



Research Article

Enhancing Green Competitive Performance of Product–Service Systems through a Dynamic Capabilities Lens

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Abstract: Incorporating environmental awareness into business operations while maintaining competitive performance is a significant challenge. To address this, many companies are enhancing their offerings by integrating services with products—a strategy known as product–service systems (PSS). This innovation aims to boost competitiveness and promote environmental consciousness. However, although PSS is recognized as a valuable approach for staying competitive, the interplay between PSS and its influencing capabilities remains insufficiently explored. This study examines the relationships among Organizational Learning Development (OLD), Supply Chain Integration (SCI), Supply Chain Digitalization (SCD), Supply Chain Agility and Resilience (SCAR), Green Supply Chain (GSC), and Product–Service Systems’ Green Competitive Performance (PSSGCP). Data were gathered through a structured survey involving 502 official motorcycle service partners in Indonesia and analyzed using SEM. The results confirm significant positive relationships between GSC and PSSGCP and between SCAR and PSSGCP. Moreover, OLD, SCI, and SCD each positively influence SCAR, whereas only OLD and SCD have direct positive effects on GSC. The analysis also reveals that OLD positively influences SCI, which subsequently impacts SCD—indicating that SCD mediates the influence of SCI on GSC. These findings provide practical and theoretical insights that enable managers and researchers to better align green and competitive performance goals. Furthermore, managers can assess the standardized loadings to evaluate each capability’s contribution to enhancing PSSGCP.

Keywords: Agile supply chain; Green competitive performance; Green supply chain; Product–service systems; Supply chain resilience

1. Introduction

Manufacturing sector companies, once solely dedicated to product manufacturing, are now embracing services as an integral part of their business strategy. This trend, known as Product–Service Systems (PSS) represents an innovative approach adopted by firms to remain competitive and effectively meet evolving customer expectations. With environmental awareness taking precedence, PSS is being redefined, initially defined as the integrated bundling of products and services to create value-added products and boost customer satisfaction (Beuren et al., 2013). The

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PSS definition now includes the producer's responsibility for the product at its end of life. PSS is perceived as an innovative bundling of products and services, aiming to offer not just a product but also services throughout the product's life cycle to maintain environmental sustainability ([Annarelli et al., 2016](#)).

Various disruptions, including natural disasters, the COVID-19 pandemic, fierce competition in the business landscape, distribution failures, and other unforeseen events, have caused interruptions in recent times. These disruptions necessitated a departure from BAS practices. Characteristics such as flexibility, speed, innovations, and responsiveness are required in erratic conditions, such as the current situation ([Al-Omoush et al., 2022](#); [Ashari et al. 2018](#)). Hence, the agility and resilience of the supply chain (SC) guide companies in the SC to operate in a stable and normal mode when disruptions occur ([Kazancoglu et al. 2022](#)).

To address these challenges, supply chain agility and resilience—collectively referred to in this study as Supply Chain Agility and Resilience (SCAR)—have gained prominence. Although both technologies share overlapping characteristics, such as speed, flexibility, and responsiveness, they serve distinct purposes. Agility focuses on swiftly responding to market changes and consumer needs, whereas resilience emphasizes the ability to absorb shocks and maintain continuity ([Gligor et al., 2019](#)). Given their common objective of improving SC performance, this study uses the integrated term SCAR to reflect their complementary roles.

However, agility and resilience alone are insufficient for long-term sustainability. Environmental awareness must also be incorporated into corporate strategies in today's context ([Singh et al., 2023](#)). Without active engagement in environmental stewardship, the degradation of natural resources, particularly raw materials critical to manufacturing operations, could threaten supply continuity. In response, companies are increasingly facing pressure from governments, stakeholders, and society to comply with environmental standards and reduce negative ecological impacts ([Abdallah et al. 2024](#)). This pressure makes GSC practices essential.

Despite the recognized importance of environmental consciousness and supply chain agility and resilience, their integration within the PSS context remains underexplored ([Ghaderi et al. 2024](#); [Ivanov, 2022](#)). While PSS has been widely studied—primarily from a consumer service and innovation perspective ([Sassanelli and Pacheco, 2024](#); [Soellner et al., 2024](#))—there is a notable gap in understanding the supply chain capabilities required to simultaneously support both green supply chain practices and supply chain agility and resilience. Existing literature tends to focus on upstream supply chain elements, emphasizing consumer-centric innovation, while overlooking critical operational aspects such as logistics management, supply chain integration, and the capacity development of weaker partners within the network. This study addresses this research gap by investigating the PSS supply chain capabilities—namely, organizational learning development (OLD), supply chain integration (SCI), and supply chain digitalization (SCD)—that are essential to strengthening both GSC and SCAR, thereby enhancing PSSGCP.

To address the weaknesses in the current body of knowledge, this study investigates three gaps, which constitute the following research questions: (1) What is the relationship between GSC and PSSGCP, as well as SCAR and PSSGCP? (2) What are the PSS SC capabilities (OLD, SCI, and SCD) affecting the GSC and SCAR? (3) What is the relationship between OLD and SCI, as well as between SCI and SCD?

This study offers a novel contribution by integrating GSC practices and SCAR within the context of PSS—an intersection that has remained underexplored in the existing literature. Unlike prior research, which primarily focuses on the upstream, consumer-facing dimensions of PSS, this study emphasizes SC capabilities—specifically OLD, SCI, and SCD—as critical enablers for both environmental sustainability and operational adaptability. This study proposes and empirically examines the role of these capabilities in enhancing PSSGCP and establishes a comprehensive and integrative framework that differentiates itself from earlier fragmented approaches to GSC and SCAR in isolation. The research is situated within the motorcycle industry supply chain, providing a relevant and dynamic context characterized by high product complexity, competitive pressures,

and increasing environmental expectations. The growing frequency of global disruptions and increasing environmental pressures, which compel firms to rethink and restructure their SC, further underscore the urgency and relevance of this research. The findings not only contribute to the academic contributions but also offer practical insights for firms aiming to achieve sustainable and resilient competitive advantages in today's volatile and sustainability-driven market landscape.

