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Achieving Sustainable Supply Chains: Applying Group Concept Mapping to Prioritize and Implement Sustainable Management Practices

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Abstract

Background: Sustainability in supply chain management (SCM) practices is becoming increasingly important as environmental responsibility and social concerns, as well as enterprises' competitiveness in terms of innovation, risk, and economic performance, become increasingly urgent. This paper aims to identify and prioritize concepts for implementing sustainable supply chains, drawing on sustainable supply chain management (SSCM) and green supply chain management (GSCM) techniques. Corporate supply chain managers across various industries, markets, and supply chain segments brainstormed management practices to enhance the sustainability of their supply chains. Four industry sectors were surveyed across five different value chain segments. *Methods:* A group concept mapping (GCM) approach incorporating multi-dimensional scaling (MDS) and hierarchical cluster analysis (HCA) was used. A hierarchy of practices is proposed, and hypotheses are developed about achievability and impact. *Results:* A decision-making matrix prioritizes eight solution concepts based on two axes: impact (I) and ease of implementation (EoI). *Conclusions:* Eight concepts are prioritized based on the optimal effectiveness of implementing the solutions. Pattern matching reveals differences between emerging and developed markets, as well as supply chain segments, that decision-makers should be aware of. By analyzing supply chains from a multi-part perspective, this research goes beyond empirical studies based on a single industry, geographic region, or example case.

Keywords: sustainability; green supply chain management practices; organizational change; group concept mapping; prioritization of implementation

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1. Introduction

This research study is primarily rooted in the concepts of sustainable supply chain management (SSCM) and green supply chain management (GSCM). GSCM and SSCM have emerged as key fields over the last 50 years, both theoretically and practically, to mitigate environmental and social externalities imposed on the natural world by modern global infrastructure. These costs are driven by the need to meet rapidly escalating consumer demand, as well as the policies, laws, and systems that support the global economy. Throughout their development, GSCM and SSCM have evolved from more environmentally focused frameworks to a model that consistently embraces the three pillars of sustainability, encompassing environmental, social, and economic pillars [1].

This research aims to go beyond the broad, quantitative analyses of GSCM and SSCM practices based on large-scale, more superficial surveys, as well as case studies that focus on single cases, industries, or geographic sites. While case studies are popular [2,3] and even deemed fundamental in SSCM and GSCM literature, they are also viewed as lacking rigor [4] and are typically of an exploratory nature, focused more on identifying future research aims instead of advancing pre-conceived hypotheses [5]. The SSCM literature, compared with GSCM, has emerged only in the past few years [6] and can benefit significantly from multi-disciplinary approaches and methods to improve the state of the art in the SSCM research field [7–9].

The challenge with highly quantitative studies is that although they are rigorous, they can often lack insight and context. At the same time, the use of case studies has received criticism for their lack of exactness and rigor [10]; however, they have also proven to be popular, particularly in areas such as supply chain management (SCM), GSCM, and SSCM, where application or practical implementation is crucial. While the importance of academic rigor has always been emphasized, the issue of relevance has often been less appreciated. In recent years, critics of academic research have emphasized the need for academic research to be more relevant, arguing that quantitative analyses often prove remote and irrelevant to practitioners and managers in the field [11]. More recent studies have suggested that academic research needs to do a better job of helping managers better understand themselves and their organizations, in more practical terms [12].

For these reasons, this research study used a mixed-methods research approach. Although mixed methods have not been used very frequently in the SSCM and GSCM fields, with less than 5% of papers deploying such methods and approaches [5,13], the application of mixed-methods research design is cited as needing greater attention [14] and is required if the SSCM and GSCM fields are to be successful in integrating multi-disciplinary tools and approaches [9,13].

This study used a convergent parallel mixed-methods research design, also known as empirical triangulation. This approach involved collecting both quantitative and qualitative data at the same time, analyzing each separately, and then combining them for interpretation. The group concept mapping (GCM) technique used in this study aligns with this method. In the initial qualitative phase, one-on-one interviews were conducted based on several prompts, during which participants shared their own ideas, words, and formulations. In the second quantitative phase, the statements from participants were cleaned, validated, and then quantified into concepts using multidimensional scaling (MDS) and hierarchical cluster analysis (HCA). In the final interpretive phase, the empirically derived clusters of concepts are visually represented in relation to each other. This allows researchers and participants to develop interpretations, including latent constructs, and gain insights to draw conclusions. The benefit of this approach is that it enables researchers to confirm, cross-validate, and corroborate their findings [15].

The history of what was initially GSCM and evolved into the field of SSCM research is rooted in industrial ecology, having emerged in the United States and gained traction in the 1960s and 1970s. Studies in this field employ an "operational approach to sustainability," focusing on three key ideas. "Firstly, that human industrial infrastructure and the broader biosphere need to be viewed in an integrated, systemic way. Secondly, industrial systems are not just economic, consisting of currency flows, but are also physical, comprising biophysical material flows. Thirdly, it recognizes the role of technology, among other factors, in playing a vital role in transitioning to a sustainable industrial system [15]" [16] (p. 180).

In recent decades, GSCM has been increasingly adopted globally, particularly in emerging markets, where issues related to industrial pollution and the need to modernize the economy have demonstrated that its practical applications can have a significant impact [17,18].

There are numerous definitions of GSCM and SSCM in the literature, along with extensive discussions on the various overlaps and pillars that comprise the different conceptual frameworks and models. The general conclusion, however, is that while GSCM is more established, with SSCM seen as an extension of GSCM, SSCM is viewed as a broader, more encompassing research field, covering multiple pillars, including social spheres and triple bottom line aspects. Nevertheless, SSCM builds upon the original foundations of the GSCM research field [1,19].

To make sense of the relationships between the GSCM and SSCM concepts and their antecedents, most notably sustainable development (SD), and avoid ambiguity and confusion, it is helpful to trace the history of these concepts and their terminology over the past 75 years. This is crucial in order to minimize the ambiguity and confusion associated with the terminology as much as possible.

A practical challenge presented by the similarity of the frameworks and their broad array of definitions is that they are often used interchangeably in everyday, informal business environments. This is also often the case in academic contexts. For example, Mutingi [20] suggests "[t]he term "green" is now widely used interchangeably on the more established "sustainability" concept, which points to a more holistic view of environmental, social and economic impact [21–23]" (p. 526).

More recently, however, it has been suggested that SSCM is the broader, more comprehensive framework from which GSCM is a subset. For example, Ahi & Searcy [1] suggest the following:

> "*Overall, the results indicate that the definitions for GSCM were generally more narrowly focused than those for SSCM, with an overwhelming emphasis on environmental issues. Though some definitions of SSCM show considerable overlap with definitions of GSCM, it is clear that SSCM is essentially an extension of GSCM.*" (p. 334)

To alleviate ambiguity and ensure cohesion, this study refers to SSCM as the overarching construct or framework that encompasses all overlapping concepts and definitions. This is illustrated in Figure 1, below. This approach is consistent with how the research was carried out during the interviews and discussion with participants, whereby stakeholders were onboarded into the research with an introduction to the different definitions. This is elaborated in more detail in the following sections.

The evolution of GSCM and SSCM is built on key concepts that emerged previously, specifically, SCM and SD. The globally accepted definition of sustainability originates from the concept of SD introduced in the Brundtland Report of 1987, which outlines the three pillars or principles of environmental, social, and economic sustainability [24]. Stemming from this definition, the business concept "triple bottom line" (TBL) was coined in 1994 as a method to practically measure and subsequently integrate management practices into business to achieve sustainable outcomes [25].

Supply Chain Management (SCM) is foundational to the concepts of GSCM and SSCM. SCM is a business and logistics concept that is distinct from environmental and social issues. Some of the earliest concepts of SCM were articulated by Forrester [26], who described the essence of an end-to-end global supply chain encompassing all aspects of physical, financial, and information flows that are both a cause and an effect of modern industrial production.

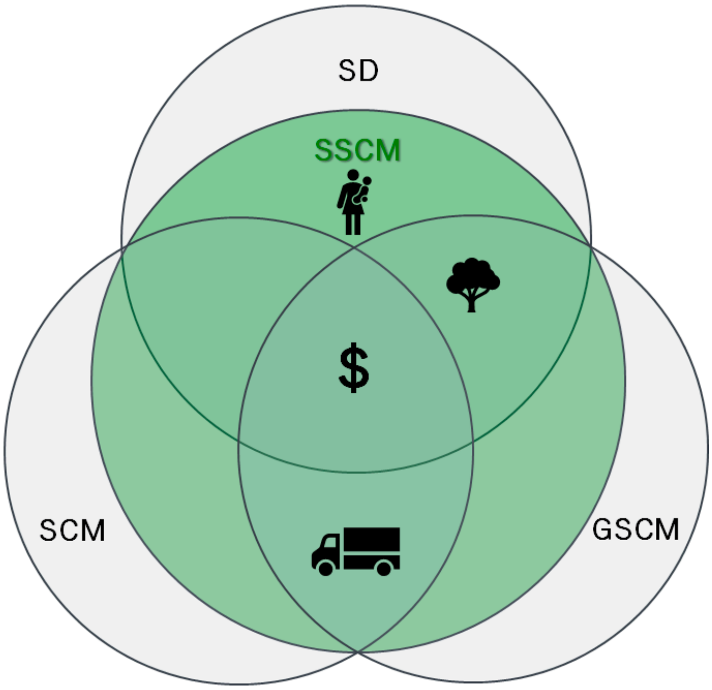


Figure 1. Intersection and relationship of key terminology.

The term supply chain management (SCM) was initially coined in 1982 by Keith Oliver, a consultant, in an oft-cited newspaper article in The Financial Times [27]. The focus of SCM was initially financial, with an additional focus on overcoming management barriers such as the tendency for disparate functions to operate separately, in so called 'functional silos' [28]. As an academic field, SCM is well established, having grown exponentially over the past 20 years, and is considered a mature and quantitatively rigorous field of research relative to other management fields. It has a significant impact and numerous interdisciplinary directions, including sustainability [29]. For example, Sinoimeri and Teta [30] analyzed 76,493 articles from 2012 to 2022, underscoring the discipline of SCM as critical for business management in terms of enterprise development and competitiveness. Their research also highlights the increasing importance of sustainability as an interdisciplinary field of study. "The terms 'Sustainability,' 'Green Supply Chain Management,' and 'Sustainable Supply Chain Management' underscore the shift towards integrating environmental concerns within Supply Chain Management, reflecting its growing significance in bolstering both operational efficiency and sustainability" [30] (p. 16). The concept of SCM as a science in its own right has evolved significantly, as many authors have emphasized its scientific nature, leveraging complex models and approaches to yield both practical and theoretical applications [31].

