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Green Entrepreneurship in Circular Supply Chain Management: How Success Factors Assist a Zero-Waste Economy

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ABSTRACT

In the wake of pressing global environmental challenges and the urgent need for sustainable development (SD), green entrepreneurship (GE) has emerged as a promising avenue for supporting economic growth while addressing environmental and social concerns in developing economies. This research paper explores the critical success factors (CSFs) of GE that can potentially impact the digitalization of circular supply chain management (CSCM) toward a net-zero economy in the Indian textile industry. The CSFs were identified through a comprehensive literature review and validated using expert feedback. To prioritize these factors, the “Best-Worst Method” (BWM) was applied, and “Total Interpretive Structural Modelling” (ISM) and “Matrice d'Impacts Croisés Multiplication Appliquée à un Classement” (MICMAC) techniques were used to classify them into clusters. The results indicate that institutional CSFs and financing for entrepreneurs received the highest priority and were identified as the key driving factors based on expert evaluations. These insights will aid entrepreneurs, managers, and policymakers in formulating effective policies and strategies for achieving SDGs.

1 | Introduction

The textile industry is a major driver of global economic growth; however, it also contributes to environmental degradation, waste challenges, and climate change (Darji and Dahiya 2023). Growing concerns about environmental degradation and resource depletion have drawn increased attention from governments, policymakers, practitioners, and civil society (Govindan 2023). Consequently, there has been a paradigm shift toward embracing sustainability activities, particularly at the intersection of entrepreneurial innovation and sustainable practices (Shahid and Reynaud 2022). This shift is crucial for transitioning to a zero-waste economy, particularly in industries with significant environmental footprints such as the textile industry. For example, GE has emerged as a vital mechanism for promoting environmentally responsible innovation, generating sustainable employment, and advancing the goals of circular economy. At the same time, CSCM, which emphasizes resource recovery, waste minimization, and digital-enabled transparency plays a crucial role in realizing sustainability at the operational level. Integrating GE with CSCM is especially critical in emerging economies such as India, where industrial growth and environmental pressures coexist. This integration seamlessly merges sustainability principles with cutting-edge digital technologies, leading to efficiency and environmental responsibility. GE leverages digital platforms to optimize the supply chain through smart recycling, renewable energy integration, and efficient resource use, from raw material sourcing to product disposal (Govindan 2023). The synergy between GE and digitalization is evident in their collective efforts toward achieving sustainability goals through a closed-loop supply chain (Mondal et al. 2023b; Wang et al. 2023). In developed countries, GE leverages digital technologies to enhance supply chain transparency, traceability, and efficiency, thereby facilitating the transition toward circularity (Mondal et al. 2023b). This synergy is particularly pronounced in the textile industry, where the alignment of GE with digitalization is pivotal for creating a net-zero economy and sustainable development. CSCM embodies principles of waste reduction, resource optimization, and product lifecycle extension. It aims to minimize waste generation by closing the loop through processes like the 3R policy (recycle, reduce, and reuse) (Del Giudice et al. 2021). Waste management is, thus, a central tenet of CSCM, with GE serving as a catalyst for driving innovation in this domain.

Several studies, like Mondal et al. (2023a), were investigated and measured GE. Habib et al. (2020) and Wang and Yang (2021) demonstrate the relationship between green entrepreneurial orientations and green supply chain management (SCM), while Meherishi et al. (2019) conduct a literature review of SCM in the circular economy. Mondal et al. (2023b) show the role of GE and its factors that facilitate digitalization. Luthra et al. (2022) identify barriers to the circular supply chain. Lu et al. (2024) use a dynamic capability view to show the integration of circular economy and Industry 4.0 (I4.0) for sustainable SCM. Luthra et al. (2022) explore solutions to overcome these barriers.

Although GE plays a significant role in advancing the circular economy and CSCM, the literature reveals two important shortcomings. First, most prior studies have examined GE and sustainability in general terms (e.g., sustainable practices, environmental innovations, or supply chain transparency), but there is a lack of focused investigation into the specific CSFs that drive digitalization for CSCM. Second, most of the existing research has been conducted in developed economies, leaving a notable gap in understanding how these dynamics operate in developing contexts such as India's textile industry, which faces unique challenges of high waste generation, resource intensity, and technological gaps. There is a lack of comprehensive understanding of how GE drives digitalization in SCM, particularly in developing economies. While the concept of GE has gained traction in the literature, there is a notable research gap in understanding the specific CSFs that drive the digitalization of waste management and CSCM within the textile industry. Previous studies (e.g., Mondal et al. 2023b; Habib et al. 2020; Wang et al. 2023) have primarily focused on the broader aspects of GE, such as sustainable practices and environmental innovations, without delving into the complex details of factors that facilitate the transition toward a zero-waste economy. While prior studies have explored the intersection of GE, digitalization, and CSCM, there remains a gap in understanding the CSFs that underpin this nexus, particularly in the context of the Indian textile industry. This research addresses the gap by focusing on the Indian textile industry, a sector with immense potential for environmental impact. This study addresses these gaps by systematically identifying, prioritizing, and analyzing the CSFs of GE that enable digitalization for CSCM within the Indian textile sector. The novelty of this research lies in its integrated multi-method approach (BWM–TISM–MICMAC), which not only ranks and clusters the CSFs but also maps their interrelationships to reveal hierarchical structures and driving–dependence dynamics. By applying this framework, we provide new insights into how financing, institutional support, technological transfer, and socio-cultural enablers collectively influence the adoption of digital circular practices in textiles. Beyond academic contribution, the findings offer practical implications for entrepreneurs, managers, and policymakers: they highlight actionable levers for accelerating sustainable transformation in one of the world's most resource-intensive industries. Despite increasing attention to sustainability, the success of GE initiatives in driving CSCM digitalization depends on a range of CSFs. While prior research has highlighted drivers of sustainable entrepreneurship and enablers of circular supply chains, little work has systematically identified, prioritized, and interpreted the CSFs for GE within the context of CSCM. This gap is particularly significant in the Indian textile industry, which faces high environmental impact yet holds strong potential for circular transformation. Hence, the study has the following research questions:

RQ1. *What are the critical success factors (CSFs) that enable GE to support CSCM digitalization in the Indian textile sector?*

RQ2. *How can these CSFs be prioritized and structurally interrelated to inform theory and practice?*

Hence to address this, the "research objectives" (RO) of this study are:

RO1. *To identify the CSFs of GE that can possibly influence the digitalization of CSCM toward a net-zero economy in the Indian textile industry.*

RO2. *To identify the top CSFs and their contextual interrelationships among them.*

RO3. *To study the most significant CSFs, based on their comparative "driving power" and "dependence power."*

To address these questions, we integrate and extend existing theoretical perspectives. Natural Resource-Based View (NRBV) emphasizes how environmental resources and green innovation create sustainable competitive advantages. Critical success factor theory (CSFT) identifies the limited set of factors that must be managed successfully for organizational performance. ST highlights the role of stakeholder alignment in shaping entrepreneurial and supply chain practices. However, these theories have seldom been applied collectively to explain GE–CSCM dynamics, and their integration with empirically derived CSFs remains underexplored. This study contributes to four keyways. First, it identifies and maps 16 CSFs of GE in CSCM digitalization through extensive review and expert validation. Second, it employs the BWM to prioritize CSFs, ensuring methodological rigor and reducing inconsistency in expert judgments. Third, it applies MICMAC analysis to explore the driving–dependence power of these CSFs, providing structural insights into their interrelationships. Fourth, it advances theoretical understanding by explicitly linking CSFs to NRBV, CSFT, and ST, thereby offering a richer framework to explain how institutional, resource-based, and stakeholder-related factors collectively shape GE in emerging economies.

This study is structured as follows: Section 2 reviews the theoretical foundations and literature on GE and its impact on digitalization in CSCM. Section 3 outlines the mixed-methods approach, including BWM, TISM, and MICMAC, used to analyze data. Section 4 presents the case study and results, focusing on the Indian textile industry. Section 5 discusses the findings and their implications for industry and policy. Section 6 summarizes the key outcomes while Section 7 highlights study limitations and future research directions. This approach provides a thorough exploration of GE and digitalization in driving a zero-waste economy.

2 | Literature Review

2.1 | Theoretical Framework

The study aims to identify and analyze the CSFs of GE that contribute to the digitalization of CSCM and support the development of a net-zero economy in alignment with the SDGs. The theoretical framework (i.e., NRBV, CSFT, and ST) provides a theoretical lens and a logical basis to identify these relevant factors from the literature and potentially represent the contexts.

2.1.1 | Natural Resource-Based View)

NRBV is a theoretical framework within the fields of strategic management and organizational theory. It centers on the significance of natural resources in determining a business's competitive advantage and overall performance. This is achieved by effectively using the distinct natural resource endowments possessed by the firm. This idea is based on the resource-based view (RBV) framework, which states that a firm's main source of lasting competitive advantage lies in its unique and valuable resources (Makhloufi et al. 2022). Prior research shows that the NRBV framework sheds light on how companies can use their natural resource advantages to foster green innovation, promote environmental sustainability, and boost economic growth in emerging nations. Meirun et al. (2020) demonstrate that firms with valuable, scarce, and irreplaceable natural resources can leverage NRBV to build unique capabilities, enhancing performance in GE, digitalization, and CSCM. The scope of natural resources is broad and includes aspects, such as raw materials, ecosystems, and renewable energy sources (Shahid and Reynaud 2022). In the context of GE, NRBV highlights CSFs that rely on effective utilization and protection of environmental resources. For instance, green innovation practices, technology transfer for research and development, and green competitive advantage align with NRBV by enabling firms to create eco-innovative processes and products that minimize resource depletion while strengthening competitiveness. Thus, NRBV guided the identification of CSFs linked to environmental resource efficiency and innovation.

