A Structured Taxonomy of Supply Chain Resilience Indicators: A Foundation for Standardized Resilience Assessment

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ABSTRACT

This study proposes a structured taxonomy of supply chain resilience indicators to support future standardization efforts in resilience assessment. An umbrella review covering the period 2010–2025 was conducted using major scientific databases. The identified indicators were systematically analyzed, consolidated, and classified according to their relevance, applicability, and generalizability. The proposed taxonomy organizes resilience indicators into three disruption phases: pre-disruption preparedness, during-disruption absorption and operational continuity, and post-disruption recovery and improvement. The results provide a coherent classification of key indicators related to visibility, flexibility, redundancy, collaboration, recovery capability, and organizational preparedness. Although the proposed taxonomy does not constitute a validated quantitative assessment model, it provides a foundation for future resilience measurement frameworks. It also contributes to the improvement of the consistency and comparability of resilience indicators.

Keywords-supply chain resilience; resilience indicators; resilience assessment; resilience taxonomy; resilience measurement; supply chain risk management

I. INTRODUCTION

Supply chain resilience has become a significant strategic concern due to increasing global disruptions caused by pandemics, geopolitical instability, climate-related events, and economic uncertainty. Modern supply chains must not only withstand disruptions but also adapt and recover rapidly while maintaining operational continuity and performance [1, 2]. Despite the growing importance of supply chain resilience, the literature still lacks a standardized framework for resilience assessment. Existing resilience indicators remain fragmented, heterogeneous, and difficult to operationalize across different industrial contexts. The need for structured resilience metrics and standardized performance indicators capable of supporting decision-making and comparative resilience evaluation has been highlighted [3]. Moreover, the complexity and multidimensional nature of supply chain risks and resilience-related assessment processes have been emphasized [4]. To address this gap, the present study proposes a structured taxonomy of supply chain resilience indicators as a preliminary

step toward the development of a standardized resilience assessment framework. A systematic literature review and comparative analysis were conducted to identify, evaluate, and classify the most relevant resilience indicators.

II. METHODOLOGY

A. Research Design

This study adopts an umbrella review approach to identify, analyze, and classify the key indicators used to assess supply chain resilience. Unlike traditional systematic literature reviews that analyze primary studies, an umbrella review synthesizes evidence from existing systematic and conceptual reviews. This higher-level review strategy consolidates fragmented knowledge, improves comparability, reduces redundancy, and helps identify the most frequently reported and operational resilience indicators in the literature [5]. The objective of this study is to develop a structured, standardized taxonomy of supply chain resilience indicators to support future resilience measurement frameworks and decision-support models. The research design follows a rigorous, reproducible methodology inspired by established review guidelines in management and engineering research [6, 7]. The overall scientific logic of the study consists of four main stages: (i) systematic identification of relevant review studies, (ii) screening and selection of high-relevance publications, (iii) extraction and consolidation of resilience indicators, and (iv) classification of indicators according to the main resilience phases: pre-disruption preparedness, during-disruption absorption, and post-disruption recovery.

B. Literature Search Strategy

The literature search was conducted using five major scientific databases widely recognized in engineering, management, and supply chain research: Scopus, Web of Science, ScienceDirect, SpringerLink, and IEEE Xplore. These databases were selected to ensure broad coverage of high-quality, peer-reviewed studies on supply chain resilience assessment. The search process covered publications from 2010 to 2025 to capture both foundational and recent contributions addressing supply chain resilience, disruption management, and resilience performance evaluation. Only studies published in English were considered. The search queries combined several keywords related to supply chain resilience and performance assessment, including "supply chain resilience," "resilience indicators," "resilience metrics," "resilience assessment," "supply chain risk management," and "performance indicators." Boolean operators (AND/OR) were used to improve the precision and comprehensiveness of the search process. The primary search string used across the databases was: ("supply chain resilience" OR "resilient supply chain") AND ("indicator*" OR "metric*" OR "performance indicator*" OR "assessment" OR "measurement") AND ("supply chain risk management" OR "disruption management"). Minor adaptations of the search syntax were applied when required by the specific indexing and search functionalities of each database.