The idea of merging environmental concerns with SCM started taking shape in the 1990s [32] and led to the GSCM concept shortly thereafter [33]. Seuring & Müller [34] expanded the definition further to more explicitly highlight social issues emerging in supply chains, referencing both the original Brundtland Report and its definition of sustainable development (SD), as well as the TBL framework originally introduced by Elkington. In this way, both SD and TBL have become pillars of the SSCM framework.

There has been a sharply growing volume of literature on both the SSCM and GSCM topics over the last 15 to 20 years. However, it remains an evolving and ongoing topic in terms of defining both terms precisely [1,35,36]). Ahi & Searcy [1] identified "22 definitions for GSCM and 12 definitions for SSCM" (p. 329). More recently, Souhli et al. [19] identified and analyzed "a total of 30 definitions for Green Supply Chain Management (GSCM) and 19 definitions for Sustainable Supply Chain Management (SSCM)" (p. 811). This underscores the notion that despite its increasing prevalence in scientific research, the actual implementation of supply chains with significant sustainable or environmental focus would benefit from clearer theoretical modelling and management strategies.

It has been suggested by Saini et al. [35] and Souhli et al. [19] that the overall vision of GSCM and SSCM may be limited from the management perspective. This is somewhat substantiated by the research, which reveals a lack of consistent cohesion across more than 50 combined definitions. This suggests that a comprehensive framework may be required to fully understand the potential impact of GSCM and SSCM on financial, social, and environmental performance. This highlights the challenge and complexity of being overly prescriptive or precise when applying these definitions, particularly in practical business contexts. Ultimately, this research does not aim to build or clarify in the direction of defining what is or is not an SSCM but instead attempts to focus on the challenges of "what" a SSCM is in the real world, "why" a given example or model of an SSCM successfully or unsuccessfully meets the determined standard, and "how" to replicate.

Because achieving sustainability is a complex problem driven by modern economic structures and exploding consumer demand worldwide, supply chain-based solutions are a key component of any overall solution [15]. "When defining the scope of Green Supply Chain Management (GSCM) [and by extension SSCM], a variety of perspectives [36] that cover key organizational activities are considered, including product design, procurement, manufacturing, packaging, logistics, and product end-of-life management [6,37]. Concepts that focus beyond the functional activities of a single organization and emphasize the decentralized nature of multiple complex actors are necessary to define the modern supply chain [38,39]. From this perspective, one can think of SSCM and GSCM as an integrated system [40]" [16] (p. 180).

When evaluating SSCM and GSCM definitions, it is also important to consider a wide context of operating conditions, for example, emerging markets [41]. This multitude of viewpoints, considering the variety of causes and solutions for mitigating environmental and social impacts through the design and deployment of SSCM practices, is notable. This study's approach to understanding SSCM focuses not only on the validity of potential approaches but also on their implementation, which is a critical topic [42]. The current authors used group concept mapping (GCM) to tailor hypothesis development towards a more inductive approach than other studies. Rather than developing broad hypotheses from singular case studies, the authors deployed a quantitative approach, generalizing from multiple in-depth observations from experts. This allowed us to develop solutions applicable to broader contexts.

Key drivers for expanding GSCM more explicitly into the social sphere include the emergence of global supply chains, the outsourcing of production to low-cost countries, and the prevalence of unfair labor practices. "For example, apparel distributors such as Nike, Disney, Levi Strauss, Benetton, Adidas, or C&A have been blamed in recent years for problems occurring during the production of their clothing" [34] (p. 334).

In recent years, SSCM and GSCM have moved significantly beyond traditional models. Key developments such as digitization [43], circular approaches to manufacturing [44], focus on lifecycle thinking [45], innovative sustainable business models [46], sustainable lifestyles [47,48], sustainable design principles [49,50], and specific products and services [51] are driving developments in the field of SSCM. Specific examples of how GSCM and SSCM have evolved in recent years include such diverse areas as using digitization, such as in the Internet of Things (IoT) [52] where sensors can be used in agriculture and other fields to increase circularity in processes and mitigate socially and environmentally harmful impacts of the supply chain.

In addition to the numerous benefits that an SSCM and GSCM approach brings to supply chain management, trade-offs must also be considered, along with a perspective that encompasses multiple stakeholders, including consumers, policymakers, individual enterprises, and entire industries. When organizations adopt SSCM approaches, such as circular manufacturing, the economic benefits are not always easily distributed across stakeholder groups or in terms of the timing of costs incurred and benefits received. This creates barriers to implementation and complexity in developing and implementing solutions [53].

Another significant barrier to achieving sustainability through circular processes, which is also a tremendous opportunity, is the lack of processes and approaches that allow better transparency of material flows across the entire lifecycle of the value chain. This can be achieved through improved tracking and traceability, which can help reduce waste, increase efficiency and spread both benefits and externalities more fairly across global populations. The increased use of product labeling is just one example [54]. Exploiting design principles in the development of novel approaches to achieving sustainability is proliferating at a significant rate. It has been observed in the end-to-end design of the entire supply chain [55], as well as the level of products and services [51] and the use of technology [56].

Culture [57] and sustainable lifestyle [58] are typically seen as softer aspects of the supply chain. Along with business processes, they are increasingly recognized as key components in the solution set to further a holistic approach to achieving sustainability.

Furthermore, the following has been noted [43]: "Research works addressing multiple parts of a supply chain are hardly found" (p. 2010). The GSCM and SSCM studies that address entire supply chains mainly focus on a single industry, are generic, and do not pertain to a specific focal firm; thus, they cannot address root causes at the grassroots level. The drawback of such studies is that they remain at a high level and thus cannot provide insight into the low-level factors necessary to initiate implementation [45].

An area of increasing strategic relevance for SSCM is the need for individual enterprises and supply chains to take action in terms of implementing SSCM. Of particular importance is the need to engage in dynamic strategic actions, which happens less frequently, rather than take only reactive actions or cooperative actions [59]. At the same time, understanding the range of specific practices for implementing sustainability is highly relevant. The SSCM and GSCM literature accurately identifies a broad range of practices. Shekarian et al. [60], for example, identify and categorize over 789 specific practices, categorizing them into a framework of 11 main categories and 38 minor practices. Kähkönen et al. [61] provide a more conceptual and theoretical framework that conceptualizes practices across three dimensions, covering external vs. internal, proactive vs. reactive, and environmental vs. social. In both cases, the specific and practical approaches, as well as the more theoretical frameworks, provide findings consistent with this research. This study, however, attempts to go further by providing a framework for decision making and prioritization.

Upon analyzing the literature surrounding sustainable supply chain management (SSCM) and green supply chain management (GSCM), it is evident that the majority have utilized empirical studies or mathematical modeling approaches, while a smaller proportion of papers have focused on literature reviews [36]. Despite the extensive use of various tools and techniques in empirical studies, the specific application of group concept mapping (GCM) approaches that incorporate multidimensional scaling (MDS) and hierarchical cluster analysis (HCA) for creating visual "concept maps" based on participants' data sorting has received limited attention. Historically, papers that employ GCM with MDS and HCA have primarily concentrated on fields such as healthcare, education, and community development, rather than in business, and particularly not in supply chain management. For instance, Group Wisdom (n.d.) notes that among their database of 489 studies, only 18 pertain to business and marketing, with none related to SCM, GSCM, or SSCM; additionally, of the 25 categories where GCM analysis has been conducted, only one—business and marketing—concerns private industrial enterprises. Meanwhile, the remainder are focused on healthcare, educational institutions, or community development organizations.

By deploying GCM, this study presents a novel approach to enhancing the understanding of GSCM. While the GCM approach has been used successfully to study value chains [62], environmental certifications [63], evaluation and program planning [64], quality performance within complex manufacturing environments [65], and improvements in government services [66], it has not been extensively used in the GSCM and SSCM fields, especially when considering a mixed-methods approach combining GCM with MDS, HCA, and empirical triangulation.

Unlike studies cited in the latest comprehensive literature reviews, which are generic and do not address specific firms, the GCM approach involves interviews with specific supply chain managers and specific companies. This study's novel elements extend its generalizability to multiple industries, geographical markets, and organizational perspectives.

This study included participants from four different industries, representing multiple organizations, markets, and diverse perspectives on the value chain. This is in contrast to other GCM studies that have considered single industries, such as the novel biomass-based value chain [64], the aluminum industry [63], or the automotive industry [65]. The four industry segments that were surveyed—metals and mining, packaged consumer food and beverage, automotive and vehicle manufacturing, and consumer electronics—were selected based on common themes and characteristics. They are global, with nodes across the end-to-end chain separated by long distances. They are recognized as negatively impacting the environment in multiple areas, including climate change (metals and mining, packaged consumer food and beverages), biodiversity loss (metals and mining, consumer electronics, and food and beverages), and the release of toxic pollutants (consumer electronics, metals and mining). They represent significant sectors of the economy in most countries.

While assessing the wide range of benefits and trade-offs, and the overall development of theory and practice identified in the GSCM literature, one of the most significant challenges that remains is how to overcome barriers to implementation [67]. To gain novel insights into these broad arrays of challenges and opportunities, and come up with practical, impactful solutions, this study seeks to answer the following questions:

- What SSCM and GSCM practices, tools, and techniques are deployed across supply chains that impact enterprises' efforts to be socially and environmentally sustainable and improve sustainability performance?
- What are the potential solutions, or solution concepts, that can be implemented to facilitate enterprises' desire to redirect their supply chains to be more socially and environmentally sustainable?
- How can companies create action plans to deploy recognized practices, tools, and techniques to restructure and fundamentally change supply chains that are not sustainable?

2. Materials and Methods

This research employs a "structured conceptualization" methodology, specifically concept mapping or group concept mapping (GCM). GCM is a structured methodology for organizing a group's ideas on any topic of interest and representing those ideas visually in a series of interrelated maps [68]. Group concept mapping facilitates cooperative process for groups of many different sizes, where participants bring a variety of backgrounds, knowledge, experience, and cultural context.

