Intelligent, Sustainable Supply Chain Management: A Configurational Strategy to Improve Ecological Sustainability through Digitization

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Abstract

The Sustainable Supply Chain Management (SSCM) research indicates a favorable correlation between sustainability practices and company efficiency. Companies possess constrained resources for implementing competitive strategies and campaigns, presenting managers with difficulty determining which sustainability efforts to prioritize. Two viable solutions to this difficulty are integrating Supply Chain (SC) agility with sustainable practices and employing the Resource Orchestrating Theory (ROT) framework to assist SC executives in making better informed sustainability-related choices. This study examines several potential pairings of corporate and SC sustainability strategies and SC agility that enhance company performance. This research employs the Resource-Dependence Theory and utilizes a configurational technique with a qualitative comparative method. The results demonstrate that superior sustainability outcomes are achieved via many pathways (equifinality), involving both elevated and diminished levels of each suggested sustainability effort and SC agility (asymmetry). The results indicate that outcomes are contingent upon the combination of behaviors rather than their impacts.

Keywords: Supply Chain, Digitization; Ecological Sustainability; Configurational Strategy.

I. INTRODUCTION

The last two years have posed significant challenges for Supply Chain Management (SCM) due to the COVID-19 epidemic and other macroeconomic changes (Rizwan et al., 2022). As several obstacles to the global Supply Chain (SC) are anticipated to persist in the foreseeable future, it is essential to find assets that enable enterprises to achieve a competitive edge. Academic study indicates that Sustainable SCM (SSCM) techniques, viewed through the Triple Bottom Line (TBL) framework of financial, ecological, and social outcomes, assist enterprises in navigating the post-COVID global business landscape (Abualigah et al., 2023). Employers appear to acknowledge the need to cultivate SSCM. Organizations like Levi Strauss, Apple, and Unilever have engaged in sustainability programs throughout their worldwide SCs, aiming to enhance the efficiency of TBL via greater openness, integration, and customer service.

The SC literature indicates a favorable correlation between sustainable strategies and excellent results. Recent debates suggest that this link is more intricate than the existing research implies, revealing uneven or absent correlations between sustainable policies and corporate performance.

The precise linkages and dynamics among different kinds of SC and corporate sustainability policies and their effects on company efficiency fluctuate, given the many routes available for organizations, mainly when many SC collaborators are engaged. The task, then, is to ascertain which combinations are optimum.

Two prospective methods assist managers in tackling these difficulties. From a resource standpoint, agility is an essential competitive element of effective SC management policies and processes. Flexibility in SC skills enhances SC effectiveness, success, return on resources, and overall organizational performance. When combined with sustainable principles, SC agility—characterized by integration, interaction, confidence, and responsiveness—substantially enhances service levels and organizational performance. Integrating sustainable standards with SC agility might be essential for establishing a competitive edge. Secondly, from a theoretical standpoint, Resource Orchestration Theories (ROT) offer managers a resolution to resource ownership and distribution challenges (Cantele et al., 2023). At its essence, ROT is an analytical framework that evaluates the performance results of various resource arrangements, enabling administrators to make informed decisions on the growth of resources and distribution. Given constrained corporate assets, executives can gain from a deeper comprehension of the optimal combination of environmentally friendly procedures and SC agility to be designed and executed.

This research aims to tackle the primary issue of organizational growth of resources. This research examines and delineates combinations of sustainability strategies and SC flexibility as assets that enhance firm sustainability results from a TBL viewpoint (Ardekani et al., 2023). This study aims to address the issue of what combinations of prominent sustainability procedures (encompassing both internal company procedures and outside SC procedures) and SC agility influence the TBL of financial, ecological, and social results, thereby enhancing firm sustainability effectiveness.

The objective is to determine if a singular subset of sustainable practices and SC flexibility has the most vital connection to efficiency or if multiple combinations exist that represent various pathways to attain excellent sustainability success. In conjunction with complex theory, the research enhances the comprehension of variable relationships to more accurately forecast and elucidate real-world business occurrences using a configurational method. Thus, the emphasis on the interaction between environmentally conscious methods and agility is driven by ROT and an understanding of causal intricacy.

