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Green entrepreneurship and digitalization enabling the circular economy through sustainable waste management - An exploratory study of emerging economy

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A R T I C L E I N F O

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A B S T R A C T

In recent years, the Circular Economy (CE) has gained attention as a strategy for achieving sustainable development through cleaner production and reducing waste and pollution. At the same time, digital technologies are recognized as crucial sustainability drivers by enabling efficiency, collaboration, and innovation. This research paper explores the factors that support Green Entrepreneurship (GE) and digitalization in the context of CE and Waste Management (WM) in Indian manufacturing "Micro, Small, and Medium Enterprises" (MSMEs). Further, the study prioritizes, establishes a contextual relationship, and clusters the GE factors that enable digitalization in the CE and WM of Indian manufacturing MSMEs. To meet research goals, the study uses a mixed-methods approach that includes a literature review, qualitative interviews with MSME managers, and theoretical support (stakeholder theory, resource-based view, dynamic capability theory, met expectation theory, and upper echelons theory) to find the enablers. Further, two-phase "Multi-Criteria Decision Making" (MCDM) tools are utilized. Initially, the quantitative "Best-Worst Method" (BWM) was used for ranking, and then "Total Interpretive Structural Modeling" (TISM) was used to establish a mutual relationship among the enablers. The strength of relationships among the enablers was established based on "dependence power" (DEP) and "driving power" (DRP). The findings through BWM analysis show that among the main category, technology-based enablers, and among sub-categories, top management and organizational coordination are the high-priority enablers/sub-enablers to optimize sustainable action. The findings also suggest that technology infrastructure for cleaner and sustainable manufacturing, knowledge of green entrepreneurs, training, the dynamic capacities of digitalization towards a CE, subsidies, and finance are driving enablers. The research contributes to understanding the enabling factors of GE and digitalization and their interdependencies for CE and sustainable development.

1. Introduction

Over the past few decades, rapid industrialization and globalization have led to numerous detrimental effects on the environment, such as environmental pollution, global warming, and the generation of waste. The proliferation of MSMEs is a compelling example of economic growth that simultaneously generates employment opportunities. However, the rise of MSMEs has also led to a range of environmental challenges, such as waste accumulation, the release of harmful gases, and pollution (Mondal et al., 2023). To tackle the aforementioned challenges, it is crucial for MSMEs to embrace sustainable business practices that contribute to the attainment of the United Nations Sustainable Development Goals (UNSDGs). This includes adopting strategies such as GE (Makhloufi et al., 2022), effective WM (Salmenperä et al., 2021), promoting CE (Agrawal et al., 2022), and leveraging digitalization for WM (Sarc et al., 2019). These sustainable business approaches help maintain environmental balance and contribute to economic and social development. Nevertheless, implementing such practices in developing and underdeveloped nations presents significant challenges. GE refers to starting a business with the aim of providing solutions to environmental problems (Mondal et al., 2023), whereas digitalization refers to the integration of technology into various business processes to make them more efficient and effective (Wu et al., 2022). The relationship between GE and the digitalization of MSMEs is close and interdependent. Both are helpful for increased competitiveness, access to new markets,

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Abbreviations

CE	"Circular economy"
GE	"Green Entrepreneurship"
WM	"Waste Management"
SD	"Sustainable Development"
BWM	"Best Worst Method"
TISM	"Total Interpretive Structural Modelling"
MICMAC	"Matrice d'impacts croisés multiplication appliquée á un classment" ("Cross-Impact Matrix Multiplication Applied to Classification")
MSME	"Micro, Small and Medium Enterprises"
MCDM	"Multi-Criteria Decision Making"
DEP	"Dependence Power"
DRP	"Driving Power"
SDG	"Sustainable Development Goals"

developing new, sustainable products and services, benefiting from the growing demand for environmentally friendly goods and services, and access to new markets and funding opportunities (Reza-Gharehbagh et al., 2022). In addition, GE has a close relationship with WM and can provide significant benefits, including reduced waste, improved WM, increased recycling, increased sustainability, and job creation (Sharma et al., 2021a, 2021b). Whereas digitalization has the potential to greatly improve WM in manufacturing MSMEs by providing them with tools to track and monitor waste, increase recycling, improve logistics, make better decisions, and become more sustainable (Rupeika-Apoga and Petrovska, 2022). Previous studies have shown that GE, digitalization, and the CE can improve waste reduction, recycling, resource efficiency, advanced tracking and monitoring, and sustainability (Agrawal et al., 2022; Mondal et al., 2023). Furthermore, effective WM plays a pivotal role in realizing the objectives of the CE, including waste reduction, increased recycling, resource recovery, and sustainable WM (Hojnik et al., 2023). The Indian manufacturing sector is a significant contributor to the country's economy but also generates a substantial amount of waste and pollution (Mondal et al., 2023). In recent years, there has been growing interest in the CE to reduce waste and promote sustainable development. At the same time, digital technologies are increasingly being seen as a critical enabler of sustainable growth, offering opportunities for increased efficiency, innovation, and collaboration (Kurniawan et al., 2022a).

Recent research by Agrawal et al. (2022), Fatimah et al. (2020), Alonso et al. (2021), Chauhan et al. (2022), and Rainville (2021) demonstrated that the utilization of digitalization is increasing over time and its relationship with the CE. These studies also highlight the increasing utilization of digital technologies and their impact on promoting sustainable practices within the economy. Nuringsih and Nuryasman (2022) studied the association between GE and CE. Yu et al. (2022) study CE perspectives and Industry 4.0 for the automotive industry, while Gupta et al. (2021) show the role of digitalization (Industry 4.0) on CE and sustainability. Schwanholz and Leipold (2020) examine the relationship between digitalization and CE. Ajwani-Ramchandani et al. (2021) studied CE and digitalization in the packaging industry, whereas Makhloufi et al. (2022) studied the manufacturing industry. Moreover, studies by Parida et al. (2019) and Rusch et al. (2023) performed literature reviews in the CE and digitalization domains. Govindan and Hasanagic (2018) studied the barriers; Pizzi et al. (2022) identified enablers of the entrepreneurial ecosystem and the and Moktadir et al. (2020) recognized critical CE success factors. Makki et al. (2020) studied barriers to green enterprise, whereas Mondal et al. (2023) assessed the role of GE in CE without considering the role of digitalization. Rupeika-Apoga and Petrovska (2022) study barriers to digital transformation, whereas Makki et al. (2020) study barriers to GE. In addition to this, Arya & Kumar (2020) performed a study and showed the challenges and management strategies of e-waste. Further, Kurniawan et al. (2022a, 2022b) show that this study shows the association between technology and CE and WM.

From the existing literature, it is clear that there are limited studies on the impact of digitalization on CE and WM. The role of digital technologies in driving the adoption of CE practices by MSMEs in the WM still needs a lot of studies. While digitalization has revolutionized many industries, there is limited research on its impact on GE domains. There is an inadequate understanding of green entrepreneurial initiatives in WM, and there is limited research on the specific initiatives that green entrepreneurs are taking in the WM sector, especially in developing countries. Further, limited studies on the scalability of GE and digitalization and their roles in CE and WM. Therefore, there is a need for more research on how GE initiatives in WM can be scaled up to have a significant impact on the CE. Some literature reviews perform systematic literature reviews, as seen in the Rusch et al. (2023) study, which can be further studied and require theoretical and qualitative validations. However, there is inadequate research available to facilitate the identification of GE and digitalization's critical enablers. Although the manufacturing sector's MSMEs contribute significantly to a country's employment and financial development, they also generate a significant amount of waste and environmental pollution. Additionally, manufacturing sectors face various challenges, such as financial constraints, insufficient technological infrastructure, waste and emissions, and resource scarcity (Endris and Kassegn, 2022). Therefore, it is important to incorporate practices that help in sustainability, such as GE and digitalization for CE and WM development in manufacturing MSMEs. Nevertheless, implementing sustainability practices entails several challenges, such as managerial complexities, a lack of effective regulatory frameworks, and knowledge gaps. In the current context, there exist various enabling factors that aid in tackling challenges. Hence, it is imperative to identify the critical enablers and prioritize them, as it may not be feasible for managers and practitioners to address all enablers simultaneously. The ranking of these enablers facilitates a better understanding of their importance, while the structural interrelationship between them elucidates how each factor is interconnected and influenced by other enabling factors. Therefore, the following research questions (RQ) are framed to address this.

RQ1. What are the enablers of GE and digitalization's effects on CE and WM in Indian manufacturing MSMEs?

RQ2. What are the key and top-priority enablers among them?

RQ3. What is the interrelationship between the enablers of GE and digitalization?