The GCM process can be described as a sequence of specific, operationally defined steps that yield a conceptual representation [69]. Conceptualization refers to the articulation of thoughts and ideas that are represented in an objective form through a structured conceptualization process, known as "concept mapping" [70–73]. In concept mapping, ideas are represented in the form of a picture or map. To construct the map, ideas first must be described or generated, and the interrelationships among them articulated. Multidimensional scaling and hierarchical cluster analysis are then applied to this information, and the results are depicted in the form of two-dimensional maps. The participants entirely determine the content of the map; they are the owners of the problem domain. Participants brainstorm initial ideas, provide information on how these ideas are related, interpret the analysis results, and later decide how the map will be utilized.

Benefits of using a concept matching approach include the ability to synthesize a diverse set of ideas and "voices" coming from participants with broad and varied experience and background [69]. It also allows "complex, causally ambiguous" systems to be visualized holistically [65]. This is significant because it facilitates autonomous ideas being grouped into comparable clusters while also permitting rigorous analysis so that common themes can be elaborated and valuable insights can then be extracted

Concept mapping is also well-suited for analyzing practical, relevant case examples in real time and has been demonstrated in previous research to be an empirically sound approach. Validity in concept mapping is interpreted as the best available approximation of the truth of propositions [74] and the trustworthiness of the methods and results [75]. Regarding construct validity, Dumont [76] examined whether the statistical analysis in concept mapping did what it was purported to do; the findings supported the validity of mapping analysis.

GCM has been applied to develop practices, tools, and techniques that are commonly found across diverse manufacturing supply chains and which impact their overall sustainability and sustainability performance. This study enrolled eight industry participants who contributed to defining the problem domain, interpreting the results, and evaluating them.

Based on previous studies conducted by the authors [65,77,78], the initial approach was to select a single enterprise as a case study site and select participants within the enterprise according to cross-functional representation. To carry this out, the authors created a list of industries and geographical regions and, using LinkedIn, selected a search criterion based on first-, second, and third-degree connections. Based on this, a long list of approximately 100 individuals coming from 8-10 industries and across multiple geographic regions in EMEA, the Americas, and Asia–Pacific was created. The authors then created a process to recruit companies and individuals into the study. During the outreach and selection process, a short list of approximately 11 people was created, based on the range of industries, geography, and experience. It was then decided that using experts from multiple industries, enterprises, and geographies would create a broader-based representation than a cross-functional group of managers within a single case site enterprise. Ultimately a broad-based panel of experts was selected over a cross-functional group of experts within a single case site.

Selectig a broad-based panel of experts vs. a cross-functional group from within a single case site emphasized a wider set of experts from varied organizations and manufacturing sectors. It also targeted a more comprehensive set of geographic markets and value chain segments. In this way, a more holistic context could be drawn upon. The conclusions are more likely to be applicable in a wider set of operating conditions. This facilitates a study that is more relevant to a wider segment, with the potential for greater relevance to a broader population of organizations and manufacturing sectors. Also, choosing participants from enterprises which are not connected in any way led to a much higher likelihood that experts would bring points of view, experiences, observations that were wholly objective and with significantly lessbias. This would be difficult to maintain if all the participants came from just one or two different companies.

By selecting a panel of individuals with extensive seniority and specific experience in specific value chain areas and across various industries, this study offers a unique and novel perspective on GSCM solutions and their implementation. Participants were selected based on functional expertise, industry, years of experience, geographical location, and the area or segment of the supply chain (value chain) applicable to their manufacturing companies. As part of the recruitment process, individuals were sent a brief presentation outlining the research aims, general instructions, and requirements for their involvement.

Seven of the eight participants were male, and one was female, reflecting the general demographics of global supply chain managers. The participant profiles are presented in Table 1.

Table 1. Profile of Participants.

Number	Industry	Yrs. Exp.	Supply Chain Segment	Managerial Level	Educ./Cert. Level	Market Focus
1	Metals and mining	18	Primary Processing	Head of Supply Chain Planning	LSS Black Belt	Western Europe
2	Metals and mining	21	Procurement	Procurement Director	EMBA	Latin America
3	Cons. Electronics	37	Procurement	Global Strategic Commodity Mgr.	BA, LSS	North America
4	Pkg. Cons. Food and Bev.	28	Sales and Distribution	CFO, Partner, Board member	CPA, CMA	North America
5	Auto. and Vehicle Mfg.	24	Value-added Mfg.	Global Mfg. Excellence Leader	MSc Eng.	Western Europe
6	Auto. and Vehicle Mfg.	26	Value added Mfg.	Co-founder, Owner	ACDMM, LSS Master Black Belt	Asia
7	Pkg. Cons. Food and Bev.	22	Raw Matl. Extraction	Vice President	MBA	Eastern Europe
8	Cons. Electronics	27	Sales & Distribution	Managing Director, Chief Sales Officer	MBA	Eastern Europe

To make sure all experts participating in the study had a clear understanding and similar viewpoint of SSCM and the study, each participant was taken through a short presentation covering common topics, definitions, concepts, and research aims. Each of the eight experts participated in the steps outlined in the table below (see Table 2).

These steps followed well-established precedents for GCM [68,70], including preparation and design, followed by an initial one-hour brainstorming session to develop a list of statements in response to a common prompt. Participants were asked to brainstorm statements by completing the following sentence which served to trigger thoughts and ideas: "A specific management practice impacting (either enhancing or limiting) industrial value chains to become sustainable is. . ." Also, participants were explained and encouraged to think broadly and without constraints. To aid the brainstorming process, the visual mind-mapping software and application Miro (Free Plan) was used to facilitate and visualize participants' responses.

After the initial brainstorming, duplications, misspellings, and wording errors were eliminated, and ambiguities were clarified. Statements were randomized and numbered so that they could be identified at each stage of the research. The list was returned, and participants were asked to identify any similar or repetitive ideas, and to edit and suggest wording and grammar to be as clear and precise as possible. They were also permitted to contribute additional ideas if they felt it was useful to the exercise. The final list of 86 statements (see Appendix A), with random numbering, was finalized and approved by experts participating in the study. The statements articulate the conceptual domain for "specific management practices enhancing/limiting industrial value chains to become sustainable".

Table 2. Research Steps.

Step 1: Preparation and Design	Step 2: Brainstorming	Step 3: Sorting and Rating	Step 4: Analysis	Step 5 Interpretation
• Consultation between co-authors. • Defining value chain segments and industries. • Structure of participants. • Recruiting of participants.	• Individual sessions for GSCM overview presentation. • Generating brainstorming statements according to the prompt. • Combining the individual lists of statements and presenting them to the participants. • Checking for redundancy and correcting grammatical and spelling errors.	• Participants sorted statements into groups. • Participants rated each statement based on two criteria.	• Sorting and tabulating statements into a matrix. • Creating potential solutions using MDS. • Selecting the final solution using group consensus.	• Develop latent constructs based on relative spatial distances. • Create a prioritization matrix.

During the second interview, participants determined the relationship between the 86 statements according to their individual perspectives, by clustering them using an unstructured process [79,80]. This involved placing virtual Post-it notes into separate piles "in which ever way seems most appropriate to you." This was also done using the Miro software application. In parallel, participants were provided with an Excel spreadsheet and requested to rate each of the statements twice on a 5-point Likert scale. The first rating was 'Ease of Implementation' (EoI) with the instruction: "Relative to the other practices mentioned, how easy is it to implement this practice (where 1 is NOT very easy and 5 is VERY easy)?". The second rating was based on the 'Impact' (I) of each statement with the instruction: "Relative to the other practices mentioned, what is the impact in terms of achieving sustainability, if a company were to implement/eliminate this practice (where 1 is NOT very impactful and 5 is VERY impactful)?". Scores for the criteria served as the basis for creating the prioritization matrix and a qualitative decision-making framework.

Using the results of the sorted statements as an input, a matrix with two axes was created, known as a binary symmetric matrix, whereby all relationships were coded. "If statements i and j were placed in the same pile by participant k, then the appropriate cell of the matrix is 1; otherwise, it is 0..." [16] (p. 185). After all individual matrices were completed, a summary matrix was then calculated to capture the combined similarity of all participants into one final matrix. Two-dimensional non-metric MDS was subsequently created based on the total similarity matrix. The purpose of this was to visualize the complex data set in a two-dimensional representation.

In reference to Kruskal and Wish [81], Trochim [70] suggested that "Since it is generally easier to work with two-dimensional configurations, ease of use considerations are also important for decisions about dimensionality. For example, when an MDS configuration is desired primarily as a foundation on which to display clustering results, then a two-dimensional configuration is far more useful than one involving three or more dimensions" (p. 58). The result of this was a "point-map" which located each statement as a point on a two-dimensional plane, where the distances between statements was determined by how often they were clustered in the same card pile or grouping. The MDS had a stress value of 0.178, which is consistent with other concept mapping applications, indicating a good fit [68]. This two-dimensional configuration explained 83.1% of the total variance.

The expected outcome of the exercise is that individual statements can be clustered on the map such that unique concepts are formed based on similarity and closeness of the statements. By creating a structure of statements on a two-dimensional map, the MDS analysis provided input for the hierarchical cluster analysis [68]. Generally, it is difficult or impossible to decide in advance on the "best" clustering method and the number of clusters to be chosen. Regarding the choice of clustering algorithms, this study relied on previous empirical studies. Trochim [70] found Ward's algorithm to be the most useful. Ward's algorithm gives solutions that minimize the within-cluster sum of squares relative to the between-cluster sum of squares at each level of joining, generally yielding more sensible and interpretable solutions than other approaches (e.g., single linkage or centroid method). All statistical calculations were performed using SYSTAT 13.2.01. Graphs were created using SYSTAT 13.2.01. Graphs were created with JMP 17.2.0 for Mac.