II. BACKGROUND

The examination of Digital Transformation (DT) in SCM has been approached from many perspectives that employ distinct conceptual terminologies (Stroumpoulis & Kopanaki, 2022). Some studies have examined the notion of Industry 4.0 in SCM and the emergence of SC 4.0, the evolution of the Internet of Things (IoT)-enabled SCs, or digital SCs. The research adheres to the comprehensive literature research demonstrating the interrelation of these many ideas under the overarching term innovative SC. An intelligent SC integrates various perspectives with the shared objective of enhancing SC operations via implementing DT, particularly foundational DT (i.e., generic digital technologies utilized across diverse applications and domains). These encompass IoT, Cloud Computing (C)C), Big Data (BD), Artificial Intelligence (AI), and

Blockchain (BC). In general, an intelligent SC is a technology framework arising from the digital revolution of SC management.

The vertical structure of the intelligent SC has been examined at two distinct levels: strategy and operations. The strategic tier of an intelligent SC encompasses the DT approach that organizations aim to use for their SC management system, taking into account the essential alignment of SC objectives with real-time data flows. The DT strategy evaluates the influence of DT on the company's perspective of its SCM. For example, General Electric (GE) established an extensive SC utilizing an IoT platform to achieve immediate outcomes and employ technology whenever feasible (Boehmer et al., 2022). Regrettably, the organization failed to get the anticipated outcomes. The share price declined sharply due to GE Digital's absence of a definitive and objective plan to connect technology with results and performance metrics. This integrated strategy, using the potential of DT alongside focused deployment in the SC, facilitates enhanced data flow in SC management operations.

The operational tier of the intelligent SC is categorized into two technology strata: foundational technology and front-end technology. Fundamental technology (i.e., basic cross-cutting technology applicable across all domains and purposes) for intelligent SCs facilitates the sharing of real-time data to expedite decision-making and operations. These foundational technologies construct systems such as IoT, CC, BD analysis, AI, and BC, which are advantageous for various SCM tasks (Rejeb et al., 2020). When utilized independently in the intelligent SC, these foundational technologies optimize data flow for enhanced integration. The interconnections between consumers and vendors and elements like SC design are altered using foundational technologies, improving transparency in this interaction. SC openness is essential for facilitating data evaluation and optimization across the SC.

These foundational technologies are executed on the backend to facilitate the functioning of front-end technology. Front-end technology is characterized as systems that provide operational functions such as transferring materials or quality control of inputs inside SC processes. Examples include collaborative automation, computer modeling, augmented reality, and three-dimensional (3D) printers. These innovations enhance SC operations, including intelligent packing machinery and sensor methods, to meet logistical standards and prevent product damage.

Certain firms have recognized how to integrate external green partnerships and internal green activities into a Green SCM system to enhance green performance (Shah & Soomro, 2021). These organizations initiated green internal practices before extending their operations to outside connections in Green SCM to strengthen oversight and oversight of their environmental practices. Establishing or enhancing exclusively internal green initiatives necessitates significant efforts to attain sustainable performance. During the product creation process, companies rely on external activities, including materials, elements, subdivisions, and adherence to environmental regulations. Organizations increasingly rely on integrating internal and external operations to achieve sustainable success. For example, the reduction of the use of resources and energy must be coordinated among the procurement, production, and packaging procedures to get optimal outcomes; however, this hinges on the standards of inputs obtained from suppliers.

III. METHODOLOGY

Notwithstanding these constraints, the study's organized technique and incorporation of sophisticated statistical methods enhance the validity and dependability of the studies, providing significant insights for both theorizing and practical implementation in the flexible and developing realm of sustainable business procedures in Indonesia. Therefore, to facilitate comprehension, organization, and implementation of research systematically and efficiently, the methodological flowchart is illustrated in Figure 1.