RQ4. What is the categorization of the enablers of GE and digitalization?

This study highlights the potential for GE and digitalization to drive sustainable growth and innovation in the Indian MSME sector and suggests strategies for policymakers, industry associations, and MSMEs themselves to promote these trends. The research provides insights into the complex interplay of factors that influence the adoption of sustainable practices in Indian manufacturing MSMEs and contributes to the growing body of literature on CE, digitalization, and entrepreneurship in developing economies.

The subsequent sections of the paper are organized as follows: Section 2 delves into an extensive literature review, which encompasses the theoretical underpinnings relevant to this study. Section 3 outlines the research framework and methodologies employed in the investigation. Moving forward, Section 4 presents the analysis and findings from the study, and Section 5 follows with a thorough discussion of the conclusions. Section 6 presents a summary of the theoretical and policy implications stemming from the research. Finally, Section 7 concludes the paper by addressing the limitations of this study and outlining future research objectives.

2. Literature review

There are several individual studies on GE, digitalization, CE, and WM, and Fig. 1(a) to Fig. 1(d) shows the summary of the bibliometric study. A bibliometric study was conducted using the Scopus scientific database, which yielded 7063 relevant journal articles. For the literature review, we utilized the Scopus database for the period from 2004 to 2022. For the keyword search, we included the terms “green entrepre*," “digitalization,” “circular economy,” and “waste management” either individually or in combination with these keywords. The following criteria were used in the search: “TITLE-ABS-KEY” ("green entrepre*" AND “digitalization”) OR ("green entrepre*" AND “circular economy”) OR ("green entrepre*" AND “waste management”) OR ("digitalization” AND “circular economy”) OR ("digitalization” AND “waste management”) OR ("circular economy” AND “waste management”). To ensure a focused selection of relevant literature, we applied several inclusion and exclusion criteria. The inclusion criteria were limited to journal papers specifically published within the business and management domains. This selection criterion is intended to ensure that the literature chosen for analysis is academically rigorous and directly relevant to our research domain. Additionally, we employed a set of exclusion criteria. Other than English paper, it is not considered here to maintain consistency and facilitate comprehension during the analysis. Further filtering out book chapters, conference proceedings, newspaper articles, and other non-journal sources from our analysis. The data were analyzed using CSV and RStudio for bibliometric analysis, focusing on four key parameters: Fig. 1(a) publication count, Fig. 1(b) keyword frequency, Fig. 1(c) word cloud visualization, and Fig. 1(d) the most significant source. The domain under investigation exhibited substantial growth in the number of scientific articles. The word cloud illustrates the prevalent words in specific contexts (Fig. 1 (a, b, c, d) (summary of the bibliometric study)). However, little is known about the enablers of GE and digitalization in developing countries like India. This section discusses the relevant literature and theoretical frameworks in the present context.

2.1. Theoretical underpinnings

This study aims to examine the enablers of GE and digitalization in the context of CE and WM. To achieve this, the study explores five theoretical perspectives: stakeholder theory (ST), dynamic capability theory (DCT), the resource-based view (RBV), met expectation theory (MET), and upper echelons theory (UET). These theories provide a comprehensive framework for understanding the enablers and mechanisms behind the successful integration of GE and digitalization in CE and WM. In the subsequent sections, each theory will be discussed in detail, highlighting its relevance and contributions to the overall research objective. The detailed discussions of theory and how theory helps to identify enablers of GE and digitalization for CE and WM are provided in Table 1.

This study used these theories to identify and influence critical enablers that affect CE and WM in manufacturing MSMEs. These theories provide a theoretical framework and logical foundation for categorizing the enablers and conducting further analysis.

2.2. Green entrepreneurship and digitalization

GE refers to the creation of new products and services that create economic opportunities while reducing negative environmental impacts and promoting sustainable development (Mondal et al., 2023). This can include products made from recycled materials, energy-efficient technologies, and sustainable transportation systems. GE covers a wide range of industries, including renewable energy, sustainable agriculture, eco-tourism, green transportation, and environmental technology (Silajdžić et al., 2015). On the other hand, digitalization in manufacturing MSMEs refers to the adoption and integration of digital technologies and processes into their operations (Bagale et al., 2021). This can include automation, data analytics, digital platforms, and other cutting-edge technologies. The inclusion of digitalization is intended to improve entrepreneurial efficiency, increase competitiveness, and enhance the overall performance of the MSME (Behl et al., 2022). Trapp and Kanbach (2021) and Reza-Gharehbagh et al. (2022) show that green entrepreneurship combined with technological activities helps in addressing the alleviation of human impact on the environment as well as solving global issues. Thus, both improve waste handling, use waste as a resource, provide a more sustainable product or service, create new business opportunities in the growing sustainable products and services market, and achieve competitiveness with sustainable development goals.

2.3. Circular economy and waste management practices

The CE is an economic model that preserves and regenerates natural resources by reducing, reusing, and recycling waste and creating closed-loop systems that limit new raw material consumption and optimize resource use (Kurniawan et al., 2022b). Circular economies decrease environmental impact, enhance resource efficiency, boost competitiveness, provide new economic possibilities, and complement linear economies (Moktadir et al., 2020; Sarc et al., 2019). It can also promote innovation and the development of new technologies and products that

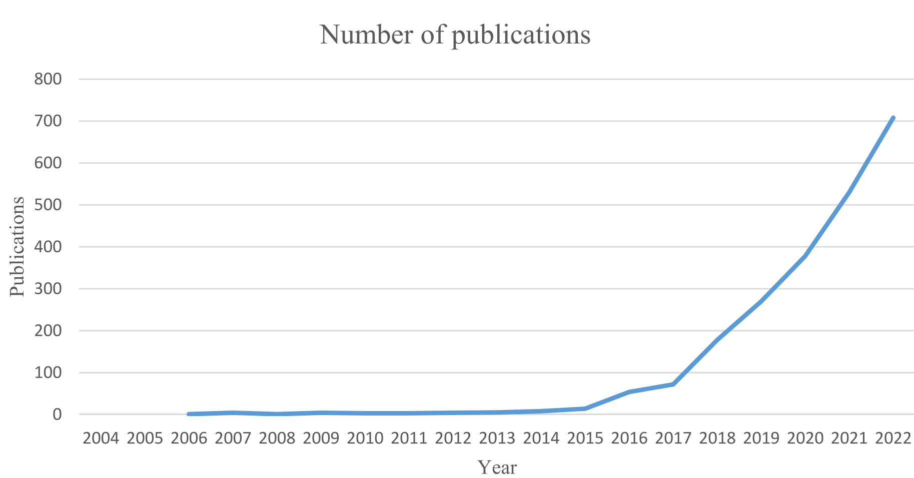

Fig. 1(a). Number of publications over the year.

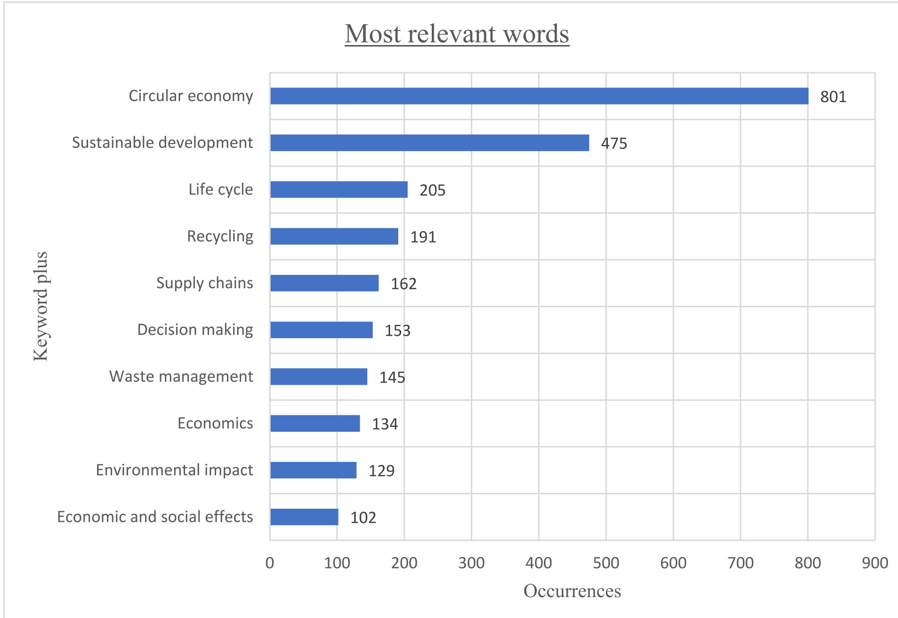

Fig. 1(b). The frequency of keywords.