A series of five potential solutions was generated, with a varying number of clusters ranging from four to eight. The five solutions were visually depicted in a bottom-up, agglomerative-type fashion, allowing both the authors and participants to interpret the relevance of the different groupings within each of the five solutions [62]. These results were then distributed to all participants for examination, interpretation, and preparation for group consensus feedback. Participants were instructed to draw on their own experiences and the research aims, and not to overthink their conclusions; instead, they were encouraged to trust their initial instincts when interpreting and deciding on the best solution. A debriefing process was then conducted with participants, allowing discussion and feedback and enabling them to share their thoughts, ideas, and conclusions. To aid the process, the results of previous interviews, the mind maps, and the individual sorting of Post-it notes conducted using Miro software were made available to participants. In this way, the "best" cluster solution was determined by group consensus. The group decision was based on a close examination of the statements and their groupings. The solution with eight clusters was deemed most representative compared with solutions with four, five, six, and seven clusters, according to both the researchers and the experts. Researchers and participants unanimously agreed on the eight-cluster solution, as it provided the most logical balance between the need for precision within specific clusters and the differentiation required to distinguish clusters into separate concepts [68]. The concept map was then visualized using a polygon representation, as depicted in Figure 2.

The last step of the research was the evaluation of the results. This consisted of two parts. In part one, the eight clusters were interpreted based on the statements and their relative positions. This allowed the development of latent constructs. The latent constructs provide value, allowing for different perspectives or "lenses" for different stakeholders to view the clusters and thus provide insight and context into practical decisions. This is important to ensure a set of solutions that is not "one size fits all" and allows for the specific circumstances of organizations and individual stakeholders who are making implementation decisions. Each cluster was labeled, including a definition based on the consolidated theme of the individual statements. Later, the average ratings were added to complete the cluster rating map.

In part two of the evaluation, the ranking of clusters according to the two scales or axes was assessed. The assessment consisted of first calculating the average ranking for each of the two scales, 'Impact' (I) and 'Ease of Implementation' (EoI), and then plotting the points on a graph. As EoI and I typically form an inverse relationship, assessing each cluster on the two dimensions can lead to the optimal solution.

Appendix A lists the clusters, their numbers, names, and definitions, as well as the individual statements contained in each cluster. Additionally, the average impact (I) and ease of implementation (EoI) values for each statement, as well as the mean ratings for each cluster, are also presented.

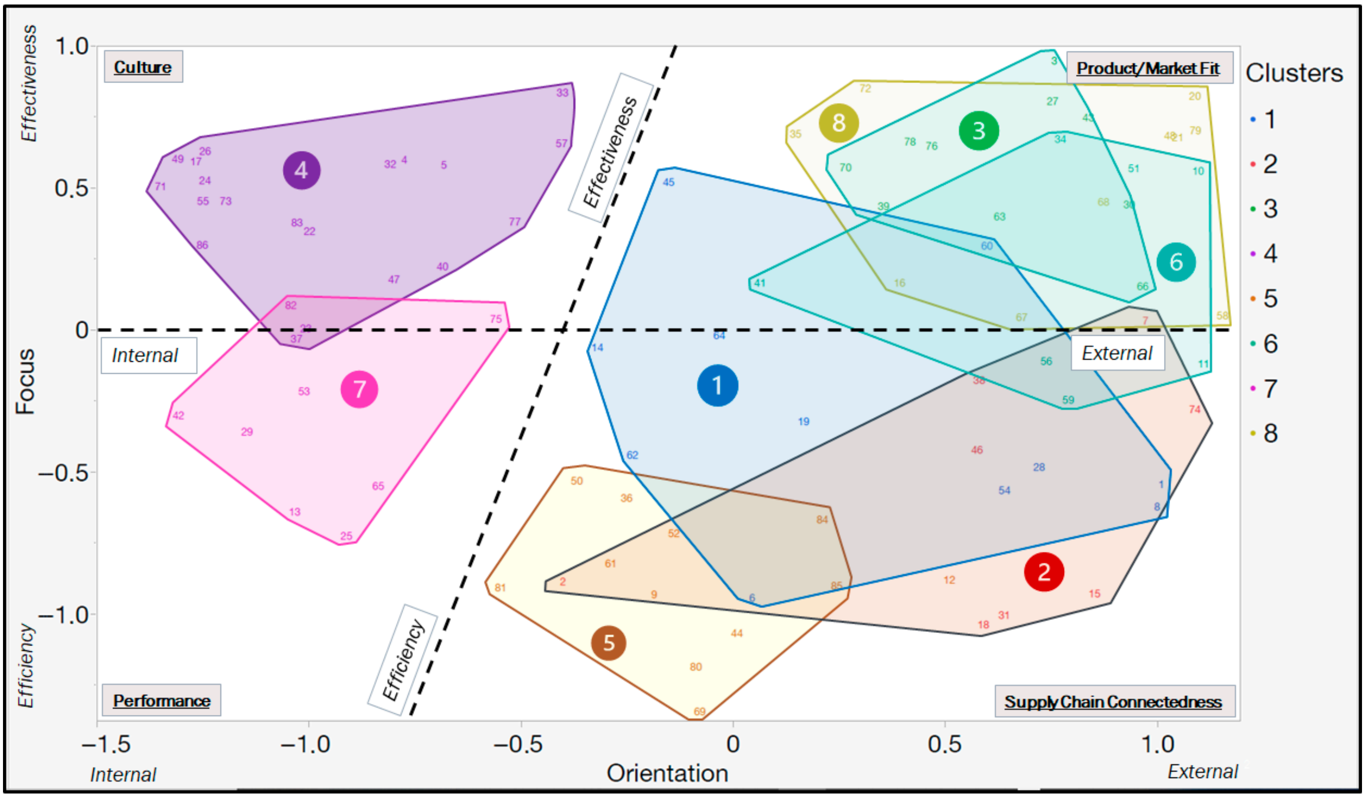


Figure 2. Concept map of management solutions impacting sustainability.

3. Results

The results show the 86 statements arranged in two dimensions. These coordinates were used to create the eight clusters chosen by participants and visually represent the conceptualization of leading management practices enabling industrial value chains to become more sustainable. The group consensus created names and definitions for each of the clusters as follows: '1. Supply Chain Waste', '2. Information Technology', '3. Product Waste', '4. Culture', '5. Suppliers', '6. Circular Manufacturing', '7. KPIs', and '8. Design'.

An additional result of the concept map was the development of latent constructs with two axes and four quadrants, overlying the conceptualized management practices and their relationships to one another. The horizontal axis, labelled "Orientation", denotes a continuum of themes and management practices that range from "Internal" to "External". The internally focused practices of performance measurement and organizational culture, centered on the mindset of stakeholders within the organization, represent the internal pole of this axis. The externally focused practices of managing suppliers and producing and designing products to meet the needs of external customers represent the external pole of the axis.

The vertical axis, labelled "Focus", shows a continuum of themes and management practices that range from "Efficiency" to "Effectiveness". The efficiency end of the scale focused on the solutions '7. KPIs', '5. Suppliers', and '2. Information Technology', representing the denominator of the productivity equation, as labor, materials from suppliers, and information are all inputs, representing the efficiency pole of this axis. The effectiveness end focuses on the solutions '8. Design', '3. Product Waste', and '4. Culture', representing the numerator of the productivity equation, as organizational culture and products are outputs, and therefore represent the effectiveness pole of the axis.

Effectiveness and efficiency are fundamental proxies of the productivity equation process, as follows:

$$\text{Productivity} = \frac{\text{Outputs}}{\text{Inputs}} \rightarrow \frac{\text{Achieving more}}{\text{with Less}} \rightarrow \frac{\text{Effectiveness}}{\text{Efficiency}} \rightarrow \frac{\text{Benefits}}{\text{Resource Usage}}$$

The two axes described above consequently form four quadrants: Q1, Culture; Q2, Product/Market Fit; Q3, Performance; and Q4, Supply Chain Connectedness.

3.1. Priority Matrix of Implementation

Concept mapping helped us to develop specific concepts and clusters. At the same time, the impact (I) and ease of implementation (EoI) ratings allowed us to prioritize the actual implementation of specific concepts and clusters.

The priority matrix (Figure 3) was created using the average ratings of I and EoI for each cluster, leading to four zones. Zone 1, the highest priority zone, is the 'Value Zone' and has the highest overall score, containing the '6. Circular Manufacturing' cluster, with a rating of 6.75 points (the sum of the two rating averages). Zone 2 is the 'Short-term Tactical Zone', containing two clusters, '7. KPIs' with a score of 6.41 points, and '4. Culture', with a score of 6.28 points. Zone 3 is the 'Longer-term Strategic Zone' and contains the '1. Supply Chain Waste' cluster, with a score of 6.30 points. Zone 4 is the 'Risk Zone' and contains the '5. Suppliers' cluster, with 6.02 points, the '2. Information Technology' cluster, with 5.97 points, the '8. Design' cluster, with 5.50 points, and the '3. Product Waste' cluster, with 5.45 points.

Figure 3. Priority Matrix for action planning.

As further elaborated in Section 4, the priority matrix is critical for facilitating real implementation. Such initiatives typically require strong backing from a board of directors, along with senior stakeholders, a task force from the middle ranks of the organization, and numerous lower-level champions and doers. Implementation requires significant financial and human capital [82] (Klassen & McLaughlin, 1996). None of these resources can be deployed without a decision-making framework. In this way, the priority matrix can provide maximum impact and value.

The priority matrix serves as the basis for several hypotheses that can be tested in future research. Given the limitations of this study, such as the limited number of participants and the broad range of industries, geographical regions, and supply chain activities it covers, there are multiple directions for future research. For example, future research can test the hypothesis that implementing the '6. Circular Manufacturing' concept is the most optimal approach to making supply chains sustainable, as it is easier to implement and has a greater impact than other concept solutions. Alternatively, the same approach could be taken with the concept solutions of '8. Design', '3. Product Waste', '5. Suppliers', and '2. IT Technology' to test whether they are riskier to implement than other concept solutions due to their relatively limited impact and greater difficulty of implementation. Even broader hypotheses can be tested, including whether prioritizing concepts leads to more efficient resource allocation and better outcomes for making supply chains sustainable.

3.2. Interpretation of Overlapping Clusters

Figure 2 reveals that the clusters overlap; there are statements within the straight-line boundaries of two or more clusters simultaneously. This was a somewhat expected outcome, as the topic of SSCM and GSCM is complex, encompassing many concepts, elements, and 'lenses' that are not yet clearly defined and universally accepted. Based on the numerous definitions of SSCM and GSCM, as elaborated in the introduction, this complexity is evident. Nonetheless, the authors felt it was essential to assess the impact of these overlaps on the validity of insights from the concept map.

In assessing the overlapping clusters, approaches to reducing the overlaps were considered such as, for example, further consolidating the 86 statements into fewer statements, or reviewing the overlapping statements and reassigning these to a different cluster using a group consensus process, or selecting a solution with fewer clusters.