2.1.2 | Critical Success Factor Theory

This theory, first introduced by Ronald Daniel in 1961 and later refined by Rockart in 1979 (Rockart 1979; Kannan 2018), suggests that there are a limited number of areas which, if managed successfully, will ensure competitive performance for an organization (Govindan 2023; Kannan 2018). CSFT emphasizes identifying the key factors crucial for achieving an organization's objectives. In the context of GE and digitalization in CSCM in developing countries, this theory helps pinpoint the CSFs needed to drive sustainability and digital transformation (Bhatia et al. 2022). CSFT helps identify and prioritize key factors for the success of GE projects and their impact on SDGs (Mondal et al. 2023a). It supports digitalization in CE and CSCM, enhancing green business practices. For GE and CSCM, this framework clarifies which CSFs are decisive for digital transformation and sustainability. For example, financing for entrepreneurs, governmental support and policies, and entrepreneurial education and training represent high-priority enablers that, if effectively managed, ensure the viability of green entrepreneurial initiatives. In this study, CSFT provided the lens to prioritize these "must-manage-well" areas.

2.1.3 | Stakeholder Theory

Stakeholder theory (ST), a managerial framework central to organizational strategy and ethics, has garnered significant attention in academic research. According to R. E. Freeman (1984), a stakeholder encompasses "any group or individual who can affect or is affected by the achievement of an organization's objectives" (R. E. Freeman 1984; Kannan 2018). ST emphasizes the importance of considering the interests and concerns of all stakeholders involved in an organization when making decisions and formulating strategies (Mondal et al. 2023a). In the context of GE and CSCM in developing economies, ST underscores the significance of engaging various stakeholders, including customers, employees, suppliers, communities, and government bodies, in shaping sustainable business practices and outcomes (Mondal et al. 2023a). The theory suggests that organizations should prioritize the needs of all stakeholders, not just shareholders, balancing financial, socio-economic, and environmental factors for strategic planning (Mondal et al. 2023a). Accordingly, environmental corporate social responsibility, social and cultural values, and openness to waste management and circular economy reflect ST's emphasis on aligning entrepreneurial actions with stakeholder expectations. ST also informs the importance of governmental support and high status of successful entrepreneurs, as these factors build legitimacy and collective action for sustainability.

This study adopts an integrative approach, combining NRBV, CSFT, and ST to examine GE, digitalization, and CSCM dynamics in the textile industry. NRBV emphasizes the sustainable use of resources for competitive advantage, explaining how textile companies can enhance profitability and resilience by leveraging their unique resource bases for sustainable practices. NRBV

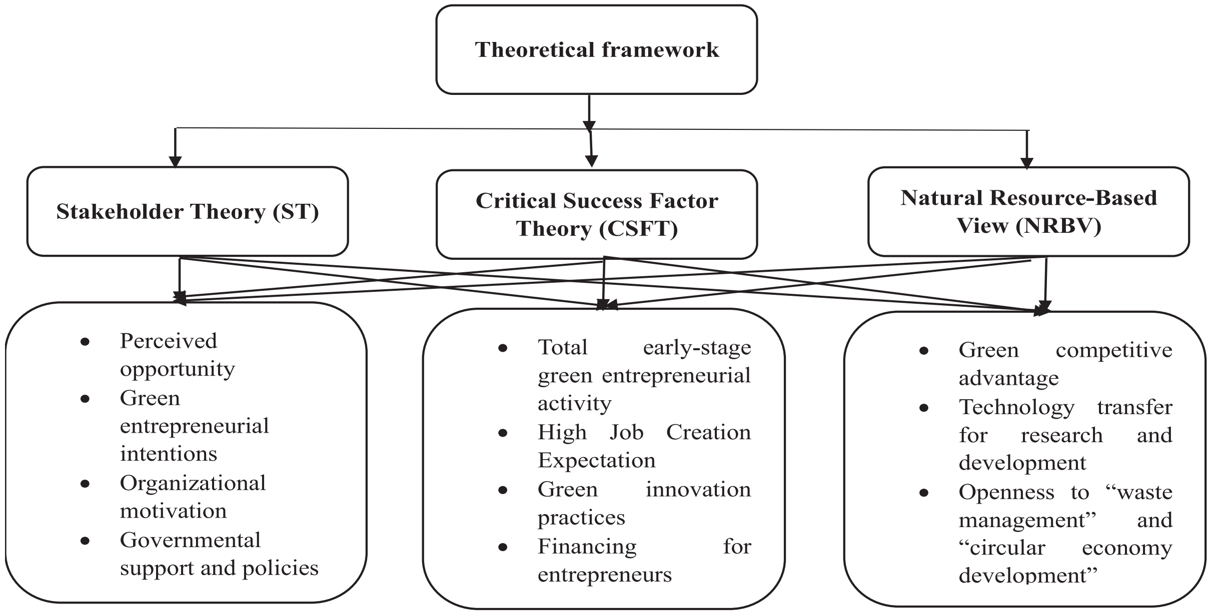

FIGURE 1 | Theoretical framework (*Source*: Author composition).

emphasizes the role of responsible use of natural resources in ensuring a sustainable competitive advantage by the firms. In the textile sector, the utilization of renewable resources, environmentally friendly materials, and energy resources can support the introduction of digital devices that help companies improve the optimization of resources and reduce waste. CSFT helps identify key areas crucial for successful digital transformation in CSCM, highlighting the factors necessary for effectively implementing digital technologies in circular supply chains, a critical step toward a net-zero economy. CSFT identifies key areas that impact the performance and sustainability of GE initiatives. CSFT focuses on determining the main success factors that have to be addressed to achieve organizational performance. In this case, CSFT is useful to prioritize institutional, technological, financial, and social enabling essential to digital transformation in CSCM. ST ensures a holistic view by considering the social, economic, and environmental effects of digitalization and circular practices. Together, these theories offer a multidimensional perspective on the factors influencing GE, digitalization, and CSCM for the textile industries. ST puts emphasis on the roles of various stakeholders, such as entrepreneurs, suppliers, consumers, policymakers, and communities, in influencing sustainable practices. Their participation is essential to legitimize and scale GE-led digital solutions of the supply chain. Using these interconnected theoretical perspectives, this study provides deeper insights into how digital technologies and GE drive CSCM.

The theoretical framework, supported by a literature review, theories, and expert opinions, is used to identify the CSFs, as shown in Figure 1.

2.2 | Green Entrepreneurship

Green entrepreneurship (GE) refers to the pursuit of innovative business ventures that prioritize environmental sustainability and economic viability (Meirun et al. 2020; Mondal et al. 2023a). It is a critical approach to addressing and adopting global environmental challenges while promoting economic growth. Green entrepreneurs focus on developing and marketing products or services that minimize environmental impact, enhance resource efficiency, and support sustainable development (Tian 2024). Existing studies provide substantial evidence for GE's role in achieving environmental and socioeconomic goals. Wang et al. (2023) highlight how GE can lead to the creation of eco-innovative products and processes, thereby, reducing resource consumption and minimizing environmental harm. Makhloufi et al. (2022) and Meirun et al. (2020) emphasize the role of green entrepreneurs in advancing SDGs, particularly in the areas of clean energy, waste reduction, and climate mitigation. GE not only drives innovation but also creates employment opportunities while also nurturing economic growth.

2.3 | Past Studies on GE, Digitalization, and CSCM

Rapid industrialization currently contributes to climate change, global warming, and related issues (Makhloufi et al. 2022). In response, governments are introducing new policies to promote green products and encourage sustainability initiatives (Bradley et al. 2021; Makhloufi et al. 2022). Beyond government initiatives, consumers, businesses, and startups are increasingly prioritizing environmental concerns (Kushwaha et al. 2015). Therefore, GE has emerged as a crucial driver of sustainable development, particularly in addressing environmental degradation, climate change, and the global shift toward circular and digital supply chains. In present time, policymakers and researchers alike have emphasized that achieving sustainability requires entrepreneurial ecosystems that integrate green innovation, stakeholder collaboration, and digital technologies (Carfora et al. 2021). Within this context, CSCM is increasingly recognized as a transformative approach that enables firms to close resource loops, reduce waste, and align with net-zero and circular economy goals (Bag 2024). Studies (Sun et al. 2020) suggest that green entrepreneurs bring new elements to the existing framework of market opportunities, such as product innovation. Green innovation drives sustainable production, supporting industrial growth, economic development, job creation, and financial wealth. By adopting environmentally friendly technologies, entrepreneurs contribute to green goods and services, green energy, and fossil fuel reduction, solving environmental issues, and ultimately advancing sustainable development (Sun et al. 2020). CSCM is seen as a safeguard against environmental degradation linked to sustainable development activities (Del Giudice et al. 2021). It addresses sustainability concerns by integrating social, economic, and environmental development. The growing interest in CSCM aligns supply chain activities with the circular economy, promoting value co-creation for broader sustainability goals (Del Giudice et al. 2021). Digitalization aids in transforming traditional circular economy into smart circular economy practices, contributing to SDGs and achieving a net-zero economy (Govindan 2023). This involves enhancing product design, efficiency, and protection, while minimizing environmental impact throughout the product lifecycle.

The textile industry faces multiple challenges in adopting green and sustainable practices, including inadequate capital, lack of technology, rising production costs, and social and cultural uncertainties (Sun et al. 2020). Additional barriers include the absence of incentives, limited public support, high green production costs, insufficient green innovation, limited natural resources, and competition (Sher et al. 2019). However, adherence to robust government policies, higher industry standards, clear regulations, and investments in sustainability can help mitigate these challenges and support a shift toward greener production (Mondal et al. 2022). R&D transfer, along with innovation, is a strategic tool to balance product price and sustainability, benefiting startups focused on greener products (Sher et al. 2019). Innovation, technological development, and green entrepreneurial growth are closely connected (Sher et al. 2019), promoting environmental innovation both locally and globally (Gast et al. 2017). Trading environmentally friendly technologies boosts economic growth and enhances environmental quality (Sun et al. 2020; Gast et al. 2017). Identifying appropriate technologies is crucial for creating frameworks that support GE and sustainable development initiatives in developing countries like India (Mondal et al. 2023a). GE offers opportunities for economic growth by addressing ecological and social challenges, while also supporting new ventures, capitalizing on opportunities, and creating jobs (Sun et al. 2020). This approach helps address industrialization challenges, such as environmental pollution, global warming, and climate change in developing nations like India (Sun et al. 2020). The CSFs identified in this study are presented in Table 1.

