Sustainable supply chain performance lesson from Malaysian manufacturing firms

Suhaiza Zailani, Muhammad Khalilur Rahman, Asif Hussain Nizamani, Azmin Azliza Aziz, Miraj Ahmed Bhuiyan and Md. Abu Issa Gazi

Abstract

Purpose – *This study aims to investigate the impact of sustainable innovation and disruptive innovation on sustainable supply chain performance of manufacturing firms in Malaysia. The study also examined the moderating role of supply chain clockspeed in the relationship between sustainable innovation, disruptive innovation and sustainable supply chain performance.*

Design/methodology/approach – *The data were collected from 231 respondents in manufacturing firms in Malaysia. The data were analyzed using the partial least square-based structural equation modelling (PLS-SEM) technique.*

Findings – *The findings revealed that sustainable innovation and disruptive innovation had a significant and positive effect on sustainable supply chain performance. Supply chain clockspeed moderated the relationship between sustainable innovation and sustainable supply chain performance. The findings also identified that there was no moderating effect on the relationship between disruptive innovation and sustainable supply chain performance.*

Research limitations/implications – *This study merely focuses on sustainable supply chain performance in Malaysian manufacturing firms. Samples from manufacturing firms in Malaysia were used in the current study, and the outcomes may vary for different nations.*

Practical implications – *To increase the firm's commercial success, it is necessary to promote sustainable supply chain practices, including supply chain clockspeed, sustainable innovation and disruptive innovation.*

Originality/value – *This study adds to the body of knowledge by explaining the positive influence of sustainable innovation and disruptive innovation on sustainable supply chain performance in Malaysian manufacturing firms while also emphasizing the moderating role of supply chain clockspeed in this relationship. The contribution of this study could enable managers to develop sustainable supply chain performance in the manufacturing sector, based on sustainable innovation, disruptive innovation and supply chain clockspeed.*

Keywords *Malaysia, Supply chain performance, Disruptive innovation, Sustainable innovation, Clock speed*

Paper type *Research paper*

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1. Introduction

Today, improving supply chain sustainability is widely recognized and increasingly integrated into management, even though some argue that sustainability matters more than profitability in business (Maryani, 2022). However, the idea of enhancing sustainability innovation by incorporating it into supply chains is still relatively new. Sustainability can encourage businesses to change how they handle supply chains. The main challenges for businesses in achieving sustainable supply chain performance (SCP) include higher costs, the complexity of monitoring supply chains and issues with responsibilities and sustainability frameworks not being aligned across supply chains (Klassen and Vereecke, 2012; Hervani *et al.*, 2022).

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Sustainable innovation (SI), disruptive innovation (DI) and supply chain speed are important factors that can significantly impact how well manufacturing companies perform in terms of sustainability. This is especially important for these companies because they have been focusing on environmental and social practices for the past two decades (Wang and Sarkis, 2013; Ba and Galik, 2023). SI and supply chain speed are also driven by voluntary and competitive factors, as the supply chain industry requires rapid innovation. Businesses are increasingly pushed to compete within supply chains, rather than just as individual companies, as industry speeds up (Hajar and Saida, 2022).

Manufacturing companies are trying to use new technologies and methods to stay ahead of their competitors (Knudsen *et al.*, 2021; Hassan *et al.*, 2021). According to Kahupi *et al.* (2021), they think that by using sustainable and DI in supply chain management, companies can gain a competitive advantage. Being at the forefront of manufacturing allows companies to show that they care about sustainable practices and want to reduce any harmful effects of what they do. To succeed, companies must keep up with innovation and improve their SCP. Sustainable SCP and technological innovation are essential for success, as mentioned by Bag *et al.* (2020), Amin *et al.* (2020) and Bakan and Yildiz (2009). Krishnan *et al.* (2021) emphasized the importance of innovation for an organization's success and SCP. Manufacturing firms that embrace digital innovation gain a competitive edge over rivals (Ferreira *et al.*, 2021) because they are competing globally to rapidly create new products that meet customer demands.

For an organization to succeed in the long term, it needs SI and DI, as mentioned by Cordova and Coronado (2021) and Sundström *et al.* (2021). According to Zhang and Zhu (2021), DI can create entirely new markets, networks, products and partnerships, potentially replacing established market leaders. Successful organizations rely on innovation to operate effectively and efficiently, especially in a changing market with increased competition and evolving technology, as noted by Christensen (2013). SI can improve existing products, making them better, faster and more affordable in today's market, as mentioned by Song *et al.* (2022). DI, on the other hand, comes from having exceptional technical skills and changing the way business is done. Zheng *et al.* (2021) explained that a manufacturing company's ability and expertise are needed for DI, which is often influenced by the current market conditions.

This study investigates how manufacturing companies perform in terms of sustainability when they use SI and DI. It also considers how the speed of their supply chains affects this relationship. So, the main question this study investigates is: Can SI and DI make manufacturing companies better at having a sustainable supply chain?

In this study, we collected data from manufacturing companies. We identified that companies doing SI, DI and working quickly in their supply chain would make their supply chain better for the environment and society. The study showed that SI and DI do make the supply chain better, and how fast a company works in its supply chain affects, and how DI helps the supply chain. This study has two important findings: firstly, it looks at how SI and DI affect SCP. Secondly, it explores how the speed of the supply chain influences the connection between DI and SCP, which has not been studied much before.

The study is organized as follows. Section 2 summarizes the review of literature related to SI, DI, supply chain clockspeed (SCS) and sustainable SCP of manufacturing firms. Section 3 discussed the research method including sampling selection and data collection process and procedures. Sections 4 and 5 present the results and discussion. Section 6 discussed the implications and conclusion.

