in the link between GSCM and FP.

4.1. Theoretical Implications.

This study formulates and empirically evaluates a research paradigm illustrating how BDAI technologies improve firm performance. Our research offers empirical evidence that implementing novel technologies (e.g., BDAI) in decision-making improves the information processing capacities of manufacturing companies. These data corroborate our assertion that manufacturing enterprises with modern technology infrastructure and sophisticated analytical capabilities can improve their firm performance. This expands the organizational information processing theory (OIPT) to the Indonesian manufacturing sector, which must be noticed more. The present study demonstrates that integrating innovative technologies, such as BDAI, facilitates GSCM and enhances green operations. The empirical association between BDAI and GSCM has yet to be established within the setting of manufacturing enterprises in Indonesia.

Moreover, the industrial sector comprises many entities with varying interests; hence, decision-making necessitates consensus among stakeholders who embrace a circular economy ideology [63]. OIPT specifically underscores the alignment of information processing capabilities inside and between organizations to enhance firm performance. This study uniquely contributes to the impact of BDAI technology systems on GSCM within the manufacturing sector. The present study provides significant insights into the effects of GSCM on FP. The present study offers new evidence, demonstrating that green supply chain collaboration is crucial in the interaction between big data analytics and artificial intelligence and firm performance. Our research shows this mechanism's role in enhancing manufacturing businesses' firm performance, transitioning from utilizing advanced technologies with information processing capabilities (BDAI) via GSCM to attain ecological performance. This outcome suggests that manufacturing companies utilizing BDAI to manage asynchronous information and intricate environmental data are more inclined to collaborate with suppliers and enhance their sustainable operations.

Moreover, a significant discovery not previously documented in the literature is that the current study offers new evidence on the moderation of the relationship between BDAI and FP by TMC. In contrast to earlier research that investigated top management commitment as a predictor [48] or as a mediator [24], this study analyses top management commitment as a moderator. To the best of our knowledge, our study is the inaugural investigation into the role of TMC in the interplay between BDAI and FP. It demonstrates that TMC moderates the relationship between BDAI and green supply chain collaboration, with a stronger positive correlation at higher levels of top management commitment than at lower levels. Additionally, TMC moderates the relationship between BDAI and FP, wherein the strength of the positive correlation diminishes at lower levels of top management commitment. Top management support is essential for the successful implementation of green projects.

Consequently, the acts of top management are critical to establishing the groundwork for sustainable operations. This pattern of results aligns with the current literature indicating that green operations are predominantly influenced by senior management decisions [64]. Consequently, the present study enhances existing knowledge by employing a novel methodology that transcends the direct correlation between BDAI and firm performance while considering the intricacies of real-world scenarios.

4.2. Practical Implications.

This study presents significant practical consequences that warrant consideration by the manufacturing sector, particularly policymakers. Initially, policymakers in the manufacturing sector have the potential to utilize BDAI technology to establish comprehensive environmental policies encompassing the full manufacturing supply chain operations. Decision makers can utilize BDAI technology to handle new indications and metrics in real-time, enhancing the visualization and comprehension of information regarding environmental activities. Secondly, our findings indicate that GSCM is a crucial component in the manufacturing sector. Consequently, organizational leaders must not solely depend on IT infrastructure for the execution of green projects but also engage in collaboration with suppliers within the supply chain to significantly contribute to a cleaner environment and an improved society. Third, our findings indicate that manufacturing firms cannot thrive solely in the current big data era by possessing quality data and efficient information processing; a robust commitment from top management to sustainable initiatives can amplify

communication and collaboration with suppliers and foster the development of shared beliefs discrete Dynamics in Nature and Society and initiatives for sustainable operations.

Consequently, TMC is a significant catalyst for sustainable operations and firm performance. Nevertheless, the present study emphasizes that organizational leaders must adequately focus on TMC and comprehend how varying degrees of top management commitment can influence BDAI on GSCM, impacting firm performance. The study's findings indicate that the beneficial effect of BDAI on GSCM is amplified by the degree of commitment from top management. Consequently, manufacturing decision-makers aiming to investigate and apply BDAI in their environmental endeavours should enhance TMC to cultivate effective collaborative efforts in green supply chains that advance ecological performance.

5. CONCLUSION

The empirical results of this study offer a refined comprehension of the application of BDAI technologies in enhancing firm performance, thereby elucidating the significance of green supply chain collaboration and, crucially, the commitment of top management in this context. Consequently, the data-driven research done for this study provides additional advantages by equipping company executives who concur with our recommendations with enhanced knowledge to assess the efficacy of their implementation in practice. According to our understanding, informed by OIPT, this study represents the inaugural academic endeavor to illustrate the correlation between BDAI adoption via GSCM and enhanced firm performance inside the Indonesian industrial sector. Our study contributes to the limited yet expanding knowledge of applying BDAI systems inside the circular economy.

5.1. Limitations and Future Research Directions

The present study provides significant contributions; nevertheless, it also possesses numerous shortcomings that may suggest new avenues for research. Initially, due to the sample being confined to the Indonesian manufacturing sector, our findings may need to be more relevant to supply chains in other nations, which is contingent upon technology capacities and national cultures that promote sustainability. Subsequent research may investigate manufacturing enterprises in additional developing countries to enhance and reinforce our conclusions. Secondly, while this study has revealed the significant significance of green supply chain collaboration as a mediator in the relationship between BDAI and FP, subsequent research investigating the moderating effect of green supply chain collaboration may provide additional valuable insights. Could a high GSCM correlate with a stronger link between BDAI and FP. Third, subsequent research may examine additional constructs, such as stakeholder pressure within the relationship. Fourth, we recommend that subsequent research corroborate the empirical findings of our study with a larger sample size and across different sectors and nations. Finally, more knowledge remains concerning implementing BDAI in enhancing firm performance; additional research is necessary to augment its efficacy in sustainable operations.

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