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Digital Transformation and Supply Chain Integration Impact on Firm Performance: The Role of Green Practices in Achieving Sustainable Supply Chain Performance

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Abstract. This study investigated the relationship between digital transformation (DT), supply chain integration (SCI), green practices (GP), sustainable supply chain performance (SSCP), and firm performance (FP). Prior studies have provided early explanations regarding DT and SCI as well as their association with sustainable supply chain performance. However, empirical evidence demonstrating the direct impact of digital transformation and supply chain innovation through green practices on sustainable supply chain practices to enhance functional performance remains limited. To address this limitation, primary data were obtained from 70 experts employed in manufacturing firms in Indonesia using a questionnaire survey conducted between September and October 2025. A conceptual model incorporating DT, SCI, GP, SSCP, and FP was developed and subsequently analyzed using partial least squares structural equation modeling (PLS-SEM) through Smart PLS 4.0 software. The results showed that DT significantly enhances both GP and SCI, while GP and SCI also have a positive influence on SSCP. Moreover, SSCP exerts a substantial beneficial effect on FP. Additionally, GP and SCI function as intermediaries between DT and SSCP, with SSCP mediating the connection between GP and FP, as well as between SCI and FP. This research is the first investigation into the synergistic effects of digital transformation on environmentally sustainable practices and supply chain integration, aimed at improving sustainable supply chain efficiency and enhancing overall corporate performance within the manufacturing industry.

Keywords: Digital Ttransformation; Green Practices; Firm Performance; Supply Chain Integration; Sustainable Supply Chain.

Abstrak. *Studi ini meneliti hubungan antara transformasi digital (DT), integrasi rantai pasokan (SCI), praktik ramah lingkungan (GP), kinerja rantai pasokan berkelanjutan (SSCP), dan kinerja perusahaan (FP). Studi-studi sebelumnya telah memberikan penjelasan awal mengenai DT dan SCI serta hubungannya dengan kinerja rantai pasokan* *berkelanjutan. Namun, bukti empiris yang menunjukkan dampak langsung transformasi digital dan inovasi rantai pasokan melalui praktik ramah lingkungan terhadap praktik rantai pasokan berkelanjutan untuk meningkatkan kinerja fungsional masih terbatas. Untuk mengatasi keterbatasan ini, data primer diperoleh dari 70 pakar yang bekerja di perusahaan manufaktur di Indonesia menggunakan survei kuesioner yang dilakukan antara September dan Oktober 2025. Sebuah model konseptual yang menggabungkan DT, SCI, GP, SSCP, dan FP dikembangkan dan kemudian dianalisis menggunakan pemodelan persamaan struktural kuadrat terkecil parsial (PLS-SEM) melalui perangkat lunak Smart PLS 4.0. Hasil menunjukkan bahwa DT secara signifikan meningkatkan GP dan SCI, sementara GP dan SCI juga memiliki pengaruh positif terhadap SSCP. Selain itu, SSCP memberikan pengaruh menguntungkan yang substansial terhadap FP. Selanjut-nya, GP dan SCI berfungsi sebagai perantara antara DT dan SSCP, dengan SSCP meme-diasi hubungan antara GP dan FP, serta antara SCI dan FP. Penelitian ini merupakan investigasi pertama tentang efek sinergis transformasi digital terhadap prak-tik berkelanjutan lingkungan dan integrasi rantai pasokan, yang bertujuan untuk mening-katkan efisiensi rantai pasokan berkelanjutan dan meningkatkan kinerja perusahaan secara keseluruhan dalam industri manufaktur.*

***Kata kunci**: Transformasi Digital; Integrasi Rantai Pasok; Praktik Ramah Lingkungan; Kinerja Perusahaan; Rantai Pasok Berkelanjutan.*