2. Literature review

2.1 Sustainable supply chain performance

Malaysia used to rely on farming, but now, it has become more industrial, and manufacturing is a big part of that. Manufacturing can have a big impact on the environment, so companies in Malaysia are paying close attention to how their actions affect the environment. Using sustainable supply chains is really important because it helps companies focus on fixing environmental issues and also brings them economic and social benefits. Some researchers like Moshood *et al.* (2021) and Zailani *et al.* (2012) studied what drives the use of sustainable supply chain management in Malaysia. Wooi and Zailani (2010) researched the extent to which ISO 14001-certified manufacturing enterprises in Malaysia adopted a green supply chain; however, this study is interested in assessing the level of Malaysian manufacturing firms' participation in the sustainable SCP. This paper focused on SI, DI and SCS within manufacturing firms and their relationship with the performance of a sustainable supply chain.

SCP refers to the activity of the supply chain in meeting customer needs, including the availability of the product and product delivery on time (Das and Hassan, 2021; Shukor *et al.*, 2020). In this study, sustainable SCP refers to the manufacturing firms that can produce products and deliver orders on time. Sundarakani *et al.* (2020) suggested that all the necessary inventory and capacity in the supply chain should be delivered and performed responsively. Many manufacturing companies have taken a strategy to measure the performance of the supply chain. This allows the firms to ensure that the supply chain can meet the requirements of its valuable customers. High-quality production and materials can lead to agile SCP (Raji *et al.*, 2021; Juan *et al.*, 2021). Sustainable SCP relies on innovation that business operators implement to support the performance of their firms.

In any field, having a sustainable advantage is important, as noted by Samani *et al.* (2019) and Shepherd and Günter (2006). Also, the performance of the supply chain has become a key way for companies to gain a competitive edge across various industries, as it encourages competition among companies rather than just within a company, as pointed out by Nandi *et al.* (2020), Hastig and Sodhi (2020). As firms are dependent on each other in a supply chain, manufacturing firms are dependent on their suppliers for raw materials and distributors for delivering the finished goods to the customers (Butt, 2021; Burgess *et al.*, 2006). Li *et al.* (2020) indicated that the manufacturing firm's performance is largely dependent on the supply chain network and the connection of suppliers and distributors with the manufacturer.

The previous studies (Munir *et al.*, 2020; Newaz *et al.*, 2020; Asamoah *et al.*, 2021) described that an integrated supply chain could lead to organizations' efficient and effective performance. Apart from this, a good partnership between players in the supply chain will also improve its performance. Zhan and Tan (2020) and Fatorachian and Kazemi (2021) highlighted the manufacturing companies' efficient and effective SCP. Supply chain firms should cooperate in the planning and forecasting stage and have a strong material replenishment plan. Poor supply chain firms are unable to meet the organization's goals and customer demands (Siagian *et al.*, 2020; Tarigan *et al.*, 2021). Thus, creating integration between supply chain players requires evaluating the SCP because it will help to improve the supply chain firms (Hastig and Sodhi, 2020).

2.2 Sustainable innovation

SI refers to integrating sustainability values into the innovation process that reflects economic value and produces positive social impacts (Weidner *et al.*, 2021). In this study, SI refers to the manufacturing firm that produces better-existing products and services, change the market, changes in technology and changes the nature of competition of the existing products and services. According to Cosenz *et al.* (2020) and Awan (2021), the idea of sustainability could refer to an improvement in a process rather than to a particular organizational innovation. Established organizations across a wide range of industries can succeed in managing SIs. SI can reflect sustainable SCP. Bag *et al.* (2020) found that there is a significant relationship between innovation and sustainable SCP in the business organization. SI can reflect sustainable SCP. Le *et al.* (2022) identified the significant effect between innovation and the supply chain in sustainable corporate performance. Boons and Lüdeke-Freund (2013) focused on SI in business models, whereas Le and Ikram (2022) conducted an empirical study, and the result indicated that SI can help improve firm performance. This study examined SI and sustainable SCP in manufacturing firms. Therefore, this study postulated that:

H1. Sustainable innovation has a positive and significant effect on sustainable supply chain performance.

2.3 Disruptive innovation

DI is defined as innovation that introduces new products or services that primarily come out in a niche market, and over time, move up the market through performance improvements (Kivimaa *et al.*, 2021; Christensen *et al.*, 2003). DI refers to technologies that make sophisticated products and services accessible to the broader market. In this study, DI refers to the manufacturing firm often introducing new products and services that initially emerge in a niche market, with different features, performance and attributes relative to the existing product. Si *et al.* (2020) stated that DIs enable innovative business models, technology and a coherent value network. Sundarakani *et al.* (2020) highlighted sustainable SCP in the face of innovation disruption. Their results indicated that DI reflects resilient, sustainable SCP.

Govindarajan and Kopalle (2006) defined DI as a set of features, performance and price attributes different from the existing product. The successive developments over time improve product characteristics to a level that satisfies customers. Laforet and Bilek (2021) explained the acceleration of technological innovations that support the better performance of global trade and the development of faster access to products for consumers. In line with this, DI can reflect the sustainable SCP of the manufacturing firm. DI is characterized by safety and becoming innovative in the supply chain, which could significantly impact manufacturing firms. Dolgui and Ivanov (2020) explored the supply chain structural dynamics and focused the disruptive technologies. Fattahi *et al.* (2020) examined supply chain resilience and DI. The new measure of their study is the expected value of supply chain cost. Sundström *et al.* (2021) proposed a business model for small and medium-sized enterprises' (SMEs') destructive innovations. They highlighted that SMEs face internal barriers to developing innovativeness that impedes the creation of effective DI for the buyer chain. This study explores the significance of DI and how it links with sustainable SCP in manufacturing firms. Therefore, we proposed that:

H2. Disruptive innovation has a significant impact on sustainable supply chain performance.