2.4 | Research Gap

Despite the growing interest in GE and CSCM, the literature reflects several shortcomings. First, most studies have examined GE or CSCM in isolation, often focusing on specific drivers such as green innovation or corporate social responsibility (e.g., Bocken et al. 2025). This fragmented approach has left limited understanding of how multiple CSFs interact to shape the effectiveness of GE in driving CSCM. While frameworks such as the NRBV, CSFT, and ST are frequently referenced in sustainability and entrepreneurship research (Hart 1995; R. E. Freeman 2010; Rockart 1979), they are often applied in general terms without being systematically linked to specific mechanisms in GE or CSCM. This lack of integration constrains the explanatory depth of prior studies. Much of the empirical evidence is concentrated in developed economies, with relatively few studies addressing emerging economies such as India (Kumar et al. 2024). Given that emerging economies face distinct challenges such as financing constraints, policy enforcement gaps, and cultural influences there is a pressing need for context-specific investigations. The Indian textile sector, as one of the country's largest and most resource-intensive industries, provides a particularly relevant setting to explore these dynamics. Previous studies have relied heavily on qualitative approaches or simple statistical models (Sehnem et al. 2019), with fewer adopting structured multi-criteria decision-making techniques. This gap limits our ability to rigorously prioritize and model interdependencies among CSFs.

To address these gaps, this study develops a theory-driven framework by systematically mapping CSFs of GE to NRBV, CSFT, and ST, thus enriching theoretical integration. It provides context-specific insights by examining the Indian textile industry, an underexplored yet highly impactful sector in terms of sustainability and resource usage. The study also applies a hybrid methodological approach (BWM-ISM-MICMAC) that enables both prioritization and structural analysis of CSFs, offering methodological novelty. Additionally, the study critically discusses both expected and unexpected findings, thereby advancing theoretical understanding and providing actionable guidance for policymakers and practitioners.

3 | Methods and Materials

As outlined in the objectives, this study aims to systematically address the CSFs in GE within the textile industry's circular supply chain. This section details the mixed-methods approach employed to explore these factors, directly aligning with our objectives to ensure a targeted and effective analysis. This study employed a multi-method approach combining the BWM, TISM, and MICMAC analysis to identify, prioritize, and interpret the interrelationships among CSFs. A four-phase research methodology was used to prioritize, develop a relationship, and cluster the CSFs (as shown in Figure 2). The hybrid methodology combining literature review, expert validation, and three analytical techniques. In the first phase of the literature review, theories and expert feedback were used to identify CSFs. The literature search was performed using online databases, such as Scopus and Web of Science (WoS) with keyword combinations ("factor" OR "enabler" OR "critical") (AND/OR) "green entreprene*" (AND/OR) ("waste" OR "waste management") (AND/OR) (("circular" AND "supply chain") OR "circular supply chain"). This was followed by expert validation (10 senior professionals from industry and academia with > 10 years of experience in sustainable practices). After identifying and categorizing the factors, expert opinion and the theoretical framework were used. BWM was then applied to identify the top CSFs needing urgent attention in the textile industry. BWM evaluated the requirements of CSFs and sub-CSFs, while TISM established

TABLE 1 | The summary of measurement variables and source of data shown below (*Source*: Author composition).

Main category CSFs	Sub-category CSFs	Code	References
Technological CSFs (TCSF)	Technology transfer for research and development	TCSF1	Fernandes et al. (2021)
	Openness to waste management and circular economy development	TCSF2	Mondal et al. (2023b)
	Green innovation practices	TCSF3	Wang and Yang (2021)
	Advanced waste tracking systems	TCSF4	Gong et al. (2022)
	Digitalization of supply chain processes	TCSF5	Gong et al. (2022)
	Blockchain for transparency	TCSF6	Gong et al. (2022)
	Collaborative industry partnerships	TCSF7	Luthra et al. (2022)
Institutional CSFs (ICSF)	Perceived opportunity	ICSF1	Experts' opinion
	Green entrepreneurial intentions	ICSF2	Kumar and Basu (2023)
	Total early-stage green entrepreneurial activity	ICSF3	Demirgüç-Kunt et al. (2020)
	Organizational motivation	ICSF4	Le et al. (2021)
	Financing for entrepreneurs	ICSF5	Silajdžić et al. (2015)
	Governmental support and policies	ICSF6	Bradley et al. (2021)
	Green business strategies	ICSF7	Experts' opinion
Human CSFs (HCSF)	Entrepreneurial education and training	HCSF1	Liu et al. (2019)
	High status to successful entrepreneurs	HCSF2	Kiran and Goyal (2021)
	Green entrepreneurial leadership	HCSF3	Mondal et al. (2023b); Le (2022)
	Skill development and training programs	HCSF4	Experts' opinion
	Employee engagement in sustainability initiatives	HCSF5	Le (2022)
	Consumer awareness and education	HCSF6	Meherishi et al. (2019)
Societal CSFs (SCSF)	High job creation expectation	SCSF1	Kiran and Goyal (2021)
	Circular economy certification	SCSF2	Experts' opinion
	Government incentives for sustainable practices	SCSF3	Li et al. (2023)
	The demand for a green product in the domestic market	SCSF4	Gast et al. (2017)
	Social and cultural values	SCSF5	Gast et al. (2017)
	Green competitive advantage	SCSF6	Gast et al. (2017); Tu and Wu (2021)
	Environmental corporate social responsibility	SCSF7	Experts' opinion

their interrelationships (Table 1). In phase 4, MICMAC analysis clustered these CSFs based on their "driving power" and "dependence power." Table 2 summarizes past studies and their methodologies.

3.1 | Best-Worst Method

Rezaei's best-worst method (BWM) approach is a recently developed "multi-criteria decision-making" (MCDM) method that utilizes a multi-case study methodology (Rezaei 2015). BWM is employed to prioritize the CSFs of GE that aid in the digitalization of CSCM and promote sustainable development. Compared to other MCDM methods, BWM offers the advantage of providing consistent results with fewer data points. Unlike the traditional "analytical hierarchy process" (AHP), which requires pairwise comparisons of all criteria (resulting in $\{n \times (n-1)/2\}$ comparisons), BWM only requires $(2n-3)$ pairwise comparisons. This reduces the number of comparisons needed while still ensuring reliable outcomes. It means BWM requires fewer pairwise comparisons and ensures higher reliability and consistency (Rezaei 2015). This straightforward process involves selecting the best and worst criteria for pairwise comparisons, providing decision-makers with more dependable results. Its

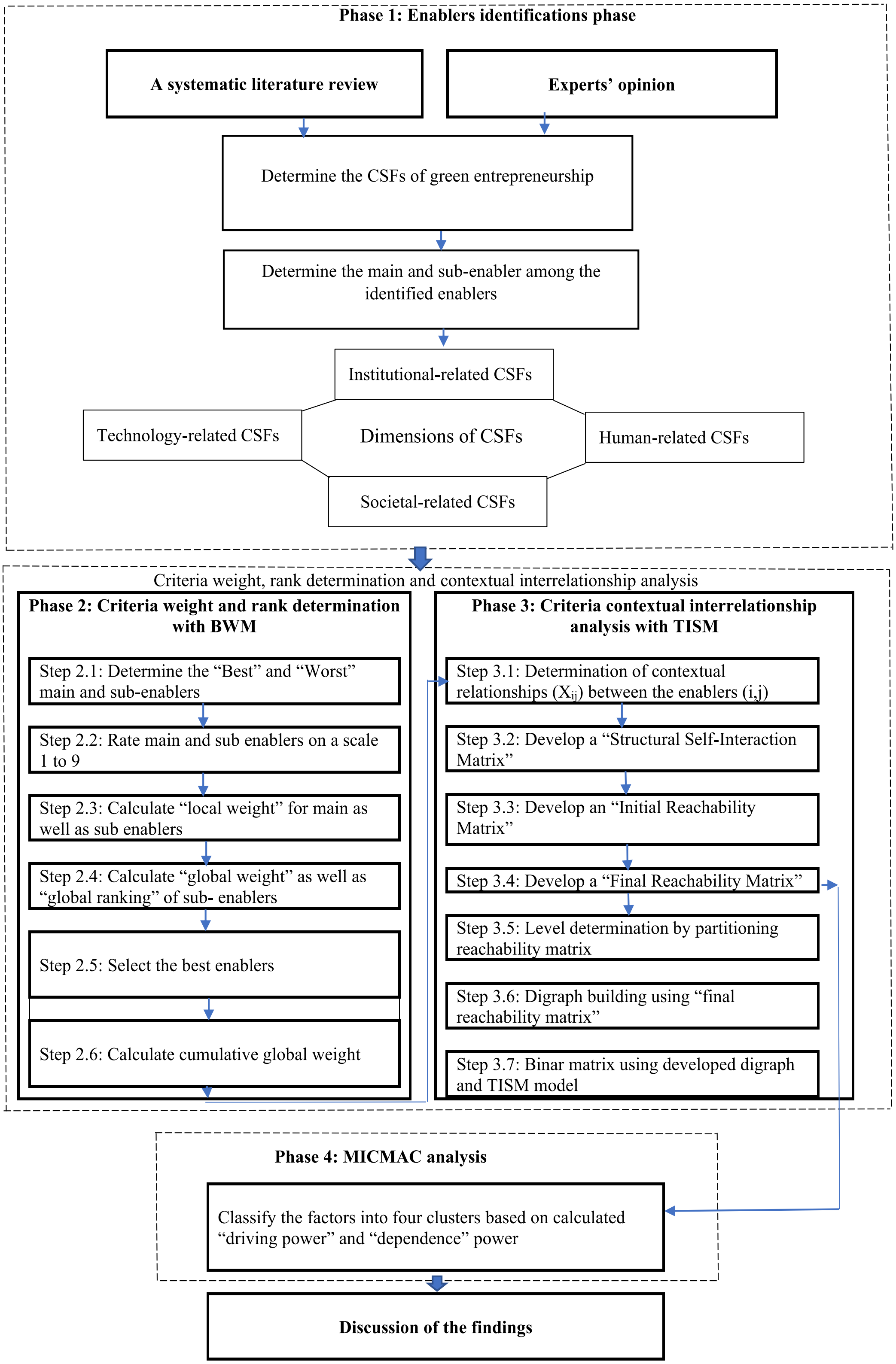

FIGURE 2 | Flow diagram for research method (*Source*: Author composition).

unique structure makes two vectors contain only positive integers (A_B and A_W), avoiding the fundamental distance problem of AHP in the form of fractions (such as $1/a$) (Rezaei 2015, 2016). Variations in the two portions of vector data arose from differing perspectives among BWM experts, as they select different best and worst criteria. This was critical for identifying the most influential factors, such as Financing for Entrepreneurs and Governmental Support.