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BACKGROUND

In the contemporary era of digital transformation (DT), organizations are progressively utilizing advanced technologies to enhance supply chain management. These technologies facilitate improved decision-making, decrease operational expenses, and enhance the overall efficacy of the supply chain (Queiroz et al., 2019). By integrating these technologies, organizations can minimize waste, enhance resource efficiency, and attain sustainability objectives, thereby supporting the advancement of sustainable supply chain performance (SSCP) (Chalid et al., 2021). Supply Chain Integration (SCI) has developed as a supplementary capability essential for maximizing the advantages of digital transformation. SCI encompasses the deliberate orchestration and harmonization of internal departments and external collaborators to optimize the movement of materials, financial resources and information (Flynn et al., 2010). Integrated supply chains enhance transparency, facilitate collaboration, and improve responsiveness, enabling organiza-tions to utilize real-time data for agile decision-making. Without integration, digital tools by themselves are insufficient to realize their full potential, rendering SCI a fundamental prerequisite for achieving operational excellence and strategic coherence.

The integration of DT and supply chain management (SCM) is especially critical for organizations seeking to enhance performance across both economic and environ-mental metrics. Organizations that adopt both digitalization and integration concurrently are more likely to attain enhanced performance through accelerated innovation processes, increased cost efficiency, higher customer satisfaction, and diminished environmental impact (Ivanov et al., 2019). As worldwide disruptions—ranging from pandemics to climate change—persist in challenging supply chain resilience, the imperative for the synergistic integration of DT and SCI has become indispensable rather than optional.

The incorporation of environmentally sustainable practices into supply chains is an essential measure for attaining sustainable performance. Sustainable practices, including green procurement, environmentally conscious manufacturing, and resource-efficient logistics, are instrumental in reducing environmental impact while strengthening supply chain resilience (Araújo et al., 2020). These practices are essential for organizations aiming to integrate their operational practices in accordance with sustainability aims, therefore facilitating the reduction of their carbon footprint and the improvement of resource efficiency.

The notion of SSCP underscores the importance of attaining a balance among environmental, social, and economic objectives within the supply (Gawankar et al., 2015). Sustainable performance within supply chains can be attained by implementing digital technologies and environmentally friendly practices that enhance resource efficiency, minimize waste, and promote positive social and environmental impacts. Although digital transformation and supply chain integration have been extensively examined in relation to enhance operational efficiency, the particular contribution of environmentally sustainable practices to enhancing sustainable SCP remains insufficiently investigated. In the context of Indonesia, a rapidly developing economy with an expanding manufacturing sector, there is limited empirical research examining how the integration of DT, SCI, and green practices affects SSCP and firm performance, including both economic and environmental outcomes within supply chains (Zhang et al., 2022).

This study aims to empirically investigate impact of DT and SCI on SSCP and organizational performance in Indonesian manufacturing firms. The research investigates mediating influence of green practices on attainment of SSCP and seeks to offer insights into how organizations can utilize digital transformation and SCI to promote sustainability while enhancing operational results. Through an analysis of manufacturing enterprises in Indonesia, this study offers insights into how businesses in emergent economies can improve their firm performance and maintain competitiveness in an increasingly digital and environmentally conscious global market.

THEORETICAL REVIEW

Digital Transformation (DT)

DT has become an essential element impacting several academic disciplines and shaping professional practices, resulting in distinctive research trajectories (Diwyarthi et al., 2022). When digitalization is woven into established workflows and traditional practices are reengineered through DT, organizations realize higher levels of efficiency and sustainability. In doing so, DT deploys digital capabilities to craft novel business processes and extend the boundaries of the prevailing business ecosystem. Thus, institutions adopting DT effectively participate in digital transformation agendas aimed at elevating system-wide integration (Lemoun et al., 2025).

The examination of digital transformation within SCM has gained considerable scholarly attention. Ahmad et al. (2022) explored the effects of DT-related technologies—including Big Data Analytics, Blockchain Technology, and the Internet of

Things—on sustainable supply chain management. Their findings affirm that DT is central to improving firm performance and advancing sustainability-oriented approaches.

Supply Chain Integration (SCI)

The concept of SCI has received substantial attention in SCM research. SCI indicates how effectively a company harmonizes its internal systems with the functions of suppliers, buyers, and external supply chain stakeholders (Ram, 2023). Consequently, companies have recognized that the strategic integration of internal divisions, supplier networks, and customer interactions constitutes a formidable means of attaining competitive advantage. This has positioned Supply Chain Integration (SCI) as a crucial practice embraced by organizations aiming to enhance performance through the closer integration of SC functions. Bagchi et al. (2005) utilized a quantitative methodology to offer a detailed outline of the ongoing implementation process of SCI among European enterprises.

