Internal Complexity

Abstract

The paper describes and analyses the topic of internal complexity and its uses for operational performance, specifically in supply chains as well as in organizational capabilities. The paper takes its insights from recent literature through a systematic review, we identified the most impactful factors regarding internal complexity for example, product variety, process diversity and the structures of organizations. The review shows how internal complexity impacts adaptability and efficiency. The review also explores how internal complexity is related to supply chain management, reviewing topics such as sustainability, resilience and innovation in industrial electronics, organizational capabilities for internal complexity, and strategic adaptivity in global supply chains. Then the paper also analyses how internal complexity has been clustered in the literature, with particular emphasis on organizational, operational, and environmental dimensions. Many different research methodologies, like case studies and quantitative approaches are used to analyze internal complexity and its management are discussed. The findings focus on the importance of internal integration, knowledge transfer, and tailored complexity management strategies in addressing challenges for better working efficiency. This paper contributes to the academic discourse by synthesizing existing knowledge and then identifying research gaps, and suggesting future research opportunities, particularly in the areas of clustering, adaptive strategies in supply chain and the evolving role of internal complexity in dynamic industrial environments.

Introduction

Internal complexity and supply chain management has attracted much attention owing to increasing social and environmental concerns, legal pressures and the need to improve business performance. As a result, supply chains are increasingly global and more complex, offering both advantages and challenges for organizations trying to incorporate sustainability into their operations. Of these challenges, however, internal complexity is defined to include structural, hierarchical, operational, and collaborative factors emerges as an important area that needs further inspection and management.

The purpose of this paper is to examine the current state of the literature on internal complexity in the supply chain management context, with a specific focus on its impact on the attainment of sustainability goals. The present study aims to systematize the examination of internal complexity in the context of supply chain management based on the analysis of academic articles and to determine further directions for research.

Internal complexity refers to the interactions that occur within an organization's supply chain and include factors such as people, departments, decision making, and technology. For instance, as organizations grow, they become more structurally complex due to the creation of new functional levels and employees. Operational complexity, which is characterized by many products and changing schedules, may disrupt flow and decrease efficiency. The proper control of these complexities is critical for sustainability as uncontrolled complexity affects decision-making, increases costs, and reduces the ability to respond to changes.

The literature review presents the two-sided impact of internal complexity. On the one hand, it can lead to inefficiencies, raise transaction costs and put a strain on resources. On the other hand, it can be a source of innovation, resilience and competitive advantage if well managed. For instance, companies that adopt complexity management tools like integrated information systems are likely to be more adaptable and more resilient over the long run. This paper shows how strong internal governance can assist organizations to manage their complex supply chain

management processes while achieving sustainability goals.

The paper is organized into four major research objectives. First, it reviews the current trends in the literature on internal complexity in supply chain management, the objects of analysis, and the methods used. Second, it examines internal complexity in connection with sustainable supply chain management, what aspects have been investigated, and how. Third, it breaks down internal complexity into structural, operational, and collaborative subcategories and discusses their features and effects on supply chain performance. Fourth, it evaluates the current study and recommends possible directions for the future investigation of the internal complexity and sustainability interface.

The findings of this study are expected to enrich the knowledge on how internal complexity affects the performance of sustainable supply chain management. Based on the clustering of internal complexity into manageable dimensions, organizations can be able to come up with focused strategies to build their resilience, improve on the efficiency of their operations and meet their sustainability goals. The findings of this analysis now can be used to inform the policymakers, practitioners, and the other researchers who are concerned with the multifaceted issues for the current supply chain management environment.

Owing to the dynamic nature of global supply chains, research and adaptation are still required. Technological advancements and changing market demands are continuing to revolutionize supply chain practices and thus understanding and controlling internal complexity becomes even much more important. This paper not only presents current knowledge but also stresses the significance of forward-looking strategies that help organizations to become agile, innovative and sustainable in a complex global environment that is growing ever more complex.

Internal complexity is one of the most important determinants of sustainability and performance in the field of supply chains. In this paper, we aim to contribute to the ongoing discussion on sustainable supply chain management by exploring the various dimensions of internal complexity and their management options.

Research background

In the following years, SSCM has garnered heightened attention owing to the social and environmental concerns, regulatory needs, and the drive for better business results. Firms are able to take advantage of and face difficulties in implementing sustainability in their businesses due to the ever-increasing global and intricate supply chains. Among the myriad challenges, one of the more evident challenges is the internal complexity that is structural, hierarchical, operational, and collaboration centric. There is more than one reason as to why, these are important factors that not only need precise and detailed research but need to be properly managed as well.

Internal complexity stems from the complicated interaction amongst employees, departmental activities within the organization's decision-making structure, including their supply chain and complicated technological systems. As firms grow, their structural complexity is bound to increase with the rise in functional levels and more staff members being hired. Along with that, operational complexity also arises from product variety, and manufacturing schedule variety which, while ensuring productivity, is guaranteed to disrupt the workflow and the overall efficiency. These complexities need to be managed effectively in order to attain sustainability, as complexity that is poorly managed tends to have adverse effects on decision making, increase expenses, and lessen the promptness to respond to market demands.

Internal complexity has a two-fold perspective in the literature concerning its impact on organizational performance. From the perspective of internal complexity, internal complexity could impair efficiency, raise transaction costs, and strain resources. For example, as Blome et al. (2014) state, disruption of quality control has been found to result from high levels of changes to the manufacturing schedule as well as a high degree of product mix. Also, Bode and Wagner (2015) show the internal complexity impact on resource planning and communication with suppler diversity understood as internal complexity in upstream processes in doesn't complicate resource planning.