TABLE 2 | Overview of past studies employed in GE, digitalization, CSCM, and net-zero economy research (*Source*: Author composition).

Authors	Year	Methodology	Case study
Kannan	2018	ISM-ANP-COPRAS-G	Indian textile industry
Govindan	2023	BWM—Grey DEMATEL	Textile industry
Bhatia et al.	2022	Partial least square	Indian small and medium manufacturing enterprises (SMEs)
Habib et al.	2020	SEM	Bangladeshi textile manufacturing firms
Del Giudice et al.	2021	SEM	Italian firms
Bag et al.	2022	SEM	South Africa manufacturing SMEs
Le	2022	Partial least square-SEM	SMEs
Luthra et al.	2022	Agglomerative hierarchical clustering (AHC)—fuzzy DEMATEL	UK, USA, Turkey and India and from manufacturing, food sector, construction and luxury fashion
Govindan et al.	2019	BWM	Electronic industry
Wang et al.	2023	SEM	Chinese firm

3.2 | TISM And MICMAC Methodology

TISM is used to establish interdependency relationships in complex decision-making studies. It helps in understanding the contextual relationships of critical influencing factors, providing valuable insights for research and decision-making processes. The study adopts the TISM approach as an advancement over conventional ISM. While ISM is widely used to study interrelationships, it has limitations such as neglecting transitive links, focusing only on the "What" and "How," and providing weak explanations for linkages. TISM, however, addresses these issues by considering transitivity, explaining both links and nodes, answering the "Why" aspect, and simplifying complex systems. The methodology emphasizes gathering qualitative insights from experienced professionals on CSFs for GE in waste management and CSCM (Baliga et al. 2021; Sindhwani et al. 2024). TISM breaks down a "complex system" into several "subsystems" and then establishes a multilayer "structural model" (Baliga et al. 2021). Complementing the TISM model is the MICMAC analysis, which acts as a catalyst for uncovering the latent indirect interrelationships among the factors. The analysis demonstrates the interconnectedness among elements by plotting them on a graph, revealing four distinct clusters based on determined power dynamics (Mondal et al. 2023b; Baliga et al. 2021). Unlike ISM, TISM adds interpretive logic, providing richer insights into why one factor influences another, which is essential for building theory-driven explanations of GE success mechanisms.

MICMAC analysis complements TISM by classifying CSFs into drivers, dependents, linkages, and autonomous factors based on their driving and dependence power. This step validates the structural model and highlights the systemic roles of CSFs in the GE ecosystem.

Thus, the hybrid BWM–TISM–MICMAC framework provides a holistic understanding of both the priority and causal structure of CSFs, which would not be possible through a single method. This integrated approach strengthens the validity of the findings and ensures a robust theoretical contribution.

4 | Case Study and Analysis

For the research objective, experts from different textile industries (Table 3) were considered. The expert interview process was designed to validate the identified CSFs and ensure their relevance to the textile industry's transition toward a zero-waste economy. This study focuses on the textile sector due to its significant contribution to GDP (2.3%) through employment creation and industrial production (13%) and its share in exports (12%) (Darji and Dahiya 2023). Out of 27 experts contacted, 10 agreed to participate, yielding a 37% response rate. A total of 10 experts were selected, representing academia (4 experts in sustainable entrepreneurship and supply chains), industry (4 experts from textile and manufacturing firms), and government/policy institutions (2 experts with experience in sustainability programs). The sample size is consistent with prior ISM/TISM and BWM studies, which have typically relied on 8–15 experts (e.g., Kusi-Sarpong et al. 2021; Kannan 2018; Moktadir et al. 2020; Zekhnini et al. 2024). Beyond this range, studies show diminishing returns, as additional experts do not substantially increase the reliability of the structural model but complicate consensus-building. The industry experts and academic professionals having over 10 years of experience in senior roles and deep expertise in green initiatives were selected from environmentally conscious companies. They were carefully chosen to ensure diverse perspectives and generalizable results for organizations in last-mile logistics. Semi-structured interviews were conducted, allowing them to share insights and validate the interrelationships among the CSFs. The interviews followed a systematic approach, ensuring consistency in the data collection process while providing flexibility to elaborate on their perspectives.

TABLE 3 | Experts' background details (*Source*: Author composition).

Expert number	Designation	Education	Year of experience	Organization type
1	General manager	B. Tech	19	Textile industry
2	Manager operation	MBA	11	Textile industry
3	CEO	MBA	12	Textile industry
4	Operation manager	B. Tech	11	Leather industry
5	Manager production planning and control	M. Tech	13	Textile industry
6	Supply chain manager (SCM)	MBA	17	Textile industry
7	Senior technical manager	B. Tech	13	Leather industry
8	Professor (academics)	PHD	17	Operation and supply chain
9	Professor (academics)	PHD	20	Textile and fabric engineering
10	Professor (academics)	PHD	12	Operation and entrepreneurship

Here expert feedback was collected in three stages. First, initial structured interviews were conducted to elicit opinions on the relative importance of CSFs and their interdependencies. Second surveys were administered where experts pairwise compared the best and worst CSFs to derive priority weights. Lastly, experts established pairwise contextual relationships among CSFs. In addition to that, follow-up validation sessions were conducted to resolve disagreements and ensure consensus.

To address concerns about subjectivity and bias, the following measures are taken:

- *Diverse expert panel*: We carefully selected a heterogeneous panel of experts including academicians, policymakers, and practitioners from the Indian textile and sustainability sector. This diversity reduced the risk of one-sided perspectives.
- *Structured elicitation process*: Experts were provided with clear definitions of each CSF, the theoretical framework, and instructions to ensure consistency in responses.
- *Anonymity of responses*: To avoid social desirability or dominance bias, individual responses were collected independently and kept anonymous during aggregation.
- *Consistency check*: In the BWM process, consistency ratios were calculated to ensure logical coherence in pairwise comparisons. Inconsistent responses were cross-checked and clarified with experts.
- *Triangulation*: Findings from expert-based methods were compared with insights from the literature to validate the robustness of results.

For BWM, the "consistency ratio" (CR) was calculated for each expert, with all values falling below the acceptable threshold of 0.1, ensuring reliability of pairwise comparisons. In TISM, interpretive logic for pairwise relationships was documented and cross-validated among experts, with over 85% agreement achieved in the first round. Divergent views were reconciled in subsequent sessions until consensus was reached. Lastly for the MICMAC analysis, the stability of driving and dependence powers was tested by sensitivity checks, confirming the robustness of the classification. Finally, triangulation was employed by comparing expert-derived results with the extant literature to validate reliability. This process improves transparency and the reliability of results. Further details are provided in Table 3.

5 | Results and Discussion

5.1 | Result Obtained From BWM

BWM was used to identify the most and least important CSFs by designating them as the 'best' and 'worst' criteria based on expert assessments. The best main/sub-CSFs were compared with other main/sub-CSFs within the same category using a scale from 1 to 9, where 1 represents "equal importance" and 9 represents "extreme importance" (Tarei et al. 2021; Rezaei 2015). Simultaneously, the "others-to-worst" (OW) matrix was constructed by comparing the relative preferences of other main/sub-CSFs to the worst main/sub-CSFs using a scale from 1 to 9. Each expert assigned scores indicating their preferences for each primary category (technical, institutional, human, and social) of CSFs and their corresponding sub-CSFs. This process generated both the "best-to-others" (BO) and OW matrices. The resulting weights, based on expert preference scores, provided category-specific local weights for the main/sub-CSFs. The list of the most and least important CSFs identified by expert 1 is shown in Table 4. Subsequently, the final local weights for CSFs and sub-CSFs were calculated by taking the average ("arithmetic mean" or geometric mean) of the local weights derived from the preference scores of each expert (Table 5). The "global weights" (GW) for sub-CSFs were calculated by multiplying the local weight of the relevant main category CSF with the local weights of the respective sub-CSFs, resulting in the generation of "global weights." Using the obtained global weights, global

TABLE 4 | Main category CSFs comparison by Expert 1 (*Source*: Author composition).

Best-to others (BO)	TCSF	ICSF	HCSF	SCSF
Best CSF: TCSF	1	2	5	9
Other-to-worst	Worst CSF: SCSF			
TCSF	9			
ICSF	5			
HCSF	4			
SCSF	1			

ranks were assigned to each sub-CSF (see Table 5). In addition, the final "consistency ratio" (CR) was determined by averaging the individual CR values acquired from each expert's response. It is important to note that any CR values below 0.1 indicate that the data is reliable and consistent (Tarei et al. 2021).