Fig. 1(c). Word cloud (considering keywords).

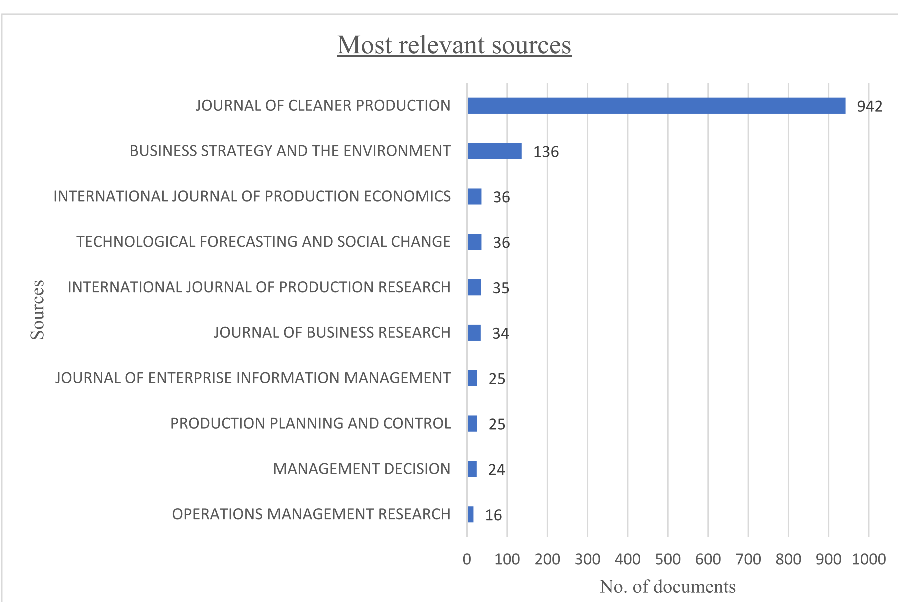

Fig. 1(d). Most relevant sources
(Note: The bibliometric data was retrieved from the Scopus database between 2004 and 2022. The inclusion and exclusion criteria: TITLE-ABS-KEY (("green entrepreneurship" or "digitalization" or "circular economy" or "waste management")) AND (LIMIT-TO (LANGUAGE "English")) AND (LIMIT-TO ("Journal")) AND (EXCLUDE (PUBYEAR, 2023))). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

are designed to be sustainable and resource-efficient. Moreover, WM is also important for manufacturing MSMEs because it affects their environmental footprint and financial performance. Implementing efficient processes and best practices in production, such as just-in-time delivery and inventory management, helps MSMEs reduce waste (Kurniawan et al., 2022a, 2022b). Investing in sorting and processing technologies

Table 1
Theoretical basis for finalizing enablers.

Theory	Basis of the theory	Main enablers	Sub enablers
Stakeholder theory (ST)	The theory describes the responsibilities of stakeholders that can affect or be affected by the organization's actions (Alkaraan et al., 2023; Greenwood and van Buren, 2010; Okafor et al., 2021). This theory provides a framework for ethical decision-making, balancing stakeholder interests, and fostering partnerships and collaboration to support manufacturing MSMEs and their communities' long-term success and sustainability. For this reason, firms must prioritize stakeholder satisfaction, which covers multiple groups such as workers, customers, suppliers, communities, and the environment, and consider their interests and well-being when making choices (Greenwood and van Buren, 2010). Previous studies by Mondal et al. (2023) and Okafor et al. (2021) suggest that this theory helps in developing sustainability activities, which further aids in GE, digitalization, CE, and WM development (Alkaraan et al., 2023). Manufacturing MSMEs can use ST to engage with employees to understand their needs and concerns and create a positive work environment that benefits both the company and the employees, creating a more sustainable business model (Greenwood and van Buren, 2010). The theory used here is used to identify important enablers that lead to financial success, create value for all stakeholders and entrepreneurs, and contribute to a sustainable future.	Organizational related factors	Top management and organizational coordination. Strategic alliance for innovation.
		Societal related factor	Social impact and long-term consumer behavior.
		Political and regulatory-related factors	Environmentally supported policy. Policies of corporate and social responsibility.
Dynamic capability theory (DCT)	DCT management theory illustrates how organizations may develop and reorganize internal as well as external business-specific skills into new capabilities needed in today's changing environment (van de Wetering et al., 2020). This theory helps MSMEs identify dynamic capabilities, including a flexible organizational structure, strong leadership, and a culture of continuous development, to compete, adapt to a fast-changing market, and succeed. A firm with strong dynamic potential helps organizations develop unique resource combinations, generating earnings and competitive advantage. Dynamic capacity evolves, builds, and extends a firm's resource capability to maintain and increase performance and gain a competitive advantage over time (Makhloufi et al., 2022). This theory is an extension of the RBV by emphasizing specific organizational processes that generate value in a dynamic market (Jiang et al., 2018; van de Wetering et al., 2020; Mondal et al., 2023). This theory helps to identify factors that promote sustainable practices, offering operational and strategic benefits while encouraging sustainable growth and a competitive edge (Makhloufi et al., 2022).	Technology related factor	Technological collaboration between firm and subcontracting firm as well as with academia. Having R&D facilities. Developing green manufacturing capabilities.
		Organizational related factors	Dynamic capabilities of companies and digitalization advances in the CE.
		Political and regulatory-related factors	Government funding for green technology development initiatives.
		Societal related factor	Public demand for green products Employee cooperation and needed competence.
		Economic and Financial related factors	Financing for CE and WM. Low initial investment.
		Political and regulatory-related factors	Adequate, flexible, and simple regulatory framework.
Resource-based view (RBV)	The RBV management theory employs an organization's resources and competencies as strategic resources to help enterprises recognize, seize, and sustainably implement environmental initiatives and gain competitive advantage (Barney, 1991; Makhloufi et al., 2022). This theory suggests that a company's resources and competencies determine its competitiveness and financial and economic benefits. This theory highlights a firm's resources and capabilities, encompassing physical and non-physical assets, enabling effective strategy execution, efficiency, and competitive advantages (Barney, 1991; Makhloufi et al., 2022; Nandi et al., 2021). According to Chaudhuri et al. (2022), waste can be used as a resource, further increasing reduction, reuse, and recycling capabilities and creating green opportunities. A further study by Nandi et al. (2021) shows how blockchain or digitalization technologies help CE and WM. The RBV theory used here to identify critical enablers of GE and digitalization for CE and WM also creates a competitive advantage.	Technology related factor	Having technology infrastructure for cleaner and sustainable production. Having proper WM and recycling facility.
		Societal related factor	Having higher social acceptance and having a good public image.
		Psychological related factors	Knowledge of green entrepreneurs.
		Economic and Financial related factors	Certainty about return on investment. Having subsidize and funds.
		Environmental related factors	Green operational practices. Ecological conservation and safe disposal of hazardous waste.
Met expectation theory (MET)	The MET is a management theory suggesting that an individual's job satisfaction is determined by the extent to which their job expectations are met (Domurath et al., 2023; Dufour et al., 2021). This theory provides valuable insights for MSMEs in the manufacturing sector to understand the importance of meeting the expectations of their stakeholders and how this can impact their success in the market. The fulfillment or surpassing of expectations leads to employee work satisfaction, whereas unfulfilled expectations result in dissatisfaction (Dufour et al., 2021; Ghosh et al., 2019). By implementing this theory, firms may boost staff satisfaction and efficiency through fair compensation, a good work environment, development opportunities, and strong employee-supervisor relationships (Domurath et al., 2023). According to this theory, motivation among employees is impacted by the following three key variables: expectation (the belief that effort will lead to performance), instrumentality (confidence that performance will be rewarded), and valence (the value linked to the rewards) (Ghosh et al., 2019). The theory identifies critical enablers that motivate employees to fulfill employee and stakeholder expectations for developing CE and WM. This further helps to lead to financial success, creating value for all stakeholders and entrepreneurs, getting competitive advantages, and contributing to a sustainable future.	Psychological related factors	Attitudes towards digitalization and CE. Entrepreneurs are out of the box thinking.
		Environmental related factors	Clean development attitudes and vision for environmental management.
Upper echelons theory (UCT)	UET is a management theory suggesting that the characteristics and behaviors of an organization's top-level managers significantly impact organizational outcomes, such as performance and structure (Saiyed et al., 2023; Sciascia et al., 2013). This theory dealt with a management-level view that these factors	Organizational related factors	Technical know-how and training of entrepreneurs.
		Psychological related factors	The leadership of a green entrepreneur.