On the other hand, though, internal complexity, if well managed, can also act as an innovative driver, resilience enhancer, and as a competitive edge. Reeves et al. (2020) claim that firms who practice complexity management using integrated information systems are likely to respond promptly to market changes and improve sustainability in the long term. This corresponds with Anderson et al. 2006, especially those who mention “good complexity enveloping potentially satisfied” because of the possibilities of product customization and “bad complexity” due to poor design systems and too many procedural layers.

With respect to internal complexity, it is necessary to understand that complexity must be defined in multiple dimensions. For example, Glenn and Malott (2004) offered two categories: component complexity which refers to the number of components of a firm and its hierarchy decision making complexity vertical levels of the firm.

With growing organizations, employee recruitment and functional levels inevitably contribute to a rise in internal complexity (Cicerelli and Ravetti, 2024). Vogel and Lasch (2016) also classify internal complexity into correlated complexity, which is stimulated by external market drivers, and autonomous complexity, which is stimulated by internal drivers such as organizational processes and product diversity.

Operational complexity, operationalized in terms of workflow and processes within a supply chain, is another important dimension. Excessive product and parts variability, like in the case of motor vehicle manufacturing, can lead to capacity conflicts and an increase in operational costs (Weingarten et al., 2017). Proper management of such operational complexities plays an important role in maintaining efficiency as well as quality control in organizations.

It is necessary to manage internal complexity with both vertical and horizontal coordination. A network model where strategies for building relationships take precedence over more traditional command hierarchy organizations is proposed by Frostenson and Prenkert (2015). IKEA's cotton sustainability initiative shows how leading firms are able to orchestrate across numerous levels to achieve operational and sustainable goals at the same time (Gong et al., 2023). In addition, it

illustrates the need for stronger internal coordination to manage supply chain complexity across different levels.

To cope with internal complexity the organization must adopt specific policy and governance structures. These are systems which are quantifiable, have defined roles, and are accountable. Systems like these leave room for misalignment which makes the diverse needs of stakeholders more complicated to solve. It needs to be understood that good governance allows the organization to meet the objectives of different stakeholders while ensuring that sustainability objectives are met.

Moreover, technology helps in dealing with internal complexity. The emergence of new technologies such as blockchain, Internet of Things (IoT), and Artificial Intelligence (AI), have brought new dynamics to the way supply chains operate.

Blockchain technology provides an immutable and open method of recording transactions, enabling companies to trace material origins and ensure compliance with sustainability procedures. IoT sensors enable real-time monitoring of supply chain operations, optimizing routes and reducing waste. Artificial intelligence and machine learning mechanize the ability to process information, allowing organizations to identify patterns and predict disruptions, improving overall sustainability performance

Methodology

The present study employs a systematic literature review of the internal complexity in supply chain management. Academic papers were reviewed and classified to finally about 50 papers to determine how internal complexity has been studied and its impact on supply chain sustainability. The review process consisted of two main phases: first, screening to evaluate the appropriateness of the abstracts, and then, reading and synthesizing the included papers. This is a structured approach that enabled a detailed examination of the current academic literature and enabled the differentiation of the main topics, missing pieces, and potential directions for future research. The papers were selected for review based on certain inclusion and exclusion criteria to only include relevant and good quality studies. Papers that examined internal complexity in the supply chain management, sustainability, operational efficiency, and organizational capabilities were included. Studies that provided no empirical evidence or were not directly related to internal complexity and supply chain management were excluded. This helped narrow the focus of the review to only very relevant studies and thus maintain a high level of analysis.

The methodological approach undertaken in the literature review was qualitative, quantitative and mixed method studies. Qualitative studies were case studies, interviews and thematic analyses that gave deep insight into internal complexity and its management. Quantitative studies used statistical models, regression analysis, and empirical testing on large datasets to quantify the impact of internal complexity on supply chain performance. Mixed method studies combined both qualitative and quantitative methods to offer a comprehensive view of the topic.

In the reviewed studies, data collection methods differed depending on the research design of the studies. The collected data was primarily conducted through surveys and interviews of supply chain professionals, procurement managers, and industry executives. These methods gave direct insight into the challenges and strategies for dealing with internal complexity. Previously published case studies, organizational reports, and industry analyses were also used as secondary data sources to validate the findings and enhance the evidence base.

The research analyses presented in the reviewed articles used coded correlation to coded analysis, or even sophisticated statistical analysis. Thematic coding was also used in many qualitative studies to analyze data using software such as NVivo to determine themes and patterns in complexity management. Regression analysis, structural equation modeling (SEM), and panel data were also used by many quantitative studies to quantify the association between supply chain performance and internal complexity. Moreover, some articles used fuzzy set qualitative comparative analysis (fsQCA) to analyze causal relationships in supply chain resilience and digital transformation as composite causes.

The review also assessed the theoretical frameworks employed in the studied investigations. Main theories were transaction cost theory which was employed to appraise procurement, supplier diversity and supply chain governance. The Resource-Based View (RBV) was used to explain how organizations are able to build their internal capabilities for the management of complexity and sustainability. Institutional Theory offered understanding of regulatory issues and CSR practices, while Complexity Theory explained the dynamics of supply chain disruptions and interdependencies.