2.4 Supply chain clockspeed

Clockspeed refers to the rate of product and process innovation in an industry (Meijboom *et al.*, 2007). The rate of product innovation proliferation leads to a rise in business process innovation, which suggests a stronger focus on managing a supply chain. Clock speed is defined as the firm's capabilities along the extended supply chain, to which total lead time could be added from suppliers through to end customers. In this study, SCS refers to the frequent changes and development of product models, designs, features, production processes and organizational paradigms. Superior SCP is a crucial prerequisite for the manufacturing firm's success (Asamoah *et al.*, 2021; Kumar *et al.*, 2021). This study investigates the moderating role of SCS that reflects the effect of SI and DI on sustainable SCP in manufacturing firm.

The creation and adoption of ecologically and socially responsible practises within an organization's supply chain constitutes SI. Several studies have found that SI has a favourable impact on SCP (Fontoura and Coelho, 2022). The clock speed of the supply chain refers to the rate at which information, materials and products flow through the supply chain. It varies greatly between industries and organisations. Some studies have highlighted the significance of SCS as a predictor of SCP (Souza-Luz and Gavronski, 2020). While the literature has explored the impact of SI and SCS on SCP individually, there is an increasing need to understand how these aspects interact. According to new research, SCS may help to mitigate the association between SI and sustainable SCP. Some research show that increasing SCS enhances the favourable association between SI and SCP, while others offer a more complex interplay (Hamidu *et al.*, 2023). More research is needed to explain these differences and gain a better understanding of the SCS's moderating influence. There is lack of empirical study the direct impact of SCS on SCP, emphasizing the importance of this factor (Hahn, 2020). A faster SCS often results in shorter lead times, allowing organizations to respond to client requests more quickly. Organisations with faster supply chain clock rates are frequently more responsive to market demand changes, allowing them to respond quickly.

Clockspeed is a measure of the rate of change in different dimensions of a company in various sectors of the economy (Thapa and Shah, 2021). These dimensions fall into three broad categories; product, process and organizational factors. The higher the rate of change, the higher the clock speed, and vice versa. For instance, the timber industry is a slow clockspeed industry, while the electronic industry is a high clockspeed industry (Fine, 2000; Chavez *et al.*, 2012). This study examines the SCS as it is crucial for innovation management in its role as a moderating relationship between innovation strategy and sustainable SCP. Mendelson and Pillai (1998) found a positive relationship between the effective use of technology by organizations and clock speed. Souza-Luz and Gavronski (2020) stated that firms with slow clock speed favour misuse over exploration, reduce costs, prioritize the need to increase efficiency and invest in process improvements. Guimaraes *et al.* (2002) examined the moderating role of clockspeed in the determinants of supplier's network performance.

Abidi *et al.* (2014) highlighted the literature on humanitarian SCP management. Hemmati *et al.* (2022) conducted an empirical investigation on sustainable SCP from the Malaysian manufacturing perspective and examined the effect of environmental purchasing, and sustainable packaging on sustainable SCP. This study focused on the effect of moderating role of SCS and the impact of SI and DI on sustainable SCP. The review of literature implied that previous studies were mostly conducted with a review of literature, issues and challenges of sustainable SCP. Hence, there are a few empirical studies that highlighted SI, DI and SCS to measure sustainable SCP, particularly in the context of the Malaysian manufacturing industry. Thus, we postulated that:

- *H3a*. Supply chain clockspeed moderates the relationship between sustainable innovation and sustainable supply chain performance.
- *H3b*. Supply chain clockspeed moderates the relationship between disruptive innovation and sustainable supply chain performance.

2.5 Underpinning theory

This research used the concept of disruptive technology, which is gaining popularity in the supply chain area. The theory of DI was first thought up by Christensen (2013) and explored the innovation transforms to the present market by introducing accessibility, simplicity, affordability, and convenience. The supply chain might be riddled with complexity and multiple processes to create a product and distribute it to suppliers or end customers (Erevelles and Stevenson, 2006). The supply chain is not constantly efficient. There is a scope for improvement. Thus, we consider the concept of DI, SI and SCS that led manufacturing firms to build a sustainable SCP. Disruptive and SI is the potential that can change how products are manufactured, distributed and tracked (Christensen *et al.*, 2003). Hence, because both emphasise sustainability as the ultimate goal for SCP, the theoretical lens offers the potential to integrate the triple bottom line (TBL) framework. The study can analyze sustainable performance from environmental, social and economic viewpoints by applying TBL principles, offering a more thorough evaluation. Based on the concept of disruptive technology, this study examined the impact of SI and DI on sustainable SCP. Based on the review of the literature, this study proposed the following conceptual model (Figure 1).

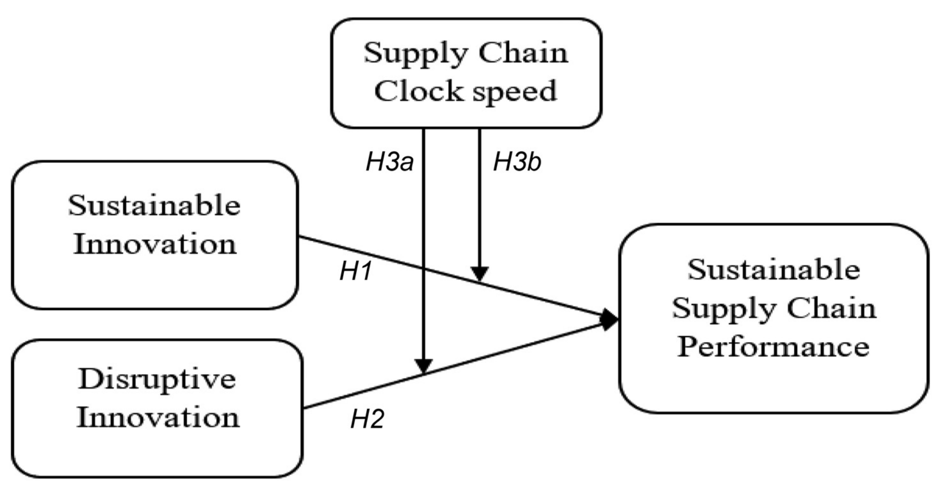
3. Research methodology

We used SmartPLS 4.0 software and a method called partial least squares structural equation modelling (PLS-SEM) to analyze how different components are related and estimate our conceptual model. We chose this strategy because it works well with lower sample sizes and is versatile in examining how theory and data fit together (Hemmati *et al.*, 2022).