Green Practices (GP)

GSCM embodies organizational efforts to systematically embed environmental priorities within each stage of supply chain activities (Sony, 2018), ranging from material evaluation and procurement to product conceptualization, manufacturing, and eventual distribution. The integration of environmentally sustainable practices in SCM contributes to decreasing waste produced during processing activities and, as a result, improves profitability. Eco-friendly methods exhibited a substantial and favorable association with economic growth. In China, the majority of firms are adopting environmentally sustainable techniques in their operations to improve profitability. Customers show interest in acquiring environmentally sustainable products, as these items appea (Alkandi, 2025) to them (Lin et al., 2013). Previous research has established a positive correlation between GSCM practices and profitability. Furthermore, prior research has produced inconclusive results concerning correlations between environmentally sustainable practices and economic performance. Green practices are directly or indirectly linked to the objective of sustainability (Alkandi, 2025). The research predominantly discusses environmentally sustainable techniques such as green purchasing (Durán-Romero et al., 2020) and green manufacturing (Raut et al., 2017).

Sustainable Supply Chain Performance (SSCP)

SSCP pertains to an organization's capacity to attain superior performance results through the adoption of sustainability practices within its supply chain (Chu, 2016). The deliberate integration of sustainability practices throughout the complete supply chain is vital for attaining favorable performance outcomes in a SSC (Gao et al., 2023) highlight that sustainability is a fundamental component of digital supply chains, as organizations seek to reduce their environmental impact and minimize waste. Digitalization can be employed to improve the sustainability of environmental supply chains, thereby fostering the development of more SSCP (Sarkis et al., 2020). Disruptive technologies such as IoT and blockchain possess the capacity for enhancement sustainability within supply chains (Aj et al., 2021), Big data analytics significantly influence the sustainability of supply chains (Bag et al., 2019). By aligning supply and demand with the company's needs, digital network development further facilitates the emergence of new markets, increases business revenue, and bolsters the pursuit of sustainable performance. The increasing awareness among consumers concerning sustainability practices, the evolving landscape of government policies, and the intensified efforts by businesses to achieve a competitive edge through digitalization and sustainability initiatives highlight the significance of analyzing these factors within the supply chain context.

Firm Performance

Integrating economic and environmental performance metrics into sustainable supply chains can significantly enhance firm performance, social responsibility, and long-term viability. By adopting frameworks that evaluate these indicators, organizations can align their operations with sustainable practices, leading to improved outcomes across multiple dimensions (Khan et al., 2020)**.** Numerous studies have clarified the economic implications; for instance, they pertain to the capacity to decrease the production of detrimental waste within the supply chain and to the expertise in cultivating plants to reduce emissions (Mamdouh & Farouk, 2024)**.** Sustainable supply chain practices (SSCPs) have been shown to improve economic performance (EP) by decreasing costs associated with energy and resource consumption (Abuzawida et al., 2023). Environmental Performance denotes the capacity to minimize expenses linked to industrial processes, including the acquisition of materials and components, energy and water use, and waste management (Mamdouh & Farouk, 2024)**.** A comprehensive evaluation framework that integrates environmental indicators can support organizations in identifying the most effective practices for achieving sustainability.

RESEARCH METHODS

The most frequently discussed environmentally sustainable practices in the literature include green purchasing and green manufacturing (Raut et al., 2017). The present study concentrates on economic and environmental performance to assess firm performance. This study theorizes a model of green practices and elucidates the assumptions within the milieu of manufacturing enterprises in Indonesia. The data were gathered in September and October 2025 using a standardized questionnaire. Subsequent to a concise elucidation and clarification of the study's objective, questionnaires were sent to the participants. Out of the 77 questionnaires distributed, only 72 responses were received. Seventy surveys were completed, and seventy-two questionnaires were collected, with two discarded owing to inadequate participant responses. A sample size of 70 forms was utilized for hypothesis testing.