For further analysis, we considered the top CSFs whose global weight was 80% contribution. We identified 17 sub-CSFs, and their corresponding codes were also modified. For further analysis, we considered CSFs, such as perceived opportunity (CSF1), green entrepreneurial intentions (CSF2), total early-stage green entrepreneurial activity (CSF3), organizational motivation (CSF4), high job creation expectation (CSF5), green innovation practices (CSF6), high status to successful entrepreneurs (CSF7), financing for entrepreneurs (CSF8),

TABLE 5 | Weight of main-category and sub-category CSFs (*Source*: Author composition).

Main category	Weight	Sub category	Local Weight	Global weight	Rank
Technological CSFs (TCSF)	0.223	TCSF1	0.184	0.041	10
		TCSF2	0.152	0.034	15
		TCSF3	0.224	0.050	7
		TCSF4	0.120	0.027	19
		TCSF5	0.109	0.024	20
		TCSF6	0.107	0.024	21
		TCSF7	0.104	0.023	22
Institutional CSFs (ICSF)	0.362	ICSF1	0.128	0.046	8
		ICSF2	0.096	0.035	13
		ICSF3	0.169	0.061	3
		ICSF4	0.081	0.029	17
		ICSF5	0.236	0.085	1
		ICSF6	0.194	0.070	2
		ICSF7	0.097	0.035	12
Human CSFs (HCSF)	0.187	HCSF1	0.271	0.051	6
		HCSF2	0.302	0.057	4
		HCSF3	0.096	0.018	24
		HCSF4	0.149	0.028	18
		HCSF5	0.104	0.019	23
		HCSF6	0.078	0.015	26
Societal CSFs (SCSF)	0.228	SCSF1	0.162	0.037	11
		SCSF2	0.063	0.014	27
		SCSF3	0.071	0.016	25
		SCSF4	0.189	0.043	9
		SCSF5	0.149	0.034	14
		SCSF6	0.130	0.030	16
		SCSF7	0.236	0.054	5

TABLE 6 | SSIM matrix.

CSF	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	O	A	O	O	V	O	O	O	O	O	O	O	O	V	A	O	—
2	V	A	O	O	V	O	O	O	O	O	A	X	V	V	O	—	
3	O	O	O	O	O	O	O	A	O	O	O	O	O	O	—		
4	O	O	V	O	X	O	A	O	O	O	O	A	X	—			
5	O	O	V	V	O	O	O	O	O	O	O	O	—				
6	V	A	O	O	O	O	O	O	O	O	O	—					
7	O	X	O	O	O	O	O	O	O	O	—						
8	O	V	O	O	O	O	O	O	X	—							
9	O	V	O	O	O	O	O	O	—								
10	O	O	O	O	O	O	O	—									
11	O	A	O	O	O	X	—										
12	V	A	O	O	V	—											
13	O	O	V	O	—												
14	A	O	X	—													
15	A	O	—														
16	O	—															
17	—																

governmental support and policies (CSF9), entrepreneurial education and training (CSF10), technology transfer for research & development (CSF11), demand for a green product in the domestic market (CSF12), openness to waste management and circular economy development (CSF13), social and cultural values (CSF14), green competitive advantage (CSF15), environmental corporate social responsibility (CSF16), and green business strategies (CSF17).

5.2 | Result Obtained From TISM

The contextual relationships between GE's important influencing components were identified by using pairwise comparison metrics. The same experts were again asked to respond "yes" or "no" to each critical factor relationship. Also, the pairwise relationships between the components were investigated and transformed to a "structural self-interaction matrix" (SSIM) using "V," "A," "X," and "O." The related path between row (i) and column (j) was expressed by ("V," "A," "X," and "O") (Tarei et al. 2021) (Table 6).

- V: "factor i affect factor j."
- A: "factor i is affected by the factor j."
- X: "factor i and j will affect each other."
- O: "factor i and j have no relationship."

The SSIM was transformed to develop the "initial reachability matrix" (IRM) (Table 7) and the "final reachability matrix" (FRM) (Table 6). To obtain the IRM from SSIM, we swapped the values of V and X, making "V" and "X" equal to 1, and "A" and "O" equal to 0, as shown in Table 7. The four cases here are:

i. If (i, j) entry is a V, then (i, j) entry in the RM matrix is set to 1 and (j, i) entry is set to 0.

ii. If the entry of (i, j) is equal to A, then the corresponding element in the RM is set to 0, and the element at position (j, i) is set to 1.

iii. If (i, j) entry is equal to X, then both (i, j) and (j, i) entries of the RM are set to 1.

iv. If the entry at position (i, j) is equal to 0, then both the entry at positions (i, j) and (j, i) of the RM matrix are set to 0.

From the IRM, we obtained the "final reachability matrix" (FRM) (as shown in Table 8) after applying the "transitivity rule." The logic used was "if a CSF(a) is related to other CSF(b) and CSF(b) further related to CSF(c)," the "CSF(a) is logically related to CSF(c)." If the industry expert does not consider this rule, transitivity in the relationship of CSF occurs, and values are altered from "0" to "1*."

5.3 | Level Partitioning

At this point, the hierarchical structure of CSF may be created using level partitioning (Mondal et al. 2023a). The antecedent sets of each factor were derived from FRM. In the context of the ISM, a "reachability set" for a CSF comprises the CSF itself and all the CSFs that it impacts. The "antecedent set" consisted of the CSFs and any other CSFs that contributed to its achievement

TABLE 7 | IRM matrix (*Source*: Author composition).

CSF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
2	0	1	0	1	1	1	0	0	0	0	0	0	1	0	0	0	1
3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0
5	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0
6	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1
7	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0
9	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0
10	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
11	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1
13	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
16	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1

TABLE 8 | FRM matrix (*Source*: Author composition).

CSF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Driving power
1	1	0	0	1	1*	0	0	0	0	0	0	0	1	1*	1*	0	0	6
2	0	1	0	1	1	1	0	0	0	0	0	0	1	1*	1*	0	1	8
3	1	0	1	1*	0	0	0	0	0	0	0	0	1*	0	0	0	0	4
4	0	0	0	1	1	0	0	0	0	0	0	0	1	1*	1	0	0	5
5	0	0	0	1	1	0	0	0	0	0	0	0	1*	1	1	0	0	5
6	0	1	0	1	1*	1	0	0	0	0	0	0	1*	1*	1*	0	1	8
7	1*	1	0	1*	1*	1*	1	0	0	0	1*	1*	1*	0	0	1	1*	11
8	1*	1*	0	0	0	1*	1*	1	1	0	1*	1*	0	0	0	1	0	9
9	1*	1*	0	0	0	1*	1*	1	1	0	1*	1*	0	0	0	1	0	9
10	1*	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3
11	0	0	0	1	1*	0	0	0	0	0	1	1	1*	0	1*	0	1*	7
12	0	0	0	1*	0	0	0	0	0	0	1	1	1	1*	1*	0	1	7
13	0	0	0	1	1*	0	0	0	0	0	0	0	1	1*	1	0	0	5
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
16	1	1	0	1*	1*	1	1	0	0	0	1	1	1*	0	0	1	1*	11
17	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	3
Dependence power	7	6	2	11	9	6	4	2	2	1	6	6	11	10	11	4	7	105/105

Note: *indicates the transitive relationship.

TABLE 9 | Level partitioning (*Source*: Author composition).

Element	Reachability set	Antecedent set	Intersection set	Level
1	1,4,5,13,14,15	1,3,7,8,9,10,16	1	III
2	2,4,5,6,13,14,15,17	2,6,7,8,9,16	2,6	III
3	1,3,4,13	3,10	3	IV
4	4,5,13,14,15	1,2,3,4,5,6,7,11,12,13,16	4,5,13	II
5	4,5,13,14,15	1,2,4,5,6,7,11,13,16	4,5,13	II
6	2,4,5,6,13,14,15,17	2,6,7,8,9,16	2,6	III
7	1,2,4,5,6,7,11,12,13,16,17	7,8,9,16	7,16	IV
8	1,2,6,7,8,9,11,12,16	8,9	8,9	V
9	1,2,6,7,8,9,11,12,16	8,9	8,9	V
10	1,3,10	10	10	V
11	4,5,11,12,13,15,17	7,8,9,11,12,16	11,12	III
12	4,11,12,13,14,15,17	7,8,9,11,12,16	11,12	III
13	4,5,13,14,15	1,2,3,4,5,6,7,11,12,13,16	4,5,13	II
14	14,15	1,2,4,5,6,12,13,14,15,17	14,15	I
15	14,15	1,2,4,5,6,11,12,13,14,15,17	14,15	I
16	1,2,4,5,6,7,11,12,13,16,17	7,8,9,16	7,16	IV
17	14,15,17	2,6,7,11,12,16,17	17	II

(Baliga et al. 2021). Level I was allocated during the first phase to the component for which the "reachability" and "intersection" factors were equal. After assigning "level I" to the "top-level" CSF, it was removed from the list of CSFs that were previously exhibited. Likewise, the procedure was repeated until each green entrepreneurial factor achieved its level. From the level partitioning, we obtained a five-level hierarchical structure, presented in Table 9.

5.4 | Formation of ISM Diagraph

After the levels of the CSFs were determined, a diagram was created to illustrate the relationship between the CSFs. This diagram includes the serial number of each CSF and an arrow to indicate the direction of the association. The studied digraphs were interactively analyzed to remove transitive links after which the ISM diagram was drawn. The ISM digraph depicts the interconnectedness of CSF elements at different levels, displaying the hierarchical five-level structure seen in Figure 3. A "unidirectional arrow" going from node "X" to node "Y" implies that "X" affects "Y." A "bidirectional line" linking the nodes "X" and "Y" indicates "X" and "Y" mutually "leading to each other and emphasizes the existence of reciprocal interactions." Figure 3 shows the ISM diagram of green entrepreneurial factors obtained through "level partitioning."