2. Theoretical framework and development of hypotheses

The Dynamic Capabilities (DC) theory guides the conceptual theoretical framework in this study. The high pressure from stakeholders and the government for green and environmental awareness, along with the dynamic and erratic business environment with frequent disruptions after the pandemic; consequently, DC offers a well-suited theoretical grounding for this analysis. Likewise, the characteristics of the collaboration within SC to provide PSS require a theory that accommodates dynamic resources and capabilities that will grow within the SC. For example, [Paiola et al. \(2013\)](#) confirmed that the development of capabilities within the SC network using DC includes customer orientation, PSS partnership, knowledge and technical expertise, and risk control.

DC is defined as the capacity of the organization to constantly integrate, renew, and reconfigure its resources and capabilities to respond to the changing environment and keep the competition ([Teece, 2007](#)). Moreover, it is difficult to enhance DC in a company as they should be progressed together within the network ([Defee and Fugate, 2010](#)). DC suits well to guide the proposed framework as the framework is developed for SC networks. This research focuses on motorcycle SC, aiming to deliver PSS. The SC network in the motorcycle industry involves collaboration among manufacturers, intermediaries, and service partners. The term "main dealer" is better known among service partners as an intermediary of the manufacturer that bridges the development of DC within the network.

In this study, OLD, SCI, and SCD are considered dynamic capabilities that should be created within a network to sense, seize, and reconfigure internal and external resources to deal with a rapidly changing environment. GSC and SCAR are essential for navigating the unpredictable business environment. Specifically, GSC is crucial for sustaining long-term performance improvements while preserving future green resources.

2.1. PSSGCP

Nowadays, companies are struggling to find themselves and survive in the business competition. Competitive performance is the result of a competitive advantage, indicating a company's ability to innovate and outperform its competitors ([Kumar et al., 2024](#)). Various performance indicators can be used, including product and service quality, delivery efficiency, flexibility, responsiveness, the ability to provide high levels of customer service, and profit generation capability ([Wiredu et al., 2024](#); [Glukhov et al. 2023](#); [Mohammadi and Mukhtar, 2018](#)). PSS offers a method to achieve differentiation by satisfying customers with not only high-quality products but also complementary services, thereby extending the lifespan of the products and supporting green initiatives.

Along the way, the erratic conditions these days required agility and resilience, but the green concept must be added to it to stay in a business for a long-term. The GSC is defined as a company's approach to achieving profits while considering the integration of environmental awareness, starting from product design, material selection, production, product delivery to consumers, and end-of-life product management, with the goal of reducing environmental impact ([Hebaz et al., 2024](#)). Hence, this study aims to identify the PSS SC capabilities required to improve the PSSGCP, which focuses on enhancing green, agility, and resilience capabilities.

2.2. GSC

GSC is defined as organizational philosophies that not only pursue business economic advantage but also enhance green efficiency by minimizing the environmental impact of industrial activities ([Gawusu et al., 2022](#)). Green SC practices should cover all activities throughout the industrial process from purchasing, production, logistics, distribution, and the end of life of the product

(Bustinza et al., 2024; Suwignjo et al. 2023). PSS serves as part of the effort to extend the product's lifespan by providing maintenance services. The scope of GSC extends from reactive environmental control to proactive efforts such as refurbishing, reusing, reducing, recycling, and remanufacturing (de Oliveira et al., 2018). Visualizing how GSC practices relate to operational SC benefits is challenging. Novitasari and Agustia (2021) did not discover a positive link between GSC and SC performance. PSSGCP merges SC performance with environmental considerations. Thus, to explore this association, the following hypotheses are proposed to be examined.

H₁. GSC positively affects PSSGCP.

2.3. SCAR

The terms "agility" and "resilience" share several similar characteristics, such as flexibility, speed, and responsiveness. Both aim to enhance SC performance, but there are slight differences between them (Sharma et al., 2024). SC agility is defined as the capability of SC to effectively and promptly acknowledge market changes, while resilience primarily focuses on how quickly the SC returns to its original state following a disruption, agility emphasizes how swiftly the SC adapts to meet consumer demands (Kumar and Singh, 2025). Therefore, this study employs the terms agility and resilience interchangeably. SC agility has been identified as a factor contributing to enhanced competitiveness and is characterized by responsiveness, innovation, swiftness, and flexibility (Aslam et al., 2024; Raj et al., 2023). SC agility also represents the firm's dynamic capabilities to sense, seize, and reconfigure firm and SC resources (Dubey et al., 2018). Capabilities required for resilience include the ability to face disruptions, hinder shock, quickly recover to the original state, speed, and flexibility, which is similar to agility (Gligor et al., 2019). Many studies on SC have shown a positive relationship between SC agility and resilience to improve firm performance (Mahesh et al., 2024). Therefore, it is hypothesized that SCAR is positively related to PSSGCP.

H₂. The SCAR positively affects PSSGCP.

2.4. OLD

OLD is defined as a dynamic process that involves creating and transferring new knowledge to improve SC capabilities. It has four components that support the inter-firm organizational learning process: commitment to learning, shared vision, willingness to consider diverse ideas, and knowledge sharing (Dovbischuk, 2022). Gaining knowledge through long-term collaboration between two or more parties improves firms' performance and resilience (Eryarsoy et al., 2022). Firms that ignore OLD prioritization have found that their response to firm performance is limited as DC for OLD accumulates gradually through consistent repetition (Pratono et al., 2019).