The studies reviewed are methodologically diverse, which reflects the complexity of the subject matter. Thus, the combination of qualitative, quantitative, and mixed-method approaches gave a comprehensive view of the internal complexity in supply chain management. The results of this review are useful to the academic discourse as they review current knowledge, identify gaps and suggest future research directions. Through the use of a systematic and structured approach, this paper provides valuable insights into the impact of internal complexity on the development of sustainable and resilient supply chains.

Descriptive results

The internal complexity is basically related to the structural and operational intricacies in an organization due to factors like uncertainty, dynamic nature, diversity, and interdependence. Most organizations face uncontrollable internal circumstances, such as fluctuations in customers' demand for products, variability in workforce requirements, and alteration in methods of production. Companies take steps to deal with these uncertainties through information sharing, development of redundancy, and scenario planning to enhance decision-making with minimal disruption to operations.

Dynamicity, or rapid internal changes, also contributes to complexity. Companies facing frequent changes in leadership, business strategies, or market positioning must apply flexible and adaptive management approaches to maintain stability. Besides, large organizations usually experience diversity on many fronts, such as product lines, team structures, and operational goals. To handle all this diversity, standardized processes, digital tools of coordination, and strong frameworks of communication are necessary for efficiency. Additionally, the interdependencies between different departments, such as procurement, production, and logistics, add to the complications. Interdependencies create challenges that can be minimized through effective cross-functional collaboration, real-time data sharing, and integrated decision-making systems.

Mastery of internal complexity requires development of unique organizational capabilities that could include process automation and the utilization of AI, cross-functional teams for coordination, and predictive analytics to forecast eventualities of risks. It can improve operational efficiency by cutting down on waste/inefficiencies, driving innovation, and creating sustainability in operations.

Another important challenge affecting corporate sustainability is supply chain complexity. Supply chain complexity emanates from managing multi-tier supplier relationships, fluctuating demand patterns, logistics coordination, and regulatory compliance. The study identifies two major strategies for coping with supply chain disruptions: buffering and bridging.

Buffering strategies are related to creating redundancies and flexibility that enable organizations to manage supply chain uncertainties. In maintaining stability, organizations use mechanisms of demand change, excess inventory, and diversification of suppliers. For instance, companies that have multiple sources of key raw materials are less exposed to supply chain disruptions due to geopolitical conflicts, natural disasters, or supplier bankruptcies. In addition, the development of redundancy—such as safety stock and backup suppliers—cushions are a company against unpredictable market fluctuations. However, these strategies may raise operational costs and require careful financial planning to balance efficiency with resilience.

Conversely, bridging strategies involve the establishment of closer relationships with supply chain partners to achieve efficiency. The firms form long-term partnerships, joint ventures, and monitor their supply chains in real-time to facilitate improvement in coordination. With strategic partnership in place by the firms with suppliers, they gain a wider perspective on supply chains for better anticipation and response to potential disruptions. However, excessive control and bureaucratic approval may delay decision-making, and therefore firms need to find an optimal balance between control and agility.

It is internal complexity due to regulatory pressures, market dynamics, technological advancement, and socio-environmental factors that drives corporate sustainability performance. Companies should grapple with these challenges to maintain their competitiveness while offering compliance with regulations on sustainability.

The regulatory frameworks significantly affect the corporate approach to sustainability. The environmental laws vary from country to country, as do the carbon emission targets and the requirements regarding sustainability reporting. Firms are compelled to constantly update their operations in response to the evolving set of standards-a challenge that is also an opportunity for sustainability-driven innovation.

The market uncertainties also add to the internal complexity. For example, rapid changes in consumer preference, trade policy, and competitive pressures put businesses under the grind to be responsive. Companies that connect their sustainability objectives to the demands of markets-like the growing consumer preference for eco-friendly and ethically sourced products-can hold an advantage over others.

More technological changes further add to the external complexity but simultaneously provide solutions for sustainability challenges. Some of the new, emerging technologies to help businesses perform better and sustainably are IoT-for-smart-resource-management, AI-driven energy optimization, and blockchain for supply chain transparency. Those companies that will manage to integrate these technologies into their operations will improve on key metrics of internal complexity ,thus enhancing business resilience in the long term.

Findings

Research objective/question 1

What is the current status in the literature regarding journals, papers, overall topics, industries, (~descriptives)

The current status of the literature reveals a strong focus on sustainability, digital transformation, complexity management, and resilience in supply chain and operations management. Research is frequently published in high-impact journals such as the Journal of Cleaner Production, Sustainability, International Journal of Production Research, Journal of Business Logistics, and International Journal of Physical Distribution & Logistics Management*. These journals consistently feature studies on corporate sustainability, procurement strategies, digital transformation, and supply chain governance.

In terms of overarching themes, sustainability in supply chain management remains a dominant research area, with particular attention to multi-tier sustainable supply chains (MTSSCs), corporate social responsibility (CSR), and circular economy practices such as reverse logistics. Another major focus is the role of Industry 4.0 technologies, including artificial intelligence (AI), blockchain, and the Internet of Things (IoT), in transforming procurement and enhancing supply chain resilience. Literature also extensively examines complexity in decision-making, particularly in global sourcing and procurement, highlighting the interplay of functional politics, intuition, and strategic rationality. Furthermore, research on supply chain design explores how firms balance efficiency, agility, and resilience, with a growing emphasis on managing supplier instability and mitigating risks.

Industries covered in the literature are diverse, spanning manufacturing and electronics, where studies examine digital transformation and reverse logistics, to food and agriculture, which focus on resilience in export supply chains. The luxury and fashion sectors are increasingly studied for their adoption of circular economy principles, while renewable energy research explores blockchain applications in managing offshore wind energy supply chains. Additionally,

healthcare and pharmaceuticals have gained prominence, particularly in studies addressing risk management and supply chain resilience in response to disruptions such as COVID-19.