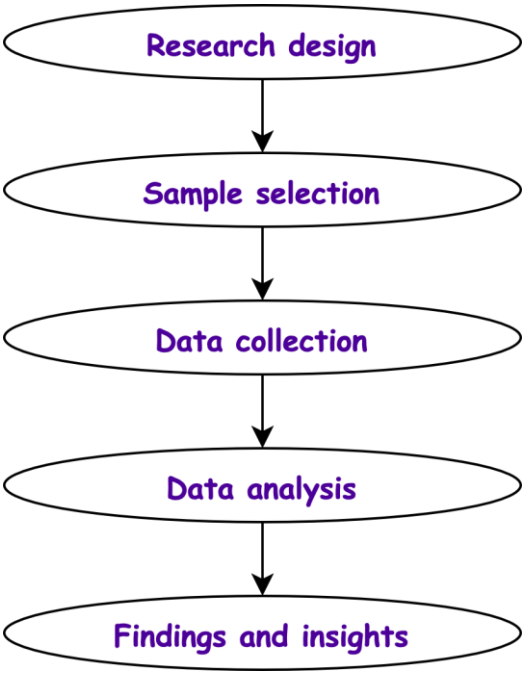

Figure 1: Workflow of the Research

SC agility is characterized as a strategic asset or resource that enables organizations to swiftly modify their strategies and operations in response to fluctuations in the outside business world. Agility allows companies to enhance flexibility in their SC procedures, swiftly adapt to changes, foresee external environmental shifts, and engage the consumer. Suppliers' adaptability is crucial for efficient and successful implementation of modifications to the international marketplace.

Integrating SC agility with sustainability standards is a vital strategic alliance, as companies require SC flexibility to swiftly and efficiently address sustainable demands in the business landscape. SC agility and SSCM are combined as a complementary and synergistic antecedent and a competing concept. The advancement of SC agility procedures can facilitate the execution of SSCM and contribute to the evolution and maintenance of environmental goals and methods in the future. Agile capacities are essential for optimizing the results of sustainability policy adoption; further study is required to investigate other characteristics of sustainability that should be incorporated. The focus on societal sustainability and the deployment of lean principles affect a firm's profitability. Analogous linkages among the fundamental elements of sustainability, SC agility, and efficiency are identified in the configurational paradigm Figure 2.