3.1 Measurements

The measurements of theoretical constructs for this research were adapted from previous research with slight changes to adapt to the context of Malaysian manufacturing firms. All of the items used a five-point Likert scale, ranging from 1 “strongly disagree” to 5 “strongly agree”. The items for the independent variables of SI were adapted from Buchanan *et al.* (2006), and items for DI were adapted from Christensen and Raynor (2013) and Govindarajan and Kopalle (2006), while the items for the moderator of SCS were adapted from Guimaraes *et al.* (2002). The items for the SCP dependent variable were adapted from Shepherd and Günter (2006). To evaluate the reliability of this study, the constructs were validated through an expert panel (academic and manufacturing firms) and pilot testing

Figure 1 Conceptual model



Source: Authors’ own creation

with 30 manufacturing firms. The result of the pilot study has identified good internal consistency (alpha values of greater than 0.70). Thus, no further changes have been made to the survey questionnaire.

3.2 Data collection and sample

A cross-sectional survey among Malaysian manufacturers has been carried out to obtain quantitative data for the statistical testing of hypotheses. The unit of analysis in this research is the manufacturing companies operating in Malaysia. The list of such companies is taken from the Federation of Malaysian Manufacturers (FMM) directory containing an extensive list of manufacturers operating in Malaysia. A total sample size of 650 manufacturing firms was drawn for distributing the questionnaires to the managers of the firms. The study focuses on the SCP of Malaysian manufacturing firms across all the manufacturing sectors. The purposive sampling method was used for collecting data from the managers of Malaysian manufacturing firms. The respondents were chosen using a purposive sampling technique because the respondents and manufacturing firms were predetermined for this study. To get accurate responses and make sure respondents met the requirements before participating in the study, the purposive sampling strategy with screening criteria was used, which is suitable to measure the respondents' opinions on SI, DI, SCS and sustainable SCP. The researchers of this study distributed the survey questionnaires to the participants via emails consisting of the Google Forms link in this study. The respondents were contacted via phone call after the questionnaires were emailed to them to ensure a maximum response rate. Targeted respondents were contacted and explained the research objectives before seeking their voluntary participation. A total of 650 questionnaires were distributed, and 236 were returned. Finally, out of 236, five responses were discarded as inconsistencies, and missing values, leaving 231 identified as valid responses for data analysis with a response rate of 35.54%.

3.3 Data analysis method

This study used the PLS path modelling technique to evaluate the convergent validity and discriminant validity in examining the measurement model analysis. Cross-loading and Fornell–Larcker criterion (1981) were used to measure the discriminant validity of the study. This study performed exploratory factor analysis (EFA) to ensure the reliability of the model before conducting PLS. Structural model analysis was used to evaluate the hypothesis relationship among SI, DI, SCS and sustainable SCP. Hence, PLS was used for exploring the prediction of sustainable SCP. PLS is suitable in the exploratory stage for theory building and prediction relationships between the independent and dependent variables. As SmartPLS 4.0 was used in this study, all the measuring items for each construct were modified from earlier studies. The authors justified their inclusion in the context of the current study without altering its original objective, even though several of the items had previously been used in prior research studies.

This study investigated the impact of SI, DI and SCS on sustainable SCP of manufacturing firms. SEM is used path modelling technique in the business literature (Shackman, 2013). However, recently, business researchers have begun to use the PLS technique to assess the hypothesis relationships of the model. PLS-SEM has some edges over the CB-SEM technique, including less stringent sample size requirements, simpler moderating relationship testing and built-in support for formative indicators, which may account for its rising popularity among international business researchers. The study uses Harman's (1976) single-factor score, in which all measurement items are loaded into one common factor. If the total variance for a single factor is less than 50%, it suggests that common method bias (CMB) does not affect the data (Podsakoff *et al.*, 2003). Hence, the highest factor accounted for 25.43% variance, lower than 50% (Podsakoff *et al.*, 2012). Thus, CMB is no issue in this study.

4. Results

4.1 Findings of demographic information

Table 1 shows the demographic information of the respondents. Of the 231 firms that participated in the research, 66.7% were private limited companies, 63.2% produced industrial products, 23.8% were from the electronic and electrical sectors, followed by 13.9% in food and beverages, and 8.7% in paper and paper products. The majority of the firm's 53.7% were based in the Selangor state, remaining in Malacca at 16.5%, Kuala Lumpur at 13.4% and other states.

4.2 Measurement model analysis

This study uses the two-step approach to data analysis (Anderson and Gerbing, 1988). The first step examines the measurement model to measure the reliability, convergent validity and discriminant validity. The second step examines the structural model using SmartPLS 4.0 software. The PLS model is more vigorous to multicollinearity and distribution variance and is appropriate to identify whether the data is normally distributed or not (Gefen *et al.*, 2011). PLS is suitable to explain complex relationships among the constructs, and it eliminates two key issues such as ineligible solutions and indeterminacy of factors (Hair *et al.*, 2014). PLS can simultaneously analyze the extent to which the measurements relate to each construction and whether the hypothesis is supported. Table 2 shows the reliability analysis of the survey questionnaires and identifies the mean score and standard deviation of each measurement

Table 1 Demographic information

Company profile	*(%)*
Organization type	
Multinational	18.6
Public limited	10.8
Private limited	66.7
Joint venture	0.9
Enterprise	3.0
Main customers	
Local	80.1
Foreign	19.9
Product type	
Consumer product	36.8
Industrial product	63.2
Company age	
Less than 3 years	1.7
3–6 years	2.6
6–9 years	2.2
9–12 years	6.5
More than 12 years	87.0
Number of employees	
Less than 5 (micro)	0.4
5–75 (small)	42.4
76–200 (medium)	29.4
201 and above (large)	27.7
Sales amount	
Less than RM300,000 (micro)	4.8
RM300,000–RM15m (small)	18.6
RM15m–RM50m (medium)	27.3
More than RM50m (large)	33.8
No answer	15.6