PLS-Structural Equation Modelling is utilized for hypothesis testing

PLS-SEM serves as a method for evaluating and analyzing intricate statistical models (Sarstedt & Liu, 2024). Numerous methodologies can be utilized to evaluate robustness of the structural model in PLS-SEM and CB-SEM, and its methodologies effectively manage the challenges posed by non-normal distributions. Additionally, it can accommodate intricate indicator variables, resulting in viable outcomes. The presence of VIF collinearity effectively alleviates the problem of prevalent (common) method variance (CMV) in PLS-SEM, as noted by (Hair et al., 2019). In light of these considerations, this research utilized PLS-SEM to evaluate the hypotheses. Furthermore, this software is readily accessible, and the usage guidelines are provided on the internet. Table 1 illustrates constructs and items and Figure 1 illustrates theoretical framework.

Table 1. Research Instrument

CONSTRUCTS		ITEMS	SOURCES
Digital Transformation (DT)	DT	1.Your organization consistently employs digital technologies in its operations. 2. Your organization implements digital transformation strategies primarily inside the supply chain. 3. Your enhanced output facilitates value generation by lowering manufacturing costs. 4. Your enhanced output facilitates value generation by yielding superior quality. 5. The processes and procedures inside your company's SC are automated to the maximum extent possible. 6. The deployment of digital technologies enables your firm to mitigate supply chain risks. 7. The integration of DT enhances the flexibility of SCM in your firm. 8. Your organization consistently utilizes digital technologies for transactions with suppliers. 9. Your organization consistently utilizes digital technologies for customer transactions. 10. Digital technologies have enhanced flow of information shared between your company and its suppliers. 11. DT facilitates the modifications required to realize your organization's strategic objectives. 12. DT technologies, including online communication channels, improve customer relationship management inside your organization. 13.DT technologies enable your firm to design and develop novel goods and services that satisfy customer needs.	(Fatorachian & Kazemi, 2021; Ghoreishi et al., 2020; Ivanov & Dolgui, 2021; Oubrahim et al., 2023; Stroumpoulis & Kopanaki, 2022)
Supply Chain Integration (SCI)	SCI	1.Your organization disseminates information to key suppliers via information networks. 2.Your organization guarantees continuous buying via networks with primary suppliers. 3.Your organization communicates demand projections and production plans to its primary suppliers. 4.Your organization discloses inventory levels and production capability to key suppliers. 5.You maintain a significant strategic alliance with your primary suppliers. 6.Your company disseminates information to its primary customers via information networks. 7 Your firm adopts various customer touchpoints and communication media to establish interactions with clients. 8.Your firm upholds a strong standard of communication with its consumers. 9.Your clientele furnish demand forecasts to your firm. 10.Your organization communicates the inventory levels and manufacturing plans to your customers. 11.Your company solicits feedback from key consumers. 12. Your organization accomplishes data integration throughout all internal operations. 13.Your organization employs integrated inventory management. 14. Your supply chain operations—comprising planning, sourcing, production, delivery, and sales—are synchronized in real-time. 15. Your company employs enterprise resource systems to consolidate various functions. 16.Your organization evaluates real-time data concerning supply, production, and demand. 17. Your organization holds regular interdepartmental meetings across internal functions.	(Bagchi et al., 2005; Danese et al., 2013, 2019; Oubrahim et al., 2023; Wong et al., 2013)