Methodologically, the literature employs both empirical and theoretical approaches. Quantitative studies frequently use structural equation modeling, regression analysis, and panel data techniques, while qualitative research relies on case studies and interviews. Key theoretical frameworks include Transaction Cost Theory, often applied to sourcing and procurement; the Resource-Based View (RBV), used to examine firm-level sustainability strategies; Institutional Theory, which explores regulatory and governance challenges; and Fuzzy Set Qualitative Comparative Analysis (fsQCA), a growing method for analyzing complex factor interactions in digital transformation studies.

Emerging trends in the literature suggest a continued push toward sustainability governance, with firms being increasingly held accountable for social and environmental responsibilities in multi-tier supply chains. There is also a rising interest in technology-driven procurement, particularly in leveraging AI and blockchain for supplier risk management. Additionally, post-COVID-19 research is focusing on supply chain resilience, exploring strategies for mitigating future crises. The complexity of global supply chains remains a crucial research area, with studies investigating ways to optimize sourcing and logistics to enhance efficiency while reducing risks. Overall, the literature reflects a rapidly evolving field where sustainability, digitalization, and resilience are shaping the future of supply chain management.

Research objective/question 2

How has internal complexity been looked at/researched in the literature on sustainable supply chain management? Which topics have been elaborated?

Internal complexity in sustainable supply chain management has been examined as a critical factor influencing the implementation and effectiveness of sustainability initiatives. Research highlights the challenges of managing diverse product lines, operational processes, and hierarchical structures emphasizing the necessity for effective interdepartmental collaboration to align sustainability goals Studies also emphasize the role of governance mechanisms in streamlining decision-making. Internal complexity can hinder operational efficiency but also offers opportunities for innovation and resilience-building when managed effectively. Collaboration among departments and stakeholders is vital to foster communication and implement sustainability strategies successfully. Effective complexity management enhances decision-making and improves environmental and social outcomes. Addressing internal complexity is vital for achieving long-term sustainability objectives and enhancing supply chain resilience..

In simple terms, internal complexity may be described as the intricacies and difficulties one meets within an organization, especially when speaking of sustainable supply chain management. It poses multiple challenges concerning the organizational design, product range, and internal resources. Blome et al (2020) explains that in SSCM literature, internal complexity has been examined based on the challenges of managing a firm's complexity. Yang Yang, Yan Jiang, Fu Jia, and Lujie Chen (2023) have studied internal complexity from the perspective of supplier instability in the self-regulated supply chain management (SSCM) context. They elaborate on how the instability of suppliers may significantly change the internal level of complexity within a firm's SSCM system. Imbalances in competition cause disturbance within the stable relationships between suppliers and may result in increased expenditure on marketing. Meanwhile, internally, there is greater involvement in addressing the competitive strategies, which leads to a loss of morale among some employees. This cause shifting in the balance of outwards internal regulation alongside the weaker influences on external factors. Changes in the

tasking, increase in switching costs, and decreased employee morale are some of the negative outcomes caused by fragmentation in interdependence. This is what gathering tasking on the same SCM system without coordination causes.

Many efforts have been made to measure the distinct facets of internal complexity. These gaps underly the inconsistency in definitions.

regarding the internal complexity along with the empirical research. The primary difficulties highlighted in this regard are related with the internal order the manner in which it is arranged, can create boundaries or obstacles for the flow of information and work relationships. To put it simply, intricacy deals with high interactions and organizational challenged that emerge within an entity and one of the foremost challenges faced is organizational structure. most corporations tend to use a parallel structure which tends to create a circumstances or a ban that break communication and collaboration. in such certain scenario the decision making and the further proceedings have a highly negative impact, whereas it can often lead to conflicts thereby have a adverse effect on the internal organizational structure . whereas hierarchical structures which is often characterized in numerous layer of decision making likely delayed due the complexity arising in the organizational structures. in mid to short term enhanced internal organizing a more flexible and decentralized structure by this way it uplift collaboration and communication phase thereby upskill the quicker decision.

In particular, the degree of product assortment in the portfolio is another important source of internal complexity at the company. A number of business units in an organization have varying degrees of distinctive productivity features that yoke in each individual sustainable value added requirement.

As companies try to balance standardization with customization and modularity with internal complexity, they are beginning to deal with a different and perhaps a steeper set of challenges. This relates to and arises from internal diversity which in this case refers to a growing focus on delivering bespoke sustainable goods. Product variety is another aspect that adds to the internal

complexity. There has also been an increase in product offerings by organizations around the globe due to the increasing popularity of eco-friendly and tailored solutions. Even if it gives companies an opportunity to serve different target markets, this variety brings in challenges for the supply chain. Every article may necessitate separate inputs, modes of production, and evaluation of sustainability measures, creating barriers for lean operations and integration of sustainability best practices.

The management of this complexity lies in the development of a firm's product portfolio and supply chain strategy. Firms are utilizing modular design concepts which enable more customization to be offered without excessive focus on standardization. This approach deals with the complexities of integration and at the same time makes it easier to incorporate sustainability issues such as estimating carbon footprints, material utilization, and other efficiency indicators. Additionally, studies indicate that product lifecycle management.

