1. Submitted to the journal " International Journal of Technology" (23-04-2025)
2. First revision (17-06-2025)
3. Revised version Round 2 (23-07-2025)
-Revisions and Amends
4. Revised version Round 3 (30-07-2025)
-Revisions and Amends
5. Paper accepted (12-08-2025)
6. Line editing (29-08-2025)
7. Final proofreading (17-09-2025)
8. Paper published (22-09-2025)
-Final paper

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[IJTech] Manuscript Submission Notification for #IE-7737

IJTech <noreply@ijtech.eng.ui.ac.id> Wed, Apr 23, 2025 at 6:58 PM
Reply-To: "noreply@ijtech.eng.ui.ac.id" <noreply@ijtech.eng.ui.ac.id>
To: dianretnosd@ukwms.ac.id

International Journal of Technology
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Manuscript Submission Confirmation

Dear Dr. DIAN DEWI,

Your manuscript entitled **"**

Enhancing the Product–Service Systems green competitive performance through the development of green, agile and resilient capabilities

" has been successfully submitted to International Journal of Technology (IJTech) Online System.

Your manuscript ID #: **IE-7737**.

Please quote the above manuscript ID in all future correspondence. If there are any changes in your postal or e-mail address, please log into IJTech Online System at https://ijtech.eng.ui.ac.id/ and edit your contact and/or personal information as appropriate.

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Thank you for submitting your manuscript to International Journal of Technology (IJTech) Online System.

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[IJTech] Result of initial screening for manuscript #IE-7737: Revise

IJTech <noreply@ijtech.eng.ui.ac.id> Tue, Apr 29, 2025 at 6:49 PM
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To: dianretnosd@ukwms.ac.id

International Journal of Technology
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Screening result: Need Revision

Dear Dr. DIAN DEWI,

I am writing to you regarding the manuscript **#IE-7737** entitled **"**

Enhancing the Product–Service Systems green competitive performance through the development of green, agile and resilient capabilities

" which you submitted to International Journal of Technology (IJTech).

After we made an initial screening we found some problems including:

1. Unsuitable Format
2. *1. Delete author information in the pdf file, The submission will undergo the blind-review process. Hence, the submitted file MUST NOT include any author information. Author information will be added after the blind-review process. 2. Delete author information in the pdf file, The submission will undergo the blind-review process. Hence, the submitted file MUST NOT include any author information. Author information will be added after the blind-review process. 3. Please revise your graphical abstract more interested with jpg or png format*

We recommend that this manuscript be revised in order to proceed to peer review.

If you plan to revise your manuscript, please indicate your intent in the following page:
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If we do not receive your intent by **06 May 2025**, we will presume that you have withdrawn your submission from IJTech.

Please do not hesitate to contact us if you need extension for this schedule.

Yours sincerely,

Prof. Dr. Yudan Whulanza
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2. First revision: Accepted (17-06-2025)

Gmail **D.N. Dian Retno Sari Dewi P. , ST., MT. <dianretnosd@ukwms.ac.id>**

[IJTech] Decision for manuscript #IE-7737: Need to be Revised

IJTech <noreply@ijtech.eng.ui.ac.id> Tue, Jun 17, 2025 at 9:42 AM
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International Journal of Technology
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Decision Result : Revise

Dear **Dr. DIAN DEWI**

We have finished the review and made decision on your manuscript entitled **[Enhancing the Product–Service Systems green competitive performance through the development of green, agile and resilient capabilities]** which was submitted to International Journal of Technology.

We have decided that your manuscript **Need to be Revised**

We also send you the review result from the reviewers. Here is the detail review result:

Notes from Editor:
1. Graphical abstract too crowded. Please revise it more interested 2. Please revise according to the reviewer's comment, and highlights the revised in different color 3. Please include at least 5 relevant IJTech articles (2023 - present) as references 4. Please upload the revised manuscript by filling * required (for response letters, you can download the template in Step 5)

Reviewer (1)

Introduction:
The objective is to investigate the relationship of organizational learning development (OLD), supply chain integration (SCI), supply chain
digitalization (SCD), supply chain agility and resilience (SCAR), green supply chain (GSC) and PSS green competitive performance (PSSGCP).
1. The introduction and literature review/theory must be reconstructed and reduce. this section is too long and not easy to understood.
2. what has been done?
3. what is the newest and improvement from this study?
4. add the real impact and advantages that related with enhancing the Product–Service Systems green competitive performance?

Methodology:
1. this section is not clear.
2. add materials (if any) and how to identify them
3. authors have to inform and explain the detail related the step and process to enhance the Product–Service Systems green competitive performance
4. add scheme for illustration the method and or process

Results and Discussion:
1. revise the legend caption for Table 1.
2. simplify the domain of constructs and items in Table 2 (if possible)
3. authors have to discuss more related the factor loading data from Table 2.
4. table 2 is too long, please revise it and add cont. if one page is not enough
5. Revise the legend caption in Figure 1
6. discuss and add more refs related the impact and advantages by enhancing the Product–Service Systems green competitive performance

References:
1. update for old refs such asBagozzi,

Yi & Phillips 1991
2. make sure the cited refs more than 36 refs including at least 5 refs from IJtech.

Other:
1. Graphical abstract is not accepted. this image is like a poster, too many text/paragraphs
2. revise the title, currently this title is not focus and too broad.
3. abstract must be re-written, currently the objective, method, variable and how to identify it, significant finding are not clear.
4. add quantitative parameters and or results (if any) in the abstract section.
5. Conclusion section is too long and too many paragraphs. this section must be only contain one paragraph and add specific future work

Originality	1 *(poor)*
Technical	1 *(poor)*
Methodology	1 *(poor)*
Readability	2 *(fair)*
Practicability	1 *(poor)*
Organization	1 *(poor)*
Importance	1 *(poor)*

Attachment from reviewer:
-

Reviewer (2)

Introduction:
The Introduction section addresses a highly relevant and timely research topic by linking Product-Service Systems (PSS) with green supply chain (GSC), agility and resilience (collectively SCAR), and dynamic capabilities. The authors clearly recognize the evolution of the manufacturing sector towards servitization and sustainability under increasing environmental and operational pressures. The linkage between PSS, green awareness, and dynamic supply chain capabilities provides an important theoretical and practical foundation.
Areas for Improvement:
1. Clarity and Structure:
The section would benefit from improved coherence and paragraph organization. At present, some transitions between ideas (e.g., from PSS to SCAR to environmental awareness) feel abrupt. Consider grouping themes more logically (e.g., PSS evolution ? disruptions ? SCAR ? green pressure ? research gap).
Consider integrating Figure 1 (if exists) or visual aid to support the proposed model in the introduction for early clarity.
2. Terminology Precision:
The acronym "SCAR" is introduced (Supply Chain Agility and Resilience) but should be explicitly defined when first mentioned for clarity.
Some terms (e.g., PSSGCP, OLD, SCI, SCD) are introduced without sufficient initial explanation. Consider briefly defining these in the Introduction instead of waiting until the theoretical framework section.
3. Literature Support:
While the section cites several relevant studies, the referencing can be enhanced in two ways:
More recent references: Incorporate more 2023–2024 publications to demonstrate the current relevance of the research problem.
Balanced citations: Some citations (e.g., Gligor et al. 2019) are repeated frequently. Consider diversifying sources for agility/resilience constructs.
4. Language and Style:
The writing requires editing for grammar, sentence structure, and clarity. For example:
Line 35: "This trend is called PSS, is an innovation offering..." – awkward and grammatically incorrect. Consider revising to: “This trend, known as Product-Service Systems (PSS), represents an innovation aimed at…”
Line 45: “Those disruptions asked for changing of the business as usual” – consider revising to: “These disruptions necessitated a departure from business-as-usual practices.”
5. Contribution Statement:
While the research questions are clearly articulated, the novelty and contribution of the paper could be made more explicit. Consider adding a dedicated paragraph summarizing:
What exactly is new in this study?
How it differs from past work on PSS or SCAR?

Why this study matters now?
6. Contextual Relevance:
The authors mention motorcycle supply chains in later sections but not in the introduction. A brief mention of the specific industrial context at the end of the introduction would help frame the study better.

Methodology:
The methodology section demonstrates a thorough and systematic approach to survey design, data collection, and preliminary analysis. The authors clearly explain the multi-stage instrument development process, sampling strategy, and response handling, contributing to the transparency and replicability of the research.
1. Survey Instrument Details:
o Although the constructs and item counts are listed (e.g., OLD, SCI, SCAR), the specific nature of the items (e.g., sample questions, scale format) is missing. Including a supplementary appendix with the full questionnaire or item examples would improve transparency and facilitate replication.
o The Likert scale used (e.g., 5-point, 7-point) should be explicitly stated in this section rather than assumed.
2. Construct Justification and Operationalization:
o While the six constructs are referenced, brief operational definitions (not just acronyms) should be provided here. For instance, explain what “PSSGCP” or “OLD” refers to conceptually, not just that they have “x” number of items.
o Also, consider citing the sources from which the items were adapted or whether they were newly developed.
3. Statistical Power and Item Retention Justification:
o Although item retention was based on power analysis and p-values, further detail could be added about how power was calculated (e.g., using which software, assumptions about effect size).
o It may also be useful to report internal consistency measures (e.g., Cronbach’s alpha) for each construct, either here or in the next section.
4. Ethical Considerations:
o The manuscript should include a statement about ethical approval or informed consent procedures, particularly since human subjects were involved in the survey. For example, was participation voluntary? Was anonymity or confidentiality assured?
5. Clarity and Writing Style:
o Minor grammatical and stylistic revisions would enhance readability. For instance:
? Line 235: “to assess the hypothesis” ? “to test the proposed hypotheses”
? Line 243: “clearly specifying the purpose” ? “and specifying the measurement objectives”
? Line 270: “only completed the initial part of the questionnaire” ? consider specifying that these were incomplete and excluded from the analysis.
6. Sample Distribution Bias:
While the dominance of one brand (75.3%) is noted and explained, the authors should briefly discuss any potential implications this concentration may have on the generalizability or balance of findings.

Results and Discussion:
The Results and Discussion section presents a comprehensive and methodologically rigorous analysis, effectively combining EFA, CFA, reliability assessment, and structural equation modeling to validate the constructs and test the proposed hypotheses. The use of both SPSS and AMOS demonstrates methodological robustness, and the reported goodness-of-fit indices meet conventional thresholds, lending strong support to the validity and reliability of the measurement and structural models.
Areas for Improvement:
1. Interpretation Depth: While results are clearly presented, the discussion could be further strengthened by offering more in-depth interpretation of why certain paths are significant or non-significant. For example, the non-significance of SCI ? GSC warrants a deeper industry-specific or theoretical explanation.
2. Theoretical Integration: Although relevant references are cited, the integration of findings with the broader theoretical frameworks (e.g., Resource-Based View, Dynamic Capabilities) could enrich the discussion and clarify how this study advances current theory.
3. Generalizability and Context: The results seem industry-specific (e.g., motorcycle industry), but the discussion does not explicitly address the contextual limitations or implications for other sectors. Consider acknowledging this and suggesting directions for replication or comparative analysis.
4. Mediation Effects: The suggestion that SCD mediates the relationship between SCI and GSC is insightful. However, this potential mediating effect is not formally tested (e.g., via bootstrapping or Sobel test). Consider including a mediation analysis or clearly stating that it is a theoretical implication rather than a tested effect.
5. Typographical Issues: Minor language inconsistencies (e.g., "and positively influence" repeated) and formatting errors (e.g., missing punctuation or spaces) in the discussion section reduce professionalism and should be corrected before publication.

With minor revisions to deepen the interpretation and clarify theoretical contributions, this section can make a valuable addition to the literature on green supply chains and competitive performance in PSS contexts.

References:
The References section is generally comprehensive and reflects a strong engagement with contemporary and high-quality literature in the fields of supply chain management, sustainability, digital transformation, and agility. The inclusion of peer-reviewed sources from reputable journals (e.g., Journal of Cleaner Production, International Journal of Production Economics, Technovation, Annals of Operations Research) significantly strengthens the scholarly rigor of the work.
However, there are a few issues that require attention to improve consistency, accuracy, and adherence to citation formatting standards:
1. Consistency in Formatting:
-Ensure uniform formatting of journal titles (e.g., some are italicized while others are not) and page numbers.
-Abbreviations such as “vol.” and “no.” should be used consistently across all entries.
-Capitalization of article titles should follow a consistent style, preferably sentence case (only the first word and proper nouns capitalized), unless another standard is specified.
2. Missing Information and Inconsistencies:
-Some entries are missing critical details such as issue numbers, volume numbers, or page ranges (e.g., line 482: Journal of Asian Development Studies – no page numbers or DOI).
-Multiple DOIs are listed for the same entry (e.g., line 521: Dewi & Hermanto 2022 – duplicate DOI).
-One DOI appears to be malformed or incomplete (e.g., line 470: “DOI:0.1080/13675567.2021. 1972949” lacks the "https://" prefix).
-Author names with inconsistent ordering or initials (e.g., “Amine Balambo, M” vs. “Chiappetta Jabbour, CJ” vs. “Jabeen, F”).
3. Redundancy and Overrepresentation:
-There is notable repetition of certain authors (e.g., DRS Dewi, YB Hermanto) with multiple entries in a short span, which may indicate overreliance on a narrow segment of literature. Consider diversifying the sources to ensure broader representation of global perspectives.
-Several articles by the same authors in the same journal/year (e.g., Dewi & Hermanto 2022, 2023, 2024 in IJSDP) may benefit from justification of their distinct contributions within the main text.
4. Minor Typographical Errors:
-Line breaks within article titles (e.g., line 471 “Order from chaos: A meta¬analysis...”) appear to include unintended characters or formatting marks (possibly artifacts from copy-pasting)

Other:

Originality	4 *(above average)*
Technical	5 *(excellent)*
Methodology	4 *(above average)*
Readability	3 *(average)*
Practicability	4 *(above average)*
Organization	5 *(excellent)*
Importance	4 *(above average)*

Attachment from reviewer:
-

Please login into application https://ijtech.eng.ui.ac.id/login for more detail.

You must respond to this revise and resubmit request before **17 Jul 2025**, after which point we will presume that you have withdrawn your submission from International Journal of Technology (IJTech) Online System.