Consistent OLD is crucial for achieving a firm's performance, such as being green, agile, and resilient (Eryarsoy et al., 2022), as well as improving the SCI. In this study, motorcycle manufacturers lack the capability to deliver PSS independently (Dewi and Hermanto, 2024). This underscores the need for strategic partnerships with intermediaries and service providers (Dewi et al., 2024). Manufacturers share expertise to boost OLD among their service partners. This learning can be facilitated through various mechanisms, such as training sessions, meetings, face-to-face discussions, technical performance reviews, and annual audits (Dewi and Hermanto, 2024). These initiatives aim to enhance partners' technical skills and performance, making them more agile and resilient in their tasks (Dewi et al., 2024). Likewise, OLD has been shown to serve as a positive moderator between the adoption of eco-friendly materials and the prolongation of product lifespan, leading to improved GSC (Yang et al., 2024). Hence, it is essential to verify if there is a direct positive correlation between OLD and GSC. Given the description provided, the following hypothesis is proposed:

H_{3a}. OLD positively affects the GSC.

H_{3b}. OLD positively affects SCAR expression.

H₆. OLD positively affects SCI.

2.5. SCI

Many SC research studies stress the capabilities to integrate within a firm and network. In fact, those studies highlighted the significant role of SCI in GSC (Pham and Pham, 2021) and SCI in SCAR (Abdelilah et al. 2023; Shukor et al., 2021). SCI involves enduring alignment between SC participants throughout all functions, featuring integrated planning and mutual decision processes (Abdulameer et al., 2020; Jajja et al., 2018). It is not adequate for a firm to integrate only internal functions within an enterprise, but it is also necessary to integrate all functions within the SC network (Jajja et al., 2018). The SC integration process may involve all the areas required as a business process in the SC, which has three entities: process integration, supplier integration, and customer integration (Shukor et al., 2021).

PSS extends the product life cycle by providing a bundle of products and services (Dewi et al., 2023). Collaboration among manufacturers, intermediaries, and service partners to provide PSS is crucial, as is the same vision to be green in their SCI. Process integration enables all stakeholders in the supply chain to access the database through unified information systems (Dadzie et al. 2023). SCI can be viewed as DC, which is essential for adapting to business and environmental changes, and it also has a positive impact on SCD (Arif et al., 2023). Strong relationships with service partners enable essential capabilities to scan, seize, and reconfigure resources, allowing the company to effectively respond to changing customer expectations (Cui et al. 2023). In the motorcycle industry context, service partner suppliers can assist in changing customer demand as they have direct contact with customers (Dewi and Hermanto, 2023). These coordinated efforts should improve resource utilization and ultimately impact SC performance. Then, we propose the following hypotheses.

- H_{4a}. SCI positively affects the GSC.
- H_{4b}. SCI positively affects SCAR expression.
- H₇. SCI positively affects SCD.

2.6. SCD

Digitalization is defined as the transformation of business routines from traditional systems to digital systems (Tiwari et al., 2024). Digitalization potentially enables the management and surveillance of energy consumption and waste (Wang et al., 2023). For instance, manual communication processes that formerly relied on paperwork can now be replaced with digital systems. Similarly, communication within SC, such as interactions between manufacturers, intermediaries, and service partners, requires considerable effort when executed manually, resulting in waste and slow process (Oubrahim et al., 2023).

Digitalization is one way to resolve and arrange data better than manual methods (Le et al., 2024). Related to inventory management, digital technology is mostly utilized to manage physical and virtual inventory in real time to reduce the cost of inventory management. Thus, it can quickly make decisions in real time, preventing faults and preventing disruptions that require swift changes (Mashayekhy et al., 2022). Digitalization also ensures tractability and offers monitoring and control (Behnke and Janssen, 2020). In the case of customer preferences, SCD can predict changes in customer behavior and swiftly respond to match customer expectations (Zhou et al., 2023). In general, digitalization facilitates the integration of SC processes, thereby ensuring a quick response to any risks linked to the SC processes (resilience) as well as being responsive and agile. Hence, its implementation can enhance both GSC and SCAR. Therefore, we propose the following hypothesis for further examination.

- H_{5a}. SCD positively affects the GSC
- H_{5b}. SCD positively affects the SCAR

3. Methods

The current section describes the methodological approach of the study, where the sequence of research activities is depicted in Figure 1.

3.1. Development of the instrument

A structured survey was conducted as part of a quantitative analysis to test the proposed hypothesis, targeting certified motorcycle service partners across Indonesia. The questionnaire was developed in five stages, which will be explained in the following paragraphs. The questionnaire consists of two parts: the first part, which consists of 10 questions, inquires about the demographic information of the participants and their companies. The second part focuses on the core of this research, which includes 37 questions about OLD (6 items), SCI (6 items), SCD (5 items), SCAR (7 items), GSC (6 items), and PSSGCP (7 items). The questionnaire is provided in Appendix A to enhance transparency and support replicability. All items were measured using a 6-point Likert scale, where 0 = strongly disagree, 1 = disagree, 2 = somewhat disagree, 3 = somewhat agree, 4 = agree, and 5 = strongly agree. Table 2 presents the definitions and conceptual descriptions of each construct—OLD, SCI, SCD, SCAR, GSC, and PSSGCP.

The survey development process was conducted in five stages (Lewis et al., 2005). The first stage involved defining each construct's domain and specifying the measurement objectives. An extensive literature review was required to establish the six constructs. In the second stage, a list of items was developed for each construct to measure them accurately. This stage produced 37 items. The third stage was pre-testing, where four experts from academia and industry were recruited to assess the questionnaire's ease of use and clarity. Based on their feedback, adjustments were made, including clarifying statements, removing ambiguous terms, and changing terminology for better understanding. The fourth stage involved pilot testing, in which 10 participants from official service partners were recruited to provide feedback for refining the instrument. The interrater agreement questionnaire was distributed to 25 service partner participants and academic experts with knowledge of the supply chain. Three criteria were used to remove items: if the mean value was less than the midpoint, if the p -value was greater than 0.05, and if the power was less than 0.8 (Sudon et al., 2013). No items were removed based on these three criteria, and all 37 items were retained.