After analyzing the overlapping statements (Appendix B), it was concluded that the overlaps were both helpful and valuable, as the combination of similarities and differences contained in both the statements and the clusters provided a greater level of insight and a more accurate reflection of reality.

For example, Statement 6, "Using standardized international environmental management systems (EMS) to ensure compliance with Sustainable Supply Chain standards," is part of cluster '1. Supply Chain Waste' but overlaps with clusters '2. Information Technology', and '5. Suppliers'. All three clusters aim to increase sustainability by using fewer resources. However, Statement 6 focuses on improving supply chain standards, rather than using technology or collaborating with suppliers. Therefore, it is logical for Statement 6 to be clustered with '1. Supply Chain Waste'; yet it still shares elements in common with the other two clusters.

The underlying strength of the GCM method lies in its ability to derive empirically validated concepts that capture the nuances and complexities of the GSCM concept. Therefore, the increased value lies in the solution with a larger number of concepts, as it incorporates a greater number of concepts, each containing both similarities and differences in their meaning. It was concluded that the eight-cluster solution, containing 86 original statements, was the most accurate and proper interpretation of the reality of GSCM in practice.

3.3. Interpreting Quadrants in the Concept Map and Priority Matrix

The combination of the concept map and the priority matrix can help both practitioners and theorists better understand the context and implications of implementing the identified practices.

The empirically quantified concepts, along with the latent constructs that emerge, help identify the context in which managers can implement effective practices. Enterprises may choose to focus on different practices given the current situation they face along the given axes, 'efficiency and effectiveness' and 'internal vs. external', identified in the concept map.

Consequently, implementation of specific practices can be prioritized according to the ranking established by the priority matrix, which measures optimal combinations of impact (I) and ease of implementation (EoI).

In this way, enterprises and executives may obtain insight and guidance into structuring concrete, practical, and time-bound implementation roadmaps.

3.3.1. Interpretation of the Culture Quadrant

The culture quadrant that includes cluster '4. Culture' is defined by the axes of 'Internal' and 'Effectiveness'. These practices relate to creating awareness around sustainability issues [see statements 17,77,83], supporting employees and other non-financial stakeholders [see statements 4,5,23,37,40,57], and developing a culture and mindset that drives sustainability behavior [see statements 24,26,32,33,55,71,73,86], actions, and policies [see statements 22,47,49].

The mean rating for I (3.01) is the second lowest among the eight clusters. However, the mean rating for EoI (3.26) is the second highest. This places the '4. Culture' cluster in Zone 2 'Short-term Tactical' within the priority matrix (see Figure 3 for a detailed explanation), denoted by relatively high EoI and relatively low I.

3.3.2. Interpretation of the Product/Market Fit Quadrant

The product/market fit quadrant is defined by the axis poles of 'External' and 'Effectiveness' and includes the '3. Product Waste', '6. Circular Manufacturing', and '8. Design' clusters.

The practices in the '3. Product Waste' cluster relate to either eliminating unsustainable materials in products and processes including packaging, toxins, and other unsustainable raw materials [see statements 3,27,43,70,76,78], or improving products and manufacturing processes to become more sustainable by improving product features and performance through practices such as labelling, packaging, and involvement of suppliers in reducing product material inputs such as water [see statements 30,39,63,66].

For the '3. Product Waste' cluster, the mean rating for I is (3.15), and EoI is (2.30). The low score on both axes places it in Zone 4 of the priority matrix, the 'Risk Zone', which implies that action should be delayed, as investing too much effort for too little reward is a risk.

The practices in the '6. Circular Manufacturing' cluster relate to increased deployment of product remanufacturing as a core approach to operations [see statements 10,51], improved and increased use of material reusage and recycling, especially for electronic waste [see statements 34,41,56], and creating supply chain processes which better leverage circular methods and principles [see statements 11,59].

For the '6. Circular Manufacturing' cluster, the rating for I (3.86) is the highest, and the rating for EoI (2.89) is the third highest. The relatively high score on both axes places it as the sole cluster in Zone 1, the Value Zone, with the highest priority for taking meaningful action.

The practices in the '8. Design' cluster relate to designing new processes which use more sustainable energy, transport, or materials [see statements 20,21,48,67] by deploying new technologies such as additive manufacturing (e.g., 3D printing) or BEV (battery electric vehicle) technology [see statements 16,35,58,68] or designing new processes that create sustainable products through enabling reusability, remanufacturing, and longer product life [see statements 72,79].

For the '8. Design' cluster, the mean rating for I is relatively high (3.23); however, the EoI rating (2.28) is the lowest, placing it in a lower priority position. Like '3. Product Waste', the low score for the '8. Design' cluster on both axes places it at a lower priority within the priority matrix. Cluster '8. Design' is also in Zone 4, again implying that action should be delayed.

3.3.3. Interpretation of the Performance Quadrant

The performance quadrant, defined by the axis poles 'Internal' and 'Efficiency', includes the '7. KPIs' cluster. These practices relate to improved use of performance targets generally [see statement 13], broadly linking employee performance to sustainability criteria [see statements 25,29,42,65,82] and creating specific, companywide goals such as reduced CO_2 emissions or meeting criteria to participate in the Dow Jones Sustainability Index [see statements 53,75].

For the '7. KPIs' cluster, the mean rating for I (2.94) is the lowest among the eight clusters. However, the mean rating for EoI (3.47) is the highest. This places the '7. KPIs' cluster in Zone 2, the 'Short-term Tactical Zone' of the priority matrix, denoted by relatively high ease of implementation (EoI) and relatively low impact.

3.3.4. Interpretation of the Supply Chain Connectedness Quadrant

The supply chain connectedness quadrant, defined by the axis poles 'External' and 'Efficiency', includes the '1. Supply Chain Waste', '2. Information Technology' and '5. Suppliers' clusters.

The practices in the '1. Supply Chain Waste' cluster relate to deploying supply chain methods that reduce transport across the extended supply chain [see statements 1,8,19,45,54], implementing either general or industry specific sustainable supply chain standards such as standardized international environmental management systems (EMS) or sustainable mining practices [6,14,28], or creating and designing supply chains which reduce CO_2 or use increased levels of renewable energy [see statements 60,62,64].

For the '1. Supply Chain Waste' cluster, the rating for I (3.44) ranks highly, and the mean rating for EoI (2.84) is the fourth highest. The relatively high score on both axes places it in Zone 3, the 'Longer-term Strategic Zone', implying action should be taken, but at a slightly lower priority than for the clusters in Zones 1 and 2.

The practices in the '2. IT Information Technology' cluster relate to deploying digital processes which focused on the timeliness and quality of information across the supply chain [see statements 2,31,38,46], using hardware technology such as sensors either in the manufacturing process or in the products to provide better information and data [7,15,72], or using software technology to collaborate with suppliers to improve information about supplier sustainability performance [18].

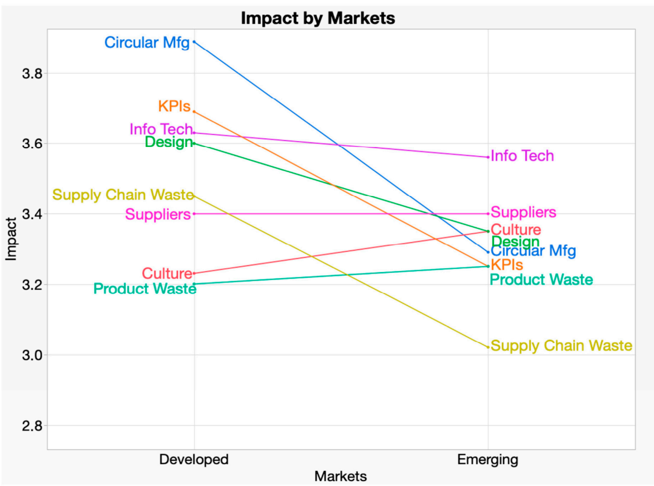
For the '2. IT Information Technology' cluster, the mean rating for I (3.16) ranks fourth from the bottom. The rating for EoI (2.81) is the third lowest. The relatively low scoring for this cluster on both axes places it in Zone 4, the 'Risk Zone', which implies that action should be delayed.

The practices in the '5. Suppliers' cluster relate to improving relationships with suppliers to be more supportive in achieving sustainability goals, not just financial goals [see statements 9,61], collaborating, promoting, and developing specific solutions together with suppliers [see statements 12,50,52,84,85], or increasing control over suppliers through certification schemes or auditing practices [see statements 36, 44,69,80,81].

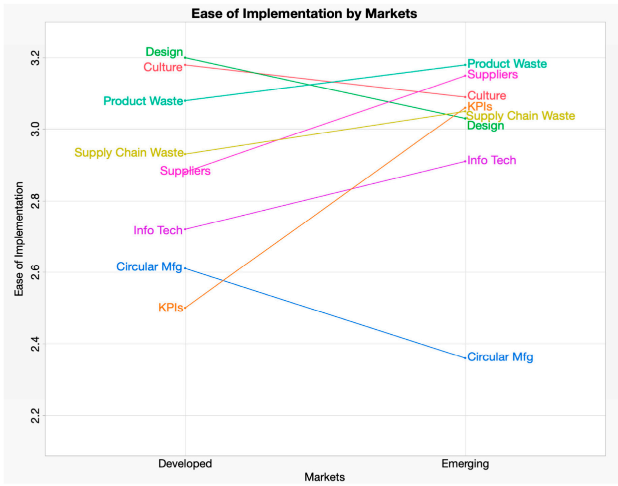
Regarding the '5. Suppliers' cluster, the mean rating for I (3.19) ranks fourth from the top. The mean rating for EoI (2.83) is the fourth lowest, placing it in a lower priority position. Like the '2. Information Technology' cluster, the low scoring for the '5. Suppliers' cluster on both axes places it in a lower-priority position. The '5. Suppliers' cluster is also in Zone 4, which also implies that action should be delayed.