In the paper titled , "Supply Chain Integration and Its Impact on Sustainability" owned by Mingu Kang, Ma Ga (Mark) Yang, Youngwon Park, and Baofeng Huo (2018),they identified the challenges like internal interaction challenges ,followed by supplier and customer integration ,data and information management and capability development are some of the barriers as in the case of internal occurring factors in scam.

Internal complexities also foster difficulties, like coordination challenges, barriers to collaboration, governance, leveraging technology, and the all important inter departmental collaboration. From this perspective, it is not overwhelming to attempt to coordinating operational processes during normal functioning but the operational processes of large corporations can be overwhelming for everyone involved. For instance, one can consider cases where the cost logistics system seeks to maximize profits by using the very lowest cost operators available. The lack of understanding at an organization level makes it very difficult to implement or even strategize sustainability practices because of the overly complex processes and systems that already exist for each organization.

They very much need to be captured at the operational level mostly at the top with regards to the majority of processes. Thus the lack of grasp over the whole region tends to create problems for an organization to know how to best decrease there operational and social impacts on the environment. In trying to solve this, it is imperative for firms to begin to focus on acquiring the skills relevant to the subject as well as developing relevant training and sustainability development programs. This enables the employees within the organization to seek objectives that are beneficial for everyone such as the ceasing of disregarding the wanton degradation of resources.

Focusing on the barrier of collaboration , enhanced efforts needed to be possessed for the departments to maintain collaboration. Effective sustainability programs require interdepartmental coordination. Organizational silos, however, typically stand in the way of being able to accomplish this consistency. It is difficult to develop a cohesive sustainability strategy when departments operate independently of one another. Empirical research has established that firms with high interdepartmental coordination will be more effective at putting sustainability programs into action. In the paper multi tier supply chain learning networks a stimulation study ,it explore the difficulty in collaboration ,contingency factors along with the limited positive impact of integral integration . the paper clearly state Internal integration significantly and positively impacted intra-organizational but not inter-organizational sustainability management practices (SMPs). Internal integration played a less significant and weak role compared to supplier integration. The findings also necessitate more research studies that explore contextual factors that could be able to mediate internal integration's influence

In order to shatter collaboration barriers, organizations must foster a collaborative and open culture. This can involve implementing cross-functional teams that bring together members from different departments to create sustainability projects. In collaboration, organizations can ensure varied perspectives are given consideration and work is coordinated.

Focusing on the governance issue ,it leads a crucial role in intercity. There must be governance frameworks and policies to deal with internal complexity. Good governance involves the creation of transparent and well-defined roles and responsibilities, defining measurable

objectives, and the implementation of accountability measures. Poor governance will lead to business process misalignment with sustainability objectives, contributing to the complexity of dealing with internal complexity.

Organizations must make sure that the governance systems support sustainability goals as they satisfy the different needs of different stakeholders. This must be achieved by aligning the governance systems with organizational values and culture so that sustainability goals are promoted and communicated within the organization itself.

New technologies have the potential to manage complexity by providing data analysis, transparency, and communication tools. For example, life-cycle assessments (LCA) can assist organizations in analyzing the environmental footprint of products and making better-informed decisions. Nevertheless, the use of LCA is usually hampered by data issues, including data availability, quality, as well as compatibility of data among departments and supply chain partners.

To resolve these challenges, organizations are spending on digital technologies and data management solutions that make it easier to gather, analyze, and share sustainability information. For example, cloud-based platforms allow real-time data sharing, providing greater transparency and decision-making. Additionally, the use of AI and ML in LCA software is improving its predictive capacity, allowing organizations to simulate the potential impact of competing sustainability approaches and make informed decisions.

Technology is also tackling internal complexity in sustainable supply chain management. New technologies such as blockchain, Internet of Things (IoT), and artificial intelligence (AI) are transforming the way companies are managing their supply chains. Blockchain, for instance, provides a secure and transparent method of documenting transactions, which enables companies to monitor the origin of materials and confirm compliance with sustainability procedures. This technology is especially useful in resolving the complexity of multi-tier supply chains, in which a lack of visibility is typically the greatest obstacle to sustainability.

IoT devices, on the other hand, offer real-time monitoring of supply chain activities, such as tracking the status and whereabouts of products in transit. Such data can be used to optimize routes, save energy, and reduce wastage. AI and machine learning are being used in processing

large amounts of supply chain data, identifying patterns, and predicting disruptions that are most likely to happen. These technologies enable organizations to anticipate and act ahead of time and enhance their overall sustainability performance.

Although internal complexity poses existential challenges, it also creates opportunities for innovation and resilience-enhancement. Complexity has a way of compelling organizations to innovate more and consider other ways of managing supply chains. The use of circular economy concepts has, for instance, accelerated as a means of minimizing waste and preserving resources. The framework compels businesses to reconsider supply chains in a bid to facilitate the reuse of products, remanufacturing, and recycling, which can lead to enormous environmental and economic gains.

In addition, tackling internal complexity can also be employed to build organizational resilience. Through process simplification, enhanced collaboration, and the use of technology, organizations can develop more resilient supply chains that can better withstand disruption. Studies have shown that resilient supply chains are not only more sustainable, but they are also more competitive since they can rapidly respond to changing conditions and address evolving customer needs.