C. Study Selection Process

The study selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and methodological rigor. The initial database search identified approximately 600 publications related to supply chain resilience and resilience assessment. After duplicate removal and preliminary screening based on titles and abstracts, irrelevant studies were excluded. The screening process was conducted through successive stages involving title screening, abstract screening, and full-text assessment. Potentially relevant studies identified during the initial screening were independently assessed by the authors through a full-text review using the predefined eligibility criteria. Any disagreements regarding study eligibility were resolved after discussion among the authors, and only studies meeting all inclusion criteria were retained for the final analytical corpus. In line with the umbrella review approach adopted in this study, priority was given to systematic reviews, literature reviews, and review-based studies focusing on resilience indicators, resilience measurement, and supply chain risk management. The final corpus was limited to high-relevance review studies to ensure methodological consistency with the umbrella review approach. These studies were retained based on their methodological rigor, thematic relevance, scientific visibility, and contribution to resilience indicator identification and classification. The overall selection process is summarized in the PRISMA flow diagram presented in Figure 1. The review was restricted to ten high-quality review studies because the objective of this research was not to synthesize primary empirical evidence directly, but rather to conduct an umbrella review of existing review-based knowledge. Each selected review synthesized a substantial number of primary studies, typically ranging from 40 to more than 60 publications. Consequently, the final taxonomy was developed from a broad evidence base that indirectly encompasses several hundred primary studies. This approach ensured methodological consistency while reducing duplication of evidence across overlapping review articles.

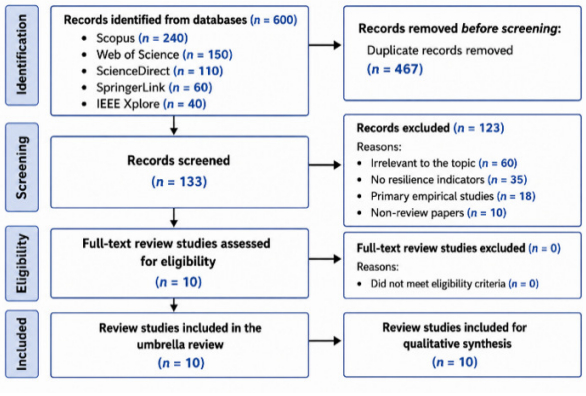

Fig. 1. PRISMA 2020 flow diagram of the umbrella review selection process.

D. Eligibility Criteria and Article Evaluation

TABLE I. SUMMARY OF SYSTEMATIC AND CONCEPTUAL REVIEWS ON SUPPLY CHAIN RESILIENCE AND SUSTAINABILITY INDICATORS

Authors	Review type	Journal/source	Quartile	Main contribution
[8]	Review and conceptual framework	Journal of Industrial Engineering International	Q2	Performance indicators and resilience framework
[9]	Systematic literature review	Production	Q2	Non-financial resilience indicators
[2]	Systematic review	Global Journal of Flexible Systems Management	Q1	Flexible strategies and resilience performance indicators
[10]	Literature review	Management Research Review	Q2	Quantitative resilience models
[11]	Systematic literature review	IEEE IEEM Conference Proceedings	—	Digital transformation and resilience indicators
[3]	Bibliometric and systematic review	Annals of Operations Research	Q1	Supply chain resilience assessment and risk management
[12]	Review study	International Journal of Production Research	Q1	Ripple effect and disruption management
[1]	Review article	International Journal of Production Research	Q1	Evolution of supply chain resilience research
[13]	Systematic literature review	Transportation Research Part E	Q1	Resilience strategies and digital technologies
[14]	Systematic review	Journal of Intellectual Capital	Q1	Human capital and organizational resilience