Green Practice (GP)	GP	1.Ascertain that suppliers fulfill their environmental goals. 2. Mandates that vendors possess certified Environmental Management Systems, such as ISO 14001. 3. Verify that acquired materials possess environmentally friendly attributes. 4. Assesses suppliers based on particular environmental standards 5. Mandates suppliers to establish and sustain an Environmental Management System (EMS). 6. Eco-friendly approaches in industrial processes that diminish fossil fuel energy usage 7. Employing sustainable materials in production 8. Reducing harmful and dangerous substances in manufacturing processes	(Lin et al., 2013; Mumtaz et al., 2018; Sony, 2019; Diwyarthi et al., 2022; Yong et al., 2020)
Sustainable Supply Chain Performance (SSCP)	SSCP	1. Your company ensures suppliers meet environmentally friendly practice goals. 2.Your organization mandates that vendors possess a certified Environmental Management System (EMS), such as ISO 14001. 3.Your company ensures purchased materials contain green (environmentally friendly) attributes. 4.Your organization assesses suppliers according to defined environmental standards. 5.Your organization mandates that suppliers establish and sustain an Environmental Management System (EMS).	(Broccardo et al., 2023; Cantele et al., 2023; Karmaker et al., 2023; Nazam et al., 2020; Rogetzer et al., 2019)
Firm Performance (FP)	FP	1.Reduced energy consumption costs 2.Reduced material purchasing costs. 3.Reduced waste processing and disposal costs. 4.Reduced air emissions. 5.Diminished liquid and solid waste. 6.Diminished utilization of hazardous and harmful substances.	(Abuzawida et al., 2023; Kenneth et al., 2012; Khan et al., 2023)

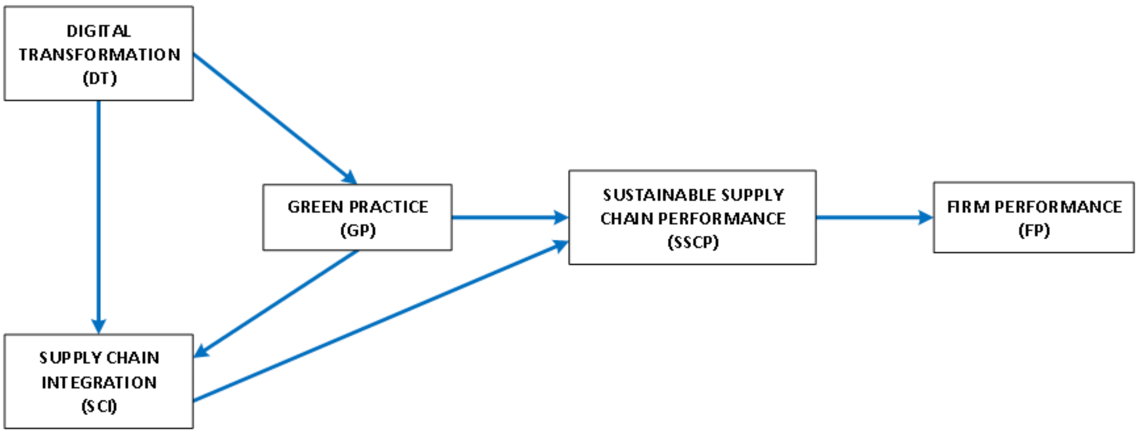

Figure 1. Theoretical Framework

RESULTS AND DISCUSSIONS

Structural modeling equations offer a more advanced approach compared to traditional linear regression, as they impose no constraints on quantity of dependent and independent variables. In contrast, standard linear regression is confined to the analysis of a solitary dependent variable.

Measurement Model

Examined the concept of convergent validity (CV) and elucidated that 2 distinct measurements of variables ought to be theoretically interconnected. According to this perspective is connected to the notion that the theoretical foundations of related measures exhibit statistical associations. The criteria established confirm the validation of both reliability and convergent validity. The evaluation of CV and reliability was performed with average variance extracted (AVE) scores and composite reliability (CR). Within the framework of SEM-PLS, a composite dependability (CR) score of 70% is considered adequate for internal consistency. Moreover, the AVE values exhibit robust convergent validity, above the acceptable threshold of 50%.

Discriminant validity pertains to the characteristics that separate one variable from others. This indicates that discriminant validity is attained when a construct is unequivocally separate from other constructs. The examination of cross-loading reveals that no significant cross-loading was observed, since all measurements displayed the highest loadings within their respective factors. This illustrates the permissible validity of the discriminant.

Furthermore, discriminant validity issues could not be consistently detected using the cross-loading criterion. They also proposed that the use of the HTMT correlation ratio is a reliable method for model testing. The HTMT ratio is advised to fall between 0 and 1. The HTMT value demonstrates that all values satisfy the previously established criteria. Thus, the model is deemed reliable, demonstrating discriminant validity, and is prepared for additional investigation.