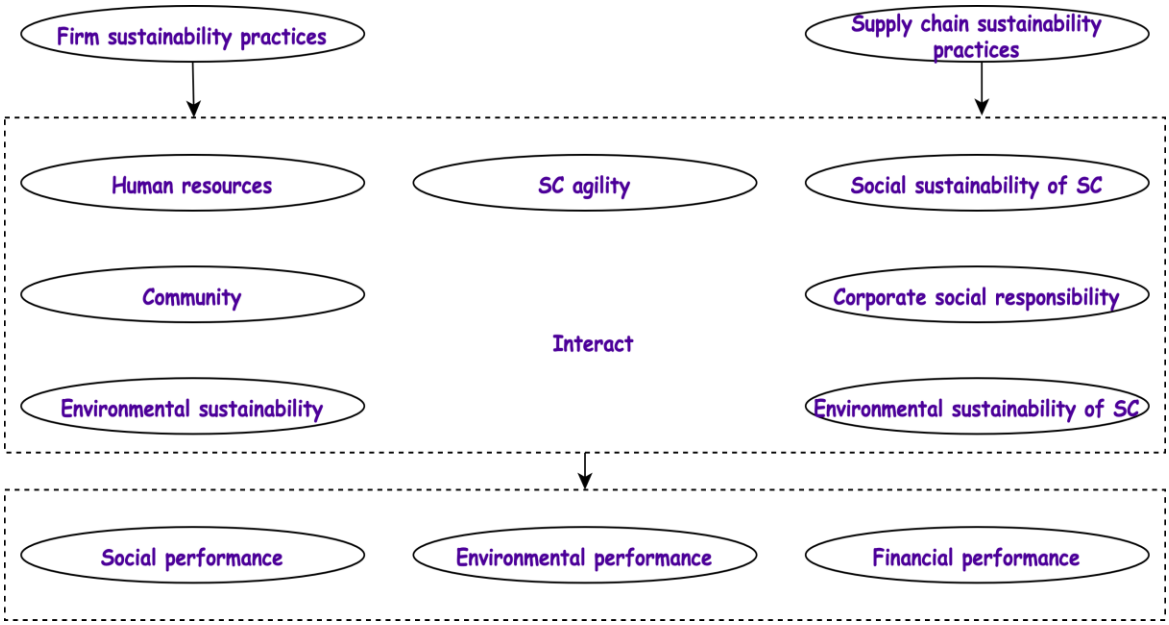

Figure 2: Workflow of the Firm Sustainability Performance

The examination of the current research on DT and SSCM indicates that a comprehensive structure is needed for the research term Smart SSCM. The research illustrates the interconnections among several elements of DT inside the SC and SSCM, namely both the inside and outside sustainable procedures and operations of the SC. The theories seek to address this gap by establishing a structure that delineates, via empirical study, what the research refers to as Smart SSCM. The research intends to demonstrate the interrelation of these characteristics and the role of the Smart factor in enhancing the SSCM characteristics to improve sustainable performance. This is depicted in the conceptual framework, which demonstrates the theoretical viewpoint on the vertical arrangement of DT and the downward external-internal arrangement of SSCM to frame the understanding of Smart SSCM, as shown in Figure 3. Validating these assumptions can yield a comprehensive theoretical framework of the fundamental components of Smart SSCM, hence facilitating practical applications. These two additions address deficiencies in the research identified in the study. The research examines the specifics of the presented theories.

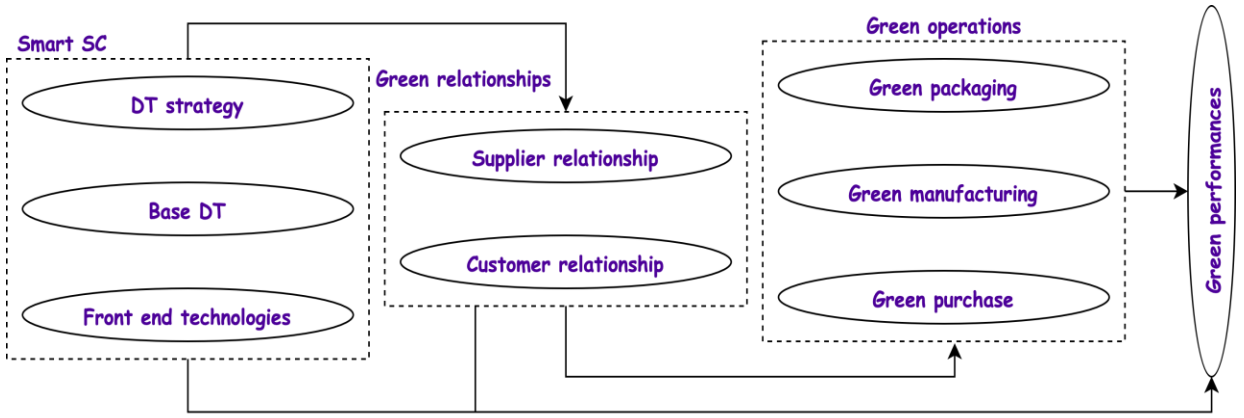

Figure 3: SSCM Architecture

3.1 Data Collection

This study employed SSCM to discern the blends of corporate and SC sustainability strategies and the influence of SC agility, resulting in elevated levels of corporate sustainability effectiveness. SSCM facilitates the identification of various conjunctural causation and equifinality, allowing researchers to more effectively navigate the complexities of the link between sustainable policies and SC flexibility, as well as the associated resources and business outcomes. It identifies the causative elements that lead to an outcome, their various arrangements, the relationship between these assemblages, and a particular result.