To ensure methodological rigor and thematic consistency, predefined inclusion and exclusion criteria were applied throughout the screening and evaluation process. Consistent with the umbrella review approach, priority was given to systematic reviews, literature reviews, and other review-based studies addressing supply chain resilience indicators, resilience assessment, and supply chain risk management. Studies were included if they met all the following criteria: they were published in peer-reviewed journals or recognized scientific conference proceedings, they presented, analyzed, or applied resilience indicators or resilience measurement approaches, they provided conceptual, methodological, or operational contributions to supply chain resilience assessment, and they were published in English between 2010 and 2025. Studies were excluded if they focused exclusively on sustainability, robustness, or risk management without explicitly addressing resilience indicators, failed to include measurable or operational resilience indicators, consisted solely of empirical case studies without review or synthesis components, or were non-scientific reports, editorials, or other non-academic publications. Applying these inclusion and exclusion criteria ensured that the selected studies were both methodologically rigorous and directly relevant to the research objectives, thereby providing a reliable foundation for developing the proposed taxonomy of supply chain resilience indicators. The selected review studies were further evaluated according to four qualitative criteria: (i) conceptual relevance, (ii) frequency and influence in the literature, (iii) practical applicability of the proposed indicators, and (iv) sectoral generalizability. This evaluation process supported the consolidation and prioritization of the most recurrent and operational resilience indicators included in the final taxonomy. In addition, priority was given to review studies published in high-impact journals and recognized scientific outlets, particularly those indexed in Q1 and Q2 journals. Preference was also given to studies providing explicit resilience indicators, resilience measurement approaches, performance metrics, or structured resilience assessment frameworks. These criteria ensured that only highly relevant and methodologically rigorous reviews were included in the final umbrella review corpus.

E. Methodological Limitations

Although the umbrella review approach provides a broad overview of existing knowledge, this study has several limitations. First, the review included only high-quality review studies; so, some recent empirical and sector-specific studies may not have been considered. Second, only English-language publications indexed in major scientific databases were included, which may have excluded relevant studies published in other languages or non-indexed sources. Finally, although predefined evaluation criteria and a systematic screening process were used, the evaluation and classification of resilience indicators involved some degree of subjective judgment.

III. RESULTS

A. Consolidated Resilience Indicators

TABLE II. CONSOLIDATED RESILIENCE INDICATORS IDENTIFIED IN THE LITERATURE

Category	Indicators
Performance under normal conditions	Order processing time; on-time delivery; inventory level; demand fulfillment capacity; delivered product quality; customer loyalty rate; customer satisfaction level; the availability of the systems; supplier delivery efficiency; supplier rejection rate
Visibility and information sharing	Shared information quality; supply chain visibility
Organizational capabilities	Workforce versatility (%); key talent retention rate; frequency of crisis/continuity training; presence of a documented and tested Business Continuity Plan (BCP); frequency of crisis simulation exercises
Network structure	Single vs. multi-sourcing; geographical dispersion; network complexity/centrality
Immediate response capabilities	Safety stock level; backup capacities; information sharing time; cybersecurity level; security risk management
Flexibility	Supply flexibility; production flexibility; transport flexibility; inventory redundancy
Operational responsiveness	Time to Survive (TTS); recovery time/downtime; emergency strategic decision time
Post-crisis recovery and performance	Time to Recovery (TTR); recovery speed; failed recovery; non-recovery rate for priority customers; late delivery delay
Customer impact	Customer impact (costs/prioritization); revenue impact from disruptions
Post-crisis cost and strategy	Recovery cost increase; cash-to-cash cycle

The selected review studies revealed a wide range of resilience indicators used to assess supply chain resilience across different contexts and disruption scenarios. These indicators cover operational, organizational, informational, financial, digital, and strategic dimensions of resilience. Table II summarizes the main indicators identified in the literature, which constitute the initial basis for the subsequent evaluation, consolidation, and classification phases of this study. The resilience indicators identified in the selected review studies were consolidated and grouped into significant resilience dimensions. This consolidation process enabled the elimination of redundancies and helped identify the most recurrent and operational indicators reported in the literature.

B. Literature Gaps

Despite the growing number of resilience indicators proposed in the literature, there are several important limitations. First, there is no standardized framework or unified methodology for assessing supply chain resilience, as existing studies rely on heterogeneous KPIs, qualitative approaches, and context-specific measurement methods, which limits comparability across industries and research settings [8, 15, 16]. Second, the absence of a universally accepted resilience measurement scale reduces the operational applicability, consistency, and benchmarking capability of resilience evaluation processes [2, 17, 18]. Furthermore, many existing studies focus primarily on isolated resilience dimensions such as flexibility, redundancy, visibility, or risk mitigation without providing an integrated and operational resilience assessment structure [12, 13, 19]. Finally, resilience indicators are rarely classified according to the different disruption phases, pre-disruption preparedness, during-disruption absorption, and post-disruption recovery, which restricts the temporal analysis of resilience capabilities and the optimization of resilience strategies [1, 3, 14].