3.4. Pattern Matching

While the action plan presented above purports to be generally applicable, it is worth considering differences between scores of specific contexts identified in the research. The contexts that were explored, 'Markets' (developed vs. emerging), and 'Supply Chain Position' (downstream vs. upstream), displayed differences in both the average impact (I) and ease of implementation (EoI) scores among clusters, as evidenced by the many crossing rungs of the ladder graphs (see Figures 4 and 5). These findings underly the importance of a "context matters" message and highlight the dangers of "one-size-fits-all" approaches when implementing solutions [83] (Trochim, 1985). Examination of sectoral differences (metals and mining, packaged consumer food and beverage, automotive and vehicle manufacturing, and consumer electronics) yielded interesting results; however, the complexity of that analysis led the authors not to explore those differences in this paper.



(**a**)

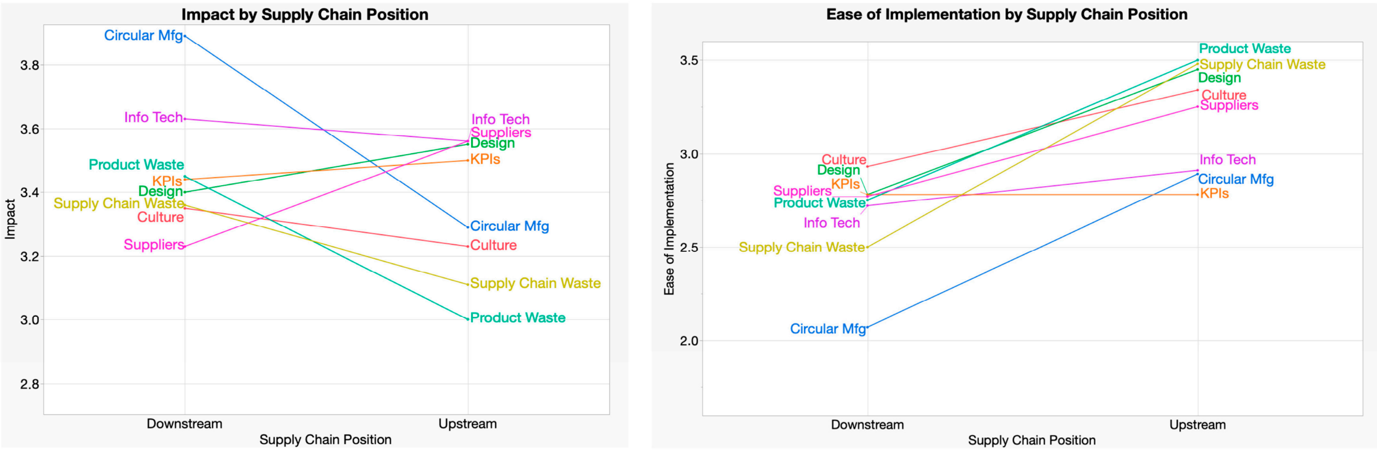


(**b**)

Figure 4. Impact (I) and ease of implementation (EoI) by markets: (**a**) Ranking impact (I) of practices identified by emerging market vs. developed market participants. (**b**) Ranking the ease of implementation (EoI) of practices identified by emerging market vs. developed market participants.

Examining the impact (I) differences between developed vs. emerging markets, significant differences were observed whereby the specific solutions '6. Circular Manufacturing' (3.89 vs. 3.29), '7. KPIs' (3.69 vs. 3.25), '1. Supply Chain Waste' (3.45 vs. 3.02), and '8. Design' (3.60 vs. 3.35), scored higher for impact in the developed markets compared with the emerging markets segment. Drivers for this difference could include several factors, such as higher costs in developed markets, the size and complexity of enterprises operating in more developed markets, and a stricter regulatory environment [84].

In terms of ease of implementation (EoI) for developed vs. emerging markets, '6. Circular Manufacturing' (2.61 vs. 2.36) and '8. Design' (3.20 vs. 3.03) also scored higher for developed markets. It is reasonable to assume that similar factors drove this outcome. For instance, if costs and the regulatory environment are higher in developed markets, there should be a greater incentive and resources to ensure these actions are implemented. Some evidence of this has been found in Central and Eastern Europe [78] (Rondinelli & Vastag, 1998).



(**a**) (**b**)

Figure 5. Impact and ease of implementation (EoI) by supply chain position: (**a**) Ranking impact (I) of practices identified by downstream supply chain vs. upstream supply chain participants. (**b**) Ranking the ease of implementation (EoI) of practices identified by downstream supply chain vs. upstream supply chain participants.

However, '7. KPIs' (2.50 vs. 3.06), and '1. Supply Chain Waste' (2.93 vs. 3.05) were shown to be more challenging to implement in developed vs. emerging markets. The drivers may be similar, but with the inverse effect. For example, the size and complexity of developed markets could make solution concepts more challenging to implement.

Examining the differences between downstream vs. upstream positions in the value chain, significant differences were observed, whereby the specific solutions '6. Circular Manufacturing' (3.89 vs. 3.29), '3. Product Waste' (3.45 vs. 3.00), and '1. Supply Chain Waste' (3.36 vs. 3.11) scored higher for impact in the downstream segment than in the upstream segment. Drivers for this difference could include factors such as proximity to end-users and dispersion of physical and geographic locations. Proximity to end users, typically found in downstream components of the supply chain, implies greater connectivity, control, and the ability to influence end users through information, transparency, and collaboration opportunities. This could be a potential factor in incentivizing complex relationships and innovative solutions.

In terms of EoI for downstream vs. upstream position in the value chain, the solution concepts '6. Circular Manufacturing' (2.07 vs. 2.89), '3. Product Waste' (2.75 vs. 3.50) and '1. Supply Chain Waste' (2.50 vs. 3.48) paradoxically scored lower for the downstream position in the value chain. One hypothesis for this could be that scale and complexity, including dispersion of physical and geographic locations, make implementation more prohibitive.

3.5. Qualitative Analysis: Mapping the Value Chain

This study's focus in the paper was to examine GSCM from a holistic perspective, addressing the multiple parts of the chain, in response to a noted weakness in the current body of GSCM research [43] (Balkumar et al., 2024, p. 2010). To differentiate this study from other empirical studies that use either theoretically constructed supply chain proxies, single-company and single-site studies, or single-industry research, four industrial supply chains were selected, each comprising five separate value chain components, accompanied by several case examples.

During this study, multiple interviews were conducted as part of the empirical GCM exercise, and the interviewees were instructed to provide statements, solutions, and ideas based on their specific corporate experience in the companies for which they worked. In total, the number of companies used as a source across all participants was twenty-four (24).

Additionally, each participant was coded according to their experience as a supply chain executive. In this way, the authors were able to construct a prototypical industrial supply chain across five distinct value chain components: raw materials extraction, procurement, primary processing, sales and distribution, and value-added manufacturing.

To analyze the potential impact of the clusters and individual solution statement, the authors mapped the individual statement to the corresponding value chain components as coded during the interview process. The result was a qualitative visualization and a quantitative impact score, enabling a better understanding of how the specific clusters and solution statements correspond holistically to the different parts of the supply chain or value chain. In this way, the authors avoided a "one size fits all" set of conclusions. At the same time, it was possible to construct a more generalizable model of how solutions can be deployed across not only the whole chain but also in specific places within the supply chain, to achieve the highest level of impact (I) and ease of implementation (EoI).

Below is a visual depiction of the end-to-end value chain, with statements and clusters overlaid (Figure 6), and supported by specific scoring for each component (Table 3).

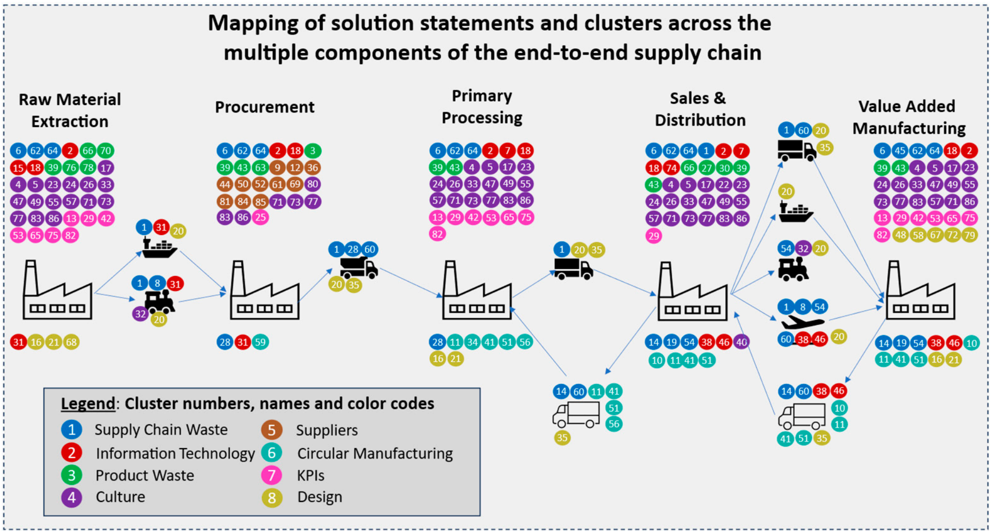


Figure 6. Mapping solution statements across the value chain.

Table 3. Scoring the different positions and functions across the value chain.

		Raw Material Extraction	Procurement	Primary Processing	Sales and Distribution	Value-Added Manufacturing	Logistics
Ease of Implementation (EoI)	Average	2.97	2.82	3.05	3.03	3.01	2.68
	Total	113.00	84.50	119.00	119.00	141.25	45.50
Impact (I)	Average	3.01	3.19	3.21	3.21	3.18	3.53
	Total	114.50	95.75	125.25	126.00	149.50	60.00
Total number of solution statements		38	38	30	39	41	17
Cluster represented		1, 2, 3, 4, 7, 8	1, 2, 3, 4, 7, 8	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 6, 7, 8	1, 2, 3, 4, 6, 7	1, 2, 4, 6, 8

Insights from the qualitative analysis reveal that impact (I), ease of implementation (EoI), and the overall volume of applicable solutions are essentially equal across the end-to-end value chain within the manufacturing nodes of the value chain. However, when the nodes between the solutions about transport and logistics are examined, significant differences are seen.

The logistics function shows a scoring with between 10 and 17% more impact (I) and with 7 to 12% less ease of implementation (EoI). One interpretation, therefore, is that internodal function and its position within the logistics value chain are significantly more challenging to implement and have a significantly greater impact. The total number of statements (only 18, compared with 30 to 42 for all other nodes) and clusters (five, compared with six to seven for all other nodes) represented by logistics is also significantly lower than those of the other value chain nodes.