(continued on next page)

Table 1 (*continued*)

Theory	Basis of the theory	Main enablers	Sub enablers
	influence top management's behavior and decision-making, which affects the organization's strategy and direction and creates capable and effective leaders who can lead the organization to success. The theory contends that entrepreneurial orientations influence firms' strategic direction and motivate them to adopt sustainable activities like CE and WM to succeed (Choudhary et al., 2022; Sciascia et al., 2013; Saiyed et al., 2023). Yang et al. (2023) show that management plays a vital role in adopting digitalization for environmental development. In manufacturing MSMEs, the UET can be applied by studying top management's characteristics, behaviors, and decision-making styles (Choudhary et al., 2022; Sciascia et al., 2013; Saiyed et al., 2023). UET helps firms get critical enablers, which help in achieving desired organizational goals.	Environmental related factors	Environmental monitoring and control.

promotes recycling and reuse to reduce landfill waste and increase sustainability (Fatimah et al., 2020). By encouraging waste reduction and recycling, MSMEs may prevent environmental impact, hence CE, and encourage sustainable development. The CE and WM practices are closely related, as the CE approach aims to minimize waste and promote the efficient use of resources. Salmenperä et al. (2021) studied the impact of CE on the economy and society in the context of WM. The relationship between the CE and WM is mutually beneficial, as proficient WM strategies are imperative for the realization of the CE.

2.4. Discussion of enablers

2.4.1. Technology-related enablers

Technology-related enablers play a crucial role in promoting sustainability activities, i.e., CE and WM, in Indian manufacturing MSMEs (Mondal et al., 2023). Technology-related enablers include digital technologies such as the "Internet of Things" (IoT), "artificial intelligence" (AI), big data analytics, and blockchain. These enablers can support improving resource efficiency, reducing waste, and enhancing overall sustainability (Bhattacharya, 2021). Several countries use technology in different ways that help in CE and waste management. Digital initiatives like the European Green Deal and Horizon Europe provide funding and support for research, development, and innovation in the fields of sustainability and digitalization that target waste reduction, recycling, and resource efficiency (Kurniawan et al., 2022c). Further, India has launched the National Resource Efficiency Policy to promote sustainable urban development, energy efficiency, waste management, and water conservation (Debnath et al., 2022). To practice sustainable practices, the government focuses on technological advancements, i.e., continuous innovation in digital technologies and the emergence of new tools and platforms (Fatimah et al., 2020). This further accelerates businesses, and entrepreneurs also focus on incorporating technology and digitalization enablers that help leverage digital tools to optimize resource use, enhance transparency, and enable circular business models (Awan et al., 2021). The technology enablers depend on certain factors like technological infrastructures (Ersoy et al., 2022), technological collaborations (Rizos et al., 2016; Fatimah et al., 2020), R&D facilities (Suchek et al., 2022; Mondal et al., 2023), proper WM and recycling facilities (Yazdani et al., 2021), as well as green manufacturing capabilities (Gupta and Dharwal, 2022), which play an essential role in CE and WM development. These enablers can support the transition towards competitiveness, profitability, and environmental performance.

2.4.2. Psychological-related factors

Psychological-related enablers refer to the psychological factors that influence the behavior of entrepreneurs and their willingness to adopt sustainable business practices (Piwowar-Sulej et al., 2021). These enablers consist of factors like environmental awareness and consciousness, attitude toward risk-taking (Agrawal et al., 2022), mindset toward innovation (Sehnem et al., 2022), and sense of responsibility (Mondal et al., 2023; Soni et al., 2023). Several nations have taken part in the Circular Economy Action Plan, advocating the acceleration of the transition to a circular economy (Barford and Ahmad, 2023). Sustainable product policies, waste reduction objectives, and eco-design principles are examples of such initiatives. Furthermore, this enabler fosters cooperation and partnerships to create sustainability and circularity, as well as raise awareness and assist in the development of legislative and regulatory frameworks (Kurniawan et al., 2022c; Ye et al., 2020). The enablers motivate entrepreneurs to adopt sustainable business practices. The psychological enablers also foster innovation in the MSME sector (Mondal et al., 2023). For instance, a mindset toward innovation can motivate entrepreneurs to adopt new sustainable technologies and practices, leading to the development of new sustainable products and services (Piwowar-Sulej et al., 2021). With psychological-related enablers, MSMEs can improve their competitiveness, effectiveness, and efficiencies, in addition to revenues and market share for the enterprise. Therefore, it is important to consider psychological-related enablers alongside technology-related enablers for the successful adoption of sustainable business practices in the MSME sector.

2.4.3. Organizational-related factors

Organizational-related enablers provide a framework for MSMEs to integrate sustainable practices into their operations, which can contribute to environmental sustainability and economic growth (Mondal et al., 2023). The enablers include leadership and organizational culture (Auh and Menguc, 2005), human resource management, strategic planning (De Angelis et al., 2018), financial resources, and collaboration and partnerships (Suchek et al., 2022). Mhatre et al. (2023) emphasize in their research that developed as well as developing countries strive to achieve a climate-neutral economy via circular economy concepts, resource efficiency, and digitalization. While governments' efforts toward a circular economy and digitization have made advancements, there is still potential for improvement in scaling up circular economy models and using organizational enablers (Moktadir et al., 2020; Suchek et al., 2022). Because of organizational developments, regulatory changes, and market dynamics, the factors affecting these activities have altered over time (Auh and Menguc, 2005; Moktadir et al., 2020; Mondal et al., 2023). Strong leadership and supportive organizational culture can inspire employees to embrace sustainability. Organizational management can ensure that employees have the necessary skills and knowledge to adapt to the evolving demands of the CE and WM (Moktadir et al., 2020). MSMEs need a clear understanding of their sustainability goals and objectives to implement sustainable practices effectively (Khurana et al., 2021). Financial resources, collaboration, and partnerships may help MSMEs adopt green and digital practices, improve profitability and reputation, and reach new markets.

2.4.4. Societal-related enablers

Societal enablers such as government policies and regulations encourage clear production, consumption, and sustainable practices (Virmani et al., 2021). Societal factors and industry associations can help raise awareness about the benefits of sustainable practices and achieving net zero in a manufacturing business (Caldera et al., 2019).

According to Kurniawan et al. (2023), social factors play a role in any nation enacting laws and measures to encourage sustainable practices. Developed countries, as well as developing countries like India, are actively pursuing sustainable development programs that meet the SDGs. Several societal enabling factors like public demand for green products (Suchek et al., 2022), higher social acceptance and a good public image (Hasan et al., 2019), long-term consumer behaviors (Khan et al., 2022), employee cooperation and needed competence (Govindan and Hasanagic, 2018), and skilled human resources all substantially impact their activities. Developed nations have well-established governance, institutions, and sustainable policies that support commitments such as carbon reduction and the development of renewable energy (Krajnc et al., 2022). In contrast, emerging nations such as India have difficulties as a result of their vast population and socioeconomic differences. India's programs, such as the Clean India Mission, align with the SDGs, emphasizing resource availability and equitable development (Lahane and Kant, 2022). The future framework would most likely prioritize governance, technology, funding, and international collaboration for the UNSDGs. As a result, India and other nations have attempted to promote sustainable practices, such as CE and WM, to achieve SDGs. Hence, societal enablers are also essential for the successful implementation of these CE and WM practices. Moreover, consumer awareness and demand for sustainable products can encourage MSMEs to adopt GE and digitalization practices for sustainability (Shah et al., 2019).

2.4.5. *Political and regulatory related enablers*

These enablers can provide critical support to businesses operating in these areas by creating a favorable policy environment, ensuring adherence to sustainable practices through regulatory frameworks, providing access to finance, and facilitating capacity-building initiatives (Botelho et al., 2022). As these variables impact the environment in how businesses operate and influence their behavior toward sustainability, numerous countries have implemented policies to address this (Kurniawan et al., 2022a). The European Green Deal has been an important political project in Europe, aiming to make the region the world's first climate-neutral continent by 2050 (Krajnc et al., 2022). It covers a variety of laws and regulations that support clean technology, renewable energy, and sustainable activities. Kurniawan et al. (2022b) show that by adopting the CE as its economic framework, the European Union (EU) stands to gain a staggering USD 2.14 trillion by 2030. When compared to the advantages obtained by a linear economic model, this is a significant 50% gain. Moving forward to 2050, the adoption of CE might result in a significant 27% increase in European GDP, above the 15% growth expected for a linear economy. Furthermore, the Circular Economy Action Plan pushes firms to embrace circularity concepts and decrease waste output (Włodarczyk et al., 2021). As a consequence, countries employ political and regulatory steps to encourage green entrepreneurship and digitization for CE and WM to achieve sustainable development goals. These activities include regulatory frameworks, financial incentives, and legislative changes aimed at supporting innovation, promoting sustainable practices, and promoting sustainable environmental development (Kurniawan et al., 2022a; Sharma et al., 2021a; Włodarczyk et al., 2021). Like in India, the government has taken several initiatives to promote GE, digitalization, CE, and WM. The National Clean Energy Fund, for example, provides financial support to MSMEs to invest in renewable energy technologies. Regulatory frameworks such as the E-Waste Management Rules, 2016, and the Plastic WM Rules, 2016 provide guidelines for businesses to dispose of waste sustainably (Ilankoon et al., 2018). Therefore, the identification of these enablers is critical to promoting GE and digitalization in the CE and WM of Indian manufacturing MSMEs. Therefore, this study considers several enabling GE and digitalization enablers that affect CE and WM. Like Kunanuntakij et al. (2017), environment-supported policies, government funding for green technology (Nandi et al., 2021), policies for corporate social responsibility (Kumar et al., 2022), and an adequate but flexible as well as simple regulatory framework (Gupta and Barua, 2016). These enablers can create a favorable business environment, ensuring the sustainable growth of these sectors and contributing to the overall development of the economy.