To test the transitive relationships for further evaluation, the same panel of experts (see Table 3) used a five-point "Likert scale" to identify the most significant "transitive links." Individuals with scores of 3.5 or higher were considered eligible for inclusion, whereas those below this criterion were excluded (Mondal et al. 2023b; Baliga et al. 2021). This higher threshold was used to guarantee a succinct depiction in the final digraph. To calculate the significant relationships, we considered each relationship as a hypothesis. If the population mean was equal to the sample mean, it is considered a null hypothesis (H_0); if the relationship is not equal, it is considered an alternative relationship (H_a). Here, the sample size ($n = 10$) and mean value is 3. A two-tailed t-test was then conducted to test the hypotheses.

H_0: There was no significant difference between the observed value and the specified mean value.

$$H_0: \text{observed mean} - \text{specified mean} = 0.$$

H_a: There was a positive significant difference between the observed mean and specified mean.

$$H_a: \text{observed mean} - \text{specified mean} \neq 0.$$

$$t = \frac{\bar{x} - \mu}{\frac{SD}{\sqrt{n}}} \tag{1}$$

Here, $\bar{x}$ = average value (observed mean), μ = specified mean (3), SD = standard deviation, and n = sample size. If the t value was greater than the threshold value ($t_{95} = 1.812$), we considered the alternate hypothesis. The rejected link was dropped from the TISM diagram. The omission of certain elements does not automatically mean that there are no transitive connections; instead, it is done to deliberately include only the most important

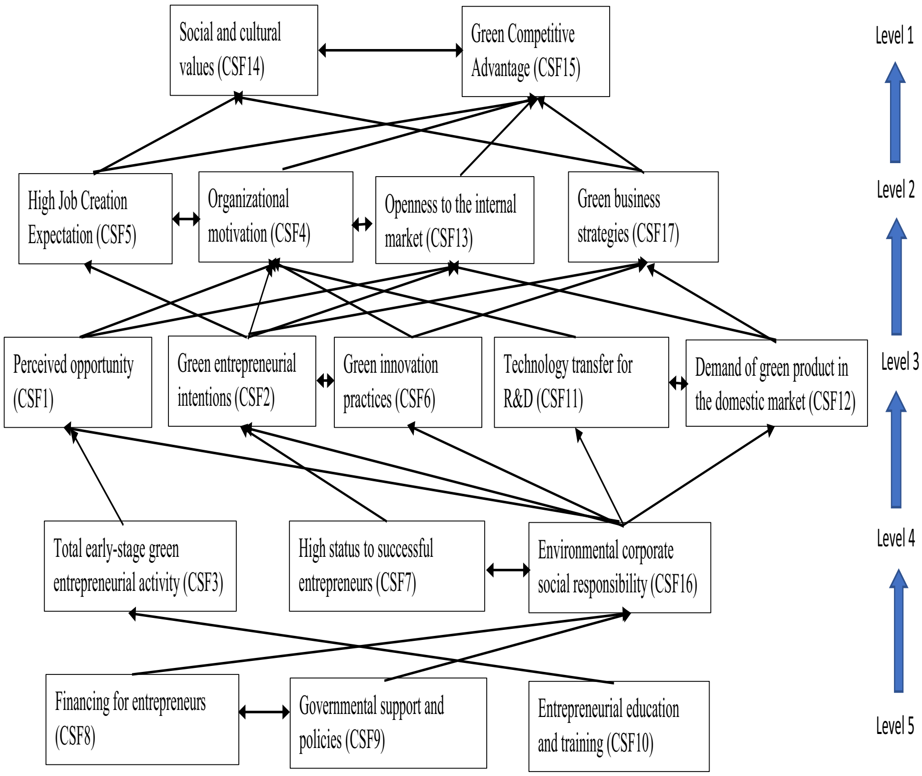

FIGURE 3 | The ISM diagraph (*Source*: Author composition).

transitive relationship in the final diagram (see Table 10 and Figure 4).

5.5 | MICMAC Analysis

In general, "matrice d'impacts croisés multiplication appliquée á un classment" or a "cross-impact matrix multiplication applied to classification" (MICMAC) is utilized to generate a "graphical representation" of components based on their "driving power" and "dependence power," as determined by the "final reachability matrix" (Mondal et al. 2023a). MICMAC analysis has certain advantages over other approaches in that it analyzes the breadth of each factor while taking into account the intensity of the "interactions between" them (Tarei et al. 2021; Baliga et al. 2021). The MICMAC analysis (see Figure 5) is discussed below.

From the MICMAC analysis, cluster 1 (autonomous CSF) has weak driving and dependency power. "Total early-stage green entrepreneurial activity" (CSF3) and "entrepreneurial education and training" (CSF10) fall in this cluster. Cluster 2 (driving CSF) has weak dependence and strong driving power. High status for successful entrepreneurs (CSF7), financing for entrepreneurs (CSF8), governmental support and policies (CSF9), and environmental corporate social responsibility (CSF16) fall in this cluster. Cluster 3 (Linkage CSF) exhibits strong driving and dependency power, creating a linkage between these factors. Perceived opportunity (CSF1), green entrepreneurial intentions (CSF2), green innovation practices (CSF6), technology transfer for research and development (CSF11), and demand for the green product in the domestic market (CSF12) are included in this group. In addition, cluster 4 ("dependent CSF") has weak drive power and strong dependence power. Organizational motivation (CSF4), high job creation expectation (CSF5), openness to waste management and circular economy development (CSF13), social and cultural values (CSF14), green competitive advantage (CSF15), and green business strategies (CSF17) belong to this group.

5.6 | Discussion

For this study, a hybrid four-phased methodology and MCDM techniques were used to achieve the research objectives. The BWM was used to prioritize the CSFs, and TISM and MICMAC analysis were used to develop hierarchical relationships and cluster the CSFs based on their relative power. The BWM result shows that among the four main categories, institutional CSFs obtained the top rank based on expert opinion (criteria normalized weight = 0.362) (see Table 5). Institutional factors play a critical role as success factors for GE in the Indian textile industry's digitalization efforts for waste management and CSCM, driving progress toward a net-zero economy. According to Mondal et al. (2023a), institutional support, such as financial institutions promoting green initiatives, promotes the adoption of digital technologies in waste management, enhancing efficiency and sustainability in the textile industry's supply chain. Institutional collaboration and partnerships, as emphasized by Mondal et al. (2023a), facilitate the integration of digital solutions for waste management and CSCM, creating a synergistic approach to address environmental challenges and ultimately contributing to the realization of a net-zero economy. Societal CSFs obtained the second rank among the main category CSFs (normalized weight = 0.228).

TABLE 10 | Validation of transitivity's in the TISM model (*Source*: Author composition).

Sr. no.	Relation link and interpretation	Average score from experts	Standard deviation (SD)	*t*-statistics	Accept/reject the relationship
1	CSF1 influence CSF5	4.2	0.789	4.811	Yes
2	CSF1 influence CSF14	3.8	0.919	2.753	Yes
3	CSF1 influence CSF15	3.7	1.160	1.909	Yes
4	CSF2 influences CSF14	4.1	1.101	3.161	Yes
5	CSF2 influences CSF15	4	0.816	3.873	Yes
6	CSF3 influences CSF4	4.1	1.101	3.161	Yes
7	CSF3 influences CSF13	3.9	1.287	2.212	Yes
8	CSF4 influences CSF14	4.1	1.287	2.703	Yes
9	CSF5 influences CSF13	3.7	0.949	2.333	Yes
10	CSF6 influences CSF5	3.9	1.101	2.586	Yes
11	CSF6 influences CSF13	3.1	1.101	0.287	No
12	CSF6 influences CSF14	3.8	1.033	2.449	Yes
13	CSF6 influences CSF15	4.3	0.823	4.993	Yes
14	CSF7 influences CSF1	3.6	0.966	1.964	Yes
15	CSF7 influences CSF4	3.5	1.509	1.048	No
16	CSF7 influences CSF5	4.6	0.516	9.798	Yes
17	CSF7 influences CSF6	3.3	1.337	0.709	No
18	CSF7 influences CSF11	2.8	1.317	−0.480	No
19	CSF7 influences CSF12	2.4	1.350	−1.406	No
20	CSF7 influences CSF13	2.9	0.994	−0.318	No
21	CSF7 influences CSF17	4.3	0.675	6.091	Yes
22	CSF8 influences CSF1	3.6	0.843	2.250	Yes
23	CSF8 influences CSF2	4.4	0.966	4.583	Yes
24	CSF8 influences CSF6	3.9	1.449	1.964	Yes
25	CSF8 influences CSF7	2.6	1.578	−0.802	No
26	CSF8 influences CSF11	3.7	0.949	2.333	Yes
27	CSF8 influences CSF12	2.8	1.476	−0.429	No
28	CSF9 influences CSF1	4.2	0.789	4.811	Yes
29	CSF9 influences CSF2	3.2	1.135	0.557	No
30	CSF9 influences CSF6	4.4	0.699	6.332	Yes
31	CSF9 influences CSF7	2.9	1.729	−0.183	No
32	CSF9 influences CSF11	3.7	0.823	2.689	Yes
33	CSF9 influences CSF12	2.9	1.524	−0.208	No
34	CSF10 influences CSF1	3.9	0.994	2.862	Yes
35	CSF11 influences CSF5	3.3	1.337	0.709	No
36	CSF11 influences CSF13	4	0.943	3.354	Yes
37	CSF11 influences CSF15	3.7	1.160	1.909	Yes

(Continues)

Sr. no.	Relation link and interpretation	Average score from experts	Standard deviation (SD)	*t*-statistics	Accept/reject the relationship
38	CSF11 influences CSF17	4.2	1.033	3.674	Yes
39	CSF12 influences CSF4	3.9	0.876	3.250	Yes
40	CSF12 influences CSF14	3.2	1.398	0.452	No
41	CSF12 influences CSF15	4.2	0.789	4.811	Yes
42	CSF13 influences CSF5	4.1	0.994	3.498	Yes
43	CSF13 influences CSF14	3.9	1.197	2.377	Yes
44	CSF16 influences CSF4	4	1.054	3.000	Yes
45	CSF16 influences CSF5	3.9	0.876	3.250	Yes
46	CSF16 influences CSF13	3.2	1.476	0.429	No
47	CSF16 influences CSF17	4.2	0.789	4.811	Yes