This invites somewhat contradictory interpretations. Having fewer solutions to apply can suggest a proxy for simplicity, which has the potential to reduce complexity in an already highly complex business area. On the other hand, the availability of only a few solutions can also denote higher risk, as there are fewer options and fallbacks should some solutions not work out as anticipated or if external conditions (economic, social, political, environmental) shift.

4. Discussion

This paper aims to address several key questions. To answer the first two questions, about (a) identifying the domain of management practices and (b) developing potential solution concepts, the study first identified a range of management practices and secondly conceptualized them into eight clusters articulated as potential solutions that corporations can deploy to achieve sustainability outcomes with varying degrees of impact (I) and ease of implementation (EoI).

These clusters form independently and empirically derived concepts, which are consistent with those extensively identified within the GSCM literature. For example, management techniques such as reverse logistics, a circular manufacturing concept [85], are viewed as a part of the proactive continuum of management practices [37] and are among several key GSCM approaches [86]. Dabees et al. [87] argue that implementation of reverse logistics is crucial for enhancing the overall sustainability of enterprises, as well as identifying a gap in theoretical frameworks that need to be further improved in this area if practical implementation is going to become more widespread.

Reducing waste across the end-to-end supply chain is cited as having a significant impact on environmental performance [88]. Kuo [89] validates the idea of reducing supply chain waste through management approaches that incorporate recycling processes analysis. Nazir et al. [90] emphasize the importance of GSCM practices in general, with a particular focus on waste reduction across the supply chain, which is highly correlated with environmental performance, especially in the context of institutional pressure. Design is cited as a key GSCM approach with significant impact [91] for improving sustainability performance, as is the importance of incorporating suppliers at various levels of the supply chain into GSCM solutions [92]. Chin et al. [93] found that green product and process design had the strongest positive relationship with sustainability performance, outperforming other practices such as supplier selection or evaluation.

Kannan et al. [94] and Dai et al. [95] also highlight the importance of selecting green suppliers, while Brandenburg [96] emphasizes the need for environmental criteria for introducing new products to reduce product waste. Li & Zhong [97] find that both green supplier selection and integration strongly correlate with and impact overall environmental performance. Technology, such as advanced green technology, is considered an important factor by Tseng et al. [98] when incorporating sustainability principles (economic, social, and environmental) into the supply chain. Stroumpoulis et al. [99] investigated the role of digital transformation, coupled with the implementation of sustainable supply chain practices, and concluded that both have a significant impact on the operational and financial performance of individual firms as well as supply chains.

In response to 'external pressure from myriad forces ranging from regulators, suppliers, customers, community stakeholders, and companies', corporate leaders are increasingly attempting to infuse GSCM principles into company culture [100]. Gao et al. [101] investigated the relationship between sustainable transformational leadership, sustainable HR practices, and the development of sustainable values among employees, which in turn positively impact sustainable organizational culture and performance.

Operational performance management is also considered a key tool for improving environmental performance and implementing SSCM and GSCM, as noted by Vanalle et al. [102] and King and Lenox [103], and is cited as a key approach for implementing SSCM and GSCM [104,105]. Kumar et al. [106] demonstrate the impact of performance management on promoting sustainability and the need to improve approaches to measuring SSCM.

Finally, the current authors attempted to answer the third question, regarding how to develop action plans, by analyzing the specific impact (I) and ease of implementation (EoI) of each management practice and subsequently extrapolating these solution concepts. In this way, the authors were able to map the de facto solution clusters into a prioritization matrix, which can facilitate management decision-making and deployment of action plans.

By ranking the four zones in priority order as described in Section 3.5, companies can prioritize the solutions indicated by the clusters on an absolute basis or according to their specific goals, for example, short-term versus long-term.

5. Conclusions

This paper conceptualizes a set of coherent SSCM and GSCM solutions that can practically and effectively be implemented in a typical industrial supply chain context across multiple industries and operating environments. The positions and relationships among the clusters that emerged led to the development of latent constructs providing insight into how supply chain experts and corporate leaders can assess different solutions through divergent and opposing lenses, for example, the internal vs. external lenses, or the efficiency vs. effectiveness lenses.

The prioritization matrix, constructed from the two comparative axes of impact (I) and ease of implementation (EoI), provides further insights into how corporate decision-makers can prioritize solutions based on short-term versus long-term approaches and overall total benefit.

While many of the conclusions are consistent with the SSCM and GSCM literature, several novel aspects of the research include quantitative modeling approaches to identify relationships between solutions and clusters that have not been previously explored in detail, combined with lower-level qualitative analysis of firm-specific examples across multiple parts of the supply chain. A weakness of the increasingly rich SSCM and GSCM literature is the limitations of many empirical analyses, which fail to address specific firms at the grassroots level and are thus too high-level, failing to produce practical and valuable insights for managers in the field and their efforts to implement SSCM practices.

Yang et al. [107] note that the literature encompasses a depth of research covering a wide range of topics, including supplier certification, lean production, design innovation, supply chain models, and customer collaboration approaches. Analysis has also been developed to aggregate and classify these approaches into comprehensive frameworks [85]. Nevertheless, this does not fully address SSCM from a multi-part perspective that is generalizable across industries, geographies, and the end-to-end components seen in a complex value chain. By employing a combination of GCM using interviews across multiple parts of the chain, coupled with a qualitative value chain analysis to identify specific instances of practices at specific firms, this study overcomes a key weakness of a large swath of existing empirical and qualitative analyses in the SSCM field. Additionally, the latent constructs and the proposed prioritization matrix introduce new dimensions and insights into the potential practical uses of the already identified approaches.

The study has several limitations including the number supply chain experts surveyed (eight people), the geographic locations (predominantly European), the coverage of the different value chain components (raw material extraction, procurement, raw material processing, value-add manufacturing, and distribution), and the industries covered (packaged food and beverage, consumer electronics, mining equipment, integrated steel coil manufacturing). To better control these dimensions, a wider panel of experts and stakeholders could be selected, including a more realistic representation of these demographic attributes.

Despite its limitations, this paper offers both empirical evidence and practical implications for practitioners and manufacturing organizations to take action by developing impactful initiatives and actions that mitigate adverse environmental impacts and foster truly sustainable supply chains.

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Institutional Review Board Statement: This study is based on the Corvinus Code on Research Ethics at Corvinus University of Budapest, which encompassed the establishment of the university regulations, including the approval of research projects involving human subjects. A key component of this regulation, in accordance with international standards, is a control questionnaire designed to assess the potential ethical risks associated with the proposed research project. The questionnaire consists of 20 questions, each with a “Yes” or “No” response option. Specifically, aforementioned regulation stipulated that the absence of any “Yes” responses in the 20 questions would consider the project exempt from the need for approval from the Ethics Committee. This research under review at Logistics clearly falls within this category.

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Abbreviations

The following abbreviations are used in this manuscript:

SCM	Supply chain management
SSCM	Sustainable supply chain management
GCM	Group concept mapping
HCA	Hierarchical cluster analysis
I	Impact
EoI	Ease of implementation
MDS	Multidimensional scaling
SD	Sustainable development
TBL	Triple bottom line
KPIs	Key performance indicators

Appendix A. [16] (pp. 189–92)

Cluster	Statement		EoI (E)	Impact (I)
1. 'Supply Chain Waste': *Reducing waste and resource usage in the supply chain delivery system.*	1	Using 3D printing to print parts for the customer to reduce transport and fuel consumption	2.75	3
	6	Using standardized international environmental management systems (EMS) to ensure compliance with sustainable supply chain standards	3.25	3.25
	8	Product distribution approaches that use rail (more local) versus air (e.g., overseas, China, etc.)	3	3.5
	14	Compliance with relevant regulations for electronic waste	3.25	3.25
	19	Investing in green infrastructure, e.g., green warehouses and facilities which use renewable energy, water recycling, automated lights, waste recycling	2.5	4
	28	Deploying sustainable mining practices	2	3.5
	45	Prioritizing battery electric vehicle (BEV) products to encourage less energy consumption during use	3.75	2.25
	54	Reducing JIT delivery practices that rely on air transport (less sustainable) vs. rail transport (more sustainable)	2.25	4
	60	Investing in fuel efficiency for our products and our customers	2.75	3.75
	62	Actively seeking to reduce the carbon footprint of the supply chain, mainly for financial reasons	2.75	3.5
	64	Investing in technologies to measure and reduce the carbon footprint	3	4
Mean			**2.84**	**3.45**
2. 'Information Technology': *Utilizing technology to gather information and support sustainability.*	2	Supplying information promptly to support sustainability practices	3.75	3
	7	Using equipment (e.g., refrigerators in supermarkets) with sensors to save energy as well as money	3.25	3.5
	15	Sustainable farming, which uses sensors to analyze soil and weather, enables more efficient production using less water	2.5	3.25
	18	Using software (EcoVadis) to screen suppliers based on sustainability criteria and ensure compliance with the code of conduct, sustainability criteria, health and safety criteria, and circularity of the supply chain	2.5	3.75
	31	Promoting a connected farm/supply chain that uses resources more efficiently	2.25	2.5
	38	Implementing systems which allow our parts and services division to know where the equipment is located, what phase of the lifecycle it is in, and customers' demand for parts and services	3	3
	46	Digitalization, which can help replace parts with less downtime, less materials consumption, less space, energy, and fuel	2.5	3.5
	74	Using equipment (e.g., pipe cleaning in pubs is necessary for brand attributes) with sensors to save energy and money	2.75	2.75
Mean			**2.81**	**3.16**