2.4.6. *Environment-related critical success factors*

Environment-related enablers are crucial in creating awareness about environmental issues, promoting sustainable practices, and providing technical expertise to businesses operating in these areas (Juma et al., 2023). Environmental sustainability is being promoted through governmental measures in several nations. The European Green Deal, proposed in 2019, aims to make Europe the first climate-neutral continent by 2050 (Filipović et al., 2022). However, several other initiatives, like the Smart Cities Mission and other measures to promote a circular economy for environmental sustainability (van Langen et al., 2021). These promote sustainable development, waste management, and innovation, focusing on circular economy concepts, sustainable production, and resource efficiency (Filipović et al., 2022; van Langen et al., 2021). The long-term circular economy and digitalization framework must emphasize policy consistency, innovation, research, education, capacity development, monitoring, and evaluation. Furthermore, the enablers consist of some critical enabling factors like environmental monitoring and control (Kurniawan et al., 2022a, 2022b), clean development attitudes, and vision for environmental management (Bonilla et al., 2013), green operational practices (Sarc et al., 2019), and safe disposal of hazardous materials (Kumar et al., 2020). Environmental enablers also provide technical expertise and support to businesses operating in the CE and WM sectors. Therefore, environment-related enablers are vital in promoting GE and digitalization in the CE and WM of Indian manufacturing MSMEs. These enablers, working towards promoting sustainable practices and providing technical expertise, can help create a sustainable and inclusive economy that benefits both businesses and the environment.

2.4.7. *Economic and financial related enablers*

Economic and financial enablers play a crucial role in promoting the reuse and recycling of materials and resources and motivating entrepreneurs to work toward adopting sustainable practices (Gupta et al., 2021). Economic and financial-related enablers such as subsidies (Awan et al., 2021), tax incentives, and access to finance are essential for MSMEs to adopt sustainable practices (Kurniawan et al., 2022a). These enablers involve funding technical developments and environments encouraging green, circular, and sustainable enterprises. Several developing and developed countries have introduced different financial programs to assist entrepreneurs and enterprises, such as grants, subsidies, and tax exemptions for sustainable activities (Sharma et al., 2021a, 2021b). In addition, numerous governments have implemented policies to support startups, such as the Digital India initiative, the Circular Economy Action Plan, resource recovery parks, and extended producer responsibility programs (Maiurova et al., 2022; Singh et al., 2022). This helps to decrease waste production, encourage recycling and reuse, and assure a circular economy, sustainable production, and healthy consumption habits to achieve SDG (Maiurova et al., 2022). The future framework for entrepreneurial and digitalization enablers will provide financial incentives, improve regulatory processes, and encourage collaboration for sustainable environmental development (Kurniawan et al., 2022a; Suchek et al., 2022). Access to finance is also crucial, as it allows MSMEs to invest in sustainable practices without compromising their financial stability (Suchek et al., 2022). Moreover, the adoption of digital technologies can facilitate the transition to a CE by improving resource efficiency and reducing waste (Gupta et al., 2021). Hence, economic and financial enablers are critical in promoting

GE and digitalization in the CE and WM of Indian manufacturing MSMEs. By providing incentives and access to finance, these enablers can encourage the adoption of sustainable practices and economic growth. A detailed discussion of the enablers is presented in Fig. 2 and Table A1.

2.5. Research gap and highlights

After conducting a thorough literature review, several research gaps have been identified based on previous studies. Although there are some studies conducted (e.g., Krajnc et al., 2022; Silajdžić et al., 2015; Rupeika-Apoga and Petrovska, 2022; Shayganmehr et al., 2021), the majority of these studies are limited in scope and focus on specific domains or functional areas. A limited number of previous studies (Jiang et al., 2018; Mathivathanan et al., 2022; Moktadir et al., 2020) have identified the factors under the purview of limited theories that influence CE or digitalization. A study by Hussain and Malik (2020), Hina et al. (2022), and Moktadir et al. (2020) identified the factors of CE that are specific to different countries. There is limited study on barriers and enablers, but less study shows how stakeholder engagement, regulation, and economic and environmental issues impact GE, digitalization, CE, and WM. Behl et al. (2023) and Milios (2021) illustrate supportive policies and a regulatory framework for promoting sustainable activities; however, there is a lack of research. In another study by Eisenreich et al. (2021), Torgautov et al. (2022), and Wong et al. (2012), they emphasize the importance of stakeholder collaboration in GE and digitalization initiatives, but there is limited research on this topic. Besides that, some previous research by Jayarathna et al. (2023) and Eskelinen et al. (2022) highlights the importance of social acceptance and engagement for implementing CE and WM. There is little study on how other elements affect CE and WM. Sohal et al. (2022) and Harish et al. (2022) show that economic constraints and financial viability pose significant challenges for GE and digitalization in WM and CE. There is less study on it; hence, further research is needed. Moreover, studies by Hina et al. (2022), Kurniawan et al. (2022b), and Fatimah et al. (2023) show that environmental concerns related to waste generation, pollution, and resource depletion are factors that negatively affect the environment and business. However, there is a research gap in

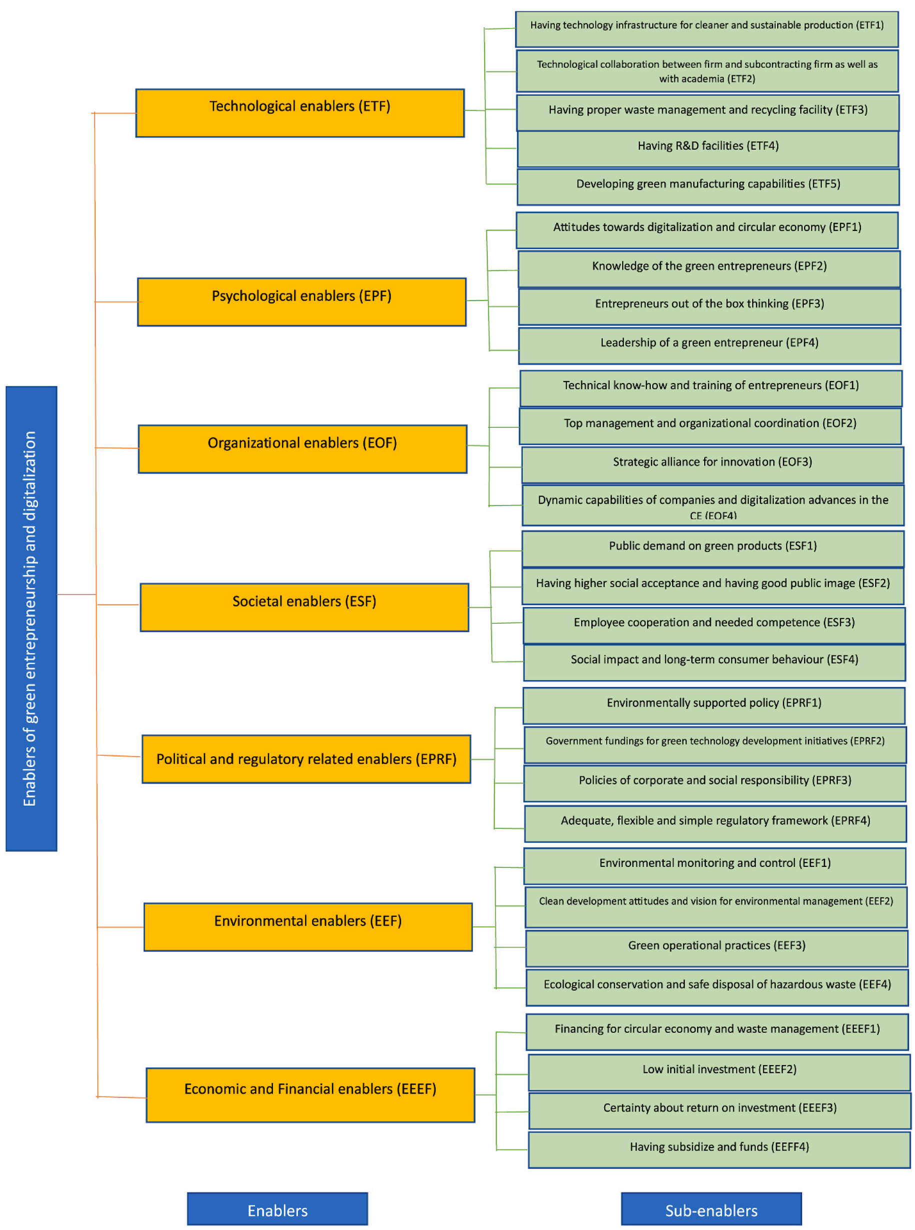

Fig. 2. Hierarchical structures of enablers.