Source: Authors' own creation

Table 2 Reliability analysis

Constructs and item measures	*Mean*	*SD*	*KT*	*SN*	*EFA*
SI					
My firm.					
SI1: often makes existing products or services better	3.694	1.008	1.312	−1.109	0.870
SI2: often changes the market conditions of existing products or services	3.371	0.895	0.209	−0.546	0.848
SI3: often introduces a revolutionary change in technology that is difficult to achieve or expensive	3.231	1.012	−0.358	−0.02	0.796
SI4: continuously incorporates new technological knowledge	3.380	0.939	−0.063	−0.444	0.855
SI5: often changes the nature of competition of the existing products or services.	3.079	0.893	0.14	−0.229	0.788
DI					
My firm often introduces new products or services that.					
DI1: initially emerge in a niche markets	3.633	1.08	−0.093	−0.588	0.840
DI2: managers tend to find difficult to recognize or anticipate	3.026	0.901	0.413	−0.016	0.819
DI3: have a different set of features relative to the existing product	3.205	0.928	0.147	−0.091	0.794
DI4: have different performance relative to the existing product	3.096	0.906	−0.145	−0.262	0.765
DI5: have different price attributes relative to the existing product	2.952	0.922	−0.277	0.062	0.821
SCS					
There are frequent changes.					
CS1: to our different product models	3.179	0.758	0.553	−0.797	0.783
CS2: in the design of dominant/core product model	3.07	0.623	1.598	−0.595	0.775
CS3: in optional feature offering	3.031	0.726	0.125	−0.46	0.700
CS4: in our dominant production process	3.192	0.653	0.925	−0.598	0.736
CS5: in the production process without the introduction of a completely new paradigm	2.817	0.628	0.961	−0.584	0.859
CS6: in our dominant organization paradigm	3.116	0.702	0.173	−0.647	0.862
Sustainable SCP (SSCP)					
My firm.					
SSCP1: is able to fulfil perfect order every time	3.952	0.789	−0.267	−0.398	0.777
SSCP2: is able to produce the product according to specification	4.114	0.796	0.076	−0.678	0.897
SSCP3: is able to deliver products on time, every time	3.655	0.68	−0.442	0.222	0.860
SSCP4: is able to fill customer orders out of available inventory	3.633	0.691	−0.171	−0.087	0.784
SSCP5: takes fewer days between receipt of orders and delivery of orders	3.799	0.848	−1.009	0.051	0.767
SSCP6: takes less time to respond to a customer inquiry	4.131	0.754	−0.377	−0.469	0.752
SSCP7: is able to fulfil customer special request	3.865	0.822	−0.884	−0.076	0.745
SSCP8: is able to respond to the competitor product offering	3.755	0.777	−0.763	0.12	0.832

Notes: Standard deviation (SD); kurtosis (KT); skewness (SN); exploratory factor analysis (EFA)
Source: Authors' own creation

item. A normality test was carried out in this study to check the skewness and kurtosis. Ghasemi and Zahediasl (2012) postulated that skewness and kurtosis explained the distribution of a data set. Skewness measures the distribution of a data set, while kurtosis examines the flatness of a distribution. Cain *et al.* (2017) suggested that validation of normality is determined by using a threshold value of ±2. Hence, all items have maintained an appropriate level of skewness and kurtosis ±2. This implies that the data are normally distributed. Hence, EFA was used to discover the factor structure of a measure and to examine its internal reliability. The average value between 0.50 and 0.60 is acceptable for sample sizes between 100 and 200 (MacCallum *et al.*, 1999); however, a higher value indicates practical significance (Patel and Patel, 2023). Hence, the EFA results identified above 0.60, which implied that higher factor loading indicates a higher significance.

The properties of the measurement model were assessed for convergent and discriminant validity. As shown in Table 3, the factor loading SI ranges between 0.813 and 0.891, DI between 0.860 and 0.892, SCS from 0.838 to 0.920 and sustainable SCP from 0.737 to 0.845. The Cronbach's alpha value is ranged between 0.904 and 0.916, whereas the composite reliability (CR) values are ranged from 0.859 to 0.925, which is greater than 0.70, indicating each construct shows strong reliability (Hair *et al.*, 2016). Convergent validity was assessed by the values of average variance extracted (AVE), whose values should exceed the 0.60 threshold set

Table 3 Convergent validity

Variable	Item	Factor loading	Cronbach's alpha	CR	AVE	VIF
SI	SI1	0.880	0.911	0.918	0.739	2.926
	SI2	0.874				2.964
	SI3	0.813				2.213
	SI4	0.891				1.057
	SI5	0.836				2.397
DI	DI1	0.870	0.904	0.925	0.766	2.941
	DI2	0.892				2.342
	DI3	0.887				1.066
	DI4	0.869				2.731
	DI5	0.860				2.627
SCS	CS1	0.890	0.916	0.859	0.789	2.492
	CS2	0.895				2.851
	CS3	0.920				2.617
	CS4	0.909				2.201
	CS5	0.875				2.130
	CS6	0.838				2.583
Sustainable SCP	SSCP1	0.771	0.912	0.915	0.619	2.019
	SSCP2	0.845				2.686
	SSCP3	0.788				2.170
	SSCP4	0.802				2.309
	SSCP5	0.775				1.956
	SSCP6	0.737				1.798
	SSCP7	0.740				2.009
	SSCP8	0.831				2.621

Notes: CR (composite reliability); AVE (average variance extracted); variance inflation factor (VIF)
Source: Authors' own creation

by Hair *et al.* (2014). Convergent validity is established if the loadings of each item of a construct exceed 0.70 (Hair *et al.*, 2011). The findings indicated that loadings of all the items exceed the minimum requirement, and the AVE values are also greater than 0.60. The variance inflation factor (VIF) is used to measure collinearity among predictor variables. The results of VIF were less than 3.0, which indicates that there was no multicollinearity issue in this study. Figure 2 presents the summary of the measurement model assessment.