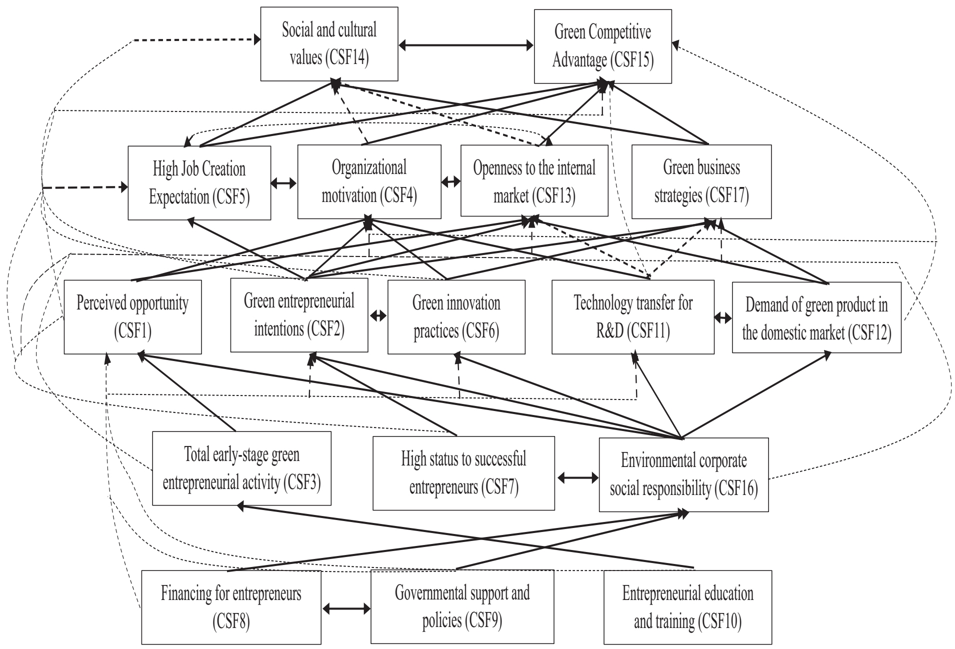

FIGURE 4 | TISM diagraph (*Source*: Author composition).

Among the sub-category CSFs, financing for entrepreneurs (ICSF5) is the most important, with a normalized weight of 0.085 (Table 5). Mondal et al. (2023b), underscore that sufficient financial support facilitates the adoption of innovative technologies and sustainable practices. The infusion of funds enables entrepreneurs to invest in digital solutions for waste management, enhancing operational efficiency, and reducing environmental impact. Moreover, financial backing empowers entrepreneurs to establish and scale circular supply chain models, supporting a transition toward a net-zero economy in the Indian textile industry (Silajdžić et al. 2015). Governmental support and policies (ICSF6) (criteria normalized weight = 0.070) are the second highest ranked among the sub-category CSFs. Mondal et al. (2023b) emphasize that supportive policies create an enabling environment to invest in digital solutions for efficient waste management and circular supply chains, aligning with SDGs. Mishra et al. (2021) and Bradley et al. (2021) argue that robust governmental backing can lead to collaborative initiatives between industry stakeholders and policymakers, creating a holistic approach to sustainable practices. The ranking of the remaining CSFs of GE that affect CSCM is as follows: ICSF5 > ICSF6 > ICSF3 > HCSF2 > SCSF7 > HCSF1 > TCSF3 > ICSF1 > SCSF4 > TCSF1 > SCSF1 > ICSF7 > ICSF2 > SCSF5 > TCSF2 > SCSF6 > ICSF4.

The TISM result shows that CSF14 and CSF15 are obtained at level one; hence, they obtain the first position and have higher dependent power. CSF 4, CSF5, CSF13, and CSF17 are obtained in level 2 (see Figures 3 and 4). Whereas CSF1, CSF2, CSF6, CSF11, and CSF12 are obtained at level 3 (see Figure 3 and Figure 4). They generally act as a linkage variable between driving and dependence power (see Figure 4). The importance

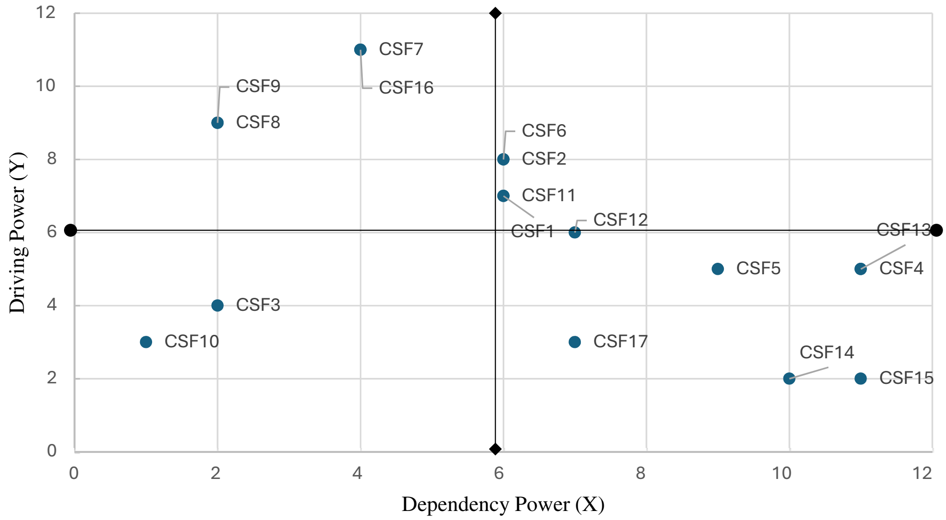

FIGURE 5 | Plotting of position coordinates of factors of GE (*Source*: Author composition).

of CSF6 and CSF11 in linkage clusters reflects the NRBV's emphasis on leveraging rare and valuable resources for competitive advantage. Globally, companies such as Patagonia and Adidas have demonstrated how eco-innovation drives competitiveness, while in India, firms in Surat's textile hub adopting recycled fibers echo similar practices. CSF3, CSF7, and CSF16 are obtained from level 4, and CSF8, CSF9, and CSF10 are obtained at level 5. As shown in Figure 4, they have higher driving power. Here, the lower level has the highest driving power, whereas the upper level has the lowest "driving power" and the highest "dependent power." The study also shows that the clustering of GE factors and their impact on SDGs is a complex and multidimensional topic that involves various aspects of entrepreneurship, innovation, policy, and societal values. In this discussion, we delve into each of these four clusters and analyze them in the context of academic literature. We also explore how these factors contribute to the development of GE and the achievement of the SDGs. Cluster 1 comprises factors with weak driving and dependency power, including "total early-stage green entrepreneurial activity" (CSF3) and "entrepreneurial education and training" (CSF10). These factors represent the foundation of GE. Academic literature emphasizes the importance of early-stage entrepreneurial activity as a precursor to the establishment of green enterprises. Green startups play a pivotal role in driving innovation in sustainable technologies and practices. Promoting a culture of entrepreneurship that emphasizes sustainability may result in both economic development and environmental advantages (Demirgüç-Kunt et al. 2020). Entrepreneurial education and training are critical for providing people with the information and skills needed to address GE issues. Numerous studies have shown a link between entrepreneurship education and the desire to participate in long-term entrepreneurial activity (Liu et al. 2019). Education programs that focus on GE may create awareness of environmental concerns and possible solutions.

Cluster 2 includes factors with strong driving power and weak dependence, such as "high status for successful entrepreneurs" (CSF7), "financing for entrepreneurs" (CSF8), "governmental support and policies" (CSF9), and "environmental corporate social responsibility" (CSF16) (Figures 4 and 5). Recognizing successful green entrepreneurs can inspire others to start sustainable businesses, highlighting the potential for both economic success and environmental benefit (Kiran and Goyal 2021).

Cluster 3 represents factors that bridge the gap between "driving power" and "dependence power," including "perceived opportunity" (CSF1), "green entrepreneurial intentions" (CSF2), "green innovation practices" (CSF6), "technology transfer for research and development" (CSF11), and "demand for green products in the domestic market" (CSF12) (Figures 4 and 5).

Cluster 4 comprises factors with strong "dependence power" and "weak drive power," including "organizational motivation" (CSF4), "high job creation expectations" (CSF5), "openness to waste management and circular economy development" (CSF13), "social and cultural values" (CSF14), "green competitive advantage" (CSF15), and "green business strategies" (CSF17) (Figures 4 and 5).

The findings show that financial, policy, and educational support mechanisms are foundational enablers of GE. This aligns with CSFT, which emphasizes that effective management of a limited number of key factors is crucial for organizational success (Rockart 1979). The study also highlights the importance of innovation and technology transfer, consistent with the NRBV, where green innovation and technological capabilities are essential for building sustainable competitive advantage. Interestingly, green competitive advantage (CSF15) emerged as highly dependent on both innovation and policy support, suggesting that firms cannot achieve environmental competitiveness in isolation; it is enabled by systemic drivers. The findings also reveal that stakeholder-related aspects such as CSR and cultural values are more dependent, echoing ST. Surprisingly, social and cultural values (CSF14) ranked lower than expected in driving power, despite the strong cultural context of sustainability in India. This nuance suggests that while societal values support GE, they may not independently drive CSCM digitalization without institutional and financial enablers. This finding indicates that while cultural values support GE, they do not independently drive CSCM digitalization. Instead, they depend on enabling policies and financial support. This nuance reinforces

Stakeholder Theory, where societal legitimacy emerges as an outcome of systemic drivers rather than a primary enabler. Similar to India, China has identified governmental support and green innovation as central enablers of circular supply chain practices (Zhang et al. 2023). In Brazil, financial support mechanisms and cultural values strongly influence green entrepreneurial outcomes, with societal norms playing a relatively stronger role than in the Indian context. In European contexts where societal norms strongly drive circular practices further highlight this divergence. These clusters reveal a layered mechanism: institutional and financial drivers enable innovation and competitiveness, which in turn strengthen stakeholder legitimacy and societal alignment. This hierarchical interpretation deepens our theoretical understanding of how NRBV, CSFT, and ST jointly explain the dynamics of GE in the textile sector. The analysis of GE factors offers a comprehensive framework for understanding sustainable business development. As highlighted in academic literature, these factors are crucial in driving GE and significantly contribute to achieving SDGs. Promoting GE through supportive policies, education, innovation, and societal values can support economic growth while addressing key environmental and social challenges.