3.2. Preliminary Data Analysis

The survey data included participants from five motorcycle companies in Indonesia, all of which are members of The Indonesian Motorcycle Association. The sampling frame consisted of approximately 6830 service partners, which were gathered by the researcher from the official websites of these motorcycle companies. The study involved managers from authorized service partners of the companies, who had at least one year of work experience. A simple random sampling technique was applied to support the broader applicability of the results.

The questionnaire was distributed in two ways: online and by mail to accommodate service partners who do not use email. A total of 2025 questionnaires were distributed, with 1025 sent online and 1,000 sent by mail. The mail survey was conducted only once without a reminder, whereas the online survey included two reminders. A total of 442 responses were received for the initial wave, and 201 responses were received for the second and third reminders. In total, 643 responses were Received (31.8% response rate). However, 100 responses from the initial wave and 41 responses from the final waves could not be processed further because they were incomplete and excluded from the analysis. Therefore, only 502 responses could be processed further.

The demographic profile data of the participants highlight an uneven market share distribution among the five motorcycle brands in Indonesia. One brand stands out with a dominant market share, as indicated by 75.3% of survey participants, followed by another brand with 18.1%. The remaining three brands have smaller market shares than these two. Most participants are based on the island of Java, making up 66.5% of the total, which aligns with Indonesia's population distribution, where the majority live in Java. Additionally, 63.8% of participants have been operating for more than 10 years, with the characteristics of long-term collaboration. The service partners are primarily micro-enterprises with fewer than 10 employees (91.6%). Among those who completed the survey, 57.2% are heads of service center workshops, and 34.9% are direct owners. A significant portion, 63.1%, has over 10 years of experience in the motorcycle industry, while 66%

have been heads of service center workshops for more than 5 years. The service center workshop heads are predominantly male (94.2%), with 45.2% aged between 36 and 45 years, and nearly all have an education level above high school.

To assess non-response bias, Levene's test for equality of variance and a t-test for the equality of means were used to determine if there were any statistically significant differences between the responses from the early ($n = 342$) and late ($n = 160$) waves. No statistically significant differences were observed between the early and late waves for the five constructs, with p -values exceeding 0.05. Thus, no non-response bias can be concluded in the data used in this study.

Several statistical techniques were used to ensure the validity and reliability of the measurement and structural models. First, we conducted exploratory factor analysis to identify the underlying factor structure and explore the dimensionality of the constructs without imposing a predefined structure. Confirmatory factor analysis was conducted to test the hypothesized measurement model and verify the factor structure identified in the EFA, ensuring that the observed variables adequately represented their respective latent constructs. Discriminant validity was assessed to confirm that the constructs were distinct. Construct reliability, such as CR, was also evaluated to ensure the internal consistency of the items measuring each construct. Additionally, to address potential biases arising from the use of self-reported survey data, CMB was assessed using techniques such as Harman's single-factor test. Finally, the structural model was evaluated using SEM to test the hypothesized relationships between constructs, examine path coefficients, model fit indices, and the explanatory power (R^2) of the dependent variables.

4. Results

4.1. Validity test

Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were conducted to validate the test. EFA was performed using SPSS version 26 to assess the scale's dimensionality, followed by CFA using AMOS version 26 to evaluate convergent, discriminant, and factorial validity. EFA was individually conducted for the six constructs, using pomax rotation and maximum likelihood extraction. The six constructs resulted in a one-factor solution, explaining a total variance of 51.44%–68.75% with factor loadings ranging from 0.47–0.88. According to [Brown \(2015\)](#), factor loadings below 0.5 are invalid. Therefore, two items were dropped from the EFA process: SCAR7 and GSC5, with factor loadings of 0.340 and 0.337, respectively.

There are three stages for confirming convergent validity. First, the chi-squared values are calculated. If the chi-squared rejects at a p -value < 0.01 ; modification indices can be used to detect shared underlying factors across the measurement items. A cautious approach should be adopted to identify and eliminate items, especially those with insufficient validity scores (refer to the interrater agreement results). These results confirm convergent validity using the following goodness-of-fit indices cutoff values: $p > 0.05$, norm $\chi^2 \leq 3$, RMSEA < 0.06 , SRMR < 0.08 , CFI ≥ 0.95 , and TLI ≥ 0.95 ([Yu, 2002](#)). After this process, several items (OLD6, SCI6, SCD5, SCAR6, and GSC6) need to be deleted. Standard factor loadings for all items ranged from 0.671 to 0.876 (greater than 0.5).

The goal of discriminant validity testing is to verify that a construct shows stronger associations with its intended measures than with variables from different constructs in the framework ([Rönkkö and Cho, 2022](#)). The six constructs demonstrated discriminant validity as each construct's average variance extracted (AVE) was greater than its squared correlation with any other construct (Table 1).

This validation step assesses whether the hypothesized latent variables form meaningful constructs by analyzing the overall model fit statistics. The obtained satisfactory fit indices verified the factorial validity of the measurement model (normed $\chi^2 = 1.929$, SRMR = 0.030, RMSEA = 0.043, CFI = 0.964, and TLI = 0.960).