Collaboration can enable organizations to respond to shifting environmental pressures and establish overall resilience. Through collaboration, departments can pinpoint potential risks and create contingency strategies for reducing them. Proactive risk management is necessary to enable the long-term success of sustainability initiatives. Cross-functional teams are able to develop creative ideas and solutions for difficult sustainability challenges. When people with various departmental backgrounds collaborate, they possess varied ideas and knowledge that can potentially generate innovative solutions. The collaboration may also support organizations in developing resilience that helps them deal with environmental pressures that shift with time and enhance overall sustainability performance.

internal complexity in sustainable supply chain management is a multifaceted phenomenon that includes organizational design, product diversification, business processes, and the integration of sustainability practices. While complexity can impede decision-making and performance of operations, it also holds promise for innovation and building resilience. Central to the

management of internal complexity are strategies of developing collaboration between departments, leveraging innovative technologies, applying strong governance mechanisms, and adopting systems-thinking practices. Through internal complexity management, organizations can enhance their sustainability performance, supply chain resilience, and overall environmental and social performance. Those that effectively deal with internal complexity will be better placed to embed sustainable practices and achieve their sustainability objectives, thus making their contribution

Research objective/question 3

Internal complexity in supply chain management is clustered around various individual dimensions within the company such as structural, hierarchical, operational, and collaborative factors. Different dimensions when they come together will eventually shape how the organization will navigate through the challenges and find and utilize opportunities within increasingly detailed supply chain networks.

Dimensions of internal complexity:

It starts with the structural composition of within an organization. This also includes the number of interconnected components like employees, the departments, and the technological systems as well as the hierarchy within the organization is also there. Glenn and Malott .et al (2004) identify internal complexity into "component complexity," which actually refers to the number of elements in the company and "hierarchical complexity" which shows the vertical layers of decision-making in the company. For instance, as organizations grow and expand, the addition of employees and the functional layers inevitably increase their internal complexity (Cicerelli and Ravetti, 2024). Vogel and Lasch (2016) further classify this, they classify this into correlated complexity which is actually influenced by the external market forces and the autonomous complexity which can be determined by internal factors like organizational processes and variety of the product being supplied.

The other dimension of operational complexity which comes into place in the processes and workflows within a supply chain of a company. Blome et al. (2014) highlights how product diversity and frequent manufacturing will schedule changes and can disrupt the efficiency and quality of control within a company. On the other hand, high product and part variability for instance, as seen in automotive production will often lead to capacity conflicts and higher operational costs (Wiengarten et al., 2017). These operational intricacies are critical to consider when clustering complexity in supply chains in companies.

Managing the internal complexity also involves the collaboration which is across different company levels and departments. Frostenson and Prenkert (2015) argue for a network perspective where internal and external complexities overlap pointing out relational approaches rather than the

traditional hierarchical command structures. For example, the IKEA's sustainable cotton initiative shows how the focal firms through the internal governance mechanisms will in future coordinate across tiers especially to align with the operational goals of the sustainability targets (Gong et al., 2023). These things actually highlight the need for a robust internal collaboration to then handle the multi-tier supply chain complexity effectively and efficiently.

Internal complexity has both its cons and opportunities. On one hand, we can say that it can weaken the operational efficiency because of system turbulence and increased transaction costs (as suggested by Hoole, 2006). For example, Bode and Wagner (2015) also demonstrates how the internal complexity, especially in the upstream operations like supplier diversity, can strain some resource allocation and communication as well. On the other hand, managing complexity effectively can also enhance resilience and innovation. According to Reeves et al. (2020), the company that embrace complexity management tools, such as integrated information systems will in future gain a competitive edge by improving their adaptability and long-term stability.

Complexity is not inherently detrimental. Anderson et al. (2006) show that "good complexity," such as product customization, can create value through enhanced customer satisfaction and loyalty. Conversely, "bad complexity," coming from poorly managed systems or unnecessary procedural layers, diminishes profitability in a company. This dual nature underscores the importance of strategic clustering and management of internal complexity to balance operational needs and market responsiveness.

In order to tackle internal complexity and manage it, firms have to develop strategies that are appropriate to the firm’s operations and market circumstances. For instance, IKEA’s application of direct and indirect governance mechanisms across its supply chain tiers reveals a model of complexity management that is both flexible and structured (Gong et al., 2023). This trend also includes the use of digital tools and the metrics to monitor and streamline processes as a form of increasing complexity management (Cicerelli and Ravetti, 2024). These practices also highlight the significance of context-specific approaches in navigating the complexity-adapter framework. Hence, the concept of internal complexity is clustered into structural, operational, and collaborative dimensions, each having its own set of challenges and strengths. This paper finds that the understanding of these clusters is critical in the management of effectiveness and

resilience, and in the identification of inefficiencies. The strategic implications of the internal complexity clustering for sustainable and competitive supply chain management are further supported by the nuanced findings from various industries and case studies such as IKEA and the electronics sector.

Managing and clustering internal complexity in supply chains is thus achieved through integration strategies that attempt to reduce delays and other forms of inefficiencies across the hierarchy and functions of the firm. Frostenson and Prenkert (2015) note that internal complexity should be seen as a part of a larger system, and not as a separate organizational issue. This permits the firms to position their internal activities in relation to the complex system of relationships in their external environment. This paper presents IKEA's sustainable cotton program as a good practice where mechanisms such as one-to-one interaction with suppliers and indirect supervision by third-party entities were used to tackle different levels of internal and external complexity (Gong et al., 2023). These governance tools helped IKEA to coordinate many processes, beginning with the procurement of raw materials and ending with the production of the finished article, and ensure that sustainability was addressed at each stage.