understanding how this factor affects, impacts, and relates to GE, digitalization, WM, and CE. In addition to most of the previous research findings (Chauhan et al., 2022; Hina et al., 2022; Piwowar-Sulej et al., 2021; Parida et al., 2019), it is evident that the majority of studies have relied on literature reviews as their primary methodology for analyzing CE or WM. Moreover, comprehensive studies still require that GE be connected with digitalization, which further helps CE and WM in manufacturing MSMEs contexts, which has not yet been proposed. As of present, there is no empirical evidence to support the aforementioned relationship. The study conducted by Mukonza (2020) utilized qualitative methods to identify GE factors. However, it is imperative to carry out further validations, both qualitative and quantitative, as they are required. The previous research found that most of the past research is from developed nations; however, particularly in developing and underdeveloped nations, the research is limited. Furthermore, to the best of our understanding, a limited number of studies concentrate on manufacturing MSMEs. To the best of our knowledge, no research has thoroughly identified and prioritized GE and digitalization enablers in terms of their relative relevance, priority, and contextual relationship to the development of CE and WM. These studies have often used diverse theoretical backgrounds to identify factors, drivers, and challenges rather than using a complete strategy that incorporates theories such as ST, DCT, RBV, MET, and UCT to characterize these discovered GE digitalization enablers. Also, some previous studies, such as Mondal et al. (2023), Moktadir et al. (2020), Govindan and Hasanagic (2018), and Patel et al. (2021), used various tools for enabler identification. To the best of our knowledge, no research has adopted an integrated strategy, like BWM-TISM and fuzzy MICMAC analysis, to prioritize and make relationships among the enablers of GE and digitalization for CE and WM within the manufacturing MSME sectors. In addition to this, a limited number of studies incorporate mixed methods (i.e., quantitative and qualitative) analysis altogether. Hence, to fulfill this research gap, this study attempts to enable identification in theoretical, methodological, and contextual aspects. Addressing these research gaps can provide information and insights to support the design and implementation of successful policies, stakeholder partnerships, and GE and digitalization initiatives to enhance CE and WM and promote sustainable development.

3. Research methodology

The first phase of the study involved the identification of potential enablers through expert opinion and a literature review. For the literature review, we used several research databases (i.e., Emerald, Web of Science, ScienceDirect, MDPI, Emerald, Springer, EBSCO, Taylor and Francis, and Google Scholar) to gather the relevant research materials. For data searches, "green entrepreneur*," "digitalization," "circular economy," "waste management," and a combination of these keywords are used as keywords. The study incorporates scholarly articles published in time frames spanning from 2000 to 2022, with a specific focus on research articles published in English. Consequently, conference proceedings, book chapters, and newspapers have been excluded from the data collection process. Further, research materials published in languages other than English have been deliberately omitted from this analysis. The research papers were then refined in accordance with our research objectives. From the published research materials, the enablers were identified and finalized; further, experts' opinions were used to verify the identified enablers. The Delphi method, which involves multiple rounds of discussion and consensus-building, was then used to finalize the list of enablers. With the use of theories and expert opinions, a comprehensive framework has been established to identify and categorize a total of twenty-nine sub-enablers. Further these sub-enablers were further categorized into seven main categories of enablers. To assess the effectiveness of the developed framework, several kinds of manufacturing MSMEs have been chosen randomly. These included metal and steel manufacturing, heavy machinery part manufacturing, electric component manufacturing, leather goods manufacturing, textile manufacturing, and engineering goods manufacturing MSMEs. The aforementioned methodology was used to evaluate these firms' activities in terms of green initiatives, digitalization efforts, the circular economy, and waste management. In the second phase, the "Best Worst Method" (BWM) was used to prioritize the enablers. This method allowed for the ranking of enablers based on the feedback received and their corresponding weights from the experts. The third phase of the study employed the "Total Interpretive Structural Modeling" (TISM) methodology to study the interactions and contextual relationships between the identified enablers. TISM helps to understand the interdependencies and influences among different factors. Finally, in the last phase of the study, fuzzy MICMAC analysis was used to cluster the enablers based on their DRP and DEP. This clustering process was carried out using a hierarchical clustering algorithm, which grouped the enablers together based on their DRP and DEP values.

This study used a mixed-methods approach, integrating qualitative approaches like literature reviews, theoretical frameworks, and expert views with quantitative methods like ranking and evaluating contextual and interdependent links. These two methodologies were combined to provide a complete decision-making framework that met research goals. The steps followed in this study are presented in Fig. 3.

3.1. Finalization of enablers of GE and digitalization

For enabler identifications, we use keywords such as ("green entrepreneur*" AND/OR "digitalization" AND/OR "waste management" AND/OR "circular economy") from the Scopus, Emerald, Web of Science, ScienceDirect, MDPI, Emerald, Springer, EBSCO, Taylor and Francis, and Google Scholar databases.

3.2. Best-Worst Method (BWM)

Rezaei's BWM technique is a relatively new MCDM method that employs a multi-case study methodology (Rezaei, 2016; Yang et al., 2023). Here, pairwise comparisons are made for the selected "best factor" to the other factors and all the other factors to the selected "worst factor." The BWM methodology offers numerous benefits compared to alternative MCDM methods like the "analytic hierarchy process." It necessitates fewer pair-wise comparisons between the enablers and factors, leading to more reliable results (Kusi-Sarpong et al., 2021). Additionally, BWM relies on the collection of data using two vectors instead of a complete matrix. As a result, the BWM technique has gained significant popularity among researchers dealing with diverse decision-making scenarios such as segmentation of suppliers (Rezaei, 2016), measurement of risk, supply chain management, medical tourism development, outsourcing and offshoring decision-making, and enabler prioritization (Kumar et al., 2019). It used different fields of research, for example, Industry 4.0 (Gupta et al., 2021), sustainability research (Kusi-Sarpong et al., 2021), and CE (Mondal et al., 2023; Moktadir et al., 2020).

3.3. Total interpretive structural modeling (TISM)

TISM is a technique used in management and decision-making that aims to identify and analyze the relationships among various factors that contribute to a specific problem or situation (Dubey and Ali, 2014). It is a method of mapping out the hierarchical relationships between variables to understand their relative importance and interdependence. TISM involves a multi-step process that includes identifying the key factors or variables related to the problem, creating a matrix of pairwise comparisons, constructing a digraph to represent the relationships between the factors, and interpreting the resulting structure. It is a powerful decision-making technique that can help managers and leaders make informed decisions in complex and uncertain situations (Baliga et al., 2021). Its ability to handle qualitative data and produce an