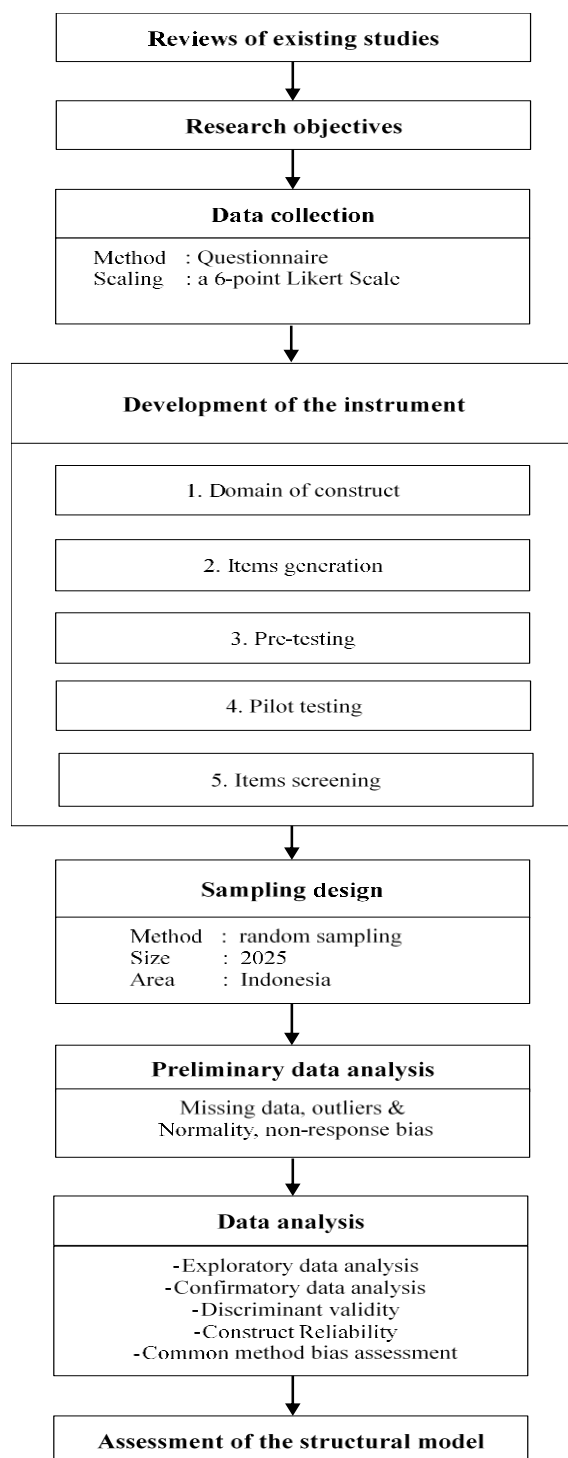


Figure 1 Methodological approach used

Table 1 Discriminant validity using the Fornell–Larcker criterion and the HTMT ratios

		Domain of the constructs				
	PSSGCP	SCI	OLD	SCD	SCAR	GSC
PSSGCP	0.815					
SCI	0.420	0.828				
OLD	0.266	0.732	0.829			
SCD	0.701	0.490	0.369	0.767		
SCAR	0.313	0.696	0.711	0.426	0.791	
GSC	0.525	0.310	0.304	0.645	0.351	0.789

4.2. Construct reliability

Three metrics were used to measure construct reliability: coefficient H, construct reliability, and Cronbach's alpha. The results confirm that the scale reliability is good, with H values ranging from 0.865 to 0.938, construct reliability ranging from 0.850 to 0.932, and Cronbach's alpha values ranging from 0.842 to 0.932 (Table 2).

Table 2 Measurement variables (constructs) and corresponding scale indicators

Code	Domain of constructs and items	References	Factor loading
<i>OLD is defined as dynamic process that involves create and transfer new knowledge aiming for improving the SC capabilities, H=0.917, Cronbach's alpha=0.916, CR=0.916</i>			
OLD ₁	Our main dealer partner has ceaselessly upgrade our knowledge of PSS and environmental awareness.	(Dewi et al. 2023)	0.846
OLD ₂	A variety of training sessions have been developed to improve our agility, quickness, innovation capabilities, and awareness of environmental issues	(Dewi et al. 2023)	0.824
OLD ₃	As a testament to our lasting collaboration, our main dealer partner has continuously provided training programs designed to enhance service partner capabilities.	(Dovbischuk, 2022)	0.840
OLD ₄	Our main dealer partner strengthen our capabilities to achieve green, agile and resilient supply chain.	(Dewi et al. 2024)	0.803
OLD ₅	We and our main dealer continuously learn about customers' needs and requirements.	(Dewi and Hermanto, 2024)	0.832
OLD ₆	Variety training courses of product and technical service has been supplied to us by the main dealer (omitted).	(Dewi et al., 2024)	-
<i>SCI is defined as long-term collaboration among stakeholders in the SC for all processes, joint planning and decision in the SC, H=0.918, Cronbach's alpha=0.916, CR=0.916</i>			
SCI ₁	We sharing information with our main dealers about sales forecast, stock level, customers' expectation and responsibilities on environmental impact.	(Jajja et al., 2018)	0.838
SCI ₂	We maintain long term collaborative agreement with our main dealer to deliver PSS and achieve environmental goals.	(Jajja et al., 2018)	0.846
SCI ₃	We maintain joint decision making with our main dealer about PSS delivery, quality improvement and resolve environment-related problems.	(Jajja et al., 2018)	0.864
SCI ₄	We maintain good communication with customers through multiple communication channels.	(Oubrahim et al., 2023)	0.781
SCI ₅	We continually seek input from customers to assess their satisfaction levels and gather feedback of Product-service systems.	(Oubrahim et al., 2023)	0.809
SCI ₆	We maintain integrated data with main dealers within our SC network (omitted).	(Tan et al., 2023)	-
<i>SCD is defined as transformation of business routines from traditional systems to digital systems, H=0.865, Cronbach's alpha=0.842, CR=0.850</i>			
SCD ₁	We have utilized digital tools to communicate with our main dealer.	(Yu et al., 2023)	0.675
SCD ₂	We have employed digital devices to record transactions with our customers.	(Yu et al., 2023)	0.713
SCD ₃	We possess the ability to exchange digitalized data with our customers to ensure effective communication of PSS.	(Qiao et al., 2023)	0.850
SCD ₄	Our system enables real-time digital data sharing with our primary dealer partner for operational, inventory, and sustainability planning purposes.	(Yu et al., 2023)	0.818
SCD ₅	We have utilized digital technologies to create innovative PSS that can appeal to untapped markets (omitted).	(Qiao et al., 2023)	-

Table 2 Measurement variables (constructs) and corresponding scale indicators (Cont.)