To accomplish this objective, an internet-based survey was employed to gather data from industrial and wholesale companies in Italy. The average size of participant enterprises was 59 workers. The manufacturing field was the most prominent, with 80 out of 160 enterprises responding. The survey was disseminated using the Lime Survey platform, accompanied by an email outlining the study's objective. Data collection transpired in three phases (the baseline questionnaire and two subsequent interviews) over three months, exclusively targeting respondents at the managerial level and above.

This procedure produced 170 replies, of which 140 were complete and usable. Nonresponse bias was evaluated using a two-wave comparison method, including early and late responders. No significant differences among the concepts were identified between the two respondent groupings. Non-response biases were not regarded as an influence on the survey outcomes.

3.2 Measures

Every factor in this research was determined after an exhaustive literature analysis and finalized by a pre-test with a panel of five executives and three scholars, each possessing competence in SC management and sustainable practices. The panel's comments enhanced the survey's organization, language, and clarity, augmenting the parameters' face validation.

The factors of interest were assessed utilizing modified versions of established scales. Human resources were evaluated using an eight-item size, the community was examined using a seven-item scale, and ecological sustainability was quantified using a seven-item scale. These three pillars comprise the organization's sustainability practices. The social stability of the SC and the environmental responsibility of the SC were assessed using nine-item measures.

Corporate social responsibility to customers was assessed using an 11-item measure. These three structures comprise SC methods for sustainability. All characteristics are evaluated on a five-point Likert scale, ranging from 1 'strongly disapprove' to 5 'strongly approve'. The metrics employed to assess corporate sustainability efficiency were social outcomes (8 things), ecological sustainability (10 things), and financial performance (7 things). The result of the parameter was assessed utilizing a five-point Likert volume, ranging from 1 'strongly disagree' to 5 'strongly agreement' (about the overall level of enhancement in every achievement item), and represents the average of the three TBL measurements: social, ecological, and financial efficiency.

The scale's reliability was assessed using Cronbach's alpha and reliability composites. The findings exceeded the 0.75 criterion established in the literature. An additional factor analysis validated the measurements' convergence validity. All component load values surpassed the suggested level of 0.6, and the average variation extraction was above the recommended upper limit of 0.5.

IV. RESULTS AND DISCUSSIONS

The assessment across the three instances for the three aspects of sustainability distinctly indicates that economic factors remain the primary determinant in assessing the adoption of new technology. The evaluation of the environmental and social dimensions averages above average (3.3) on a scale of five. Throughout the documentation of the case research, it became evident that specific standards for evaluating the social and environmental dimensions, aside from statutory mandates, still need to be established in figure 4.