Yours sincerely,

Prof. Dr. Yudan Whulanza
Editor in Chief
International Journal of Technology (IJTech)
p-ISSN : 2086-9614
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List of Changes

Manuscript: **Enhancing Product–Service Systems' Green Competitive Performance through a Dynamic Capabilities Lens**

Response and Revision made by Author(s)

Reviewer #1:

No	Comments	Revision/Changes
1	**Introduction:** The objective is to investigate the relationship of organizational learning development (OLD), supply chain integration (SCI), supply chain digitalization (SCD), supply chain agility and resilience (SCAR), green supply chain (GSC) and PSS green competitive performance (PSSGCP). 1. The introduction and literature review/theory must be reconstructed and reduce. this section is too long and not easy to understood. 2. what has been done? 3. what is the newest and improvement from this study? 4. add the real impact and advantages that related with enhancing the Product–Service Systems green competitive performance?	Yes, we have thoroughly considered all your suggestions. 1. The introduction and literature review sections have been revised and streamlined to enhance clarity, coherence, and readability. Redundant explanations have been removed, and the content has been restructured for a more logical flow. The first paragraph presents an overview of Product-Service Systems (PSS), tracing its evolution and conceptual development. The second paragraph contextualizes the increasing prevalence of business disruptions and underscores the necessity for organizational agility and resilience as strategic responses. The third paragraph defines the constructs of supply chain agility and resilience, setting the foundation for subsequent discussion. The fourth paragraph highlights the critical need to integrate environmental awareness into corporate performance strategies, especially in the face of sustainability pressures. The fifth paragraph identifies a notable research gap, namely the insufficient integration of environmental sustainability, agility, and resilience within the PSS framework. The sixth paragraph delineates the research questions and articulates the intended contributions of the study to both academic scholarship and managerial practice. Finally, the seventh paragraph is dedicated to contribution statement

		(Introduction section has been re-arranged). 2. The study clearly outlines what has been done, namely the investigation of the interrelationships among OLD, SCI, SCD, SCAR, GSC, and their impacts on PSS Green Competitive Performance (PSSGCP) (final paragraph in the Introduction section). **3.** The novelty and improvements of this study lie in the integration of green supply chain practices and supply chain agility, resilience within the PSS context, which has not been extensively explored in previous literature. Additionally, it introduces a comprehensive framework incorporating critical supply chain capabilities to enhance PSSGCP **(final paragraph in the Introduction section).** **4.** The study also highlights the practical impacts and advantages of enhancing PSSGCP, including improved environmental performance, operational flexibility, and competitive advantage—especially relevant for industries facing volatile markets and sustainability pressures **(final paragraph in the Introduction section).**
2	**Methodology:** 1. this section is not clear. 2. add materials (if any) and how to identify them 3. authors have to inform and explain the detail related the step and process to enhance the Product–Service Systems green competitive performance 4. add scheme for illustration the method and or process	Yes, we have already addressed all your suggestions in the current version of the manuscript. The **methodology section** has been clearly structured and includes: 1. A detailed explanation of the **materials and survey development process**, carried out in **five stages**, as recommended in prior literature (Lewis, Templeton & Byrd, 2005). 2. Clear descriptions of the **constructs, item counts, measurement scale (6-point Likert**

		scale), and definitions, all of which are provided in the main text and summarized in **Table 2**. 3. A comprehensive explanation of the **steps taken to enhance PSS Green Competitive Performance (PSSGCP)** through the integration of OLD, SCI, SCD, SCAR, and GSC constructs. 4. A summary of the **sampling process, distribution methods, response rate, and participant profile**, as well as **non-response bias testing** using Levene's test and t-tests. 5. Additionally, a **schematic diagram (Figure 1)** has been included to **illustrate the research process**, ensuring clarity and enhancing the reader's understanding of the methodological framework. We trust these additions and clarifications improve the rigor and transparency of the methodology section.
3	**Results and Discussion:** 1. revise the legend caption for Table 1. 2. simplify the domain of constructs and items in Table 2 (if possible) 3. authors have to discuss more related the factor loading data from Table 2. 4. table 2 is too long, please revise it and add cont. if one page is not enough 5. Revise the legend caption in Figure 1 6. discuss and add more refs related the impact and advantages by enhancing the Product–Service Systems green competitive performance	All six points have been carefully revised and addressed as follows: 1. **The legend caption for Table 1 has been revised** to clearly describe the contents of the table: domain of constructs 2. The content of Table 2 remains unchanged, as all listed domains and items are essential for the analysis and subsequent discussion. **3. A detailed discussion of the factor loading data from Table 2 has been added**, emphasizing the strength of item loadings, justification for retaining or removing items, and the implications for construct validity **(It has been added in the first paragraph of Discussion section).** 4. While the table could not be condensed, pagination improvements were made by

		adding clear section headers when the table extends across pages. 5. **The legend caption for Figure 1 has been revised** to provide a more informative description of the structural model findings. 6. **A more comprehensive discussion has been added regarding the impact and advantages of enhancing Product–Service Systems green competitive performance**, supported by recent and relevant literature. This includes environmental benefits, increased customer value, innovation opportunities, and long-term sustainability advantages **(It has been added in the second paragraph of Discussion section).**
4	**References:** 1. update for old refs such asBagozzi, Yi & Phillips 1991 2. make sure the cited refs more than 36 refs including at least 5 refs from IJtech.	All issues have been fixed. **The outdated reference to Bagozzi, Yi & Phillips (1991) has been updated with more recent literature,** and the reference list has been expanded to include **more than 70 citations**, including **at least 5 references from *IJTech (International Journal of Technology)*** as required.
5	**Other:** 1. Graphical abstract is not accepted. this image is like a poster, too many text/paragraphs 2. revise the title, currently this title is not focus and too broad. 3. abstract must be re-written, currently the objective, method, variable and how to identify it, significant finding are not clear. 4. add quantitative parameters and or results (if any) in the abstract section. 5. Conclusion section is too long and too many paragraphs. this section must be only contain one paragraph and add specific future work	Thank you for your valuable feedback. We have carefully revised the manuscript and addressed all the points raised: 1. **Graphical Abstract**: The previous image has been replaced with a new graphical abstract that follows the journal guidelines—minimal text, clear visuals, and concise representation of the study's objective and findings. 2. **Title**: The title has been revised to better reflect the core focus and scope of the study. 3. **Abstract**: The abstract has been completely rewritten to clearly present the objective, research method, variables, and the approach used to identify them. Significant findings are now also clearly stated. 4. **Quantitative Parameters**: Thank you for your suggestion. However,

		it cannot be added due to the word limit in the abstract. Detailed information on quantitative parameters and statistical results has been thoroughly presented in the results and discussion sections of the paper. 5. **Conclusion Section**: The conclusion has been revised into a single, concise paragraph that summarizes the key findings and includes a clear statement regarding future work. We hope these revisions meet the journal's standards and improve the clarity and impact of our manuscript. Thank you again for your constructive suggestions.

Reviewer #2:

No	Comments	Actions by the authors
1	1. Clarity and Structure: The section would benefit from improved coherence and paragraph organization. At present, some transitions between ideas (e.g., from PSS to SCAR to environmental awareness) feel abrupt. Consider grouping themes more logically (e.g., PSS evolution ? disruptions ? SCAR ? green pressure ? research gap). Consider integrating Figure 1 (if exists) or visual aid to support the proposed model in the introduction for early clarity.	Revised. The authors appreciate the advice by the reviewer. We have addressed this now with significantly changes in the introduction section. The introduction section of this study has been systematically restructured to enhance clarity and coherence. The first paragraph presents an overview of Product-Service Systems (PSS), tracing its evolution and conceptual development. The second paragraph contextualizes the increasing prevalence of business disruptions and underscores the necessity for organizational agility and resilience as strategic responses. The third paragraph defines the constructs of supply chain agility and resilience, setting the foundation for subsequent discussion. The fourth paragraph highlights the critical need to integrate environmental awareness into corporate performance strategies, especially in the face of sustainability pressures. The fifth paragraph identifies a notable research gap, namely the insufficient integration of environmental sustainability, agility, and resilience within the PSS framework. The sixth paragraph delineates the research questions

		and articulates the intended contributions of the study to both academic scholarship and managerial practice. Finally, the seventh paragraph is dedicated to contribution statement.
2	2. Terminology Precision: The acronym "SCAR" is introduced (Supply Chain Agility and Resilience) but should be explicitly defined when first mentioned for clarity. Some terms (e.g., PSSGCP, OLD, SCI, SCD) are introduced without sufficient initial explanation. Consider briefly defining these in the Introduction instead of waiting until the theoretical framework section.	Has been added to the Introduction section. The term SCAR, along with its definition and acronym, is introduced in Paragraph 3; the term GSC is introduced in Paragraph 4 to ensure conceptual clarity. Furthermore, key constructs such as PSSGCP (Product-Service System Green Competitive Performance), OLD (Organizational Learning and Development), SCI (Supply Chain Integration), and SCD (Supply Chain Design) are explicitly defined in Paragraph 5 to provide a clear foundation for the study's analytical framework.
3	3. Literature Support: While the section cites several relevant studies, the referencing can be enhanced in two ways: More recent references: Incorporate more 2023–2024 publications to demonstrate the current relevance of the research problem. Balanced citations: Some citations (e.g., Gligor et al. 2019) are repeated frequently. Consider diversifying sources for agility/resilience constructs.	Yes, we have carefully considered your suggestions. In response, we have incorporated several more recent references from 2023–2025 to ensure the current relevance of the research problem and theoretical foundation. Additionally, we have taken steps to diversify the citations related to the agility and resilience constructs by including alternative and complementary sources, thereby reducing overreliance on a single author (e.g., Gligor et al., 2019). These enhancements strengthen the theoretical depth and contemporaneity of the literature review.
4	4. Language and Style: The writing requires editing for grammar, sentence structure, and clarity. For example: Line 35: "This trend is called PSS, is an innovation offering..." – awkward and grammatically incorrect. Consider revising to: "This trend, known as Product-Service Systems (PSS), represents an innovation aimed at…" Line 45: "Those disruptions asked for changing of the business as usual" – consider revising to: "These disruptions necessitated a departure from business-as-usual practices."	Yes, we have carefully considered your suggestion. The manuscript has been thoroughly revised to improve grammar, sentence structure, and overall clarity. These revisions were made to ensure that the writing is more precise, coherent, and aligned with academic standards.
	5. Contribution Statement: While the research questions are clearly articulated, the novelty and contribution of the paper could be made more explicit. Consider adding a dedicated paragraph	A dedicated concluding statement that summarizes the novelty, differentiation, and timeliness of the study **has been added in Paragraph 7.**

	summarizing: What exactly is new in this study? How it differs from past work on PSS or SCAR? Why this study matters now?	
	6. Contextual Relevance: The authors mention motorcycle supply chains in later sections but not in the introduction. A brief mention of the specific industrial context at the end of the introduction would help frame the study better.	The contextual relevance of the motorcycle supply chain as the empirical setting for this research **is articulated in Paragraph 7.**
	Methodology: The methodology section demonstrates a thorough and systematic approach to survey design, data collection, and preliminary analysis. The authors clearly explain the multi-stage instrument development process, sampling strategy, and response handling, contributing to the transparency and replicability of the research. 1. Survey Instrument Details: o Although the constructs and item counts are listed (e.g., OLD, SCI, SCAR), the specific nature of the items (e.g., sample questions, scale format) is missing. Including a supplementary appendix with the full questionnaire or item examples would improve transparency and facilitate replication. o The Likert scale used (e.g., 5-point, 7-point) should be explicitly stated in this section rather than assumed.	Yes, we have already considered all your suggestions. The full questionnaire has been included as an appendix to enhance transparency and replicability, and the methodology section now explicitly states that all items were measured on a 6-point Likert scale (0=strongly disagree, 1=disagree, 2= somewhat disagree, 3=somewhat agree, 4= agree and 5=strongly agree).
	2. Construct Justification and Operationalization: o While the six constructs are referenced, brief operational definitions (not just acronyms) should be provided here. For instance, explain what "PSSGCP" or "OLD" refers to conceptually, not just that they have "x" number of items. o Also, consider citing the sources from which the items were adapted or whether they were newly developed.	Yes, we have fully considered all your suggestions. Brief **operational definitions** for all six constructs—**OLD, SCI, SCD, SCAR, GSC**, and **PSSGCP**—have been provided in **Table 2**, and a corresponding reference has been added in the methodology section directing readers to **see Table 2 for construct definitions**. Additionally, the **sources from which the items were adapted** or whether they were **newly developed** have also been clearly cited in Table 2 to ensure transparency and traceability of the measurement items.
	3. Statistical Power and Item Retention Justification: o Although item retention was based on power analysis and p-values, further detail could be added about how power was	Yes, we have considered your suggestion. Although AMOS does not provide a built-in tool for power analysis, the adequacy of the sample size was assessed based on established guidelines for Structural Equation Modeling

	calculated (e.g., using which software, assumptions about effect size). o It may also be useful to report internal consistency measures (e.g., Cronbach's alpha) for each construct, either here or in the next section.	(SEM). According to Hair et al. (2010), a minimum sample size of 200 is generally considered sufficient for models with several latent constructs and observed indicators using Maximum Likelihood Estimation (MLE). Our study involves 6 constructs and 37 measurement items, and with a final sample size of 502 respondents, the model satisfies and significantly exceeds this threshold. Therefore, the study has adequate statistical power to detect meaningful effects and support reliable parameter estimation. Additionally, Cronbach's alpha values for each construct have been reported in Table 2 to demonstrate internal consistency and reliability.
	4. Ethical Considerations: o The manuscript should include a statement about ethical approval or informed consent procedures, particularly since human subjects were involved in the survey. For example, was participation voluntary? Was anonymity or confidentiality assured?	Yes, we have already addressed this concern. **Informed consent** was obtained at the beginning of the questionnaire. Participation in the survey was entirely **voluntary**, and respondents were clearly informed that their responses would be used exclusively for research purposes. A consent statement was included, indicating that by selecting "Yes," participants agreed to take part in the study. Furthermore, **anonymity and confidentiality were assured**, as no personal or identifying information was collected. The consent statement in the questionnaire reads as follows: "Choosing 'Yes' indicates your consent to participate in this survey. Your responses will be used exclusively for research and may appear in academic outputs such as journal articles and conference presentations. All data will be collected anonymously and kept strictly confidential. If you would like a summary of the study's findings, please contact the researcher at dianretnosd@ukwms.ac.id."
	5. Clarity and Writing Style: o Minor grammatical and stylistic revisions would enhance readability. For instance: ? Line 235: "to assess the hypothesis" ? "to test the proposed hypotheses" ? Line 243: "clearly specifying the purpose" ? "and specifying the measurement objectives" ? Line 270: "only completed the initial part of the questionnaire" ? consider specifying	I truly appreciate your feedback on the minor grammar corrections—I've revised the text as advised and marked my changes in yellow highlights.

	that these were incomplete and excluded from the analysis.	
	6. Sample Distribution Bias: While the dominance of one brand (75.3%) is noted and explained, the authors should briefly discuss any potential implications this concentration may have on the generalizability or balance of findings.	Thank you for your observation. We acknowledge that **75.3% of the sample is concentrated on one motorcycle brand,** which reflects the actual **market dominance** of this brand within the Indonesian motorcycle industry. This concentration may introduce some **limitations in terms of generalizability**, particularly when interpreting results across brands with significantly different market positions or operational practices. However, the dominance also provides valuable insight into the practices of the **industry leader,** which can serve as a benchmark for other brands. This limitation has now been acknowledged and discussed in the revised **limitations section** of the manuscript to maintain transparency and guide future comparative research across more balanced brand representations.
	Results and Discussion: The Results and Discussion section presents a comprehensive and methodologically rigorous analysis, effectively combining EFA, CFA, reliability assessment, and structural equation modeling to validate the constructs and test the proposed hypotheses. The use of both SPSS and AMOS demonstrates methodological robustness, and the reported goodness-of-fit indices meet conventional thresholds, lending strong support to the validity and reliability of the measurement and structural models. Areas for Improvement: 1. Interpretation Depth: While results are clearly presented, the discussion could be further strengthened by offering more in-depth interpretation of why certain paths are significant or non-significant. For example, the non-significance of SCI ? GSC warrants a deeper industry-specific or theoretical explanation.	Thank you for your valuable feedback. The suggested improvement regarding the need for deeper interpretation of the non-significant path between SCI and GSC has been addressed. A more in-depth explanation, including industry-specific and theoretical perspectives, has been added to **Paragraph 4 in the Discussion section** to strengthen the interpretation and contextual relevance of the findings.
	2. Theoretical Integration: Although relevant references are cited, the integration of findings with the broader theoretical frameworks (e.g., Resource-Based View, Dynamic Capabilities) could enrich the discussion and clarify how this study advances current theory.	**This suggestion has been added to the final paragraph in the discussion section**, where the findings are integrated with Dynamic Capabilities theory to clarify how the study advances existing theory.