Code	Domain of constructs and items	References	Factor loading
<i>SCAR is defined as the capability of SC to acknowledge effectively and promptly to the market changes and quickly recover to the original state, H=0.895, Cronbach's alpha=0.892, CR=0.893</i>			
SCAR ₁	We continuously enhance our PSS to rapidly boost customer satisfaction levels.	(Kim and Chai, 2017)	0.805
SCAR ₂	We continuously enhance the reliability of our PSS delivery through rapid improvements.	(Kim and Chai, 2017)	0.804
SCAR ₃	We continuously reconfigure our PSS supply chain capabilities to swiftly adapt to evolving market demands.	(Al-Omoush et al., 2022)	0.750
SCAR ₄	We continuously drive innovation in our PSS offerings to maintain market leadership.	(Boon-itt et al., 2017)	0.794
SCAR ₅	We have capabilities and resources to deal with disruption and quickly recover from it .	(Shukor et al., 2021)	0.804
SCAR ₆	We continuously reconfigure our supply chain resource capacity to rapidly mitigate demand disruptions (omitted).	(Belhadi et al. 2022)	-
SCAR ₇	Our team proactively reconfigures production capacities to seamlessly customize orders based on client requirements (omitted).	(Belhadi et al. 2022)	-
<i>GSC is defined as organizational principles that aim to achieve both profit and economic benefits while also improving ecological efficiency by reducing the environmental impact of industrial activities, H=0.874, Cronbach's alpha=0.866, CR=0.868</i>			
GSC ₁	Our product is designed and manufactured to facilitate recycling, rework, and repair.	(El Khoury et al. 2023)	0.801
GSC ₂	Our product is designed and manufactured using eco-friendly materials with a long material lifespan and reduce negative impacts on the environment.	(El Khoury et al. 2023)	0.724
GSC ₃	Our product is manufactured in accordance with environmental standards and regulations.	(El Khoury et al. 2023)	0.836
GSC ₄	We prolong the product lifespan through the provision of a bundle Product-service systems.	(Dewi et al., 2023)	0.791
GSC ₅	Our company has electric motorcycle to support low emission (omitted).	(El Khoury et al. 2023)	-
GSC ₆	The company prioritizes the management of environmental issues concerning PSS delivery (omitted).	(El Khoury et al. 2023)	-
<i>PSSGCP is defined as a company's approach to achieve good quality, flexibility, profits and delivery while considering the integration of environmental awareness, H=0.938, Cronbach's alpha=0.932, CR=0.932</i>			
PSSGCP ₁	We have high speed of PSS offering deliveries.	(Choi et al., 2018)	0.825
PSSGCP ₂	We have high volume/ capacity flexibility.	(Choi et al., 2018)	0.841
PSSGCP ₃	We have a high degree of PSS variety offering.	(Akin Ateş et al. 2022)	0.838
PSSGCP ₄	We have high performance of PSS quality offering.	(Akin Ateş et al. 2022)	0.845
PSSGCP ₅	We have high level of customer satisfaction.	(Akin Ateş et al. 2022)	0.876
PSSGCP ₆	We have high level of PSS profitability.	(Akin Ateş et al. 2022)	0.671
PSSGCP ₇	We have reduced the use of harmful, toxic, and hazardous substances in our products.	(Pham and Pham, 2021)	0.794

4.3. Assessment of common method bias

Harman's single-factor test is used to assess common method variance (CMV). We found an average variance extracted of 32.5% by placing all construct items into one factor and utilizing maximum likelihood extraction, indicating no significant CMV (Podsakoff et al., 2003). To further evaluate CMV, a common latent factor (CLF) was incorporated into the measurement model. The results showed that the differences in regression weights were less than 0.2 in the CFA models with and without the CLF, confirming the absence of CMV (MacKenzie et al., 2011).

4.4. Assessment of the structural model

The results confirmed an appropriate model fit for the proposed structural framework, with normed $\chi^2 = 2.269$, SRMR = 0.040, RMSEA = 0.050, CFI = 0.95, and TLI = 0.95 (Figure 2). Given a PCFI value of 0.87, the model is also considered parsimonious.

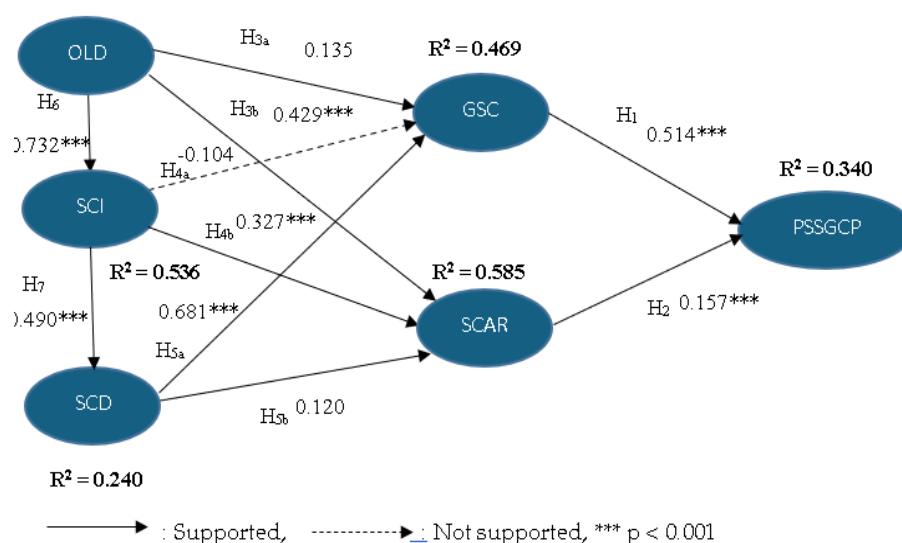


Figure 2 Structural model findings including path coefficients and explained variances