C. Selection and Evaluation of Key Indicators

To support the selection and prioritization of supply chain resilience indicators, a qualitative multi-criteria evaluation approach was adopted based on four complementary dimensions: conceptual relevance, frequency in the literature, practical applicability, and sectoral generalizability. Conceptual relevance assesses the extent to which an indicator reflects one or more of the core dimensions of resilience, namely anticipation, absorption, adaptation, and recovery. Frequency in the literature evaluates how consistently an indicator appears across the selected review studies, with more frequently reported indicators considered to have stronger scientific support. Practical applicability refers to the feasibility of measuring an indicator using operational data commonly available within organizations, such as enterprise resource planning, customer relationship management, financial, or logistics systems. Sectoral generalizability examines the extent to which an indicator can be applied across different industries and supply chain contexts rather than being limited to a specific sector. This evaluation framework was used to identify the most operational, recurrent, and transferable indicators and to support the development of the proposed resilience taxonomy. Table III outlines the qualitative evaluation criteria employed in this study.

TABLE III. QUALITATIVE EVALUATION GRID OF SUPPLY CHAIN RESILIENCE INDICATORS

Criterion	Low level	Moderate level	High level
Conceptual relevance	Weak or implicit theoretical link to resilience; mentioned occasionally without a clear conceptual framework	Partial or contextual link; integrated into some models without explicit centrality	Direct, central, and explicitly justified link in the resilience literature
Frequency	Rare (≤ 3 studies)	Moderate (4-7 studies)	Frequent (> 7 studies)
Practical applicability	Difficult to implement; depends on unavailable data or complex processes	Feasible under certain conditions (training, tools, organizational maturity)	Easily measurable or directly operational using common means (IT systems, ERP, standard KPIs)
Sectoral generalizability	Specific to a single sector (e.g., automotive, healthcare)	Applicable to a few sectors with similar characteristics	Cross-sectoral: used and validated across multiple distinct industries

D. Evaluation of Key Resilience Indicators

TABLE IV. EVALUATION AND CATEGORIZATION OF KEY RESILIENCE INDICATORS

Category	Indicator	Relevance	Frequency	Applicability	Generalization
Organizational and information management	Collaboration	High	Frequent	Medium	Cross-sector
	Information sharing	High	Frequent	High	Cross-sector
	Supply chain visibility	High	Frequent	Medium	Cross-sector
	Trust among partners	Medium	Moderate	Low	Cross-sector
Flexibility and adaptability	Supply flexibility	High	Frequent	Medium	Cross-sector
	Production flexibility	High	Frequent	Medium	Cross-sector
	Transport flexibility	Medium	Moderate	Medium	Cross-sector
Redundancy and robustness	Safety stock level	High	Frequent	High	Cross-sector
	Backup capacity	High	Frequent	Medium	Cross-sector
	Inventory redundancy	High	Moderate	Medium	Cross-sector
Operational performance	On-time delivery	High	Frequent	High	Cross-sector
	Order processing time	Medium	Moderate	High	Cross-sector
Recovery capability	TTR	High	Frequent	Medium	Cross-sector
	Recovery Speed	High	Moderate	Medium	Cross-sector
Digital and cybersecurity	IT systems availability	High	Moderate	High	Cross-sector
	Cybersecurity level	Medium	Rare	Medium	Sector-specific
Organizational preparedness	Crisis training	High	Moderate	Medium	Cross-sector
	BCP	High	Moderate	Medium	Cross-sector
Network structure	Multi-sourcing	High	Moderate	Medium	Cross-sector
	Network complexity	Medium	Rare	Low	Cross-sector

Based on the proposed qualitative evaluation framework, the identified resilience indicators were categorized according to their operational role and resilience contribution. The

evaluation process highlighted the most recurrent, operational, and transferable indicators across different supply chain contexts. Table IV presents the consolidated evaluation of the key resilience indicators identified in the literature.

E. Final Classification of Resilience Indicators

To assess supply chain resilience, the selected indicators were classified according to three disruption phases (Figure 2, Table V): pre-disruption preparedness, during-disruption absorption and operational continuity, and post-disruption recovery and improvement. The proposed temporal classification highlights the multidimensional nature of supply chain resilience and emphasizes that resilience capabilities evolve across different disruption phases. Pre-disruption indicators mainly support preparedness and anticipation; during-disruption indicators focus on operational continuity and adaptive response, while post-disruption indicators assess recovery efficiency and long-term performance restoration.