Structural Model Assessment

The findings indicate that the direct impact of green practices on SCI is substantial (H3), whereas green practices do not significantly mediate the relationship between DT and SCI (H1), nor does SCI significantly mediate the relationship between GP and SSCP (H10).

Table 2. Hypothesis Test Results

Hypothesis	Effects	Coefficient	t-statistics	P-values
1	DT → GP	0,747	15,240	0,000
2	DT → SCI	0,640	3,631	0,000
3	GP → SCI	0,183	1,037	0,300
4	GP → SSCP	0,583	6,996	0,000
5	SCI → SSCP	0,316	4,372	0,000
6	SSCP → FP	0,679	9,275	0,000

Table 3. Mediation Test Results

Hypothesis	Effects	Coefficient	t-statistics	P-values
7	DT → GP → SCI	0,137	1,027	0,304
8	DT → GP → SSCP	0,436	6,425	0,000
9	DT → SCI → SSCP	0,202	2,690	0,007
10	GP → SCI → SSCP	0,058	0,925	0,355
11	GP → SSCP → FP	0,396	4,756	0,000
12	SCI → SSCP → FP	0,215	4,299	0,000

The absence of collinearity issues in our estimate model is indicated by the variance inflation factors (VIFs) < 5. indicating no collinearity issues in our estimation model. VIF values range from 0.20 to 0.150, with moderate effects ranging from 0.150 to 0.350, and values at or above 0.350 indicating substantial effects. F-squared values indicate that all values exceed 0.020 and 0.350. These observations indicate a substantial impact on the validity and reliability of model constructs. Predictive relevance, which assesses predictive power of the constructs, is presented. The R^2 value is considered significant if it exceeds 26%. Furthermore, the model demonstrates predictive relevance if the Q^2 value exceeds zero. The R^2 and Q^2 values meet the acceptable criteria for the dependent variables.

The findings indicated that GP and SCI are positively influenced by the implementation of DT inside the organization (H1) and (H2). Moreover, environmentally friendly practices and SCI directly enhance sustainable SCP, as indicated by hypotheses H4 and H5. The SSCP demonstrated a positive impact on FP (H6). The results have also demonstrated that all favorably impacted individuals have a robust connection. A one percent increase in DT will result in a 0.747% change in green practices and a 0.640% change in SCI; green practices and SCI will respectively lead to changes of 0.583 and 0.316 in SSCP; SSCP will induce a 0.679% change in FP. It is advisable for firms to utilize DT in their GP and SCI. These results align with the study conducted on manufacturing enterprises, indicating that digital technology positively influence green production and green design.

Adopting sustainable techniques, including eco-friendly sourcing, value chain mapping, sustainable design, the use of biofuels in logistics, and recycling, enhances product quality and decreases costs. Green manufacturing alleviates the detrimental impacts of production processes by reducing waste within the manufacturing system, hence enhancing both economic and environmental results for enterprises.