The ten hypotheses were tested using SEM. The results indicate that GSC positively affects PSSGCP, with a coefficient of 0.514 ($p < 0.001$), supporting H1. Hypothesis H2, which posits that SCAR positively impacts PSSGCP, is supported by a path coefficient of 0.157 ($p < 0.001$). Similarly, H3a is validated, showing that OLD influences GSC, with a coefficient of 0.135; likewise, H3b is supported, demonstrating that OLDD shows a positive correlation with SCAR, with a coefficient of 0.429 ($p < 0.001$). Moreover, OLD positively affects SCI with a coefficient of 0.732 ($p < 0.001$), supporting H6. SCI does not have a significant impact on GSC (H4a), but H4b is supported, showing that SCI positively affects SCAR with a coefficient of 0.327 ($p < 0.001$). Additionally, SCI is positively associated with SCD with a coefficient of 0.490 ($p < 0.001$), supporting H7. Lastly, SCD has a significant impact on GSC ($H_{5a}=0.681$, $p < 0.001$), and H5b is supported, indicating that SCD has a significant positive effect on SCAR, with a coefficient of 0.120. The R^2 values for SCI, SCD, GSC, SCAR and PSSGCP: 0.536, 0.240, 0.469, 0.585, and 0.340, respectively.

Although indirect effect hypotheses were not explicitly formulated, they are explored in this section to enhance the depth of analysis. The significance of the mediation paths was evaluated using bias-corrected bootstrapping with 2,000 random samples. Table 3 summarizes the eight significant mediation paths. SCI fully mediates the relationship between OLD and SCD, underscoring its role in enabling digital transformation. SCD fully mediates the path from SCI to GSC, demonstrating that SCI influences green practices only when operationalized through digitalization. The effect of OLD on GSC is partially mediated by SCI and SCD, with significant direct and indirect effects. Similarly, the relationship between OLD and SCAR shows partial mediation through SCD, indicating that digital capabilities complement OL. The path from SCI to SCAR is partially mediated by SCD, although the indirect effect is relatively small. Three full mediation paths are identified for PSSGCP: (1) OLD affects PSSGCP through GSC, SCAR, and SCD; (2) SCI influences PSSGCP via SCD and SCAR; and (3) SCD impacts PSSGCP through GSC and SCAR. These results indicate that enhancing PSSGCP depends on the integration and mediation of SCI, SCD, GSC, and SCAR rather than on direct effects alone.

Table 3 Mediation paths of the indirect effects between antecedents and PSSGCP

Path (mediation type)	Mediator	Indirect effect	Interpretation
OLD - SCD (full)	SCI	0.328	SCI fully mediate the relationship
OLD-GSC (partial)	SCI, SCD	0.158	Both direct and indirect significant
OLD-SCAR	SCD	0.323	Both direct and indirect significant
(partial)	SCD	0.320	Only indirect path significant
SCI-GSC (full)	SCD	0.069	Minor mediation via SCD
SCI-SCAR(partial)	GSC, SCAR, SCD	0.221	Fully mediated through multiple paths
OLD-PSSGCP(full)	SCD, SCAR	0.151	Fully mediated through multiple paths
SCI-PSSGCP (full)	GSC, SCAR	0.333	Fully mediated through multiple path
SCD-PSSGCP (full)			

5. Discussions

OLD items exhibit strong loadings ranging from 0.803 to 0.846, confirming that the items reflect the training and knowledge-sharing initiatives provided by the main dealer. This supports the conceptualization of OLD as a dynamic process aimed at improving SC capabilities. SCI items also show robust loadings between 0.781 and 0.864, reinforcing the importance of long-term collaboration, joint decision-making, and customer engagement in achieving effective integration. SCD has slightly more varied loadings, ranging from 0.675 to 0.850. Although SCD1 and SCD2 fall just below the ideal threshold, they are still considered acceptable in the early stages of scale development. The strongest loading (0.850) for SCD3 highlights the importance of digitalized communication with customers. SCAR items load between 0.750 and 0.805, indicating consistent performance across items related to PSS innovation, adaptability, and recovery capabilities. GSC indicators show adequate loadings from 0.724 to 0.836, validating the focus on green design, regulatory compliance, and lifecycle management. PSSGCP items are generally high-loading, with values between 0.671 and 0.876. The slightly lower PSSGCP6 loading (0.671) is still within acceptable limits, especially when theoretical support exists. The highest loading (0.876) underlines the importance of customer satisfaction in competitive performance. Additionally, by analyzing the items' standardized loadings, executives can identify key capability priorities for boosting PSSGCP, allowing motorcycle company managers to systematically focus their strategic efforts where they will have the greatest impact.