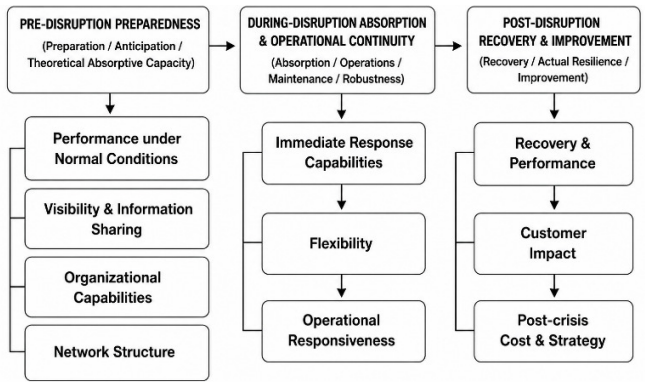

Fig. 2. Temporal classification framework of supply chain resilience indicators.

TABLE V. FINAL CLASSIFICATION OF SUPPLY CHAIN RESILIENCE INDICATORS ACROSS DISRUPTION PHASES

Disruption phase	Category	Main indicators
Pre-disruption preparedness	Performance under normal conditions	Order processing time; on-time delivery; inventory level; demand fulfillment capacity; delivered product quality; customer satisfaction
	Visibility and information sharing	Shared information quality; supply chain visibility
	Organizational capabilities	Workforce versatility; crisis training; BCP; simulation exercises
	Network structure	Multi-Sourcing; geographical dispersion; network complexity
During-disruption absorption and operational continuity	Immediate response capabilities	Safety stock level; backup capacities; information sharing time; cybersecurity level
	Flexibility	Supply flexibility; production flexibility; transport flexibility; inventory redundancy
	Operational responsiveness	TTS; recovery downtime; emergency strategic decision time
Post-disruption recovery and improvement	Recovery and performance	TTR; recovery speed; late delivery delay
	Customer impact	Customer impact; revenue impact from disruptions
	Post-crisis cost and strategy	Recovery cost increase; cash-to-cash cycle

IV. DISCUSSION

A. Comparison with Existing Resilience Indicator

The findings of this study confirm that supply chain resilience is a multidimensional and dynamically evolving concept that cannot be adequately assessed through isolated or fragmented indicators alone. Although previous review studies have identified numerous resilience-related indicators, the literature is characterized by heterogeneous classification approaches and the absence of a unified assessment structure. To better position the contribution of the proposed taxonomy, Table VI compares the reviewed studies with the proposed framework.

As shown in Table VI, previous review studies have primarily focused on identifying resilience indicators associated with specific dimensions such as agility, flexibility, visibility, collaboration, redundancy, security, recovery, or organizational capabilities. While these studies have significantly contributed to the understanding of supply chain resilience, most of them examine indicators from isolated perspectives and do not provide a comprehensive structure capable of organizing indicators throughout the disruption lifecycle. The proposed taxonomy extends previous review studies in three important ways. First, it consolidates resilience indicators extracted from multiple systematic reviews into a single coherent framework. Second, it introduces a temporal classification based on the three major disruption phases: pre-disruption preparedness, during-disruption absorption and operational continuity, and post-disruption recovery and improvement. Third, indicators are organized into operational categories that facilitate their interpretation and practical application by researchers and practitioners. Unlike previous classifications that focus primarily on resilience dimensions or capabilities, the proposed framework provides an integrated structure that captures the dynamic evolution of resilience throughout disruption management. This multidimensional organization improves the consistency, comparability, and interpretability of resilience indicators and provides a foundation for future resilience assessment standardization efforts.

B. Research Implications and Contribution to Resilience Standardization

The results highlight that resilience capabilities vary significantly depending on the disruption phase. Pre-disruption indicators mainly support anticipation and preparedness activities, whereas during-disruption indicators are more strongly associated with operational continuity, adaptive response, and robustness. In contrast, post-disruption indicators focus primarily on recovery efficiency, service restoration, and long-term performance stabilization. This distinction demonstrates that resilience should not be considered a static organizational capability, but rather a progressive and adaptive process evolving throughout disruption management stages. From a managerial perspective, the proposed taxonomy may support organizations in identifying resilience gaps, prioritizing corrective actions, and improving strategic decision-making under disruption conditions.