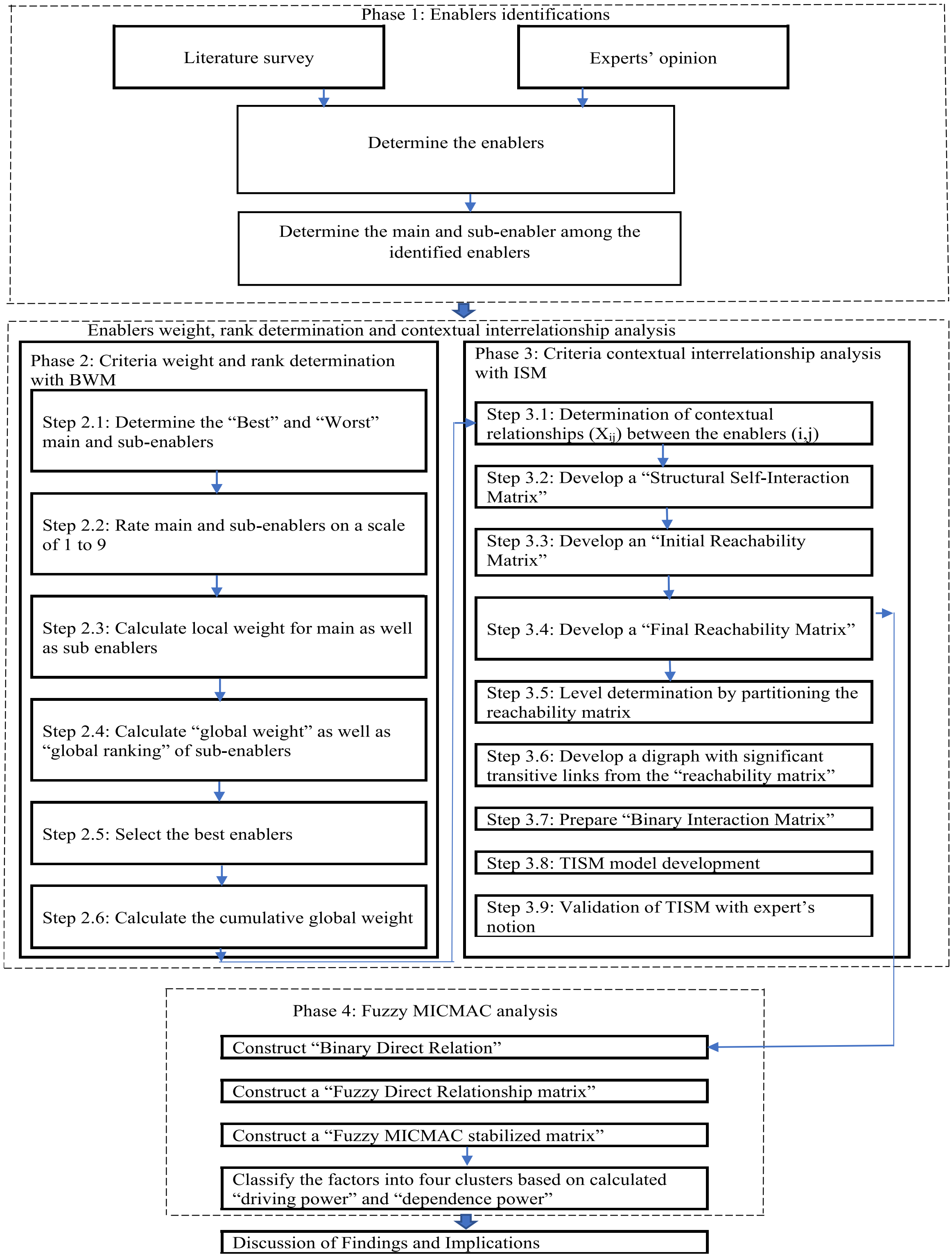

Fig. 3. Flow chart (Author's compilations).

interpretable graphical representation of the problem makes it a valuable tool in many fields, including engineering, management, and public policy. ISM is a widely used tool for identifying elements and establishing key relationships among them. It helps improve our understanding of system structures and simplifies complex models. However, ISM methods have limitations, such as not considering transitive links in the digraph and providing only a weak explanation for direct linkages (Baliga et al., 2021; Dahiya et al., 2021; Mathivathanan et al., 2022). TISM aids in developing hierarchical structures for complex relationships, with domain experts providing explanations for these relationships. It enables in-depth analysis and overcomes the limitations of ISM by offering logical explanations of how factors are interconnected (Mathivathanan et al., 2022). Additionally, TISM allows for explicit explanations of both direct and transitive links within the model (Baliga et al., 2021). Hence, it is used in several fields of research CE (Mathivathanan et al., 2022), WM (Sharma et al., 2021a, 2021b; Ali et al., 2022), and entrepreneurship research (Dahiya et al., 2021).

3.4. Fuzzy MICMAC analysis

It is a decision-making technique used to identify and analyze the relationships among factors in a complex system. It is an extension of the MICMAC method, which is a tool for analyzing the interdependence of factors in a system (Mondal et al., 2023). The fuzzy MICMAC analysis method uses fuzzy logic to handle the uncertainty and imprecision associated with the input data (Sharma et al., 2022). It combines the principles of fuzzy sets and the MICMAC method to generate a fuzzy MICMAC matrix that represents the relationships between the factors in a system. The main advantage of fuzzy MICMAC analysis is its ability to handle imprecise and uncertain data, which is common in many real-world decision-making situations. It is particularly useful in situations where the data is qualitative or subjective, and the relationships between the factors are not well understood. It also raises sensitivity among facilitators based on their significance to one another (Khan and Haleem, 2015; Patel et al., 2021). Therefore, fuzzy MICMAC analysis has several advantages over traditional MICMAC analysis. Further, it incorporates subjective opinions, provides more nuanced results, is robust to small variations in the input data, and provides a more comprehensive understanding of the complex system and the factors that affect it (Kumar et al., 2019; Sharma et al., 2022).

4. Case study analysis and application of the proposed methodology

4.1. Case study

This study focuses on MSMEs and particularly the manufacturing industry to assess their GE and CE practices. The reason for choosing the manufacturing MSMEs sector is because of its important contribution to any country's development. Manufacturing MSMEs produce the highest number of goods (i.e., manufacturing production, small-part manufacturing, manufacturing of components, etc.) (Mondal et al., 2023). These MSMEs also create the highest number of jobs, trade and exports, contributions to taxes, and poverty alleviation, which also have the highest contribution to economic development. Further manufacturing MSMEs also have a sufficient contribution to India's Gross Domestic Product (GDP). The MSMEs that have a sufficient contribution in the domestic market also have a significant contribution in the global market (Sen et al., 2022). Although MSMEs contribute value-added activities, they also negatively impact the environment by generating waste products during the manufacturing process and not managing them properly (Khurana et al., 2021). It also faces several challenges related to technology, most importantly technology-related, then financial-related, regulatory complexities, stakeholder pressures, employee, skill, and labor-related waste generation, and lacks proper digitalization techniques that help in proper waste management, waste minimization, etc. (Mondal et al., 2023). In addition to this manufacturing, MSMEs are using a linear manufacturing system to satisfy demand (Mondal et al., 2023). To achieve the objectives, fifteen experts from diverse backgrounds in both industry and academia were chosen (Table 2). These experts possess at least ten years of experience, hold top positions, and specialize in green initiatives, digitalization, the circular economy, and waste management. The selection criteria ensured that the outcomes would be applicable to various aspects of business and reduce bias. The data collection process involved utilizing the Delphi technique, a structured communication method that utilizes questionnaires or surveys to gather anonymous opinions and feedback from the expert panel. This technique minimizes bias and the influence of dominant individuals within the group, enabling informed decision-making and predictions based on the identified enablers (Kusi-Sarpong et al., 2021).

4.2. Research framework and methods

A combined mixed-method approach, i.e., an extensive literature review and the Delphi method, is used to identify and finalize the enablers. This process involves identifying the enablers through a literature review of past studies, then putting them before the panel of experts (Table 2) for their deliberations to add or delete any enablers. Here, several rounds of discussions are performed in order to finalize the enablers, and twenty-nine enablers were finalized (Table A1). Further, the identified enablers were categorized into seven main categories and twenty-nine sub-categories with the help of theoretical support and expert opinions. The steps followed in this study are outlined in Fig. 3.

4.3. Calculate weight and rank using the best-worst methodology

After the panel of experts finalizes the enablers, the next phase is to assess the weight and rank of these identified enablers. All the experts were then asked to rate each main and sub-category enabler. The best enablers here are those that need to be addressed first, and the worst enablers are those that are least severe from the study's point of view. On a pairwise comparison of each main category and sub-category enabler with other corresponding enablers on a scale of 1–9, a numeric value of 1 represents "equal importance," and a numeric value of 9 represents "extreme importance." All experts were requested to assess all enablers on this scale. The weight of each category's enablers is calculated using the BWM methodology. Here, the ratings of the main criteria enablers by expert one is shown in Table 3. After getting a report of pairwise main criteria and sub-criteria, the next step is to calculate the

Table 2
Description of experts.