	3. Generalizability and Context: The results seem industry-specific (e.g., motorcycle industry), but the discussion does not explicitly address the contextual limitations or implications for other sectors. Consider acknowledging this and suggesting directions for replication or comparative analysis.	**This suggestion has been added as a limitation of the research in the conclusion section,** where the industry-specific context of the motorcycle sector is acknowledged and directions for future replication or comparative studies in other sectors are suggested.
	4. Mediation Effects: The suggestion that SCD mediates the relationship between SCI and GSC is insightful. However, this potential mediating effect is not formally tested (e.g., via bootstrapping or Sobel test). Consider including a mediation analysis or clearly stating that it is a theoretical implication rather than a tested effect.	Thank you for the insightful comment. The mediation effect has been formally tested using **bias-corrected bootstrapping with 2,000 samples**, and the results are presented in **Table 3**.
	5. Typographical Issues: Minor language inconsistencies (e.g., "and positively influence" repeated) and formatting errors (e.g., missing punctuation or spaces) in the discussion section reduce professionalism and should be corrected before publication. With minor revisions to deepen the interpretation and clarify theoretical contributions, this section can make a valuable addition to the literature on green supply chains and competitive performance in PSS contexts.	This has already been fixed. All typographical and formatting issues in the discussion section, including repeated phrases and missing punctuation or spaces, have been carefully corrected to ensure clarity and professionalism.
	References: The References section is generally comprehensive and reflects a strong engagement with contemporary and high-quality literature in the fields of supply chain management, sustainability, digital transformation, and agility. The inclusion of peer-reviewed sources from reputable journals (e.g., Journal of Cleaner Production, International Journal of Production Economics, Technovation, Annals of Operations Research) significantly strengthens the scholarly rigor of the work. However, there are a few issues that require attention to improve consistency, accuracy, and adherence to citation formatting standards: 1. Consistency in Formatting: -Ensure uniform formatting of journal titles (e.g., some are italicized while others are not) and page numbers. -Abbreviations such as “vol.” and “no.”	Thank you for your constructive feedback on the References section. We have carefully reviewed and revised the entire reference list to address the issues raised. Specifically: 1. **Consistency in Formatting**: o Journal titles, article titles, volume, issue numbers, and page ranges have been standardized following the required citation style. o Sentence case has been applied consistently to article titles. o Abbreviations such as "vol." and "no." are now used uniformly across entries. 2. **Missing Information and Inconsistencies**: o Missing volume, issue numbers, page ranges, and DOIs have been added where applicable.

	should be used consistently across all entries. -Capitalization of article titles should follow a consistent style, preferably sentence case (only the first word and proper nouns capitalized), unless another standard is specified. 2. Missing Information and Inconsistencies: -Some entries are missing critical details such as issue numbers, volume numbers, or page ranges (e.g., line 482: Journal of Asian Development Studies – no page numbers or DOI). -Multiple DOIs are listed for the same entry (e.g., line 521: Dewi & Hermanto 2022 – duplicate DOI). -One DOI appears to be malformed or incomplete (e.g., line 470: "DOI:0.1080/13675567.2021.1972949" lacks the "https://" prefix). -Author names with inconsistent ordering or initials (e.g., "Amine Balambo, M" vs. "Chiappetta Jabbour, CJ" vs. "Jabeen, F"). 3. Redundancy and Overrepresentation: -There is notable repetition of certain authors (e.g., DRS Dewi, YB Hermanto) with multiple entries in a short span, which may indicate overreliance on a narrow segment of literature. Consider diversifying the sources to ensure broader representation of global perspectives. -Several articles by the same authors in the same journal/year (e.g., Dewi & Hermanto 2022, 2023, 2024 in IJSDP) may benefit from justification of their distinct contributions within the main text. 4. Minor Typographical Errors: -Line breaks within article titles (e.g., line 471 "Order from chaos: A meta¬analysis...") appear to include unintended characters or formatting marks (possibly artifacts from copy-pasting) Other:	○ Duplicate and malformed DOIs have been corrected or removed. ○ Author name formats have been standardized, ensuring consistent use of initials and surname order. 3. **Redundancy and Overrepresentation**: ○ We have reviewed and, where necessary, reduced repeated entries by the same authors to avoid overrepresentation. ○ For retained entries with the same author(s) across years, we have ensured each has a distinct and justified contribution to the manuscript. ○ The repeated references to certain authors (e.g., DRS Dewi, YB Hermanto) within a short span have been carefully reviewed and deleted where appropriate to ensure a more diverse and representative citation base. ○ The multiple articles by the same authors in the same journal and year (e.g., Dewi & Hermanto 2022, 2023, 2024 in IJSDP) have been reviewed and deleted to avoid redundancy and overrepresentation. We have ensured a more balanced and diverse set of references in the revised manuscript. 4. **Typographical Errors**: ○ All typographical issues, such as line breaks and formatting artifacts within titles, have been corrected to ensure clean and accurate citations. We believe these improvements enhance the clarity, consistency, and scholarly quality of the References section. Thank you once again for your helpful suggestions.

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Research Article

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

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Abstract: Incorporating environmental awareness into business operations while maintaining competitive performance presents 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 foster 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 in current literature. 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 Structural Equation Modelling (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, while only OLD and SCD show direct positive effects on GSC. The analysis also reveals that OLD positively influences SCI, which subsequently impacts SCD—indicating that SCI's influence on GSC is mediated through SCD. These findings provide practical and theoretical insights, enabling managers and researchers to better align green and competitive performance goals. Furthermore, managers can assess the standardized loadings to evaluate the contribution of each capability to enhancing PSSGCP.

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

1. Introduction

Companies in the manufacturing sector, 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, initially defined as the integrated bundling of products and services to create value-added products and boost customer satisfaction (Beuren, Ferreira & Miguel 2013), is being redefined. The PSS definition now includes the producer's responsibility for the product at its end

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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, Battistella & Nonino 2016).

In recent times, various disruptions, including natural disasters, the COVID-19 pandemic, fierce competition in the business landscape, distribution failures, and other unforeseen events, have caused interruptions. These disruptions necessitated a departure from business-as-usual practices. The characteristics such as flexibility, speed, innovations and responsiveness are required in the erratic condition such as nowadays (Al-Omoush, Palacios-Marqués & Ulrich 2022; Ashari et al. 2018). Hence, the agility and resilience of supply chain (SC) guide the companies in the SC to be operated as stable and normal mode when disruptions occur (Kazancoglu et al. 2022).

To address these challenges, the concepts of supply chain agility and resilience—collectively referred to in this study as Supply Chain Agility and Resilience (SCAR)—have gained prominence. While both 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 supply chain performance, this study uses the integrated term SCAR to reflect their complementary roles.

However, agility and resilience alone are insufficient for long-term sustainability. In today's context, environmental awareness must also be incorporated into corporate strategies (Singh, Hamid & Garza-Reyes 2023). Without active engagement in environmental stewardship, the degradation of natural resources could threaten supply continuity, particularly raw materials critical to manufacturing operations. 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 Green Supply Chain (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 & 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. Addressing this research gap, this study investigates 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 PSS Green Competitive Performance (PSSGCP).

Addressing the weaknesses in the current body of knowledge, this study investigates three gaps which constitute the research questions of this study are as follows (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 existing literature. Unlike prior research that predominantly centers 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. By proposing and empirically examining the role of these capabilities in enhancing PSSGCP, this study establishes a comprehensive and integrative framework that differentiates itself from earlier fragmented approaches to either 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 urgency and relevance of this research are further underscored by the growing frequency of global disruptions and increasing environmental pressures, which compel firms to rethink and restructure their SC. As such, 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 hypotheses development

The conceptual theoretical framework in this study is guided by the Dynamic Capabilities (DC) theory. 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 requires theory that accommodates dynamic resources and capabilities that will grow within 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. The DC was proposed by Teece, Pisano & Shuen (1997) highlighted the significance of continuous organizational learning and innovation.

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 to keep the competition (Teece 2007). Moreover, DC is hard to be enhanced in solely company as they should be progressed together within the network (Defee & Fugate 2010). DC suits well to guide the proposed framework as the framework is developed for SC network. This research focuses on the motorcycle SC, aiming to deliver PSS. To accomplish this, 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 as dynamic capabilities that should be created within a network, to be able to sense, seize and reconfigure internal and external resources to deal with rapid changing environment. In response to this challenge, GSC and SCAR are essential for navigating the unpredictable business environment. Specifically, GSC is crucial for sustaining long-term performance improvements while preserving green resources needed for the future.

2.1. PSSGCP

Companies are struggling to find themselves and survive in the business competition, nowadays. Competitive performance is the result of a competitive advantage, indicating a company's ability to innovate and surpass its competitors (Kumar et al. 2024). As such, 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 & Mukhtar 2018). PSS offers a method to achieve differentiation by satisfying customers with not just 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 to stay in a business for a long-term, the green concept must be added to it. 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, Oulfarsi

& Eddine 2024). Hence, this study aims to identify the PSS SC capabilities required to improve the PSSGCP which focus on enhancing green, agility and resilience capabilities.

2.2. GSC

GSC is defined as organizational philosophies to not only pursue economic advantage of business but also enhancing the green efficiency by minimizing environmental impact of industrial activities (Gawusu et al. 2022). The green SC practices should cover all activities throughout the industrial process from purchasing, production, logistics, distribution and the product end of life (Bustinza, Vendrell-Herrero & Chiappetta Jabbour 2024; Suwignjo et al. 2023). PSS actually serves as part of the effort to extend the product lifespan by providing product 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). It is challenging to visualize how GSC practices relate to operational SC benefits. Novitasari and Agustia (2021) didn't discover a positive link between GSC and SC performance. PSSGCP merges SC performance with environmental considerations. Thus, to explore this association, below are the proposed hypotheses 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 acknowledge effectively and promptly to the 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 & 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 as its capabilities to sense, seize and reconfigure firm and SC resources (Dubey et al. 2018). Capabilities required for resilience are capabilities 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 in SC showed that there is a positive relationship between SC agility and resilience to improved firm's performances (Mahesh, Srivastava & Muthappa 2024). Therefore, it is hypothesized that SCAR are positively related to PSSGCP.

H2. SCAR positively affects PSSGCP.

2.4. OLD

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

Considered as strategic capabilities, continual OLD is crucial for achieving firm's performance such as being green, agile and resilient (Eryarsoy et al. 2022), as well as improving the SCI. In this study, it is evident that motorcycle manufacturers lack the capability to deliver PSS independently (Dewi & Hermanto 2024). This underscores the necessity for strategic partnerships with the 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 & Hermanto 2024). These initiatives aim to enhance the technical skills and performance of partners, making them more agile and resilient in their tasks (Dewi et al. 2024). Likewise, OLD has 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 in this research to verify if there is a direct positive correlation between OLD and GSC. Given the description provided, the following hypothesis is proposed.

H3a. OLD positively affects GSC.

H3b. OLD positively affects SCAR.

H6. OLD positively affects SCI.

2.5. SCI

The capabilities to integrate within firm and network is stressed by many SC research studies; in fact, those studies highlighted the significant role of SCI in GSC (Pham & Pham 2021), as well as 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. (Jajja, Chatha & Farooq 2018; Abdulameer, Ibrahim & Yaacob 2020). It is not adequate for a firm to integrate only the internal function within an enterprise but also it is required to integrate all functions within the SC network (Jajja, Chatha & Farooq 2018). The SC integration process may involve all areas that are required as a business process in the SC, has three entities: process integration, supplier integration and customer integration (Shukor et al. 2021).

PSS is one way to extend the product life cycle by providing a bundle of product and service (Dewi et al. 2023). Collaboration among manufacturers, intermediaries and service partners to provide PSS is crucial, as well as 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, essential for adapting to business and environmental changes and it also has a positive impact on SCD (Arif, Shah & Khan 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 to the customer demand changes as they have direct contact with customers (Dewi & Hermanto 2023). These coordinated efforts should improve the utilization of resources and finally impact the SC performance. Then we propose the following hypotheses.

H4a. SCI positively affects GSC.

H4b. SCI positively affects SCAR.

H7. SCI positively affects SCD.

2.6. SCD

Digitalization is defined as transformation of business routines from traditional systems to digital systems (Tiwari, Sharma & Jha 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 substituted with digital systems. Likewise, communication within SC, like interactions between manufacturers, intermediaries and service partners, demands considerable effort when executed manually, resulting in waste and slow process (Oubrahim, Sefiani & Happonen 2023).

Digitalization is one way to resolve and arrange data better than manual (Le et al. 2024). Related to inventory management, digital technology is mostly utilized to manage physical and virtual inventory in real time to reduce cost of inventory management, thus can quickly make decisions in real time, preventing faults, also if there is disruption and needs swift changes (Mashayekhy et al. 2022). Besides that, digitalization also ensures tractability, offers monitoring and controlling (Behnke & Janssen 2020). Also in the case of customer preferences, SCD can predict customer

behaviour changes and to swiftly respond to match the customers' expectations (Zhou et al. 2023). In general, it can be concluded that 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 the GSC and SCAR. As such, we propose the following hypothesis for further examination.

H5a. SCD positively affects GSC

H5b. SCD positively affects SCAR

3. Methods

The current section describes the study's methodological approach, 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 through five stages, which will be explained in the following paragraphs. The questionnaire consists of two parts: the first part inquires about the demographic information of the participants and their companies with a total of ten questions. 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). To enhance transparency and support replicability, the questionnaire is provided in Appendix A. 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. Definitions and conceptual descriptions of each construct—OLD, SCI, SCD, SCAR, GSC, and PSSGCP—are presented in Table 2.

The survey development process was carried out in five stages (Lewis, Templeton & Byrd 2005). The first stage involved defining the domain of each construct and specifying the measurement objectives. This required an extensive literature review to establish the six constructs. In the second stage, a list of items for each construct was developed to measure them accurately. This stage produced 37 items. The third stage was pre-testing, where four experts from academics and industry were recruited to assess the ease of use and clarity of the questionnaire. 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, where 10 participants from official service partners were recruited to provide feedback for refining the instrument. In the final stage, the interrater agreement questionnaire was distributed to 25 service partner participants and academic experts with knowledge of the supply chain. There were three criteria for removing 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 (Sud-on et al. 2013). Based on these three criteria, no items were removed, 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, 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 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 1000 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, while 201 responses were received for the second and third reminders. In total, 643 responses were

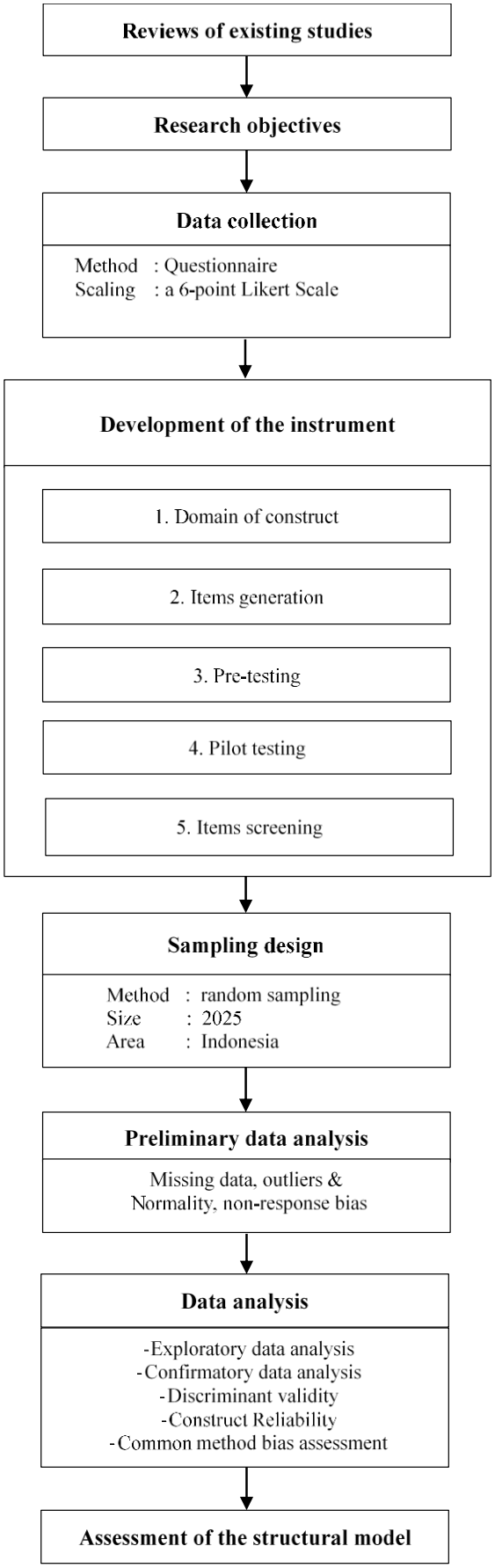

Figure 1 Research method

received (31.8 percent response rate). However, 100 responses from the initial wave and 41 responses from the final waves could not be processed further because these were incomplete and excluded from the analysis. Therefore, only 502 responses could be processed further.

The demographic profile data of the participants highlighting 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 percent of survey participants, followed by another brand with 18.1 percent. The remaining three brands have smaller market shares compared to these two. Most participants are based on the island of Java, making up 66.5 percent of the total, which aligns with Indonesia's population distribution, where the majority live in Java. Additionally, 63.8 percent 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 percent). Among those who completed the survey, 57.2 percent are heads of service centre workshops, and 34.9 percent are direct owners. A significant portion, 63.1 percent, have over 10 years of experience in the motorcycle industry, while 66 percent have been heads of service centre workshops for more than 5 years. The service centre workshop heads are predominantly male (94.2 percent), with 45.2 percent aged between 36-45 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 utilized to determine if there were any statistically significant differences between the responses from the early wave (n=342) and the late wave (n=160). The results indicated no statistically significant differences between the early and late waves for the five constructs, with p-values exceeding 0.05. Thus, it can be concluded that there is no non-response bias in the data used in this study.