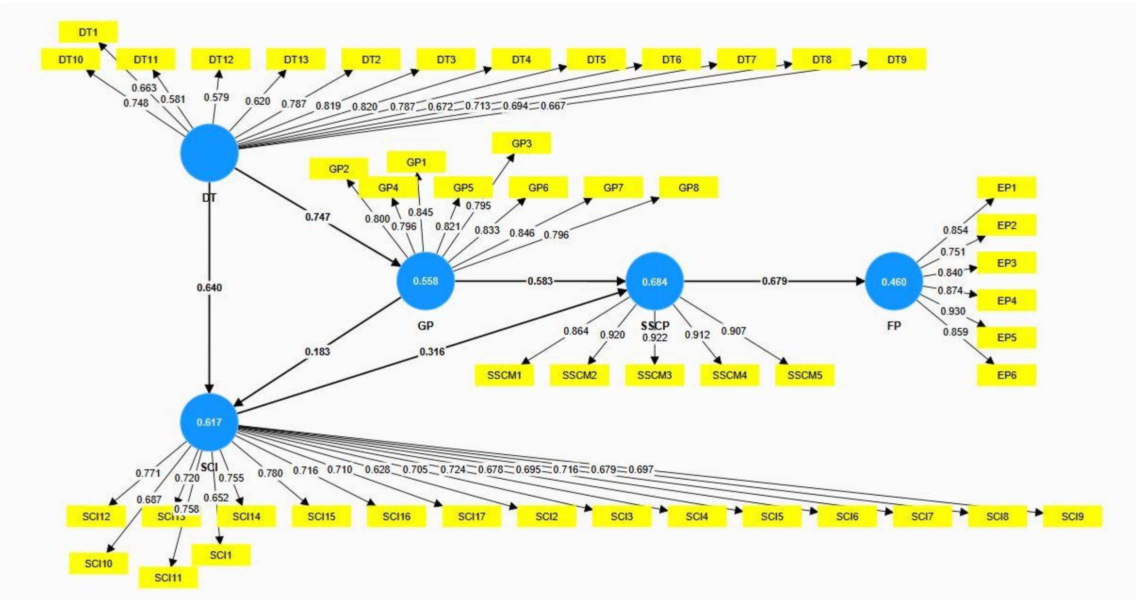

Figure 2. Structural Model Results

The findings of the current study align with previous studies indicating that green purchasing does not substantially influence economic performance. GP is regarded as an exterior dimension of GSCM. Consequently, it cannot be administered or implemented by a solitary company independently. Effective green purchasing necessitates a robust collaborative partnership between producers and suppliers. The effectiveness of GSCM procedures requires the engagement of the dominant firm.

Limited scholarly attention has been directed toward examining the intermediary role of GSCM practices in the relationship between Industry 4.0 and both economic and environmental performance. Earlier investigations primarily focused on how supply chain activities mediate the connection between information technology adoption and organizational performance. The present study demonstrates, through mediation analysis, that GSCM practices shape the influence of Industry 4.0 on economic performance while simultaneously acting as a linking mechanism between Industry 4.0 and environmental performance. These results further reinforce the significance of GSCM practices in strengthening the association between Industry 4.0 and sustainability performance.

CONCLUSIONS AND RECOMMENDATIONS

The results of the analysis showed is as follows. Digital Transformation directly positively affected to Green Practices and also to Supply Chain Integration. Green Practices and also Supply Chain Integration directly positively affected to Sustainable Supply Chain Performance. Sustainable Supply Chain Performance directly positively affected to Firm Performance. Green Practices and Supply Chain Integration as a mediated between Digital Transformation and Sustainable Supply Chain Performance. Sustainable supply chain Performance as a mediated between Green Practice and Firm Performance, also as a mediated between Supply Chain Integration and Firm Performance.

Green practices exert no substantial direct influence on supply chain integration. Green Practices do not affect the relationship between Digital Transformation and Supply Chain Integration, nor does Supply Chain Integration affect the relationship between Green Practices and Sustainable Supply Chain Performance. The analysis provides significant insights for management in industrial organisations. This research demonstrates that digital transformation fosters sustainable growth. Moreover, digital transformation optimizes the management of real-time data and information pertaining to products or production, hence enhancing the effectiveness of the decision-making process. Implementing digital transformation in digital technology infrastructure can significantly enhance operational efficiency and environmental management outcomes for industrial organizations. The discovery underscores the significance of digital technology across all phases of supply chain operations, as they facilitate the improve-ment of cleaner manufacturing capacities. This study advocates for organisations to embed sustainable concepts inside their business practices to optimise advantages.

Managers ought to focus on improving logistics, procurement, and production through the adoption of digital technology, since this will provide flexibility and reduce costs by collaborating with supply chain partners. The manager should utilise digital technologies to ensure comprehensive management of all supply chain activities and stages, encompassing procurement, production, product design, and the identification of improvement opportunities. In conclusion, it can be said that industrial digital transformation improves sustainability performance and promotes the adoption of eco-friendly practices; hence, manufacturing enterprises should integrate digital technology into their systems to maximise benefits.

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