TABLE VI. COMPARISON OF EXISTING RESILIENCE REVIEW FRAMEWORKS AND THE PROPOSED TAXONOMY

Study	Review scope	Indicator identification	Indicator consolidation	Temporal classification	Operational categories
[9]	Security and organizational factors	Yes	No	No	No
[8]	Resilience capabilities	Yes	No	No	No
[10]	Recovery indicators	Yes	No	No	No
[13]	Resilience dimensions	Yes	Partial	No	Partial
[11]	Resilience factors	Yes	Partial	No	Partial
[17]	Operational metrics	Yes	Partial	No	Partial
[14]	Flexibility and supplier indicators	Yes	No	No	Partial
[19]	Recovery and disruption indicators	Yes	Partial	Partial	Partial
[18]	Human and continuity capabilities	Yes	No	No	Partial
[2]	Service and performance indicators	Yes	No	No	No
Proposed taxonomy	Integrated resilience indicators	Yes	Yes	Yes	Yes

The framework may also facilitate the development of resilience dashboards and monitoring systems capable of evaluating preparedness, response, and recovery capabilities simultaneously. Furthermore, the classification can assist managers in aligning resilience investments with specific disruption phases and operational priorities. The study additionally emphasizes that resilience assessment should not rely exclusively on quantitative operational indicators. Qualitative dimensions such as organizational culture, workforce adaptability, collaboration, leadership, crisis management practices, and knowledge management are essential components of resilient supply chains. Integrating these qualitative dimensions into future resilience assessment models could improve the realism and applicability of resilience evaluation frameworks. Although this study does not yet propose a standardized resilience measurement scale, scoring model, or quantitative assessment methodology. By consolidating resilience indicators from multiple systematic review studies and organizing them within a unified temporal framework, the proposed taxonomy represents a first step toward the future development of standardized resilience assessment models. Future research could extend this work by validating the proposed taxonomy through expert evaluation, Delphi studies, multicriteria decision-making methods, structural equation modeling, factor analysis, and industrial case studies to develop a comprehensive and empirically validated resilience measurement framework.

V. CONCLUSIONS

Supply chain resilience is a significant strategic capability for organizations facing increasing disruptions and uncertainty in global supply networks. This study highlighted the fragmentation and heterogeneity of resilience indicators proposed in the literature. It addressed this limitation by developing a structured and temporally organized taxonomy of supply chain resilience indicators. The proposed framework consolidates the most relevant indicators. It classifies them according to the main disruption phases: pre-disruption preparedness, during-disruption absorption and operational continuity, and post-disruption recovery and improvement. The proposed classification provides both researchers and practitioners with a more coherent and operational basis for resilience assessment and resilience-oriented decision-making. It may support organizations in identifying vulnerabilities, strengthening preparedness capabilities, and improving recovery planning across different supply chain contexts. This study should be viewed as a conceptual and methodological foundation rather than a fully validated resilience assessment model. Although the proposed taxonomy contributes to improving the consistency and comparability of resilience indicators, it does not yet provide a standardized measurement scale, weighting mechanism, scoring model, or quantitative assessment methodology. Consequently, the practical applicability and robustness of the taxonomy require further empirical investigation. Future research should focus on the validation of the proposed taxonomy through expert evaluation, Delphi studies, industrial case studies, and empirical analyses involving practitioners and supply chain specialists. In addition, future work may support the development of a quantitative resilience assessment model based on the proposed indicators, including the construction of an aggregated resilience score using statistical approaches such as structural equation modeling, factor analysis, and multicriteria decision-making methods. Such developments could contribute to the establishment of more robust, comparable, and standardized resilience evaluation frameworks for supply chains.

DECLARATION OF COMPETING INTERESTS

The authors declare that there are no competing interests.

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DATA AVAILABILITY

The data supporting the findings of this study are derived from publicly available scientific publications cited in the manuscript. No new datasets were generated or analyzed during this study.

AI USE AND DECLARATION OF GENERATIVE AI USE

During the preparation of this work, the authors used ChatGPT (OpenAI) solely to assist with language refinement, text restructuring, and formatting. After using this tool, the authors reviewed, edited, and validated all generated content and take full responsibility for the content of this publication.

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