Data analysis in this study involved several statistical techniques to ensure the validity and reliability of the measurement and structural models. First, Exploratory Factor Analysis was conducted to identify the underlying factor structure and to explore the dimensionality of the constructs without imposing a predefined structure. This was followed by Confirmatory Factor Analysis to test the hypothesized measurement model and to 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 from one another. Construct reliability, such as Composite Reliability (CR), was also evaluated to ensure internal consistency of the items measuring each construct. Additionally, to address potential biases arising from the use of self-reported survey data, Common Method Bias (CMB) was assessed using techniques such as Harman's single-factor test. Finally, the structural model was evaluated using Structural Equation Modelling to test the hypothesized relationships between constructs, examining 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 dimensionality of the scale, followed by CFA using AMOS version 26 to evaluate convergent validity, discriminant validity, and factorial validity. EFA was individually conducted for the six constructs, utilizing promax rotation and maximum likelihood extraction. The six constructs resulted in a one-factor solution, explaining a total variance of 51.44–68.75 percent with factor loadings ranging from 0.47–0.88. According to Tinsley and Tinsley (1987), factor loadings below 0.4 are considered invalid. Therefore, from the EFA process, two items were dropped: SCAR7 and GSC5, with factor loadings of 0.340 and 0.337, respectively.

There are three stages to confirm convergent validity. First, calculate the chi-squared values, then if the chi-squared rejects at a p -value < 0.01; modification indices can be utilized to detect shared underlying factors across the measurement items. A cautious approach should be adopted to identify and eliminate items, especially ones with insufficient validity scores (refer to the interrater agreement results). These results confirm evidence of convergent validity using the following goodness of fit indices cut-off values: $p > 0.05$, norm $\chi^2 \leq 3$, RMSEA < 0.06, SRMR < 0.08, CFI ≥ 0.95, and TLI ≥ 0.95 (Hu & Bentler 1998; Yu 2002). After this process, several items need to be deleted (OLD6, SCI6, SCD5, SCAR6 and GSC6). Standard factor loadings for all items ranging from 0.671-0.876 (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 & Cho 2022). The six constructs demonstrated discriminant validity as each one's average variance extracted (AVE) was greater than its squared correlation with any other construct (Table 1).

Table 1 Discriminant validity

	Domain of 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

This validation step assesses if hypothesized latent variables form meaningful constructs by analyzing overall model fit statistics. The satisfactory fit indices obtained 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).

4.2. Construct reliability

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

Table 2 Measurement variables (constructs) and their corresponding scale indicators

Code	Domain of constructs and items	References	Factor loading
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			
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

Code	Domain of constructs and items	References	Factor loading
OLD_5	We and our main dealer continuously learn about customers' needs and requirements.	(Dewi & 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)	-
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			
SCI_1	We sharing information with our main dealers about sales forecast, stock level, customers' expectation and responsibilities on environmental impact.	(Jajja, Chatha & Farooq 2018)	0.838
SCI_2	We maintain long term collaborative agreement with our main dealer to deliver PSS and achieve environmental goals.	(Jajja, Chatha & Farooq 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, Chatha & Farooq 2018)	0.864
SCI_4	We maintain good communication with customers through multiple communication channels.	(Oubrahim, Sefiani & Happonen 2023)	0.781
SCI_5	We continually seek input from customers to assess their satisfaction levels and gather feedback of Product-service systems.	(Oubrahim, Sefiani & Happonen 2023)	0.809
SCI_6	We maintain integrated data with main dealers within our SC network (omitted).	(Tan et al. 2023)	-
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			
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)	-
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			
$SCAR_1$	We continuously enhance our PSS to rapidly boost customer satisfaction levels.	(Kim & Chai 2017)	0.805
$SCAR_2$	We continuously enhance the reliability of our PSS delivery through rapid improvements.	(Kim & Chai 2017)	0.804

Code	Domain of constructs and items	References	
$SCAR_3$	We continuously reconfigure our PSS supply chain capabilities to swiftly adapt to evolving market demands.	(Al-Omoush, Palacios-Marqués & Ulrich 2022)	0.750
$SCAR_4$	We continuously drive innovation in our PSS offerings to maintain market leadership.	(Boon-itt, Wong & Wong 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)	-
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			
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)	-
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			
$PSSGCP_1$	We have high speed of PSS offering deliveries.	(Choi, Min & Joo 2018)	0.825
$PSSGCP_2$	We have high volume/ capacity flexibility.	(Choi, Min & Joo 2018)	0.841
$PSSGCP_3$	We have a high degree of PSS variety offering.	(Akın Ateş et al. 2022)	0.838
$PSSGCP_4$	We have high performance of PSS quality offering.	(Akın Ateş et al. 2022)	0.845
$PSSGCP_5$	We have high level of customer satisfaction.	(Akın Ateş et al. 2022)	0.876
$PSSGCP_6$	We have high level of PSS profitability.	(Akın Ateş et al. 2022)	0.671
$PSSGCP_7$	We have reduced the use of harmful, toxic, and hazardous substances in our products.	(Pham & Pham 2021)	0.794

4.3. Common method bias assessment

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

4.4. Assessment of structural model

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

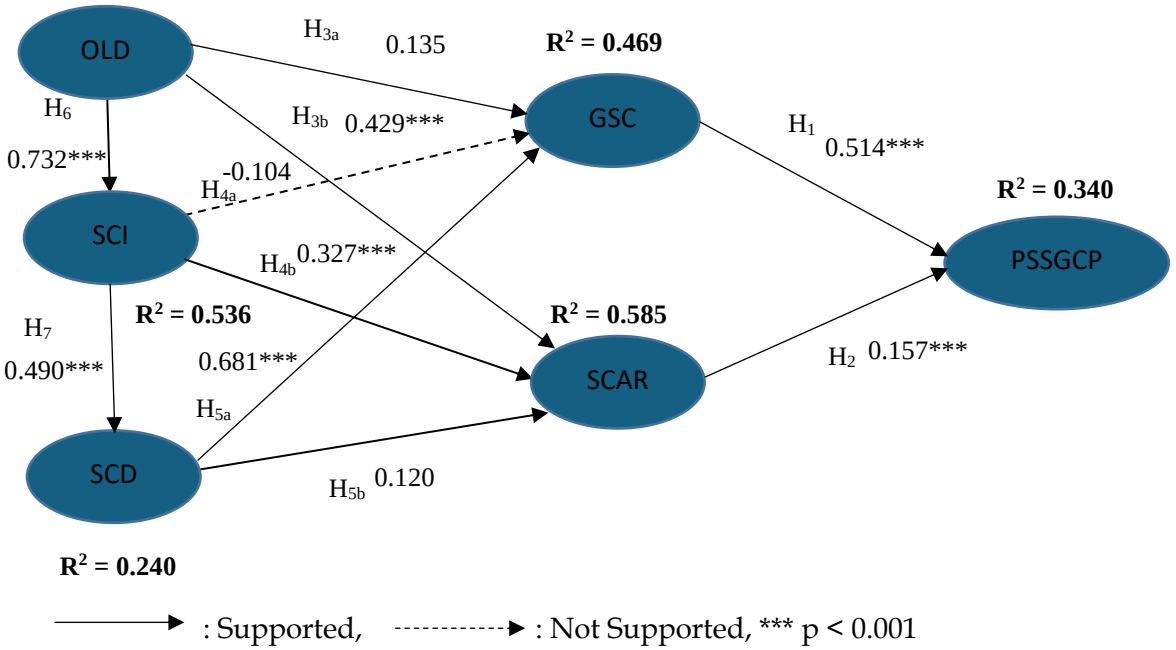

Figure 2 Structural model findings including path coefficients and explained variances

The ten hypotheses were tested using Structural Equation Modelling. 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 OLD 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 to 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 to GSC (H5a=0.681, $p < 0.001$), likewise H5b is supported, displaying 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, this section explores them to enhance the depth of analysis. The significance of the mediation paths was evaluated through bias-corrected bootstrapping based on 2,000 random samples. Table 3 summarizes eight significant

mediation paths. The relationship between OLD and SCD is fully mediated by SCI, emphasizing SCI's role in enabling digital transformation. The path from SCI to GSC is also fully mediated by SCD, highlighting that SCI must be operationalized through digitalization to impact green practices. The effect of OLD on GSC is partially mediated by SCI and SCD, with both direct and indirect effects significant. Similarly, the relationship between OLD and SCAR shows partial mediation through SCD, indicating that digital capabilities complement organizational learning. The path from SCI to SCAR is partially mediated by SCD, though the indirect effect is relatively small. Regarding PSSGCP, three full mediation paths are identified: (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 highlight 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

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 (partial)	SCD	0.323	Both direct and indirect significant
SCI-GSC (full)	SCD	0.320	Only indirect path significant
SCI-SCAR(partial)	SCD	0.069	Minor mediation via SCD
OLD-PSSGCP(full)	GSC,SCAR,SCD	0.221	Fully mediated through multiple paths
SCI-PSSGCP (full)	SCD, SCAR	0.151	Fully mediated through multiple paths
SCD-PSSGCP (full)	GSC, SCAR	0.333	Fully mediated through multiple path

5. Discussions

OLD items exhibit strong loadings ranging from 0.803 to 0.846, confirming that the training and knowledge-sharing initiatives provided by the main dealer are well reflected in the items. 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 significance 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. While 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 loading of PSSGCP6 (0.671) is still within acceptable limits, especially when theoretical support exists. The highest loading (0.876) underlines the role of customer satisfaction in competitive performance. Also, 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.

PSSGCP reflect a firm's ability to integrate environmental sustainability with high operational and market performance. First, 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 capability 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 offering reflects innovation and customization, allowing firms to cater to diverse customer needs while embedding sustainable features into each variant. High performance of PSS quality offering 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 performance in speed, flexibility, variety, and quality, 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 investigate 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 PSSGCP. This study reveals that GSC has a significant positive effect on PSSGCP, as well as SCAR is positively associated with PSSGCP as supported by hypothesis 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 positively impacts the GSC, as well as SCD positively impact the GSC. The observed outcomes corroborate the results reported by Evangelista and Hallikas (2022), which emphasize the important role of SCD in achieving green objectives, as well as the findings of Yang *et al.* (2024), which confirm OLD as a positive moderator for improving sustainability. Only SCI 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 suggests that while SCI is important, it is not sufficient on its own to directly drive GSC. Instead, SCI must first enable the organization to digitally transform its supply chain processes (SCD). These digital capabilities, in turn, create the necessary transparency, responsiveness, and process efficiency required to implement and scale environmentally sustainable practices. Thus, without the digital infrastructure and capabilities provided by SCD, the strategic alignment facilitated by SCI 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 environmental performance improvements. The general assumption in the existing literature is that SCD accelerates improvements of SCI (Shi *et al.*, 2023; Liu *et al.*, 2022). However, in this study, we found the opposite due to 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. The integration in their SC positively impacts the enhancement of SCD capabilities.

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

It is noteworthy that 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 survey's development and has been tested to be valid and reliable. Regarding practical implications, 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, as well as 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 in fact be effectively

shared and developed through strong collaboration within the motorcycle industry supply chain. The findings illustrate that with strategic and ongoing collaboration, even deeply embedded capabilities such as agility, innovation, and green awareness can be disseminated across organizational boundaries.

6. Conclusions and future research

This study underscores the crucial role of green supply chain, agility, and resilience in enhancing PSS green competitive performance. 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 key to strengthening these capabilities. The findings show that effective green supply chain not only support environmental goals but also achieve high quality, flexibility, profitability, and reliable delivery. By connecting green, agile, and resilient supply chain concepts within a dynamic capabilities framework, this study provides a holistic perspective and offers practical insights for motorcycle industry practitioners seeking to improve their PSS green competitive performance. Despite these valuable insights, this study has several limitations that warrant further research. First, the study primarily examines supply chain performance 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 evolving landscape of the topic. Future research could incorporate social indicators to provide a more complete evaluation of sustainability performance. Lastly, this study relies on cross-sectional survey data, capturing performance at a single point in time to assess performance. However, this performance is likely to shift over time. It would be insightful to use a longitudinal approach to track changes in performance and the capabilities that evolve with these changes.

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Author Contributions

Conceptualisation, 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 collections, 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

Appendix- Questionnaire

Participation Consent

☐ Yes ☐ No

Choosing "Yes" indicates your consent to participate in this survey. Your responses will be used exclusively for research and may appear in academic outputs such as journal articles, and conference presentations. All

data will be collected anonymously and kept strictly confidential. If you would like a summary of the study's findings, please contact the researcher at dianretnosd@ukwms.ac.id

Eligibility Question

Please indicate your managerial experience at an official service partner of the Indonesian motorcycle sector:

☐ Less than 1 year ☐ More than 1 year

Participants with more than one year of managerial experience are eligible to proceed with the questionnaire.

Please express the extent to which you agree or disagree with each of the following statements by circling the number that best represents your opinion.

(0 = Strongly disagree, 1 = Disagree, 2 = Somewhat disagree, 3 = Somewhat agree, 4 = Agree, 5 = Strongly agree)

Our main dealer partner has ceaselessly upgrade our knowledge of PSS and environmental awareness.	0	1	2	3	4	5
A variety of training sessions have been developed to improve our agility, quickness, innovation capabilities, and awareness of environmental issues	0	1	2	3	4	5
As a testament to our lasting collaboration, our main dealer partner has continuously provided training programs designed to enhance service partner capabilities.	0	1	2	3	4	5
Our main dealer partner strengthen our capabilities to achieve green, agile and resilient supply chain.	0	1	2	3	4	5
We and our main dealer continuously learn about customers' needs and requirements.	0	1	2	3	4	5
Variety training courses of product and technical service has been supplied to us by the main dealer.	0	1	2	3	4	5
We sharing information with our main dealers about sales forecast, stock level, customers' expectation and responsibilities on environmental impact.	0	1	2	3	4	5
We maintain long term collaborative agreement with our main dealer to deliver PSS and achieve environmental goals.	0	1	2	3	4	5
We maintain joint decision making with our main dealer about PSS delivery, quality improvement and resolve environment-related problems.	0	1	2	3	4	5
We maintain good communication with customers through multiple communication channels.	0	1	2	3	4	5
We continually seek input from customers to assess their satisfaction levels and gather feedback of Product-service systems.	0	1	2	3	4	5
We maintain integrated data with main dealers within our SC network.	0	1	2	3	4	5
We have utilized digital tools to communicate with our main dealer.	0	1	2	3	4	5
We have employed digital devices to record transactions with our customers.	0	1	2	3	4	5
We possess the ability to exchange digitalized data with our customers to ensure effective communication of PSS.	0	1	2	3	4	5
Our system enables real-time digital data sharing with our primary dealer partner for operational, inventory, and sustainability planning purposes.	0	1	2	3	4	5

We have utilized digital technologies to create innovative PSS that can appeal to untapped markets.	0	1	2	3	4	5
We continuously enhance our PSS to rapidly boost customer satisfaction levels.	0	1	2	3	4	5
We continuously enhance the reliability of our PSS delivery through rapid improvements.	0	1	2	3	4	5
We continuously reconfigure our PSS supply chain capabilities to swiftly adapt to evolving market demands.	0	1	2	3	4	5
We continuously drive innovation in our PSS offerings to maintain market leadership.	0	1	2	3	4	5
We have capabilities and resources to deal with disruption and quickly recover from it .	0	1	2	3	4	5
We continuously reconfigure our supply chain resource capacity to rapidly mitigate demand disruptions (omitted).	0	1	2	3	4	5
Our team proactively reconfigures production capacities to seamlessly customize orders based on client requirements	0	1	2	3	4	5
Our product is designed and manufactured to facilitate recycling, rework, and repair.	0	1	2	3	4	5
Our product is designed and manufactured using eco-friendly materials with a long material lifespan and reduce negative impacts on the environment.	0	1	2	3	4	5
Our product is manufactured in accordance with environmental standards and regulations.	0	1	2	3	4	5
We prolong the product lifespan through the provision of a bundle Product-service systems.	0	1	2	3	4	5
Our company has electric motorcycle to support low emission	0	1	2	3	4	5
The company prioritizes the management of environmental issues concerning PSS delivery (omitted).	0	1	2	3	4	5
We have high speed of PSS offering deliveries.	0	1	2	3	4	5
We have high volume/ capacity flexibility.	0	1	2	3	4	5
We have a high degree of PSS variety offering.	0	1	2	3	4	5
We have high performance of PSS quality offering.	0	1	2	3	4	5
We have high level of customer satisfaction.	0	1	2	3	4	5
We have high level of PSS profitability.	0	1	2	3	4	5
We have reduced the use of harmful, toxic, and hazardous substances in our products.	0	1	2	3	4	5

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3. Revised version received (09-07-2025)

-Revisions and Amends

-Revised version with highlights

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[IJTech] Decision for manuscript #R1-IE-7737: Need to be Revised

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Decision Result : Revise

Dear **Dr. DIAN DEWI**

We have finished the review and made decision on your manuscript entitled **[Enhancing Product–Service Systems' Green Competitive Performance through a Dynamic Capabilities Lens]** which was submitted to International Journal of Technology.