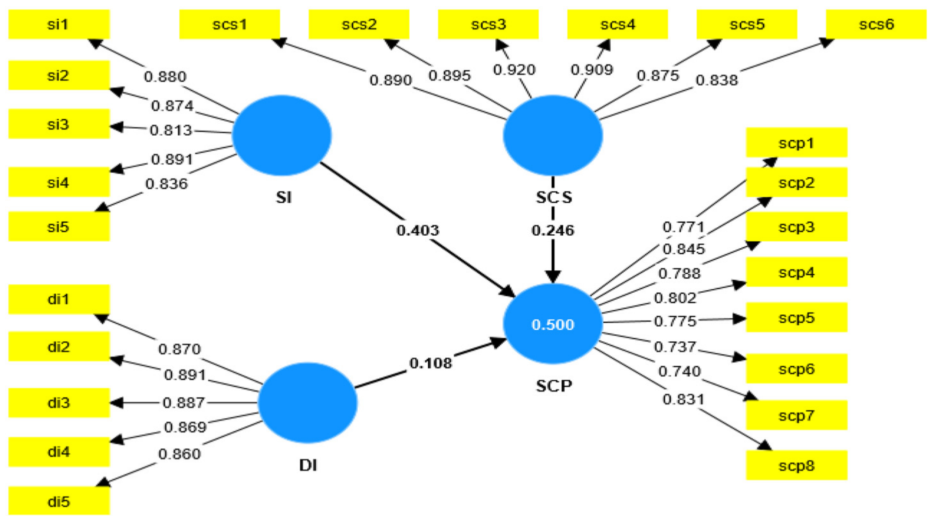
In this study, the discriminant validity is identified using the Fornell–Larcker criterion (Fornell and Larcker, 1981) and factor loadings test of the items, which should be larger than the cross-loadings of items. This criterion states that the correlation between a construct and any other construct must be bigger than the square root of the average variance retrieved by the construct. The results revealed that the item loadings were strong on their respective constructs as compared to other constructs. The AVE values for each variable are compared with the correlation between the other constructs. Table 4 presents the discriminant validity of the constructs. The result shows that the AVE score is more significant than the squared inter-construct correlation value. Thus, the results confirm that discriminant validity is achieved for this study.

In addition, for the robustness of the discriminant validity, we used cross loading. According to Table 5, the results of cross-loadings value indicated above 0.50, which specified that the model achieved a significant level of convergent and discriminant validity. Sarstedt *et al.* (2022) stated that high loadings over 0.50 present high reliability.

4.3 Structural model analysis

The findings revealed that SI and DI explained 50.0% of sustainable SCP variance. For evaluating the hypothesis test, Table 6 shows that SI has a significant and positive relationship with SCP. The standardized regression coefficient of this construct was beta = 0.403

Figure 2 Measurement model



Source: Authors' own creation

Table 4 Discriminant validity

Characteristics	*DI*	*SCP*	*SCS*	*SI*
DI	0.875			
Sustainable SCP (SSCP)	0.607	0.787		
SCS	0.815	0.655	0.888	
SI	0.741	0.679	0.797	0.859

Source: Authors' own creation

(t = 4.636) at a significant level of $p < 0.01$. Thus, *H1* is accepted. DI significantly impacts sustainable SCP (beta = 0.108 (t = 1.971) at a significant level of $p < 0.05$), and the result supports *H2*. In addition, the findings indicated that SCS has no moderating effect on the relationship between DI and sustainable SCP (beta = –0.033, $p > 0.05$). The result identified that SCS moderates the effect of SI on sustainable SCP (beta = 0.246, (t = 2.962) at a significant level of $p < 0.01$) in the manufacturing firm; therefore, *H3a* is supported, and *H3b* is not supported. Figure 3 illustrates the summary of the structural model assessment.

Each variable's performance was assessed using importance-performance matrices analysis (IPMA). The IPMA's current findings can be divided into two categories: performance, which is essential to stress managerial efforts, and importance (total effect). The robustness of the study's findings was taken into consideration using IPMA (Henseler *et al.*, 2015). As such, sustainable SCP was identified as the target variable for this study. Findings indicated that SCS was the highest effect on sustainable SCP, followed by SI and DI (Figure 4). The results of IPMA indicated that SCS presented a performance of 81.248 and a total effect of 0.246, SI indicated a performance of 79.326 and a total effect of 0.403, whereas DI presented a performance of 78.528 and a total effect of 0.108.

5. Discussion

The findings revealed that SI has a significant and positive impact on sustainable SCP (*H1*). This finding is related to Bag *et al.* (2020) who investigated the significant and positive

Table 5 Cross-loading

Items	*DI*	*SCP*	*SCS*	*SI*
Item_di1	0.870	0.529	0.754	0.659
Item_di2	0.891	0.542	0.725	0.657
Item_di3	0.887	0.556	0.710	0.634
Item_di4	0.869	0.523	0.709	0.673
Item_di5	0.860	0.506	0.670	0.623
Item_scp1	0.456	0.771	0.518	0.533
Item_scp2	0.502	0.845	0.558	0.581
Item_scp3	0.479	0.788	0.498	0.495
Item_scp4	0.505	0.802	0.517	0.530
Item_scp5	0.528	0.775	0.544	0.586
Item_scp6	0.405	0.737	0.450	0.484
Item_scp7	0.433	0.740	0.454	0.465
Item_scp8	0.500	0.831	0.568	0.582
Item_scs1	0.719	0.599	0.890	0.735
Item_scs2	0.702	0.566	0.895	0.699
Item_scs3	0.726	0.598	0.920	0.708
Item_scs4	0.703	0.583	0.909	0.706
Item_scs5	0.714	0.603	0.875	0.711
Item_scs6	0.786	0.539	0.838	0.688
Item_si1	0.676	0.646	0.720	0.880
Item_si2	0.631	0.609	0.743	0.874
Item_si3	0.567	0.488	0.600	0.813
Item_si4	0.667	0.611	0.712	0.891
Item_si5	0.634	0.544	0.636	0.836