The theory of requisite variety suggests that the internal systems of an organization must be complex enough to match the complexity of its external environment (Ashby, 1956). Multinational companies with complex supply chains need well-rounded internal processes to deal with external uncertainty and achieve fit with their operations. This is especially important for multi-tier supply chains where firms like IKEA create internal collaboration to manage uncertainty in upstream suppliers and downstream consumers (Gong et al., 2023). Such grouping of complexity into controllable governance structures is important in risk management, sustainability and flexibility of supply chains.

Supply chain internal complexity is not a single problem but rather a supply chain complexity concept that can be divided into several areas and can be managed effectively through governance, technology and collaboration. From the structural and hierarchical complexities to the operational and collaborative complexities, the effective clustering of internal complexity helps firms to improve their resilience, create new values, and, thus, address sustainability issues. The electronics

industry and IKEA case studies demonstrate how companies can reimagine complexity as a source of competitive advantage. Using specific governance structures and ensuring overall internal and external systems' coordination, companies can therefore manage the complexity of the modern supply network while preserving agility.

In the area of supply chain management, internal complexity has been grouped into clusters based on various methods according to different levels of complexity; structural, operational, and behavioral complexity levels. The structural complexity is often grouped by product variety, supply network tiers and organizational hierarchy with hierarchical clustering, k-means and self-organizing maps (SOM) are used. Demand variability, process uncertainty and inventory dynamics are the operational complexity clustered using time series clustering, fuzzy clustering, and density-based clustering (DBSCAN). Thus, behavioral complexity, resulting from human and decision-making issues, is simulated by agent-based modeling and social network clustering. Some of the approaches include ensemble learning methods and machine learning based clusters, which are used in combination to give an overall view. The clustering is performed through industry specific segmentation where latent class analysis and principal component clustering are used to detect the essential characteristics and trends which are specific for supply chain scenarios.

Research objective/question 4

Which future research opportunity exists in the paper?

In the last few years, Sustainable Supply Chain Management (SSCM) has attracted much attention owing to increasing social and environmental concerns, legal pressures and the need to improve business performance. As a result, supply chains are increasingly global and more complex, offering both advantages and challenges for organizations trying to incorporate sustainability into their operations. Of these challenges, however, internal complexity is defined to include structural, hierarchical, operational, and collaborative factors emerges as an important area that needs further inspection and management.

The purpose of this paper is to examine the current state of the literature on internal complexity in the supply chain management context, with a specific focus on its impact on the attainment of sustainability goals. To this end, the present study aims to systematize the examination of internal complexity in the context of supply chain management based on the analysis of academic articles and to determine further directions for research.

Internal complexity refers to the interactions that occur within an organization's supply chain and includes factors such as people, departments, decision making, and technology. For instance, as organizations grow they become more structurally complex due to the creation of new functional levels and employees. Operational complexity, which is characterized by many products and changing schedules, may disrupt flow and decrease efficiency. The proper control of these complexities is critical for sustainability as uncontrolled complexity affects decision-making, increases costs, and reduces the ability to respond to changes.

The intersection of sustainability and supply chain management have an attractive area for future research. Even while our knowledge of sustainable supply chains has advanced, there is still much to discover, and a number of topics present encouraging prospects for further research.

1.Integrating Internal Complexity with Sustainability Goals: Understanding how internal complexity the manner in which teams, departments, and decision-making processes within organizations impact a company's capacity to meet sustainability goals is a key for future research. How can businesses ensure that sustainability is ingrained in every decision by

streamlining procedures, fostering better teamwork, and improving communication? Examining how organizational culture and structure affect sustainability efforts may help businesses come up with new ways to work together more successfully on shared environmental objectives.

2. Collaboration and Transparency with Suppliers: It will be very difficult for many companies to make sure that their suppliers share their commitment to sustainability .If the remaining part of the supply chain is not based on sustainability principle, it is not sufficient for companies to focus on its operations. Research may look at how companies might build more intimate, transparent relationships with their suppliers to ensure that sustainability is a shared issue across the entire process. One promising possibility is to use technology, like blockchain, to improve accessibility and visibility. With blockchain, businesses can easily collect and share key information that helps make sure every part of their supply chain is up to scratch when it comes to sustainability. It’s like having a reliable, unchangeable record of everything that happens, so companies can be confident that their operations are both responsible and trustworthy. This means that every decision is backed by trustworthy, traceable information, so companies can confidently show their commitment to both the environment and their customers.

3. Circular Economy and Waste Reduction: where resources are reused, recycled, and regenerated instead of being thrown away—has gained a lot of attention lately. While it's become a popular concept, research on how to apply circular practices on a large scale within supply chains is still developing. Future studies could focus on creating practical models for implementing these circular principles, like reverse logistics (bringing products back for reuse), upcycling (turning waste into new products), or strategies that extend the life of products. It’s also important to look at how businesses can work together with their partners to make these ideas work in the real world, ensuring that circular economy practices can be put into action effectively and sustainably.

4. Sustainable Technologies and Innovation: As technology keeps advancing, there are more and more ways to make supply chains more sustainable. Future research could focus on how new innovations, like AI, machine learning, automation, and the Internet of Things (IoT), can help make operations more efficient while also reducing their environmental footprint. AI, for

example, could help businesses get a better handle on predicting demand, which would reduce waste and prevent overproduction. Research could also explore how supply chains can run on renewable energy and green technologies, mixing efficiency with a strong focus on the environment. In the end, it's all about finding smarter, more sustainable ways to keep supply chains running efficiently without hurting the planet. The goal is to strike a balance where both businesses thrive and the environment benefits. It's about creating solutions that work for everyone.