We have decided that your manuscript **Need to be Revised**

We also send you the review result from the reviewers. Here is the detail review result:

Notes from Editor:
1. The maximum of the research article length is up 20 pages 2. Please revise according to the reviewer's comment, and highlights the revised in different color 3. Please upload the revised manuscript by filling * required (for response letters, you can download the template in Step 5) 4. Please move Appendix- Questionnaire to supplementary file

Reviewer (1)

Introduction:
1. what is the meaning the H1 to H7 and H5a and Hb? why they put in below as a hypothesis?

Methodology:
1. revise the legend caption in Figure 1.

Results and Discussion:
1. Table 2 and its legend must be in similar page and add cont.
2. Figure 2 is similar with graphical abstract.

References:
update for old refs:

Teece, DJ, Pisano, G & Shuen, A 1997, 'Dynamic capabilities and strategic management', Strategic management journal, vol. 18, no. 7, pp. 509–533, retrieved from .
Tinsley, HEA & Tinsley, DJ 1987, 'Uses of facto

Other:
1. abstract need improvement and add quantitive finding
2. graphical abstract is not accepted, remove title and text, revise it.

Originality	1 *(poor)*
Technical	1 *(poor)*
Methodology	1 *(poor)*
Readability	1 *(poor)*
Practicability	1 *(poor)*
Organization	1 *(poor)*
Importance	1 *(poor)*

Attachment from reviewer:
-

Reviewer (2)

Introduction:
The introduction is well-structured and clearly outlines the research problem, objectives, and significance of the study. It provides adequate background and justification for the study, engaging the reader from the outset.

Methodology:
The methodology is appropriate and rigorously applied

Results and Discussion:
The results are clearly presented, supported by relevant figures and tables. The discussion effectively interprets the findings in light of existing literature, highlighting key contributions and implications.

References:
The references are relevant, up-to-date, and formatted correctly. The bibliography reflects a comprehensive engagement with the current literature in the field.

Other:
The conclusion effectively summarizes the study's main findings and offers thoughtful insights for future research and practical application.

Originality	5 *(excellent)*
Technical	4 *(above average)*
Methodology	5 *(excellent)*
Readability	5 *(excellent)*
Practicability	4 *(above average)*
Organization	5 *(excellent)*
Importance	5 *(excellent)*

Attachment from reviewer:
-

Please login into application https://ijtech.eng.ui.ac.id/login for more detail.

You must respond to this revise and resubmit request before **30 Jul 2025**, after which point we will presume that you have withdrawn your submission from International Journal of Technology (IJTech) Online System.

Yours sincerely,

Prof. Dr. Yudan Whulanza
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List of Changes

Manuscript: : **Enhancing Product–Service Systems' Green Competitive Performance through a Dynamic Capabilities Lens**

Response and Revision made by Author(s)

Reviewer #1:

No	Comments	Revision/Changes
1	What is the meaning the H1 to H7 and H5a and Hb? why they put in below as a hypothesis?	Thank you for your observation regarding the placement and labeling of the hypotheses (H1–H7, H5a, H5b) in our manuscript. To clarify, hypotheses are **testable statements** derived from the **theoretical framework of a study.** They are formulated based on prior research, theory, and logical reasoning, and serve as the foundation for empirical testing. Each hypothesis reflects a proposed relationship between two or more constructs in the research model. The use of systematic labels such as H1, H2, ..., H7 helps organize and communicate these relationships clearly and consistently throughout the manuscript. In cases where a broader hypothesis is broken down into more specific dimensions, we use sub-labels such as H5a and H5b. For example, if H5 concerns a general relationship, H5a and H5b represent that relationship under two different conditions or variables. As is standard in empirical research, we first present the theoretical background and literature review to explain the reasoning behind each hypothesized relationship. Then, after each section or at the end of the theoretical framework, we formally state the hypotheses. This structure ensures that the reader understands the logical foundation of each hypothesis before it is tested in the analysis. We hope this clarifies the purpose and placement of the hypotheses in the manuscript. We are of course open to adjusting the presentation if you feel it would improve clarity for the reader.

2	Revise the legend caption in Figure 1.	Thank you for your suggestion. I have revised the legend caption in Figure 1 accordingly. **However, if it still does not meet your expectations, I would greatly appreciate any specific suggestions** you may have for improvement.
3	Table 2 and its legend must be in similar page and add cont.	Thank you for your valuable suggestion regarding Table 2 and its legend. We acknowledge that Table 2 is quite lengthy and, due to formatting constraints, **it could not be accommodated on a single page.** To maintain clarity and readability across multiple pages, we have included the **table title (Code, Domain of constructs and items, References and Factor Loadings)** at the top of each subsequent page where the table continues. This approach is intended to help readers easily follow the content and structure of the table throughout the manuscript. **Additionally, we have ensured that the full table legend appears on the first page of the table to provide the necessary context**. Should you prefer an alternative formatting style, we would be happy to revise accordingly.
4	Figure 2 is similar with graphical abstract.	Thank you for your attentive feedback regarding the similarity between Figure 2 and the graphical abstract. We sincerely appreciate your diligence in ensuring the clarity and distinctiveness of our visual elements. **To address your comment: We will revise the graphical abstract to ensure it is visually and conceptually distinct from Figure 2.** The graphical abstract will be redesigned to highlight the study's core findings and broader implications. Figure 2 will retain its current role as a detailed methodology/result visualization. This separation will better align with journal standards, ensuring the graphical abstract serves as a standalone summary while Figure 2 remains focused on technical specifics. We appreciate your guidance in

		enhancing the manuscript's presentation.
5	Update for old refs	Thank you for the valuable suggestion**. I have reviewed and updated all the older references** in the manuscript to ensure they are current and relevant.
6	Abstract need improvement and add quantitive finding	Thank you for your constructive feedback. **The abstract has been carefully structured to include the five essential components:** (1) Background, (2) Purpose, (3) Methods, (4) Results, and (5) Conclusions. **The quantitative findings are already presented in the results section of the abstract,** as follows: *"The results confirm significant positive relationships between GSC and PSSGCP, and between SCAR and PSSGCP. Moreover, OLD, SCI, and SCD each positively influence SCAR, while only OLD and SCD show direct positive effects on GSC. The analysis also reveals that OLD positively influences SCI, which subsequently impacts SCD—indicating that SCI's influence on GSC is mediated through SCD."* As per academic convention, specific numerical values are not included in the abstract; instead, we summarize whether the hypotheses were supported or not. We believe this approach maintains readability while conveying the key insights. That said, if there are **particular aspects you feel are still lacking or unclear, we would greatly appreciate your specific suggestions** to help us further enhance the clarity and quality of the abstract.
7	Graphical abstract is not accepted, remove title and text, revise it.	Thank you for the feedback. I have significantly revised the graphical abstract by removing the title and text, and adjusting the layout to better meet the journal's requirements. Please let me know if further modifications are needed.

Reviewer #2:

No	Comments	Revision/Changes
1	The introduction is well-structured and clearly outlines the research problem,	We are grateful for the recognition of the clarity and structure of the introduction. We

	objectives, and significance of the study. It provides adequate background and justification for the study, engaging the reader from the outset.	aimed to present the research problem and objectives in a compelling and well-justified manner, and we are pleased that this was well received.
2	The methodology is appropriate and rigorously applied	Thank you for acknowledging the appropriateness and rigor of our methodological approach. We invested significant effort in ensuring the methodology aligns with the research questions and offers reliable insights.
3	The results are clearly presented, supported by relevant figures and tables. The discussion effectively interprets the findings in light of existing literature, highlighting key contributions and implications.	We appreciate the positive evaluation of our results and discussion. It is reassuring to know that the presentation and interpretation of the findings were clear, well-supported, and meaningfully connected to the existing literature.
4	The references are relevant, up-to-date, and formatted correctly. The bibliography reflects a comprehensive engagement with the current literature in the field.	Thank you for recognizing the relevance and currency of our references. We strived to engage with the most recent and pertinent studies to ensure our work is well-grounded within the current academic discourse.
5	The conclusion effectively summarizes the study's main findings and offers thoughtful insights for future research and practical application.	We are thankful for your comments on the conclusion. We aimed to succinctly summarize our findings while also providing valuable insights for both future research and practical applications. We sincerely thank the reviewer for the positive and encouraging feedback on our manuscript. We greatly appreciate the thoughtful and constructive evaluation across all sections of our work. Once again, we truly appreciate your time and effort in reviewing our manuscript. Your feedback is both motivating and helpful in guiding our continued research in this area.

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Research Article

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

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Abstract: Incorporating environmental awareness into business operations while maintaining competitive performance presents 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 foster 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 in current literature. 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 Structural Equation Modelling (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, while only OLD and SCD show direct positive effects on GSC. The analysis also reveals that OLD positively influences SCI, which subsequently impacts SCD—indicating that SCI's influence on GSC is mediated through SCD. These findings provide practical and theoretical insights, enabling managers and researchers to better align green and competitive performance goals. Furthermore, managers can assess the standardized loadings to evaluate the contribution of each capability to enhancing PSSGCP.

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

1. Introduction

Companies in the manufacturing sector, 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, initially defined as the integrated bundling of products and services to create value-added products and boost customer satisfaction (Beuren, Ferreira & Miguel 2013), is being redefined. The PSS definition now includes the producer's responsibility for the product at its end

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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, Battistella & Nonino 2016).

In recent times, various disruptions, including natural disasters, the COVID-19 pandemic, fierce competition in the business landscape, distribution failures, and other unforeseen events, have caused interruptions. These disruptions necessitated a departure from business-as-usual practices. The characteristics such as flexibility, speed, innovations and responsiveness are required in the erratic condition such as nowadays (Al-Omoush, Palacios-Marqués & Ulrich 2022; Ashari et al. 2018). Hence, the agility and resilience of supply chain (SC) guide the companies in the SC to be operated as stable and normal mode when disruptions occur (Kazancoglu et al. 2022).

To address these challenges, the concepts of supply chain agility and resilience—collectively referred to in this study as Supply Chain Agility and Resilience (SCAR)—have gained prominence. While both 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 supply chain performance, this study uses the integrated term SCAR to reflect their complementary roles.

However, agility and resilience alone are insufficient for long-term sustainability. In today's context, environmental awareness must also be incorporated into corporate strategies (Singh, Hamid & Garza-Reyes 2023). Without active engagement in environmental stewardship, the degradation of natural resources could threaten supply continuity, particularly raw materials critical to manufacturing operations. 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 Green Supply Chain (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 & 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. Addressing this research gap, this study investigates 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 PSS Green Competitive Performance (PSSGCP).

Addressing the weaknesses in the current body of knowledge, this study investigates three gaps which constitute the research questions of this study are as follows (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 existing literature. Unlike prior research that predominantly centers 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. By proposing and empirically examining the role of these capabilities in enhancing PSSGCP, this study establishes a comprehensive and integrative framework that differentiates itself from earlier fragmented approaches to either 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 urgency and relevance of this research are further underscored by the growing frequency of global disruptions and increasing environmental pressures, which compel firms to rethink and restructure their SC. As such, 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 hypotheses development

The conceptual theoretical framework in this study is guided by the Dynamic Capabilities (DC) theory. 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 requires theory that accommodates dynamic resources and capabilities that will grow within 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 to keep the competition (Teece 2007). Moreover, DC is hard to be enhanced in solely company as they should be progressed together within the network (Defee & Fugate 2010). DC suits well to guide the proposed framework as the framework is developed for SC network. This research focuses on the motorcycle SC, aiming to deliver PSS. To accomplish this, 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 as dynamic capabilities that should be created within a network, to be able to sense, seize and reconfigure internal and external resources to deal with rapid changing environment. In response to this challenge, GSC and SCAR are essential for navigating the unpredictable business environment. Specifically, GSC is crucial for sustaining long-term performance improvements while preserving green resources needed for the future.

2.1. PSSGCP

Companies are struggling to find themselves and survive in the business competition, nowadays. Competitive performance is the result of a competitive advantage, indicating a company's ability to innovate and surpass its competitors (Kumar et al. 2024). As such, 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 & Mukhtar 2018). PSS offers a method to achieve differentiation by satisfying customers with not just 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 to stay in a business for a long-term, the green concept must be added to it. 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, Oulfarsi & Eddine 2024). Hence, this study aims to identify the PSS SC capabilities required to improve the PSSGCP which focus on enhancing green, agility and resilience capabilities.

2.2. GSC

GSC is defined as organizational philosophies to not only pursue economic advantage of business but also enhancing the green efficiency by minimizing environmental impact of industrial activities (Gawusu et al. 2022). The green SC practices should cover all activities throughout the industrial process from purchasing, production, logistics, distribution and the product end of life (Bustinza, Vendrell-Herrero & Chiappetta Jabbour 2024; Suwignjo et al. 2023). PSS actually serves as part of the effort to extend the product lifespan by providing product 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). It is challenging to visualize how GSC practices relate to operational SC benefits. Novitasari and Agustia (2021) didn't discover a positive link between GSC and SC performance. PSSGCP merges SC performance with environmental considerations. Thus, to explore this association, below are the proposed hypotheses to be examined.

H_1. 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 acknowledge effectively and promptly to the 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 & 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 as its capabilities to sense, seize and reconfigure firm and SC resources (Dubey et al. 2018). Capabilities required for resilience are capabilities 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 in SC showed that there is a positive relationship between SC agility and resilience to improved firm's performances (Mahesh, Srivastava & Muthappa 2024). Therefore, it is hypothesized that SCAR are positively related to PSSGCP.

H_2. SCAR positively affects PSSGCP.

2.4. OLD

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

Considered as strategic capabilities, continual OLD is crucial for achieving firm's performance such as being green, agile and resilient (Eryarsoy et al. 2022), as well as improving the SCI. In this study, it is evident that motorcycle manufacturers lack the capability to deliver PSS independently (Dewi & Hermanto 2024). This underscores the necessity for strategic partnerships with the 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 & Hermanto 2024). These initiatives aim to enhance the technical skills and performance of partners, making them more agile and resilient in their tasks (Dewi et al. 2024).

Likewise, OLD has 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 in this research 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 GSC.

H_{3b}. OLD positively affects SCAR.

H_6. OLD positively affects SCI.

2.5. SCI

The capabilities to integrate within firm and network is stressed by many SC research studies; in fact, those studies highlighted the significant role of SCI in GSC (Pham & Pham 2021), as well as 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. (Jajja, Chatha & Farooq 2018; Abdulameer, Ibrahim & Yaacob 2020). It is not adequate for a firm to integrate only the internal function within an enterprise but also it is required to integrate all functions within the SC network (Jajja, Chatha & Farooq 2018). The SC integration process may involve all areas that are required as a business process in the SC, has three entities: process integration, supplier integration and customer integration (Shukor et al. 2021).

PSS is one way to extend the product life cycle by providing a bundle of product and service (Dewi et al. 2023). Collaboration among manufacturers, intermediaries and service partners to provide PSS is crucial, as well as 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, essential for adapting to business and environmental changes and it also has a positive impact on SCD (Arif, Shah & Khan 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 to the customer demand changes as they have direct contact with customers (Dewi & Hermanto 2023). These coordinated efforts should improve the utilization of resources and finally impact the SC performance. Then we propose the following hypotheses.

H_{4a}. SCI positively affects GSC.

H_{4b}. SCI positively affects SCAR.

H_7. SCI positively affects SCD.

2.6. SCD

Digitalization is defined as transformation of business routines from traditional systems to digital systems (Tiwari, Sharma & Jha 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 substituted with digital systems. Likewise, communication within SC, like interactions between manufacturers, intermediaries and service partners, demands considerable effort when executed manually, resulting in waste and slow process (Oubrahim, Sefiani & Happonen 2023).

Digitalization is one way to resolve and arrange data better than manual (Le et al. 2024). Related to inventory management, digital technology is mostly utilized to manage physical and virtual inventory in real time to reduce cost of inventory management, thus can quickly make decisions in real time, preventing faults, also if there is disruption and needs swift changes (Mashayekhy et al. 2022). Besides that, digitalization also ensures tractability, offers monitoring and controlling (Behnke & Janssen 2020). Also in the case of customer preferences, SCD can predict customer behaviour changes and to swiftly respond to match the customers' expectations (Zhou et al. 2023). In general, it can be concluded that 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 the GSC and SCAR. As such, we propose the following hypothesis for further examination.