Source: Authors' own creation

Table 6 Path coefficient

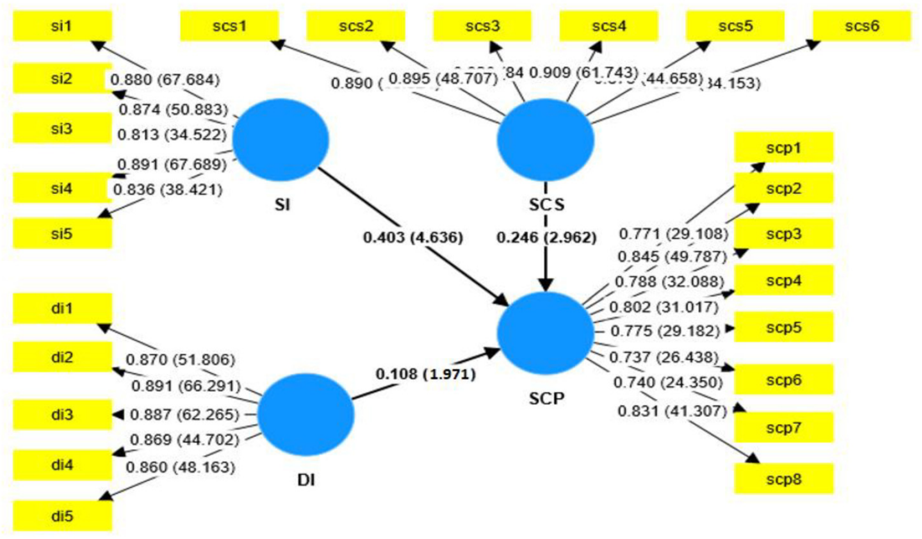
HR	*Beta (β)*	*SD*	*t-value*	*R^2*	*Results*
SI → SCP	0.403	0.087	4.636^{**}	0.500	Supported
DI → SCP	0.108	0.069	1.971^{*}		Supported
Moderating effect					
SCS → SCP	0.246	0.083	2.962^{**}		–
CS*SI→ SCP	0.213	0.053	4.033^{**}		Supported
CS*DI→ SCP	−0.033	0.050	0.649		Not supported

Notes: Hypothesis relationship (HR); sustainable innovation (SI); disruptive innovation (DI); supply chain clockspeed (SCS); sustainable supply chain performance (SCP). Significant level $^{**}P < 0.01$; $^{*}P < 0.05$
Source: Authors' own creation

relationship between SI and sustainable SCP in the mining industry. The manufacturing industry can improve sustainable SCP using SI. Shan and Shi (2020) highlighted the sustainable development of the supply chain and supply collaborative chain innovation in the context of Chinese enterprises. Junaid *et al.* (2022) indicated that SI can lead to aid sustainable SCP of manufacturing firms.

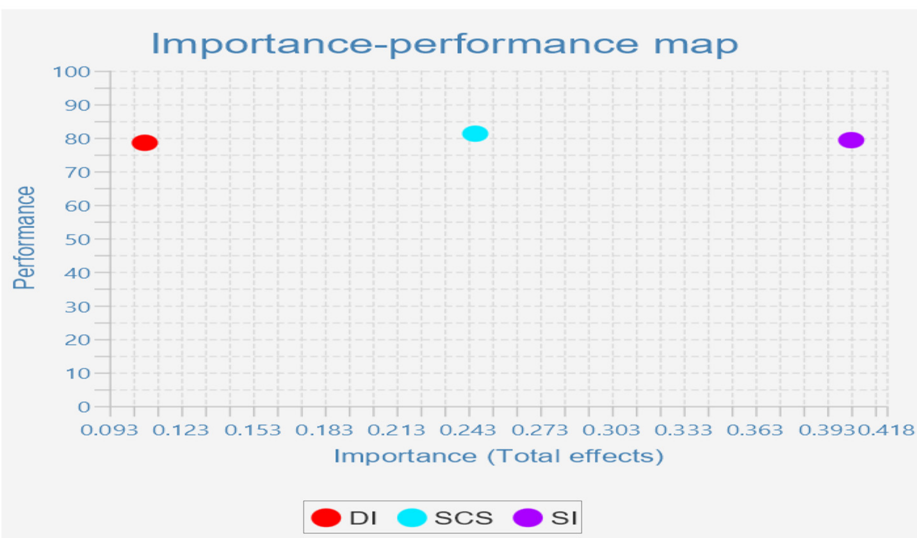
The results indicated that DI has a significant and positive impact on sustainable SCP (*H2*). This finding is relevant to Saberi *et al.* (2019) who investigated the relationship between technology and sustainable SCP and found that disruptive technology can address and aid sustainable SCP. DI can assist a firm's product and supply chain process (Wang *et al.*, 2022). Wamba *et al.* (2020) and Choi *et al.* (2020) explained DI in the context of SCP. DI can create opportunities for manufacturing firms to gain and maintain a competitive advantage and enhance SCP (Wang *et al.*, 2022). Chen *et al.* (2022) believed that DI can aid significant change in the mainstream market.