Cluster	Statement		EoI (E)	Impact (I)
3. 'Product Waste': *Reducing waste and resource usage in products.*	3	Eliminating consumables that are contaminated with non-recyclable elements, toxins, etc.	2.5	3
	27	Eliminating the use of unsustainable packaging to meet consumers' demand for convenience	3	3.25
	30	Increased use of sustainable packaging to meet consumers' demand for reusability and recyclability	2.75	3.75
	39	Using sustainable labelling initiatives like fair trade, eco-rating, and FSC labels, etc.	2.75	3
	43	Eliminating plastic materials due to plastic waste, which is difficult and expensive to recycle	1.75	4
	63	Sustainable procurement, which uses less water in the production of the product	2.5	3.25
	66	Packaging standards that incentivize producers NOT to use GMOs	2	2
	70	Eliminating GMO-based food products despite the costs of doing so	1.25	1.75
	76	Eliminating unsustainable raw materials for food products, like palm oil, which are cheap	2.75	4
	78	Eliminating products, even if they are profitable, that rely on unsustainable mining practices	1.75	3.5
Mean			**2.30**	**3.15**
4. 'Culture': *People's mindset culture*	4	Employee benefits program that supports/encourages sustainable commuting (e.g., EV charging points made available)	4.25	2.75
	5	Using diversity programs to drive awareness of ESG practices through better reporting, making companies more desirable to work with	3.75	2.75
	17	Creating awareness: e.g., the CEO has declared that sustainability aligns with the company vision and "must win battles"	4.25	2.75
	22	Renewable initiatives driven by salespeople, via regular monthly brainstormings	4	2.25
	23	Valuing 'fairness' to stakeholders, including communities, suppliers, etc.	4	2.75
	24	Nurturing a collaborative mindset that promotes businesspeople/functions and sustainability people/functions working together	3.5	3.75
	26	Creating a sustainability culture	2.5	4
	32	Management behaviors leading to responsible choices, such as replacing road transport with rail transport	2.5	3.5
	33	Innovation and design mindset that promotes the idea that innovation and sustainability work together	2.25	3.5
	37	Incentivizing employees to practice sustainable procurement	3.5	4
	40	Incentivizing the use of EVs (electric vehicles) for salespeople	3.5	2.75
	47	Creating sustainability policies that go "beyond compliance"	3	3
	49	Building sustainability into the corporate mission	3.75	3.25

Cluster	Statement		EoI (E)	Impact (I)
4. 'Culture': *People's mindset culture*	55	Management behaviors leading to responsible choices, such as increased use of renewable energy	3.5	3.25
	57	Investing in safety, both for employees and in our products, to provide safety to customers	2.25	2.25
	71	Creating a company culture based on sustainability, by creating and documenting behaviors, training, etc.	2.5	3
	73	Fostering a mentality and culture that incentivizes investment and innovation and moves away from being cost-conscious	1.5	3.25
	77	Communicating and prioritizing sustainability messages in standard and high-profile communications	4.5	2.5
	83	PR and business values based on "being green"	3.25	2.5
	86	"Walking the walk" and not just "talking the talk"	3	2.5
Mean			**3.26**	**3.01**
5. 'Suppliers': *Increasing sustainability by focusing on suppliers.*	9	Not putting undue economic pressure on our suppliers	1.75	2.75
	12	Promoting supply chain solutions to manufacture products based on renewable energy	2.5	2.75
	36	Certifying not only your suppliers but also that your suppliers' suppliers are compliant with sustainability practices	3.25	4
	44	Certifying supply chains to become sustainable	3	2.75
	50	Creating awareness or understanding of cost/benefits or trade-offs of using sustainable procurement approaches	3.5	2.75
	52	Sustainable procurement practices that lead to better relationships with farmers, which promote more sustainable practices at the local level	2.5	3.5
	61	Supporting suppliers in their target setting and implementation	2.5	3.5
	69	Regular assessments and audits of suppliers	3.5	3.75
	80	Procurement practices using sustainability certification and traceability	2.75	3
	81	Strictly following up on the performance targets of suppliers	3.75	2.25
	84	Procurement practices actively seek out local packaging solutions	3	3
	85	Eliminating or significantly reducing procurement and outsourcing to LCCs (low-cost countries), which leads to long transport routes and less compliant policies for people and the planet	2	4.25
Mean			**2.83**	**3.19**

Cluster	Statement		EoI (E)	Impact (I)
6. 'Circular Manufacturing': *Improving sustainability by creating circular manufacturing processes.*	10	Remanufacturing in all product lines	3	3.5
	11	Implementing circularity in our supply chain processes results in more efficient material usage and remanufacturing	2.75	3
	34	Eliminating the inefficient processing of returned materials, e.g., burning motherboards for gold, which leads to pollution	2.25	4
	41	Recycling and reuse of materials	3.5	4.5
	51	Moving back to remanufacturing products due to cost and availability reasons	3.5	4.25
	56	Processing and reusing electronic waste	2	4.25
	59	Sustainable procurement practices ensure recyclable steel or other recyclable components	3.25	3.5
Mean			**2.89**	**3.86**
7. 'KPIs': *Improving Sustainability through deployment of performance management and measurement systems*, e.g., *key performance indicators (KPIs) or other forms of measurement.*	13	Strictly following up on company performance targets	3.25	3
	25	Establishing sustainability criteria for decision making in different functions and departments, for example, procurement	3.5	3.5
	29	Considering sustainability targets in every target-setting group or department	3.75	3
	42	Target setting for sustainability in a top-down way, to all departments, individual ratings, and compensation	4	2.75
	53	Having a goal to reduce CO_2 significantly in the next decade	4.5	2.75
	65	Using KPIs that connect business to sustainability	3.25	3
	75	Participating in the Dow Jones Sustainability Index to enforce accountability on companies to meet sustainability KPIs from fund managers	3	3
	82	Sustainability goals that impact or correspond broadly to many individual jobs	2.5	2.5
Mean			**3.47**	**2.94**
8. 'Design': *Improving Sustainability through design processes in product design, new technology, or supply chains.*	16	Using promising new technologies that are still immature or in the initial phases of development	1.75	2
	20	Product development practices and processes that support sustainable transport	2.5	3
	21	Designing products that use renewable energy	2.25	4
	35	Making sustainable products, e.g., battery electric vehicles (BEV) a priority	2	4
	48	Reducing the weight of our products by redesigning parts with less weight, so less fuel is consumed	2.5	2.5
	58	Deploying additive manufacturing (3D printing), which can drive a sustainable approach by reducing the need for steel	2.5	3

Cluster	Statement		EoI (E)	Impact (I)
8. 'Design': *Improving Sustainability through design processes in product design, new technology, or supply chains.*	67	Eliminate a centralized manufacturing strategy, which creates more transportation for the distribution of vehicles, parts, and services	2	3.5
	68	Prioritizing battery electric vehicle (BEV) products to promote cleaner air, less pollution, and improved health and safety, requiring less energy during use	2.5	3.25
	72	Product design processes incentivizing refurbishment or design for disassembly	2.5	3.25
	79	Designing products for a long life	2.25	3.75
Mean			2.28	3.23

Appendix B

Cluster No.	Overlapping Statements	Similarities of Each Cluster	Explanations for Specific Statements and Their Association with a Specific Cluster
1 & 2	1, 8, 28, 46, 54	The '1. The 'Supply Chain Waste' cluster focuses on reducing waste. The 'Info Tech' cluster is about increasing sustainability. These are similar concepts.	Statement #46 ('2. Info Tech' cluster) emphasizes digitalization. All other statements focus on supply chain-specific practices.
2 & 5	2.,9,12,61	The '2. Info Tech' and '5. Suppliers' clusters are both about increasing sustainability and becoming more sustainable.	Statement #2 ('2. Info Tech' cluster) focuses on 'supplying information promptly', an IT concept.
3 & 8	27, 43, 70, 76, 78	The '3. Product Waste' and '8. Design' clusters both pertain to the sustainability of products.	Statements from cluster #3 ('3. Product Waste') pertain to unsustainable elements of products in use rather than in the design phase.
4 & 7	23, 37, 82	The '4. Culture' and KPI clusters both focus on enhancing sustainability through organizational behaviors.	Statement #82 ('4. Culture' cluster) is about creating goals, which is part of performance management systems, as opposed to culture.
6 & 8	51,10	The '6. Circular Manufacturing' and '8. Design' clusters both aim to improve sustainability through enhanced processes.	Statements from cluster ('6. Circular Manufacturing') pertain specifically to remanufacturing, a core principle of circular manufacturing.

Cluster No.	Overlapping Statements	Similarities of Each Cluster	Explanations for Specific Statements and Their Association with a Specific Cluster
1 & 2 & 5	6, 5, 84, 85	The '1. The 'Supply Chain Waste' cluster focuses on reducing waste. The '2. Info Tech' and '5. Suppliers' clusters are both about increasing sustainability and becoming more sustainable, similar concepts.	Statement #6 ('1. Supply Chain Waste' cluster) emphasizes increasing sustainability using supply chain standards such as standardized international environmental management systems (EMS) certification, rather than collaborating with suppliers or leveraging IT.
1 & 2 & 6	38, 56,59	The '1. The 'Supply Chain Waste' cluster focuses on reducing waste. The '2. Info Tech' and '6. Circular Manufacturing' clusters focus on improving sustainability and becoming more sustainable, which are related concepts.	Statement # 38 emphasizes digital technology, an IT concept, rather than circular manufacturing concepts such as reusing, recycling, or remanufacturing.
1 & 6 & 8	16,67	The '1. Supply Chain Waste' cluster is about reducing waste. The '6. Circular Manufacturing' and '8. Design' clusters pertain to improving sustainability, all similar concepts.	Statements #16 (promising new technologies) and #67 (centralized manufacturing), both part of '8. Design cluster: Emphasize design principles rather than reducing waste or implementing circular manufacturing.
2 & 3 & 6	7	The '3. The Product Waste' cluster pertains to the sustainability of products. The '2. Info Tech' and '6. Circular Manufacturing' clusters focus on improving sustainability and becoming more sustainable, which are related concepts.	Statement #7 ('2. Info Tech' cluster) emphasizes using equipment with sensors, rather than unsustainable elements of products in use or circular manufacturing processes.
3 & 6 & 8	30, 34, 39, 51, 63,66, 68	The '3. Product Waste', '6. Circular Manufacturing', and '8. Design' clusters focus on reducing waste and increasing sustainability through various aspects of product and process, whether in the design phase or in use.	Statements #34 (material returns) and #51 (remanufacturing) emphasize circular manufacturing processes. Statement #68 '8. Design' cluster) emphasizes the design of new products and technologies (battery electric vehicle (BEV).
1 & 3 & 6 & 8	60	The '1. Supply Chain Waste', 3. Product Waste', '6. Circular Manufacturing', and '8. Design' clusters all pertain to reducing waste and increasing sustainability through aspects of product, process, and the supply chain itself, whether in the design phase or in use.	Statement #60 ('1. Supply Chain Waste' cluster) emphasizes the carbon footprint of the supply chain itself rather than focusing on the product, process, or design elements.

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