H_{5a}. SCD positively affects GSC

H_{5b}. SCD positively affects SCAR

3. Methods

The current section describes the study's methodological approach, 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 through five stages, which will be explained in the following paragraphs. The questionnaire consists of two parts: the first part inquires about the demographic information of the participants and their companies with a total of ten questions. 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). To enhance transparency and support replicability, the questionnaire is provided in Appendix A. 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. Definitions and conceptual descriptions of each construct—OLD, SCI, SCD, SCAR, GSC, and PSSGCP—are presented in Table 2.

The survey development process was carried out in five stages (Lewis, Templeton & Byrd 2005). The first stage involved defining the domain of each construct and specifying the measurement objectives. This required an extensive literature review to establish the six constructs. In the second stage, a list of items for each construct was developed to measure them accurately. This stage produced 37 items. The third stage was pre-testing, where four experts from academics and industry were recruited to assess the ease of use and clarity of the questionnaire. 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, where 10 participants from official service partners were recruited to provide feedback for refining the instrument. In the final stage, the interrater agreement questionnaire was distributed to 25 service partner participants and academic experts with knowledge of the supply chain. There were three criteria for removing 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 (Sud-on et al. 2013). Based on these three criteria, no items were removed, 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, 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 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 1000 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, while 201 responses were received for the second and third reminders. In total, 643 responses were

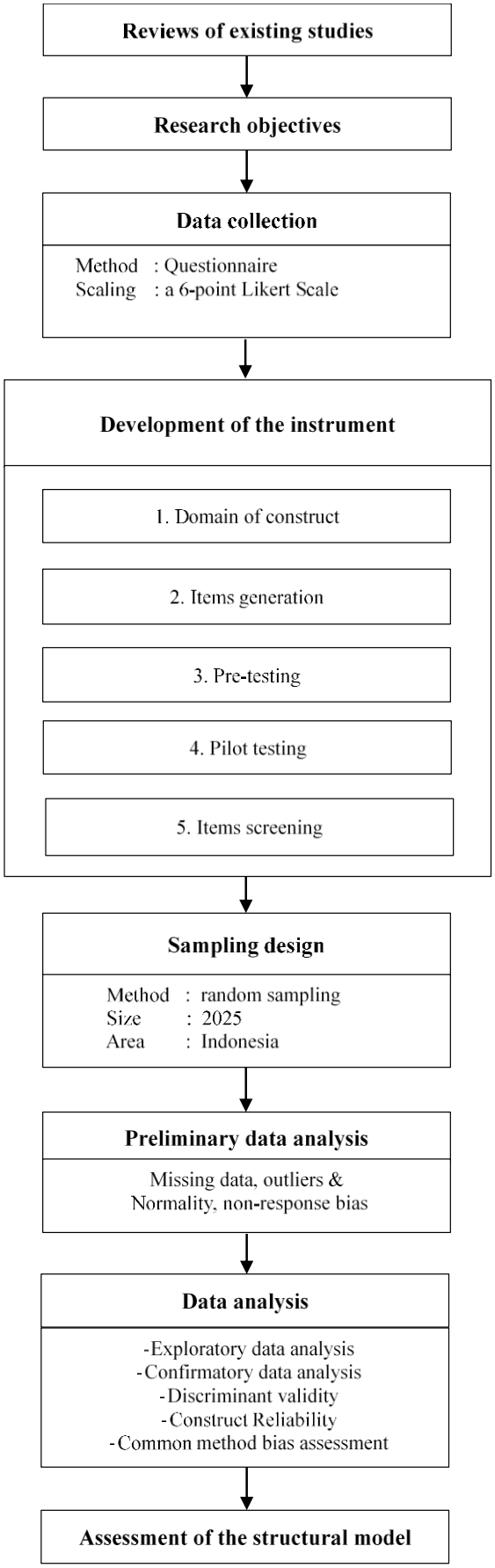

Figure 1 Methodological approach

received (31.8 percent response rate). However, 100 responses from the initial wave and 41 responses from the final waves could not be processed further because these were incomplete and excluded from the analysis. Therefore, only 502 responses could be processed further.

The demographic profile data of the participants highlighting 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 percent of survey participants, followed by another brand with 18.1 percent. The remaining three brands have smaller market shares compared to these two. Most participants are based on the island of Java, making up 66.5 percent of the total, which aligns with Indonesia's population distribution, where the majority live in Java. Additionally, 63.8 percent 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 percent). Among those who completed the survey, 57.2 percent are heads of service centre workshops, and 34.9 percent are direct owners. A significant portion, 63.1 percent, have over 10 years of experience in the motorcycle industry, while 66 percent have been heads of service centre workshops for more than 5 years. The service centre workshop heads are predominantly male (94.2 percent), with 45.2 percent aged between 36-45 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 utilized to determine if there were any statistically significant differences between the responses from the early wave (n=342) and the late wave (n=160). The results indicated no statistically significant differences between the early and late waves for the five constructs, with *p*-values exceeding 0.05. Thus, it can be concluded that there is no non-response bias in the data used in this study.

Data analysis in this study involved several statistical techniques to ensure the validity and reliability of the measurement and structural models. First, Exploratory Factor Analysis was conducted to identify the underlying factor structure and to explore the dimensionality of the constructs without imposing a predefined structure. This was followed by Confirmatory Factor Analysis to test the hypothesized measurement model and to 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 from one another. Construct reliability, such as Composite Reliability (CR), was also evaluated to ensure internal consistency of the items measuring each construct. Additionally, to address potential biases arising from the use of self-reported survey data, Common Method Bias (CMB) was assessed using techniques such as Harman's single-factor test. Finally, the structural model was evaluated using Structural Equation Modelling to test the hypothesized relationships between constructs, examining 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 dimensionality of the scale, followed by CFA using AMOS version 26 to evaluate convergent validity, discriminant validity, and factorial validity. EFA was individually conducted for the six constructs, utilizing promax rotation and maximum likelihood extraction. The six constructs resulted in a one-factor solution, explaining a total variance of 51.44–68.75 percent with factor loadings ranging from 0.47–0.88. According to Brown (2015), factor loadings below 0.5 are considered invalid. Therefore, from the EFA process, two items were dropped: SCAR7 and GSC5, with factor loadings of 0.340 and 0.337, respectively.

There are three stages to confirm convergent validity. First, calculate the chi-squared values, then if the chi-squared rejects at a p -value < 0.01; modification indices can be utilized to detect shared underlying factors across the measurement items. A cautious approach should be adopted to identify and eliminate items, especially ones with insufficient validity scores (refer to the interrater agreement results). These results confirm evidence of convergent validity using the following goodness of fit indices cut-off values: $p > 0.05$, norm $\chi^2 \leq 3$, RMSEA < 0.06, SRMR < 0.08, CFI ≥ 0.95, and TLI ≥ 0.95 (Hu & Bentler 1998; Yu 2002). After this process, several items need to be deleted (OLD6, SCI6, SCD5, SCAR6 and GSC6). Standard factor loadings for all items ranging from 0.671-0.876 (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 & Cho 2022). The six constructs demonstrated discriminant validity as each one's average variance extracted (AVE) was greater than its squared correlation with any other construct (Table 1).

Table 1 Discriminant validity

	Domain of 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

This validation step assesses if hypothesized latent variables form meaningful constructs by analyzing overall model fit statistics. The satisfactory fit indices obtained 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).

4.2. Construct reliability

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

Table 2 Measurement variables (constructs) and their corresponding scale indicators

Code	Domain of constructs and items	References	Factor loading
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			
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

Code	Domain of constructs and items	References	Factor loading
OLD_5	We and our main dealer continuously learn about customers' needs and requirements.	(Dewi & 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)	-
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			
SCI_1	We sharing information with our main dealers about sales forecast, stock level, customers' expectation and responsibilities on environmental impact.	(Jajja, Chatha & Farooq 2018)	0.838
SCI_2	We maintain long term collaborative agreement with our main dealer to deliver PSS and achieve environmental goals.	(Jajja, Chatha & Farooq 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, Chatha & Farooq 2018)	0.864
SCI_4	We maintain good communication with customers through multiple communication channels.	(Oubrahim, Sefiani & Happonen 2023)	0.781
SCI_5	We continually seek input from customers to assess their satisfaction levels and gather feedback of Product-service systems.	(Oubrahim, Sefiani & Happonen 2023)	0.809
SCI_6	We maintain integrated data with main dealers within our SC network (omitted).	(Tan et al. 2023)	-
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			
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)	-
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			
$SCAR_1$	We continuously enhance our PSS to rapidly boost customer satisfaction levels.	(Kim & Chai 2017)	0.805
$SCAR_2$	We continuously enhance the reliability of our PSS delivery through rapid improvements.	(Kim & Chai 2017)	0.804

Code	Domain of constructs and items	References	Factor loading
$SCAR_3$	We continuously reconfigure our PSS supply chain capabilities to swiftly adapt to evolving market demands.	(Al-Omoush, Palacios-Marqués & Ulrich 2022)	0.750
$SCAR_4$	We continuously drive innovation in our PSS offerings to maintain market leadership.	(Boon-itt, Wong & Wong 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)	-
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			
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)	-
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			
$PSSGCP_1$	We have high speed of PSS offering deliveries.	(Choi, Min & Joo 2018)	0.825
$PSSGCP_2$	We have high volume/ capacity flexibility.	(Choi, Min & Joo 2018)	0.841
$PSSGCP_3$	We have a high degree of PSS variety offering.	(Akın Ateş et al. 2022)	0.838
$PSSGCP_4$	We have high performance of PSS quality offering.	(Akın Ateş et al. 2022)	0.845
$PSSGCP_5$	We have high level of customer satisfaction.	(Akın Ateş et al. 2022)	0.876
$PSSGCP_6$	We have high level of PSS profitability.	(Akın Ateş et al. 2022)	0.671
$PSSGCP_7$	We have reduced the use of harmful, toxic, and hazardous substances in our products.	(Pham & Pham 2021)	0.794

4.3. Common method bias assessment

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

4.4. Assessment of structural model

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

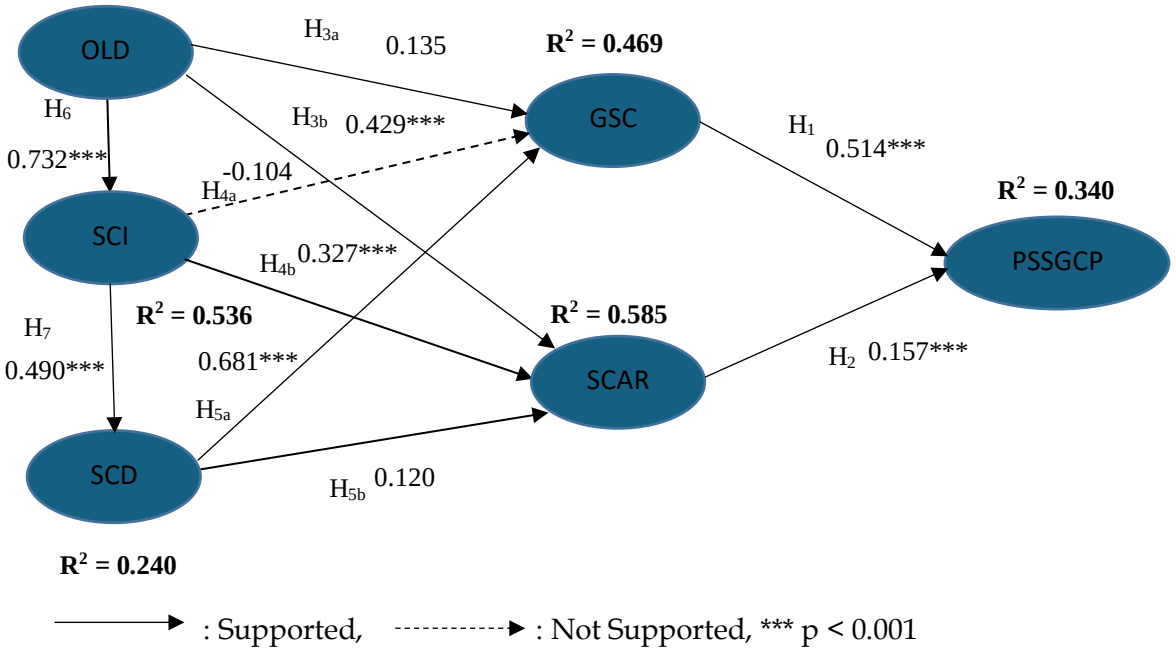

Figure 2 Structural model findings including path coefficients and explained variances

The ten hypotheses were tested using Structural Equation Modelling. 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 OLD 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 to 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 to GSC (H5a=0.681, p < 0.001), likewise H5b is supported, displaying 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, this section explores them to enhance the depth of analysis. The significance of the mediation paths was evaluated through bias-corrected bootstrapping based on 2,000 random samples. Table 3 summarizes eight significant

mediation paths. The relationship between OLD and SCD is fully mediated by SCI, emphasizing SCI's role in enabling digital transformation. The path from SCI to GSC is also fully mediated by SCD, highlighting that SCI must be operationalized through digitalization to impact green practices. The effect of OLD on GSC is partially mediated by SCI and SCD, with both direct and indirect effects significant. Similarly, the relationship between OLD and SCAR shows partial mediation through SCD, indicating that digital capabilities complement organizational learning. The path from SCI to SCAR is partially mediated by SCD, though the indirect effect is relatively small. Regarding PSSGCP, three full mediation paths are identified: (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 highlight 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

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 (partial)	SCD	0.323	Both direct and indirect significant
SCI-GSC (full)	SCD	0.320	Only indirect path significant
SCI-SCAR(partial)	SCD	0.069	Minor mediation via SCD
OLD-PSSGCP(full)	GSC,SCAR,SCD	0.221	Fully mediated through multiple paths
SCI-PSSGCP (full)	SCD, SCAR	0.151	Fully mediated through multiple paths
SCD-PSSGCP (full)	GSC, SCAR	0.333	Fully mediated through multiple path

5. Discussions

OLD items exhibit strong loadings ranging from 0.803 to 0.846, confirming that the training and knowledge-sharing initiatives provided by the main dealer are well reflected in the items. 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 significance 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. While 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 loading of PSSGCP6 (0.671) is still within acceptable limits, especially when theoretical support exists. The highest loading (0.876) underlines the role of customer satisfaction in competitive performance. Also, 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.

PSSGCP reflect a firm's ability to integrate environmental sustainability with high operational and market performance. First, 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 capability 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 offering reflects innovation and customization, allowing firms to cater to diverse customer needs while embedding sustainable features into each variant. High performance of PSS quality offering 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 performance in speed, flexibility, variety, and quality, 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 investigate 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 PSSGCP. This study reveals that GSC has a significant positive effect on PSSGCP, as well as SCAR is positively associated with PSSGCP as supported by hypothesis 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 positively impacts the GSC, as well as SCD positively impact the GSC. The observed outcomes corroborate the results reported by Evangelista and Hallikas (2022), which emphasize the important role of SCD in achieving green objectives, as well as the findings of Yang *et al.* (2024), which confirm OLD as a positive moderator for improving sustainability. Only SCI 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 suggests that while SCI is important, it is not sufficient on its own to directly drive GSC. Instead, SCI must first enable the organization to digitally transform its supply chain processes (SCD). These digital capabilities, in turn, create the necessary transparency, responsiveness, and process efficiency required to implement and scale environmentally sustainable practices. Thus, without the digital infrastructure and capabilities provided by SCD, the strategic alignment facilitated by SCI 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 environmental performance improvements. The general assumption in the existing literature is that SCD accelerates improvements of SCI (Shi *et al.*, 2023; Liu *et al.*, 2022). However, in this study, we found the opposite due to 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. The integration in their SC positively impacts the enhancement of SCD capabilities.

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

It is noteworthy that 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 survey's development and has been tested to be valid and reliable. Regarding practical implications, 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, as well as 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 in fact be effectively

shared and developed through strong collaboration within the motorcycle industry supply chain. The findings illustrate that with strategic and ongoing collaboration, even deeply embedded capabilities such as agility, innovation, and green awareness can be disseminated across organizational boundaries.