Figure 3 Structural model



Source: Authors' own creation

Figure 4 IPMA: Sustainable SCP



Source: Authors' own creation

The findings also indicated that SCS has a higher significant and positive impact on sustainable SCP. This finding is relevant to the previous research (Laforet and Bilek, 2021; Mellor *et al.*, 2014), where the author indicated that firms with higher SCS lead to higher sustainable SCP. Sustainable SCP is affected by the speed of the supply chain. The results show a significant moderating effect of SCS between SI (β = 0.213, t = 4.033) and sustainable SCP at a significant level $p < 0.01$ (*H3a*).

The study provides moderate empirical support for the model, representing 55.8% of the variance for sustainable SCP, which is reflected by SI and DI. It also implied that the speed of the supply chain has a significant moderating relationship between SI and sustainable SCP. This is because changes in a SI strategy are radical and fast. Thus, a fast-moving supply chain will translate radical changes into better sustainable SCP. On the other hand, a slower supply chain will be unable to cope with the drastic changes of a DI strategy.

The results revealed that there is an insignificant moderating effect of SCS between DI ($\beta =$ –0.033, $t = 0.649$) and sustainable SCP at a significant level $p > 0.05$; thus, *H3b* is not supported. However, SCS is crucial for the DI that leads to aiding sustainable SCP of the manufacturing firms. Meena and Girija (2022) specified that product complexity can be changed due to the clockspeed in many industries, rapid changes in technology and the constant appearance of new products on the market. Mishra *et al.* (2022) and Hahn (2020) indicated that DI and clockspeed can lead to profitability for the firms. When DI has a continuous strong and direct impact on sustainable SCP, regardless of supply chain speed, SCS may not moderating role in the relationship between DI and sustainable SCP. In such circumstances, DIs may be so transformative that they produce long-term improvements regardless of supply chain speed, reducing the need for SCS to control the relationship.

6. Implications

6.1 Theoretical implication

Based on the findings, SI, DI and SCS can lead to aid significant performance in sustainable supply chain manufacturing firms. SI and DI can create supply chain integration, information sharing and transparency, which lead to aid sustainable SCP in the firm. In addition, these innovations and SCS allow for huge performance improvement within the firms. This paper achieved the objective to analyze the relationship between SI, DI, SCS and sustainable SCP. This study identified that SI and DI drivers are significant predictors of sustainable SCP. Innovation strategies play an important role in a firm's sustainable SCP. Therefore, this study contributes to sustainable SCP and supply chain innovation strategy by identifying the optimal innovation strategy based on a firm's supply chain speed.

6.2 Practical implication

Manufacturing firms require sustainable and DI for minimizing waste, risk-taking activities, experiments and sustainable SCP. The previous studies have explained the importance and benefits of SCP, but no study has investigated the impact that the SCS on the effect of SI, DI and sustainable SCP in the manufacturing industry. This study examined the hypothesis and ensured the generality of the results in the context of a manufacturing firm in Malaysia. With a focus on SI and DI, the study provides insights into the SCS practice in the manufacturing firm that may lead to successfully dealing with sustainable SCP in the manufacturing industry. With these insights in hand, a manufacturing firm will be able to decide to apply disruptive and SI and SCS practice to achieve success and sustainable SCP in the manufacturing industry.

6.3 Managerial implication

This study will enable the firm managers to focus on an innovation strategy that will improve their firm's sustainable SCP based on the clock speed of the firm. It also allows policymakers at the government level to make policies that help firms introduce DI strategies that bring drastic improvements in their processes and the industry. This study examines a firm's SCS moderating the role between DI, SI and sustainable SCP. A proper innovative strategy must be determined in a firm to allocate time and resources to a new idea that can lead to employee needs and the speed of the firm's SCP. Managers within a firm should be able to identify differing demands for SI and DI. For DI, a firm should identify the potential competitive advantages and become flexible with the investigation and risks involved. It is crucial for the manager of the firm that the manager should clarify that the traditional method for dealing with SI may lead to the failure of DI. The prevalence of private limited firms, local owners and SMEs among respondents highlights the significance of tailoring business assistance programmes and policies to these entities' individual needs. Managers should consider developing adaptable and targeted strategies to address the unique challenges and opportunities confronting SMEs and locally held enterprises. Furthermore, developing strong relationships within the local business community can stimulate collaboration and mutually beneficial partnerships, thereby improving the overall business environment.

7. Limitations and future research directions

This study has several limitations. Firstly, this study merely focuses on Malaysian manufacturing firms as a sample population for collecting data; thus, the results might be different in different regions. Secondly, the study used a cross-sectional design rather than a longitudinal design, and the results are limited to that particular time. Thirdly, we have a small sample size, collected from one manufacturing firm and in a single country (Malaysia). In this study, we focused on measuring the general sustainable SCP, but we did not evaluate specifically economic and environmental sustainability. So, in the future, it is important for researchers to examine and assess the economic and environmental aspects of sustainable SCP. Future research that draws from a wider range of sectors may be able to overcome this constraint. The sample size and sampling from a particular sector may explain the correlations in the data. Future researchers might broaden the scope of their study by using these findings as a starting point to build more complex models that assess how green technology innovation, green management capability and employees' performance affects the performance of sustainable supply chains in the manufacturing sector. Future research can also look into how Industry 4.0 might be used to manage supply chain risks while taking the manufacturing sector into account. Future research can incorporate a time-series analysis looking at the effect of changes in a firm's clockspeed on the innovation strategy. The future researcher may also investigate any differences in the results based on a firm's clock speed by incorporating an equal number of low-, medium- and high-clockspeed firms.

8. Conclusion

The analysis and findings indicated that SI and DI are found to have crucial factors as they have a significant and positive relationship with the sustainable SCP of the manufacturing firm in the context of Malaysia. For the robustness of this study, the authors of this study examined the moderating role of SCS in the model. The results revealed that SCS moderates the effect of SI and DI on sustainable SCP in manufacturing sector. The supply chain manufacturing firm should consider SI and DI in developing the sustainable SCP of the organization. The manufacturing firm can apply an SCS strategy for the efficiency of SCP.

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