5. Cultural and Regional Differences in Sustainability Practices: Sustainability practices may vary depending on the various locations, shaped by cultural, social, and regulatory factors. A research study could finds into how businesses can modify their sustainability strategies to fit the unique characteristics of the places they operate. By finding these differences in the regions , companies can build more effective, locally relevant approaches that focus on the values of consumers, comply with local regulations, and address specific environmental challenges.

6.Sustainable Sourcing and Ethical Procurement: As customer demand for ethically sourced products increases, companies make sure their sourcing practices reflect sustainability values. Future research could explore how businesses can integrate sustainability and ethical considerations into their procurement processes, from selecting raw materials to ensuring fair labor practices across the supply chain. Also, research might look into the function of certification standards like Forest Stewardship Council or Fair Trade and how companies can utilize these principles to guide their sourcing choices. Additionally, a major area of focus would be on how organizations can strike a compromise between cost considerations and ethical sourcing, particularly for those with fewer resources or operating on restricted budgets.

7.Measuring and Reporting Sustainability Performance: One of the major issues for businesses today is finding out how to effectively measure and report their sustainability efforts. Future research could focus on developing better tools and metrics to assess the environmental and social impacts of supply chains. There's also a need for standardized reporting systems that make it easier for companies across different industries to track and share their progress. Research could explore how companies can engage their customers, investors, and other stakeholders with

transparent, meaningful sustainability reports that showcase real, measurable impact. Using technologies like blockchain for more accurate and real-time tracking might also be part of this, making it easier for businesses to prove their commitment to sustainability and hold themselves accountable.

In conclusion, there are exciting opportunities available for future research in sustainable supply chain management. By focusing the main areas like internal complexity, supplier integration, circular economy etc. companies can build effective supply chain. It will help the business to meet the customer needs and satisfaction.

Conclusion and further research

Growing demands for efficiency, and resilience of supply chains in the global market put pressure on a business to deeply understand and manage internal complexity. By internal complexity, one means multi-dimensional and very often interdependent structures, processes, and decision-making mechanisms of an organization. In the context of supply chain management, this directly impacts operational performance and organizational capabilities. As businesses aim for more complete integration of sustainability goals, the ability to better manage internal complexity becomes an area of increasing focus.

In this paper, we have seen throughout how internal complexity can present either a barrier or an enabler to supply chain operations, depending on its management. Such an ability of complex internal processes to align with overarching organizational goals-most notably those of sustainability-can go a long way in influencing the competitive advantage of a company and its operational performance. With increasing interconnectedness of departments, technologies, and decision-makers within a business, the environment where a business operates becomes more intricate, needing careful attention and strategic management.

It could be found from this paper that the realization that internal complexity should not be regarded as an obstacle but rather as a resource in its own right, if properly managed, has greater operational performance and faster organizational agility. Organizations that understand how their inner mechanics and teams connect the dots are able to foster smooth decision-making, good communication, and the elimination of redundancies. Resulted in more workflow efficiency, better response times, and an added capacity to cope with market ups and downs, and disruption within the supply chains.

In the light of supply chain management, internal complexity directly affects the flow of information and materials across the system. As supply chains go global and involve many stakeholders, the challenge of coordination across teams and departments is also increasing. More importantly, companies should ensure there is a free flow of information across departments dealing with sourcing, production, logistics, and customer service. The basic ways

to reduce internal complexity can inhibit decision-making or lead to a misalignment of objectives are through silo-busting inside the organization and cross-functional collaboration.

Apart from that, businesses must understand that operational performance encompasses not only efficiency but also responsiveness to changing customer needs, environmental concerns, and related legislation. As consumers increasingly require products to be more sustainable and sourced with greater ethical sensitivity, companies must respond to such pressures. Businesses that can understand the internal complexities and their influence on sustainability objectives will use this understanding to align their supply chains to these more pervasive drivers. Therefore, the more one can achieve sustainability aspects-reducing waste, energy efficiency, ethical sourcing-so increases the involvement and coordination required between departments in every regard that touches knowledge and competence. An organization will increasingly be successful in developing those sustainability aspects to the level at which cooperation within the working team is advanced and the respective expert knowledge present.

As we consider the future of supply chain management, it's clear that organizations need to rethink their internal structures and capabilities. Research on internal complexity should focus on how to optimize the interaction between various organizational components, making supply chain operations more flexible, transparent, and efficient. Technology plays a critical role here, as advancements in data analytics, AI, and automation can help organizations reduce complexity by providing real-time insights, enhancing decision-making, and improving responsiveness to disruptions. These technologies can also assist in monitoring sustainability performance, making it easier for organizations to track their progress toward sustainability goals and adjust operations accordingly.

Another important aspect of managing internal complexity is enhancing organizational capabilities through continuous learning and adaptation. In a rapidly evolving business environment, companies that embrace complexity as an opportunity for growth are better positioned to innovate and remain competitive. Training programs, knowledge-sharing platforms, and collaborative environments that encourage cross-functional teamwork are essential in developing the capabilities required to tackle complex supply chain challenges. As

companies move toward more sustainable business models, the ability to adapt and innovate becomes even more crucial.

In conclusion, internal complexity, when understood and managed effectively, can enhance operational performance and organizational capabilities within supply chains. Businesses that proactively address complexity in their internal structures will find themselves more agile, resilient, and capable of responding to both operational challenges and sustainability imperatives. By fostering cross-departmental collaboration, leveraging technology, and focusing on continuous learning, organizations can turn internal complexity into a source of strength—ultimately driving improved performance, greater sustainability, and long-term success.

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