6. Conclusions and future research

This study underscores the crucial role of green supply chain, agility, and resilience in enhancing PSS green competitive performance. 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 key to strengthening these capabilities. The findings show that effective green supply chain not only support environmental goals but also achieve high quality, flexibility, profitability, and reliable delivery. By connecting green, agile, and resilient supply chain concepts within a dynamic capabilities framework, this study provides a holistic perspective and offers practical insights for motorcycle industry practitioners seeking to improve their PSS green competitive performance. Despite these valuable insights, this study has several limitations that warrant further research. First, the study primarily examines supply chain performance 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 evolving landscape of the topic. Future research could incorporate social indicators to provide a more complete evaluation of sustainability performance. Lastly, this study relies on cross-sectional survey data, capturing performance at a single point in time to assess performance. However, this performance is likely to shift over time. It would be insightful to use a longitudinal approach to track changes in performance and the capabilities that evolve with these changes.

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Author Contributions

Conceptualisation, 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 collections, 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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4. Revised version Round 3 (30-07-2025)
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   -Revised version with highlights

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Introduction:
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Methodology:
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Results and Discussion:
1. the long table need to add cont. for next page. such as Table 2.
2. all legend caption in Tables 1 and 3 need revision and complete with any sub legend or others information

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1. many images in the graphical abstract are blurry and contain the brand, revise this.

Originality	2 *(fair)*
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Methodology	2 *(fair)*
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List of Changes

Manuscript: : **Enhancing Product–Service Systems' Green Competitive Performance through a Dynamic Capabilities Lens**

Response and Revision made by Author(s)

Reviewer #1:

No	Comments	Revision/Changes
1	**Results and Discussion:** 1. The long table need to add cont. for next page. such as Table 2. 2. All legend caption in Tables 1 and 3 need revision and complete with any sub legend or others information	1. Thank you for your valuable suggestion. We have revised Table 2 and added the indication "(cont.)" to the subsequent pages to ensure clarity and continuity across multiple pages. 2. Thank you for pointing this out. We have carefully revised the legend captions for both Table 1 and Table 3. The updated captions now include more detailed descriptions of the contents and the statistical criteria used.
2	Other: 1. Many images in the graphical abstract are blurry and contain the brand, revise this.	Thank you for your constructive feedback. In response, we have replaced the images in the graphical abstract with higher-resolution visuals to ensure clarity. Additionally, all brand-related elements have been removed to maintain academic neutrality and meet publication standards.

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Research Article

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

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Abstract: Incorporating environmental awareness into business operations while maintaining competitive performance presents 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 foster 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 in current literature. 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 Structural Equation Modelling (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, while only OLD and SCD show direct positive effects on GSC. The analysis also reveals that OLD positively influences SCI, which subsequently impacts SCD—indicating that SCI's influence on GSC is mediated through SCD. These findings provide practical and theoretical insights, enabling managers and researchers to better align green and competitive performance goals. Furthermore, managers can assess the standardized loadings to evaluate the contribution of each capability to enhancing PSSGCP.

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

1. Introduction

Companies in the manufacturing sector, 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, initially defined as the integrated bundling of products and services to create value-added products and boost customer satisfaction (Beuren, Ferreira & Miguel 2013), is being redefined. The PSS definition now includes the producer's responsibility for the product at its end

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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, Battistella & Nonino 2016).

In recent times, various disruptions, including natural disasters, the COVID-19 pandemic, fierce competition in the business landscape, distribution failures, and other unforeseen events, have caused interruptions. These disruptions necessitated a departure from business-as-usual practices. The characteristics such as flexibility, speed, innovations and responsiveness are required in the erratic condition such as nowadays (Al-Omoush, Palacios-Marqués & Ulrich 2022; Ashari et al. 2018). Hence, the agility and resilience of supply chain (SC) guide the companies in the SC to be operated as stable and normal mode when disruptions occur (Kazancoglu et al. 2022).

To address these challenges, the concepts of supply chain agility and resilience—collectively referred to in this study as Supply Chain Agility and Resilience (SCAR)—have gained prominence. While both 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 supply chain performance, this study uses the integrated term SCAR to reflect their complementary roles.

However, agility and resilience alone are insufficient for long-term sustainability. In today's context, environmental awareness must also be incorporated into corporate strategies (Singh, Hamid & Garza-Reyes 2023). Without active engagement in environmental stewardship, the degradation of natural resources could threaten supply continuity, particularly raw materials critical to manufacturing operations. 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 Green Supply Chain (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 & 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. Addressing this research gap, this study investigates 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 PSS Green Competitive Performance (PSSGCP).

Addressing the weaknesses in the current body of knowledge, this study investigates three gaps which constitute the research questions of this study are as follows (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 existing literature. Unlike prior research that predominantly centers 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. By proposing and empirically examining the role of these capabilities in enhancing PSSGCP, this study establishes a comprehensive and integrative framework that differentiates itself from earlier fragmented approaches to either 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 urgency and relevance of this research are further underscored by the growing frequency of global disruptions and increasing environmental pressures, which compel firms to rethink and restructure their SC. As such, 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 hypotheses development

The conceptual theoretical framework in this study is guided by the Dynamic Capabilities (DC) theory. 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 requires theory that accommodates dynamic resources and capabilities that will grow within 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 to keep the competition (Teece 2007). Moreover, DC is hard to be enhanced in solely company as they should be progressed together within the network (Defee & Fugate 2010). DC suits well to guide the proposed framework as the framework is developed for SC network. This research focuses on the motorcycle SC, aiming to deliver PSS. To accomplish this, 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 as dynamic capabilities that should be created within a network, to be able to sense, seize and reconfigure internal and external resources to deal with rapid changing environment. In response to this challenge, GSC and SCAR are essential for navigating the unpredictable business environment. Specifically, GSC is crucial for sustaining long-term performance improvements while preserving green resources needed for the future.

2.1. PSSGCP

Companies are struggling to find themselves and survive in the business competition, nowadays. Competitive performance is the result of a competitive advantage, indicating a company's ability to innovate and surpass its competitors (Kumar et al. 2024). As such, 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 & Mukhtar 2018). PSS offers a method to achieve differentiation by satisfying customers with not just 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 to stay in a business for a long-term, the green concept must be added to it. 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, Oulfarsi & Eddine 2024). Hence, this study aims to identify the PSS SC capabilities required to improve the PSSGCP which focus on enhancing green, agility and resilience capabilities.

2.2. GSC

GSC is defined as organizational philosophies to not only pursue economic advantage of business but also enhancing the green efficiency by minimizing environmental impact of industrial activities (Gawusu et al. 2022). The green SC practices should cover all activities throughout the industrial process from purchasing, production, logistics, distribution and the product end of life (Bustinza, Vendrell-Herrero & Chiappetta Jabbour 2024; Suwignjo et al. 2023). PSS actually serves as part of the effort to extend the product lifespan by providing product 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). It is challenging to visualize how GSC practices relate to operational SC benefits. Novitasari and Agustia (2021) didn't discover a positive link between GSC and SC performance. PSSGCP merges SC performance with environmental considerations. Thus, to explore this association, below are the proposed hypotheses to be examined.

H_1. 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 acknowledge effectively and promptly to the 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 & 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 as its capabilities to sense, seize and reconfigure firm and SC resources (Dubey et al. 2018). Capabilities required for resilience are capabilities 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 in SC showed that there is a positive relationship between SC agility and resilience to improved firm's performances (Mahesh, Srivastava & Muthappa 2024). Therefore, it is hypothesized that SCAR are positively related to PSSGCP.

H_2. SCAR positively affects PSSGCP.

2.4. OLD

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

Considered as strategic capabilities, continual OLD is crucial for achieving firm's performance such as being green, agile and resilient (Eryarsoy et al. 2022), as well as improving the SCI. In this study, it is evident that motorcycle manufacturers lack the capability to deliver PSS independently (Dewi & Hermanto 2024). This underscores the necessity for strategic partnerships with the 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 & Hermanto 2024). These initiatives aim to enhance the technical skills and performance of partners, making them more agile and resilient in their tasks (Dewi et al. 2024).

Likewise, OLD has 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 in this research 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 GSC.

H_{3b}. OLD positively affects SCAR.

H_6. OLD positively affects SCI.

2.5. SCI

The capabilities to integrate within firm and network is stressed by many SC research studies; in fact, those studies highlighted the significant role of SCI in GSC (Pham & Pham 2021), as well as 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. (Jajja, Chatha & Farooq 2018; Abdulameer, Ibrahim & Yaacob 2020). It is not adequate for a firm to integrate only the internal function within an enterprise but also it is required to integrate all functions within the SC network (Jajja, Chatha & Farooq 2018). The SC integration process may involve all areas that are required as a business process in the SC, has three entities: process integration, supplier integration and customer integration (Shukor et al. 2021).

PSS is one way to extend the product life cycle by providing a bundle of product and service (Dewi et al. 2023). Collaboration among manufacturers, intermediaries and service partners to provide PSS is crucial, as well as 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, essential for adapting to business and environmental changes and it also has a positive impact on SCD (Arif, Shah & Khan 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 to the customer demand changes as they have direct contact with customers (Dewi & Hermanto 2023). These coordinated efforts should improve the utilization of resources and finally impact the SC performance. Then we propose the following hypotheses.

H_{4a}. SCI positively affects GSC.

H_{4b}. SCI positively affects SCAR.

H_7. SCI positively affects SCD.

2.6. SCD

Digitalization is defined as transformation of business routines from traditional systems to digital systems (Tiwari, Sharma & Jha 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 substituted with digital systems. Likewise, communication within SC, like interactions between manufacturers, intermediaries and service partners, demands considerable effort when executed manually, resulting in waste and slow process (Oubrahim, Sefiani & Happonen 2023).

Digitalization is one way to resolve and arrange data better than manual (Le et al. 2024). Related to inventory management, digital technology is mostly utilized to manage physical and virtual inventory in real time to reduce cost of inventory management, thus can quickly make decisions in real time, preventing faults, also if there is disruption and needs swift changes (Mashayekhy et al. 2022). Besides that, digitalization also ensures tractability, offers monitoring and controlling (Behnke & Janssen 2020). Also in the case of customer preferences, SCD can predict customer behaviour changes and to swiftly respond to match the customers' expectations (Zhou et al. 2023). In general, it can be concluded that 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 the GSC and SCAR. As such, we propose the following hypothesis for further examination.

H_{5a}. SCD positively affects GSC

H_{5b}. SCD positively affects SCAR

3. Methods

The current section describes the study's methodological approach, 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 through five stages, which will be explained in the following paragraphs. The questionnaire consists of two parts: the first part inquires about the demographic information of the participants and their companies with a total of ten questions. 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). To enhance transparency and support replicability, the questionnaire is provided in Appendix A. 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. Definitions and conceptual descriptions of each construct—OLD, SCI, SCD, SCAR, GSC, and PSSGCP—are presented in Table 2.

The survey development process was carried out in five stages (Lewis, Templeton & Byrd 2005). The first stage involved defining the domain of each construct and specifying the measurement objectives. This required an extensive literature review to establish the six constructs. In the second stage, a list of items for each construct was developed to measure them accurately. This stage produced 37 items. The third stage was pre-testing, where four experts from academics and industry were recruited to assess the ease of use and clarity of the questionnaire. 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, where 10 participants from official service partners were recruited to provide feedback for refining the instrument. In the final stage, the interrater agreement questionnaire was distributed to 25 service partner participants and academic experts with knowledge of the supply chain. There were three criteria for removing 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 (Sud-on et al. 2013). Based on these three criteria, no items were removed, 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, 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 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 1000 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, while 201 responses were received for the second and third reminders. In total, 643 responses were

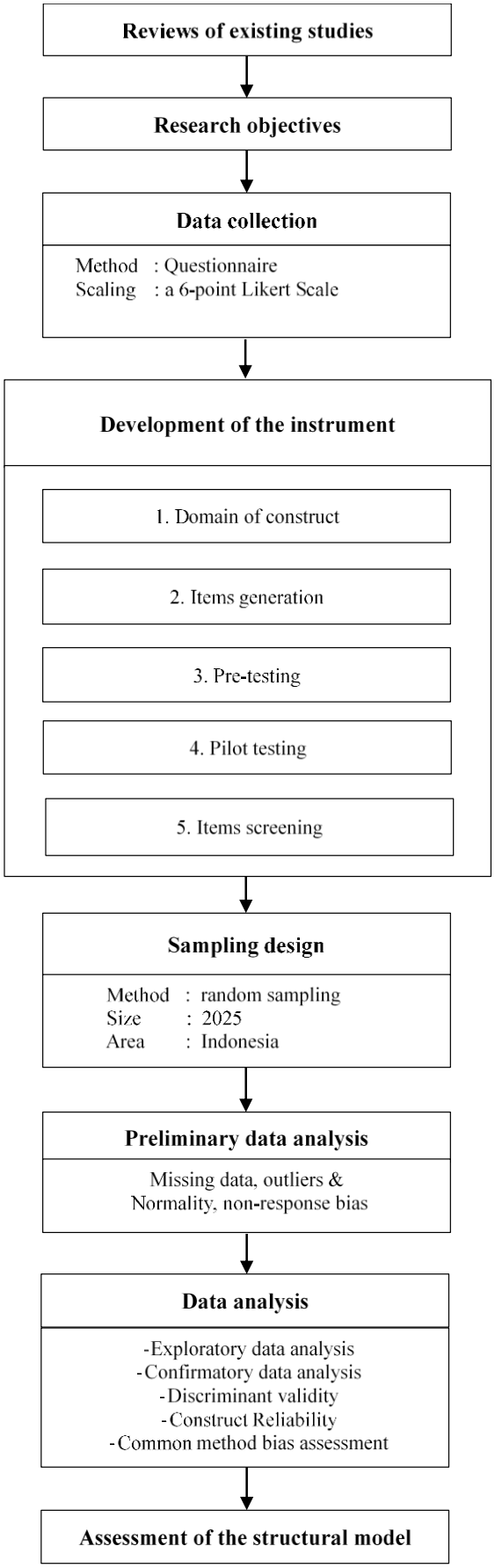

Figure 1 Methodological approach

received (31.8 percent response rate). However, 100 responses from the initial wave and 41 responses from the final waves could not be processed further because these were incomplete and excluded from the analysis. Therefore, only 502 responses could be processed further.

The demographic profile data of the participants highlighting 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 percent of survey participants, followed by another brand with 18.1 percent. The remaining three brands have smaller market shares compared to these two. Most participants are based on the island of Java, making up 66.5 percent of the total, which aligns with Indonesia's population distribution, where the majority live in Java. Additionally, 63.8 percent 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 percent). Among those who completed the survey, 57.2 percent are heads of service centre workshops, and 34.9 percent are direct owners. A significant portion, 63.1 percent, have over 10 years of experience in the motorcycle industry, while 66 percent have been heads of service centre workshops for more than 5 years. The service centre workshop heads are predominantly male (94.2 percent), with 45.2 percent aged between 36-45 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 utilized to determine if there were any statistically significant differences between the responses from the early wave (n=342) and the late wave (n=160). The results indicated no statistically significant differences between the early and late waves for the five constructs, with *p*-values exceeding 0.05. Thus, it can be concluded that there is no non-response bias in the data used in this study.

Data analysis in this study involved several statistical techniques to ensure the validity and reliability of the measurement and structural models. First, Exploratory Factor Analysis was conducted to identify the underlying factor structure and to explore the dimensionality of the constructs without imposing a predefined structure. This was followed by Confirmatory Factor Analysis to test the hypothesized measurement model and to 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 from one another. Construct reliability, such as Composite Reliability (CR), was also evaluated to ensure internal consistency of the items measuring each construct. Additionally, to address potential biases arising from the use of self-reported survey data, Common Method Bias (CMB) was assessed using techniques such as Harman's single-factor test. Finally, the structural model was evaluated using Structural Equation Modelling to test the hypothesized relationships between constructs, examining 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 dimensionality of the scale, followed by CFA using AMOS version 26 to evaluate convergent validity, discriminant validity, and factorial validity. EFA was individually conducted for the six constructs, utilizing promax rotation and maximum likelihood extraction. The six constructs resulted in a one-factor solution, explaining a total variance of 51.44–68.75 percent with factor loadings ranging from 0.47–0.88. According to Brown (2015), factor loadings below 0.5 are considered invalid. Therefore, from the EFA process, two items were dropped: SCAR7 and GSC5, with factor loadings of 0.340 and 0.337, respectively.

There are three stages to confirm convergent validity. First, calculate the chi-squared values, then if the chi-squared rejects at a p -value < 0.01; modification indices can be utilized to detect shared underlying factors across the measurement items. A cautious approach should be adopted to identify and eliminate items, especially ones with insufficient validity scores (refer to the interrater agreement results). These results confirm evidence of convergent validity using the following goodness of fit indices cut-off values: $p > 0.05$, norm $\chi^2 \leq 3$, RMSEA < 0.06, SRMR < 0.08, CFI ≥ 0.95, and TLI ≥ 0.95 (Hu & Bentler 1998; Yu 2002). After this process, several items need to be deleted (OLD6, SCI6, SCD5, SCAR6 and GSC6). Standard factor loadings for all items ranging from 0.671-0.876 (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 & Cho 2022). The six constructs demonstrated discriminant validity as each one's average variance extracted (AVE) was greater than its squared correlation with any other construct (Table 1).