The PSSGCP reflects a firm's ability to integrate environmental sustainability with high operational and market performance. First, the high speed of PSS offering deliveries indicates a responsive and efficient service model, which enhances customer satisfaction and market agility. High volume/capacity flexibility shows the firm's ability to adapt production and service outputs based on fluctuating demand, which is essential in dynamic and environmentally conscious markets. The high degree of PSS variety reflects innovation and customization, allowing firms to cater to diverse customer needs while embedding sustainable features in each variant. The high performance of PSS quality offerings demonstrates the firm's ability to maintain superior standards, which builds trust and supports long-term relationships with customers. High levels of customer satisfaction are critical outcomes of the combined speed, flexibility, variety, and quality performance, reinforcing customer loyalty and positive environmental perception. Additionally, high levels of PSS profitability ensure that environmental initiatives are economically viable, proving that green practices can be both sustainable and financially beneficial. Finally, the reduction in the use of harmful, toxic, and hazardous substances directly supports environmental goals and regulatory compliance while also contributing to safer and eco-friendlier products. Collectively, these indicators confirm that a well-executed green PSS strategy can simultaneously deliver environmental value, customer satisfaction, and competitive business performance.

Integrating green awareness and achieving competitive business goals are two crucial aspects highlighted in recent studies (Kumar et al., 2024). However, most recent studies have investigated

competitive performance and green awareness as separate entities (Zhu et al., 2022). Existing research rarely explores how to manage green and competitive performance as a unified measure, known as the PSSGCP. This study reveals that GSC has a significant positive effect on PSSGCP, and that SCAR is positively associated with PSSGCP, as supported by Hypotheses 1 and 2, respectively. This is the first contribution to the body of knowledge, where our findings suggest that GSC and SCAR have a positive impact on PSSGCP. Furthermore, the results of this research contribute to the existing literature in multiple aspects.

This study shows that OLD and SCD positively impact the GSC. The observed outcomes corroborate the results reported by Evangelista and Hallikas (2022), emphasizing the important role of SCD in achieving green objectives, and the findings of Yang et al. (2024), confirming OLD as a positive moderator for improving sustainability. SCI alone does not significantly impact the green supply chain. However, there is a significant path from OLD to SCI and SCD, which positively affects GSC. This finding indicates that although SCI is important, it alone cannot directly drive GSC. Instead, SCI must first enable the organization to digitally transform its SCD. These digital capabilities create the necessary transparency, responsiveness, and process efficiency required to implement and scale environmentally sustainable practices. Thus, without the SCD's digital infrastructure and capabilities, the SCI's strategic alignment may lack the operational leverage needed to impact GSC outcomes. This highlights the sequential and complementary nature of capabilities in achieving green performance: integration enables digitalization, which then enables improvements in environmental performance. The general assumption in the existing literature is that SCD accelerates the improvement of SCI (Shi et al., 2023; Liu et al., 2022). However, in this study, we found the opposite because of the nature of the motorcycle industry, where long-term collaboration and close relationships in their SC result in strong integration between manufacturers, main dealers, and service partners. Integration in their SC positively enhances SCD capabilities.

This study further demonstrates that OLD, SCI, and SCD positively impact SCAR. All three constructs positively impact SCAR. This aligns with prior research findings (Abdelilah et al., 2023; Eryarsoy et al., 2022). Similarly, the existence of a significant path from OLD to SCI and SCD positively affects SCAR, confirming that all three constructs are important for enhancing SCAR.

This study contributes to extending the use of DC into the context of PSS and SC. This is demonstrated by the use of DC as the underpinning theory, which was thoroughly detailed in the development of the survey and has been tested to be valid and reliable. The research underscores how collaborative SCI between core stakeholders (manufacturers, main dealers, and service partners) is essential for successful PSS implementation. OLD, represented by knowledge transfer and training provided by manufacturers and main dealers to service partners, and SCD, which adopts technological advancements to build a green, agile, and resilient SC, are also highlighted. This study further shows that dynamic capabilities—often described as company-specific, tacit, and difficult to imitate or transfer—can be effectively shared and developed through strong collaboration within the supply chain of the motorcycle industry. The findings illustrate that even deeply embedded capabilities such as agility, innovation, and green awareness can be disseminated across organizational boundaries with strategic and ongoing collaboration.

6. Conclusions and future research

This study underscores the crucial role of the green supply chain, agility, and resilience in enhancing the green competitive performance of PSS. Grounded in the dynamic capabilities theory, it highlights the importance of developing organizational capabilities—such as flexibility, robustness, and responsiveness—to navigate disruptions and capitalize on opportunities in a volatile environment. The integration of organizational learning development, supply chain integration, and supply chain digitalization is identified as the key to strengthening these capabilities. The findings show that an effective GSC not only supports environmental goals but also achieves high quality, flexibility, profitability, and reliable delivery. This study provides a holistic perspective and offers practical insights for motorcycle industry practitioners seeking to

improve their green competitive performance by connecting green, agile, and resilient supply chain concepts within a dynamic capabilities framework. Despite these valuable insights, this study has several limitations that warrant further research. First, the study primarily examines SCP within a specific industry context, which may limit the generalizability of its findings across different sectors. Second, the geographical scope of the study is confined to Indonesia. Future research could apply this framework to different industries and broader geographical areas to achieve more generalizable conclusions. Additionally, the study focuses on a predetermined set of performance indicators; expanding this scope to incorporate emerging factors such as the circular economy, block chain technology, and artificial intelligence-driven supply chain would provide deeper insights into the topic's evolving landscape. Future research could incorporate social indicators to provide a more complete evaluation of sustainability performance. Finally, this study relies on cross-sectional survey data, capturing performance at a single time point to assess performance. However, this performance is likely to shift over time. Using a longitudinal approach to track changes in performance and the capabilities that evolve with these changes would be insightful.

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Author Contributions

Conceptualization, D.R.S.D. and Y.B.H.; methods, D.R.S.D., J.M. and M.F.; analysis, D.R.S.D. and M.F.; data collection, D.R.S.D. and J.M.; writing—draft preparation, D.R.S.D.; writing—review and editing, D.R.S.D. and M.F.; graphics, D.R.S.D. and Y.B.H.; project administration, D.R.S.D., M.F., and J.M. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflicts of interest.

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