6 | Implications

This study provides insights for managers, policymakers, and practitioners seeking to understand the factors enabling digitalization and CSCM for sustainable practices. It identifies 27 CSFs that aid green entrepreneurs integrate digital technologies (like Industry 4.0 and 5.0) and circular supply chain development to achieve net zero.

6.1 | Managerial Implications

The study highlights that institutional support ranks highest among the CSFs, emphasizing the role of financial institutions and collaborations in advancing green projects and digital technologies in the textile industry. Entrepreneurs and managers should actively pursue institutional support to promote the use of green and digital technologies for sustainable operations. Entrepreneurial financing, the top CSF among sub-categories, underscores the need for securing financial resources to invest in digital waste management and circular supply chain solutions. Building strong relationships with financial institutions and collaborating with industry stakeholders can enhance the efficiency and sustainability of waste management and circular supply chain strategies. The study also emphasizes the importance of entrepreneurial education and training in driving new business ventures. Policymakers may utilize these findings to develop supporting legislation, incentives, and subsidies to promote green initiatives and digitization in waste management and CSCM. Financial incentives, subsidies, and regulatory frameworks are examples of proactive government interventions that may promote innovation and technological adoption. Policymakers should prioritize building an enabling environment for entrepreneurs by enacting policies that align with the SDGs, notably SDG 8 ("decent work and economic growth"), SDG 9 ("industry, innovation, and infrastructure"), and SDG 13 ("climate action"). Policymakers, research institutions, managers, practitioners, and industry participants should prioritize supporting innovation and technology transfer in research and development. Collaboration between research institutes and green entrepreneurs may help speed the development and uptake of sustainable textile solutions. Entrepreneurs may use these CSFs to drive GE and make a substantial contribution to achieving SDGs.

6.2 | Practical and Policy Implications

For entrepreneurs and managers in the textile industry, the findings highlight three priorities. First, securing financial resources and government support is foundational for scaling green initiatives. Second, building technological capabilities through R&D and innovation is essential to create products and processes that are both sustainable and competitive. Third, aligning with societal values and CSR expectations enhances legitimacy and long-term market acceptance, even though these factors emerge as dependent outcomes. These implications provide actionable pathways for firms to navigate the complexities of digitalizing circular supply chains while maintaining profitability and sustainability. For practitioners, the findings highlight that institutional support, financing mechanisms, and government policies are the most influential drivers in enabling textile firms to adopt digital CSCM practices. This offers actionable pathways for entrepreneurs and managers to design strategies that integrate digital technologies for waste reduction, traceability, and efficiency. For policymakers, the study underscores the need for targeted financial incentives, technology transfer schemes, and educational initiatives that can accelerate the textile industry's transition toward a zero-waste economy. Governments should provide targeted financial incentives, strengthen R&D collaboration platforms, and design policies that encourage technology transfer and innovation adoption. Furthermore, integrating CSR and circular economy goals into policy mandates can accelerate stakeholder engagement. For emerging economies, such interventions are critical to overcoming systemic barriers and creating an ecosystem where sustainability-driven entrepreneurship can flourish.

6.3 | Theoretical Implications

By systematically mapping CSFs onto three theoretical lenses NRBV, CSFT, and ST this study extends theoretical integration in sustainability research. Unlike prior studies that apply these theories in isolation, our framework demonstrates how resource efficiency (NRBV), managerial prioritization (CSFT), and stakeholder alignment (ST) collectively explain the dynamics of GE in the context of CSCM digitalization. By employing a hybrid four-phased methodology and MCDM techniques, the study contributes to the existing body of knowledge by offering a structured approach to identifying, prioritizing, and analyzing the CSFs. This study advances both academic knowledge and practical understanding of GE in CSCM, particularly within the Indian textile industry. The NRBV demonstrated that resource-based capabilities such as green innovation practices and technology transfer for R&D only achieve competitive advantage when supported by institutional enablers such as financing and policy. This highlights that in emerging economies, environmental resources and innovation must be complemented by systemic drivers, extending NRBV beyond firm-level capabilities to ecosystem-level dynamics. CSFT provides empirical evidence that success in GE–CSCM digitalization depends on prioritizing a few foundational enablers—financing for entrepreneurs, governmental support and policies, and entrepreneurial education and training. These drivers form the base layer upon which other CSFs depend. By showing how the influence of factors cascades from drivers to dependents, we contribute to a more layered application of CSFT in sustainability contexts. ST shows that stakeholder-related factors such as environmental CSR, societal values, and openness to waste management emerge as dependent outcomes rather than primary drivers. This challenges the conventional ST assumption that stakeholder pressures initiate sustainable action. Instead, in the GE–CSCM nexus, stakeholder legitimacy consolidates after institutional and technological enablers are in place, suggesting a contextual nuance specific to developing economies. Its novelty lies in applying an integrated hybrid methodology (BWM–TISM–MICMAC) to not only identify but also structure and prioritize the CSFs that drive digitalization for sustainable supply chains. Unlike previous studies that examined GE in general or in developed economies, this study provides context-specific insights into the textile sector of an emerging economy. The research presents a more nuanced and complete framework for studying the variables driving GE by relying on these different theoretical underpinnings. A main theoretical contribution is also found in the identification and interrelationship study of 17 important components that have a considerable influence on CSFs. These elements encompass a wide range of concerns, including entrepreneurial education and training, government backing, green innovation methods, and corporate social responsibility.

Although this study is grounded in the Indian textile industry, its implications resonate globally, particularly for emerging economies facing similar resource constraints and institutional challenges. The prioritization of financing, policy, and technological innovation reflects universal enablers of GE in circular supply chains. At the same time, the finding that societal and cultural values are dependent rather than driving factors suggests that sustainability transitions may require institutional scaffolding even in culturally sustainability-oriented regions. These insights extend the debate on how to align business strategy with environmental objectives across different global contexts.

7 | Conclusions

This research provides valuable insights into the role of GE in the context of developing economies, with a particular focus on the Indian textile industry. It identifies and analyzes 27 CSFs of GE that help in a mixed-methods approach, incorporating a literature review, expert opinions, and the application of the BWM, TISM, and MICMAC techniques. Drawing upon the past literature, theoretical frameworks (NRBV, ST, and CSFT), and expert opinion, this study identifies and finalizes CSFs and then ranks and establishes an interrelationship among them. This study identifies and prioritizes 16 CSFs for GE in enabling the digitalization of CSCM in the Indian textile industry. The findings reveal that institutional factors rank as the top CSF, followed by social, technological, and human-related CSFs. This study contributes to the literature on GE and CSCM by providing a novel, structured framework for analyzing and prioritizing CSFs in the Indian textile industry. While prior research has discussed GE and digitalization in broad terms, this is among the first studies to systematically examine how specific institutional, social, technological, and human factors interact to drive digital circular practices in textiles. The integrated methodology (BWM–TISM–MICMAC) allows for a nuanced understanding of both the relative importance and the interrelationships of CSFs, offering insights beyond traditional linear analysis. This methodological contribution enhances the academic discourse on GE, circularity, and sustainable supply chains in developing economies. Mondal et al. (2023a) highlight the role of digitalization in integrating GE with the circular economy. Using TISM, the study groups the CSFs into four clusters (i.e., autonomous, driving, linkage, and dependence) based on their driving and dependence power. Our findings will help entrepreneurs adopt green practices and develop strategies to enhance business sustainability. The study also highlights the key role of entrepreneurial education, government support, and financing in promoting GE, significantly influencing the development of CSCM for environmentally and socially responsible business practices. From an industry perspective, the study delivers directly applicable insights: financial support and institutional backing emerge as the most influential enablers, suggesting that access to capital and strong policy frameworks are crucial for textile firms seeking to digitize and adopt zero-waste models. These findings not only provide entrepreneurs with a roadmap for prioritizing investments but also equip policymakers with evidence to design interventions aligned with SDGs and India's sustainability goals.

This study also has several limitations. It primarily focuses on the Indian textile industry, limiting the generalizability of the findings to other industries or regions. Future research should explore different sectors to enhance the applicability of the identified CSFs. It relies on expert opinions from a specific set of individuals within the textile sector. The focus on the Indian textile sector, while contextually rich, may limit the generalizability of the results to other industries or regions. Comparative studies across sectors or countries could help validate and refine the identified CSFs. Future research can involve more experts from academia and industry while exploring additional factors like collaboration between academia, the private sector, and civil society in addressing sustainability challenges. Future studies could triangulate expert-based insights with empirical performance data to enhance robustness. As findings are based on a specific timeframe, shifts in environmental, economic, or policy conditions may impact the identified CSFs. A longitudinal study could mitigate this limitation. The prioritization and ranking of CSFs rely on expert opinions, introducing a level of subjectivity. A more objective approach, such as a broader survey, could enhance the reliability of the findings. Future studies can further explore CSFs and examine their interdependence and relationships with techniques like the Decision-Making Trial and Evaluation Laboratory (DEMATEL). Structural equation modeling (SEM) could also be used with more extensive data to develop and test causal relationships. Research should investigate CSFs in GE and digitalization across various industries to identify commonalities and differences, providing a deeper understanding of the dynamics involved. Additionally, studies assessing the sustained impact of GE on the SDGs over several years would offer valuable insights into its contributions. Expanding the geographical scope to include data from multiple countries and industries would enhance the study's applicability.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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