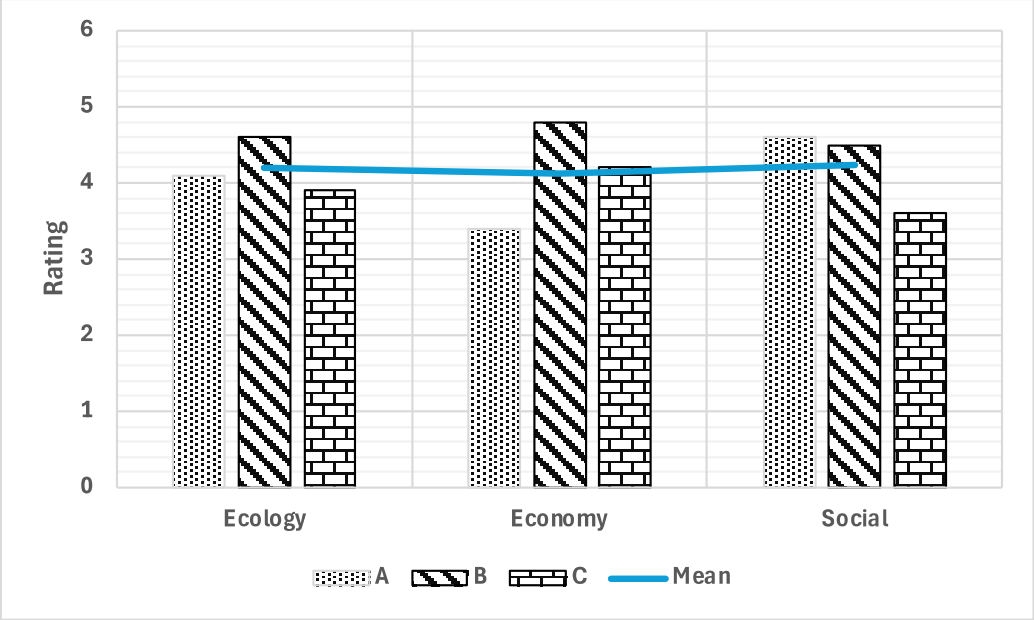

Figure 4: SSCM Analysis

This article presents three fundamental use cases: an internet-based solution for enhancing visibility in shipping and implementing automated guided vehicles for internal logistics.

Case A is a technology provider for transport leadership, delivering platform solutions for SC openness. The innovations under consideration include information and communication technology for facilities' auto-ID methods for data generation, CC for connecting SC collaborators through tracking programs and the estimated arrival time, and mobile devices for data generation, information visualization, and interaction among SC collaborators. This online solution offers services that enhance the entire truckload efficiency.

Case B is a cloud-based visibility system for outbound shipping. It resembles case A but exclusively emphasizes outgoing transportation and establishing visibility. Load optimization and other functionalities are currently outside the project's scope.

Case C assesses self-guiding cars about their automated technology, cloud-based data storage and processing, and analysis for optimizing routes. Automated guided trucks are employed for internal transport to deliver materials and ensure the continuity of production lines.

All three scenarios include substantial enterprises with annual revenues over €500 million, with the questioned practitioners occupying managerial roles and overseeing digital transformation initiatives in transportation and SC administration.