Table 1 Discriminant validity using Fornell–Larcker Criterion and HTMT Ratios

	Domain of 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

This validation step assesses if hypothesized latent variables form meaningful constructs by analyzing overall model fit statistics. The satisfactory fit indices obtained 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).

4.2. Construct reliability

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

Table 2 Measurement variables (constructs) and their corresponding scale indicators

Code	Domain of constructs and items	References	Factor loading
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			
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

Table 2 (continued) Measurement variables (constructs) and their corresponding scale indicators

Code	Domain of constructs and items	References	Factor loading
OLD_5	We and our main dealer continuously learn about customers' needs and requirements.	(Dewi & 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)	-
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			
SCI_1	We sharing information with our main dealers about sales forecast, stock level, customers' expectation and responsibilities on environmental impact.	(Jajja, Chatha & Farooq 2018)	0.838
SCI_2	We maintain long term collaborative agreement with our main dealer to deliver PSS and achieve environmental goals.	(Jajja, Chatha & Farooq 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, Chatha & Farooq 2018)	0.864
SCI_4	We maintain good communication with customers through multiple communication channels.	(Oubrahim, Sefiani & Happonen 2023)	0.781
SCI_5	We continually seek input from customers to assess their satisfaction levels and gather feedback of Product-service systems.	(Oubrahim, Sefiani & Happonen 2023)	0.809
SCI_6	We maintain integrated data with main dealers within our SC network (omitted).	(Tan et al. 2023)	-
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			
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)	-
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			
$SCAR_1$	We continuously enhance our PSS to rapidly boost customer satisfaction levels.	(Kim & Chai 2017)	0.805
$SCAR_2$	We continuously enhance the reliability of our PSS delivery through rapid improvements.	(Kim & Chai 2017)	0.804

Table 2 (continued) Measurement variables (constructs) and their corresponding scale indicators

Code	Domain of constructs and items	References	Factor loading
$SCAR_3$	We continuously reconfigure our PSS supply chain capabilities to swiftly adapt to evolving market demands.	(Al-Omoush, Palacios-Marqués & Ulrich 2022)	0.750
$SCAR_4$	We continuously drive innovation in our PSS offerings to maintain market leadership.	(Boon-itt, Wong & Wong 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)	-
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			
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)	-
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			
$PSSGCP_1$	We have high speed of PSS offering deliveries.	(Choi, Min & Joo 2018)	0.825
$PSSGCP_2$	We have high volume/ capacity flexibility.	(Choi, Min & Joo 2018)	0.841
$PSSGCP_3$	We have a high degree of PSS variety offering.	(Akın Ateş et al. 2022)	0.838
$PSSGCP_4$	We have high performance of PSS quality offering.	(Akın Ateş et al. 2022)	0.845
$PSSGCP_5$	We have high level of customer satisfaction.	(Akın Ateş et al. 2022)	0.876
$PSSGCP_6$	We have high level of PSS profitability.	(Akın Ateş et al. 2022)	0.671
$PSSGCP_7$	We have reduced the use of harmful, toxic, and hazardous substances in our products.	(Pham & Pham 2021)	0.794

4.3. Common method bias assessment

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

4.4. Assessment of structural model

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

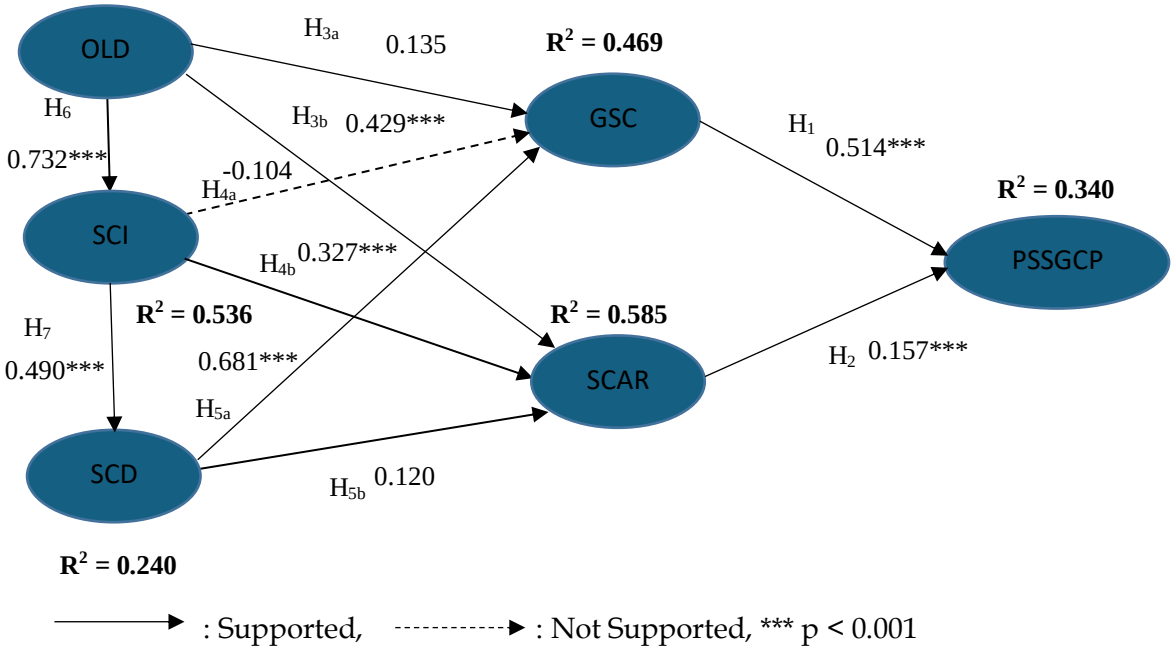

Figure 2 Structural model findings including path coefficients and explained variances

The ten hypotheses were tested using Structural Equation Modelling. 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 OLD 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 to 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 to GSC (H5a=0.681, $p < 0.001$), likewise H5b is supported, displaying 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, this section explores them to enhance the depth of analysis. The significance of the mediation paths was evaluated through

bias-corrected bootstrapping based on 2,000 random samples. Table 3 summarizes eight significant mediation paths. The relationship between OLD and SCD is fully mediated by SCI, emphasizing SCI's role in enabling digital transformation. The path from SCI to GSC is also fully mediated by SCD, highlighting that SCI must be operationalized through digitalization to impact green practices. The effect of OLD on GSC is partially mediated by SCI and SCD, with both direct and indirect effects significant. Similarly, the relationship between OLD and SCAR shows partial mediation through SCD, indicating that digital capabilities complement organizational learning. The path from SCI to SCAR is partially mediated by SCD, though the indirect effect is relatively small. Regarding PSSGCP, three full mediation paths are identified: (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 highlight 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 (partial)	SCD	0.323	Both direct and indirect significant
SCI-GSC (full)	SCD	0.320	Only indirect path significant
SCI-SCAR(partial)	SCD	0.069	Minor mediation via SCD
OLD-PSSGCP(full)	GSC,SCAR,SCD	0.221	Fully mediated through multiple paths
SCI-PSSGCP (full)	SCD, SCAR	0.151	Fully mediated through multiple paths
SCD-PSSGCP (full)	GSC, SCAR	0.333	Fully mediated through multiple path

5. Discussions

OLD items exhibit strong loadings ranging from 0.803 to 0.846, confirming that the training and knowledge-sharing initiatives provided by the main dealer are well reflected in the items. 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 significance 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. While 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 loading of PSSGCP6 (0.671) is still within acceptable limits, especially when theoretical support exists. The highest loading (0.876) underlines the role of customer satisfaction in competitive performance. Also, 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.

PSSGCP reflect a firm's ability to integrate environmental sustainability with high operational and market performance. First, 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 capability 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 offering reflects innovation and customization, allowing firms to cater to diverse customer needs while embedding sustainable features into each variant.

High performance of PSS quality offering 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 performance in speed, flexibility, variety, and quality, 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 investigate 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 PSSGCP. This study reveals that GSC has a significant positive effect on PSSGCP, as well as SCAR is positively associated with PSSGCP as supported by hypothesis 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 positively impacts the GSC, as well as SCD positively impact the GSC. The observed outcomes corroborate the results reported by Evangelista and Hallikas (2022), which emphasize the important role of SCD in achieving green objectives, as well as the findings of Yang *et al.* (2024), which confirm OLD as a positive moderator for improving sustainability. Only SCI 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 suggests that while SCI is important, it is not sufficient on its own to directly drive GSC. Instead, SCI must first enable the organization to digitally transform its supply chain processes (SCD). These digital capabilities, in turn, create the necessary transparency, responsiveness, and process efficiency required to implement and scale environmentally sustainable practices. Thus, without the digital infrastructure and capabilities provided by SCD, the strategic alignment facilitated by SCI 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 environmental performance improvements. The general assumption in the existing literature is that SCD accelerates improvements of SCI (Shi *et al.*, 2023; Liu *et al.*, 2022). However, in this study, we found the opposite due to 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. The integration in their SC positively impacts the enhancement of SCD capabilities.

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

It is noteworthy that 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 survey's development and has been tested to be valid and reliable. Regarding practical implications, 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, as well as 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 in fact be effectively shared and developed through strong collaboration within the motorcycle industry supply chain. The findings illustrate that with strategic and ongoing collaboration, even deeply embedded capabilities such as agility, innovation, and green awareness can be disseminated across organizational boundaries.

6. Conclusions and future research

This study underscores the crucial role of green supply chain, agility, and resilience in enhancing PSS green competitive performance. 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 key to strengthening these capabilities. The findings show that effective green supply chain not only support environmental goals but also achieve high quality, flexibility, profitability, and reliable delivery. By connecting green, agile, and resilient supply chain concepts within a dynamic capabilities framework, this study provides a holistic perspective and offers practical insights for motorcycle industry practitioners seeking to improve their PSS green competitive performance. Despite these valuable insights, this study has several limitations that warrant further research. First, the study primarily examines supply chain performance 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 evolving landscape of the topic. Future research could incorporate social indicators to provide a more complete evaluation of sustainability performance. Lastly, this study relies on cross-sectional survey data, capturing performance at a single point in time to assess performance. However, this performance is likely to shift over time. It would be insightful to use a longitudinal approach to track changes in performance and the capabilities that evolve with these changes.

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Author Contributions

Conceptualisation, 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 collections, 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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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.

H_1. 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.

H_2. 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.

H_6. 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.
H_{7}. 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 $\geq$ 0.95, and TLI $\geq$ 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).

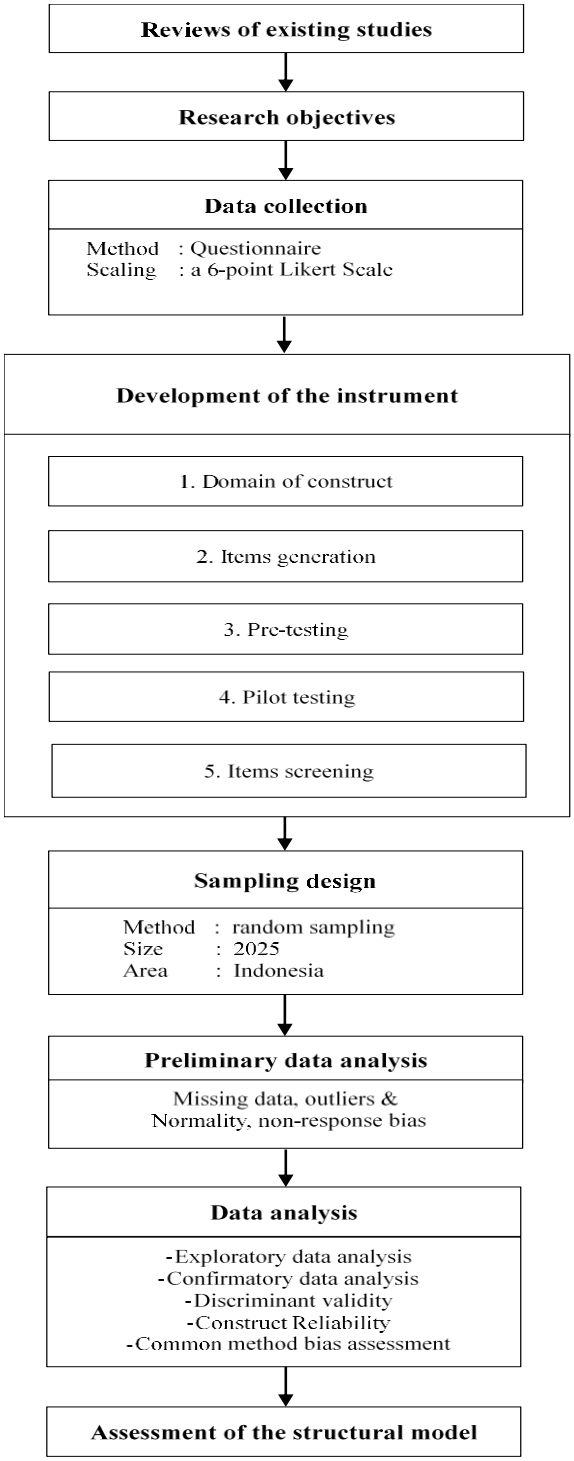

Figure 1 Methodological approach used

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
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			
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)	-
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			
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)	-
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			
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
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			
$SCAR_1$	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)	-
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			
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)	-
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			
$PSSGCP_1$	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.	(Akın Ateş et al. 2022)	0.838
$PSSGCP_4$	We have high performance of PSS quality offering.	(Akın Ateş et al. 2022)	0.845
$PSSGCP_5$	We have high level of customer satisfaction.	(Akın Ateş et al. 2022)	0.876
$PSSGCP_6$	We have high level of PSS profitability.	(Akın 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 χ^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.

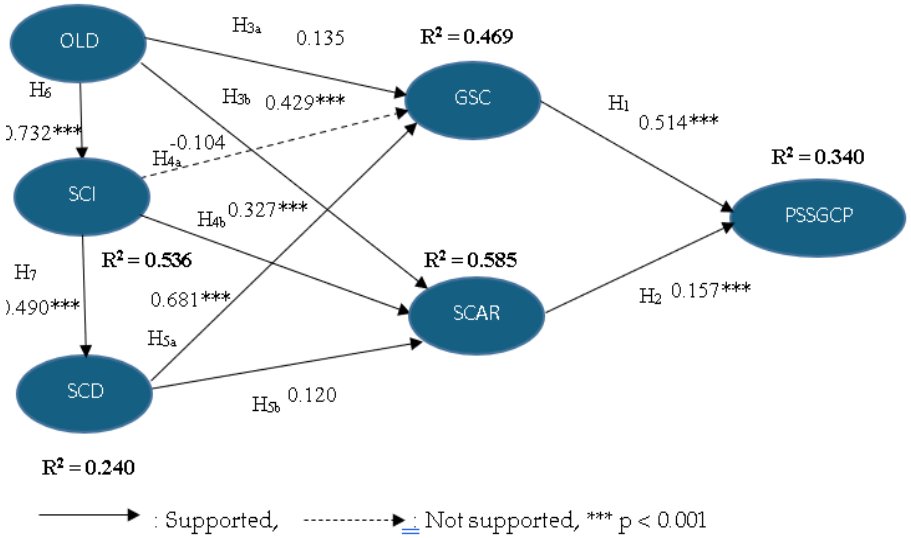

Figure 2 Structural model findings including path coefficients and explained variances

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 (H5a=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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Journal Publishing

Dear

1. Dr. Dian Retno Sari Dewi
2. Dr. Yustinus Budi Hermanto
3. Dr. Jaka Mulyana
4. Dr. Mohamed Farah

Greetings from Depok!

On behalf of the Editorial Board, I am pleased to inform you that your article entitled **Enhancing Green Competitive Performance of Product–Service Systems through a Dynamic Capabilities Lens** has been published online in *Volume 16 Issue 5, Sep 2025*. You can check the online version at: https://ijtech.eng.ui.ac.id/issue/102

The articles are available to be accessed and downloaded free of charge.

Thank you for your contribution to IJTech and we look forward to a good collaboration in the next future.

Yours sincerely,

Prof. Dr. Yudan Whulanza
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