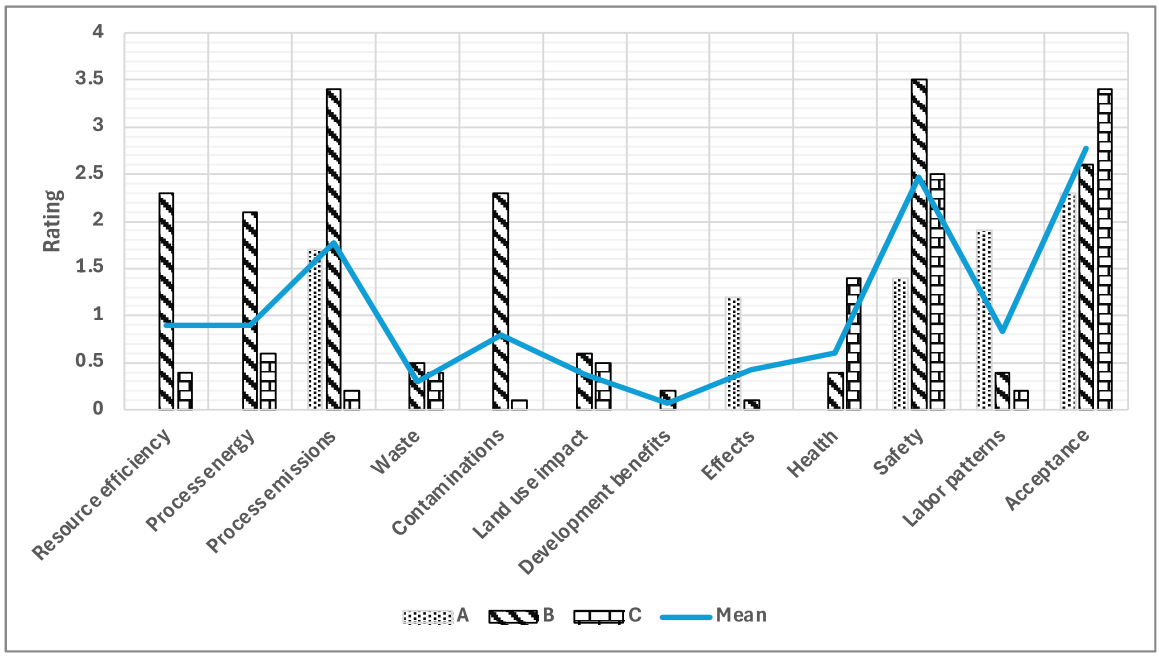

Figure 5: Social and Ecological Analysis

The information in figure 5 is as follows: The mean for every factor within the ecological and social categories is computed first. An indicator for every one of the two aspects is provided based on this mean, leading to a total rating. This method provided equal importance to the two categories and their subcriteria, regardless of the number of responses inside each subcriterion. Calculating a general average based only on the ratings provided by every study respondent within each subcriterion would yield a result of 1, therefore resulting in a somewhat higher rating. The mean scores for each case are the following: 1.72 for case A (2 for the ecological dimension and 1.34 for the societal aspect), 1.25 for case B (1.7; 0.91), and 0.92 for case C (0.19; 1.37). Cases A and B, which exemplify visibility solutions for transportation, are founded on ICT and cloud computing. The incorporation and visible features of these approaches exert a more significant favorable influence on the aspect of the environment than on the social aspect. Their overall score surpasses the automated guided vehicle scenario (case C). The implementation of automation technology indicates a minor positive alteration in the ecological aspect and an average positive effect in social elements, contingent upon the assumption that adopting the solution yields a significantly favorable influence.

Regarding the consequences of the new technology remedies, all three case study respondents assert that these technologies contribute to their overarching digital change plan, which involves developing novel company structures in case A. Case B fosters openness and visibility, essential components of the digital transformation plan, facilitating advances such as artificial intelligence and machine learning. Regarding innovation, a single case partner asserts that the deployed solution would foster novel companies, while the other two contend that it does not influence innovation-related modifications. The organizational frameworks are optimized to accommodate the adopted solutions, allowing low-skilled personnel to perform alternative tasks. Leadership is enhanced by augmented transparency and decision-making support. Leadership is empowered to be more proactive in devising and envisioning innovative structures and methodologies.

V. CONCLUSION

This study indicates that enhancing the efficiency of TBL depends on specific combinations of strategically chosen sustainability measures and SC agility rather than the comprehensive development of all possible resources associated with SC sustainability. This entails managing connections among many stakeholders while concentrating on both internal divisions and SC partnerships. Management can utilize various combinations of resources in assignment choices to influence outcomes for performance, contingent upon their orchestration and integration of those resources. Companies must cultivate a sustainability-oriented culture that enables management to adapt resource operations in response to the modifications and difficulties posed by problems, creativity, and emerging technologies. This study examines the correlation between inside and outside sustainability procedures, SC agility, and firm triple-bottom-line performance in a novel way.

Literature indicates that SSCM research predominantly focuses on "external" SC sustainability, evaluated through performance impacts or perceived demands. This research integrates environmentally friendly procedures associated with the SC with "inner" corporate sustainability policies under a unified configurational paradigm.

Prior empirical research has frequently examined societal or environmental activities in isolation and assessed their individual effects on social achievement, sustainability, or economic performance. The article integrates the ROT model with the theories of complexity and the technique to establish a theoretical structure that accounts for various combinations of assets, resulting in elevated levels of a complete measure of business success. This study examines a comprehensive and novel discourse on sustainability, incorporating ecological and social dimensions and inner (firm) and outside activities, collectively illustrating the multifaceted nature of managerial decisions.

This research has several shortcomings but offers avenues for investigation. Initially, although SSCM provides valuable information on business phenomena, supplementary methodologies like archival or additional information can enhance the generality of the findings and bolster external reliability. Exploring the prospective uses of SSCM as an inductive method for experimental thinking is a fruitful direction for future sustainability and SCM studies. This prompts a reevaluation and scrutiny of existing conceptions in the subject.

The information used in this research was gathered inside the Italian business setting, so it constrains corporate national culture and leadership decision-making to a singular geographic locale. Future studies could investigate more global locations, particularly developing economies, where attitudes toward sustainability measures could be more developed and adequately controlled.

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