Expert	Year of expertise (Years)	Area of expertise	Education level	Designation
Expert 1	13	Industry	B. Tech	Manager- Operation
Expert 2	15	Industry	B. Tech	General manager
Expert 3	11	Industry	MBA HR	Manager human resource
Expert 4	12	Industry	MTech	Deputy manager-operation
Expert 5	20	Industry	B. Tech	Senior production manager
Expert 6	18	Industry	B. Tech	Manager-Technology management
Expert 7	17	Industry	MBA	General manager
Expert 8	15	Industry	BE	Technical manager
Expert 9	13	Industry	Diploma	Assistant manager-Operations
Expert 10	16	Industry	B. Tech	Senior manager
Expert 11	11	Associate professor	PhD	Production and operation management
Expert 12	12	Professor	PhD	Industrial engineering
Expert 13	17	Professor	PhD	Entrepreneurship
Expert 14	15	Professor	PhD	Environmental science
Expert 15	13	Professor	PhD	Operation

Table 3
Expert 1 response on main category enablers.

Best-to-Others	ETF	EPF	EOF	ESF	EPRF	EEF	EEEF
Best enablers: EOF	3	7	1	5	4	9	2
Others-to-worst	Worst enablers: EEF						
ETF	5						
EPF	2						
EOF	9						
ESF	5						
EPRF	3						
EEF	1						
EEEF	6						

weight. Using BWM, the main and sub-category enabler weights for all the enablers are calculated, and then the average weight is obtained through rating. The weight obtained by individual enablers is called ("local weight") LW (Fig. 4). The final "consistency ratio" (CR) is calculated as the average of individual CR values obtained from each expert's data. Our analysis reveals that all numerical CR values are below 0.1, indicating the high reliability and consistency of the data. After calculating the LW of sub-enablers, the GW was calculated by multiplying the weight of each sub-enabler with the corresponding main category enabler's weight. The rank is assigned based on the GW obtained (Fig. 5).

A closer observation of the cumulative GW of enablers (see Fig. 6) suggests that the first nineteen enablers contribute to 80% of the overall representation. The first nineteen enablers identified as top management and organizational coordination (EOF2), having technology infrastructure for cleaner and sustainable production (ETF1), having subsidized and funds (EEFF4), having proper WM and recycling facility (ETF3), dynamic capabilities of companies and digitalization advances in the CE (EOF4), public demand on green products (ESF1), financing for CE and WM (EEEF1), knowledge of the green entrepreneurs (EPF2), strategic alliance for innovation (EOF3), low initial investment (EEEF2), government fundings for green technology development initiatives (EPRF2), developing green manufacturing capabilities (ETF5), leadership of a green entrepreneur (EPF4), social impact and long-term consumer behaviour (ESF4), technical know-how and training of entrepreneurs (EOF1), clean development attitudes and vision for environmental management (EEF2), technological collaboration between the firm and subcontracting firm as well as with academia (ETF2), certainty about return on investment (EEEF3), adequate, flexible and simple regulatory framework (EPRF4). The remaining ten enablers, collectively representing only 20% of the total weight, were excluded from further analysis due to their lack of significant contribution. Further, the enablers were once again coded (as shown in Table 4) for further analysis.

4.4. TISM result

4.4.1. Structural self-interaction matrix (SSIM)

To get contextual relationships, the first step is to develop the SSIM matrix. SSIM is created by symbolizing the relationship between the selected enabler (i) and the enabler (j) (Table 4). Here the relationship is formed as shown in Table 5 through "V," "A," "X," and "O.". The obtained SSIM (Table A2) is derived by substituting "V," "A," "X," and "O" based on the response obtained from experts (Table 2), as illustrated in Table A2.

4.4.2. Developing reachability matrix (RM)

The RM helps to develop the "initial reachability matrix" (IRM) and the "final reachability matrix" (FRM). In the first step, the IRM is obtained by putting "V," "A," "X," and "O" with (0 and 1) (Table 5) into Table A2. Here, numeric values are substituted as 1 and 0 as per the substitution method. By applying the "transitivity rule" to the IRM, we

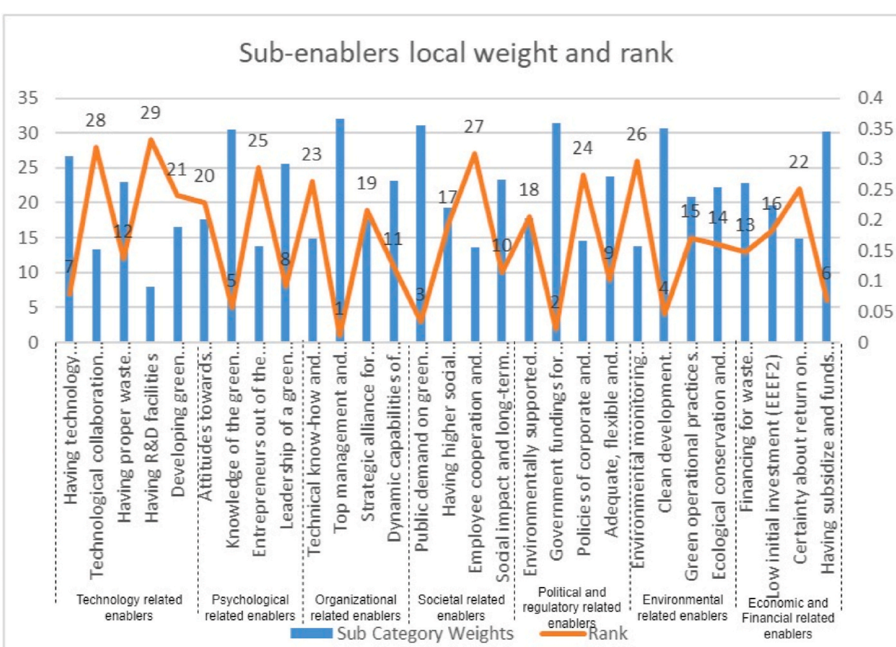

Fig. 4. Plot of local weight.

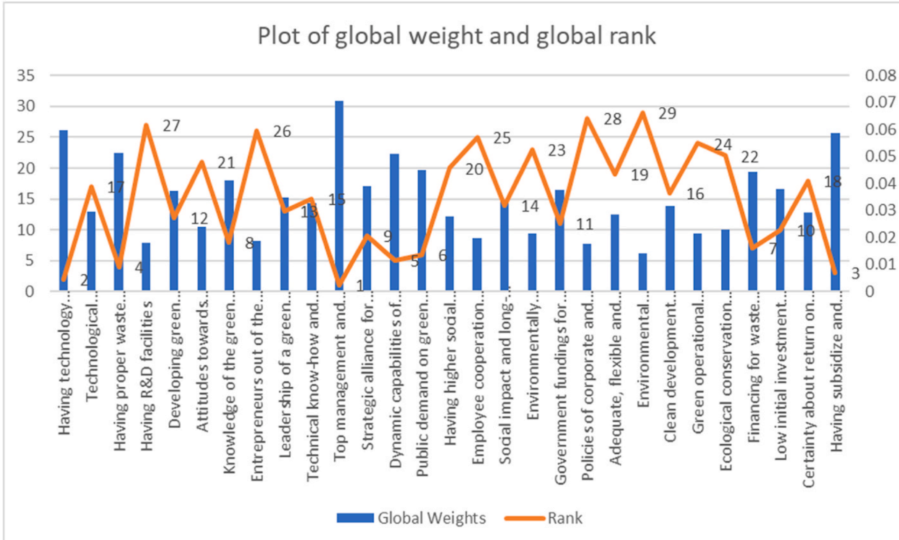

Fig. 5. Plot of global weight.

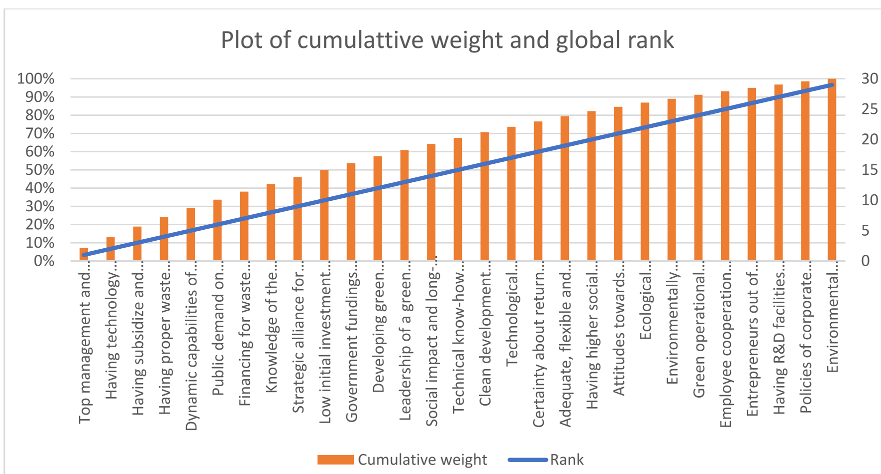

Fig. 6. Plot of the cumulative global weight.

obtain the FRM (Table A3). In Table A3, the cells marked with "*" indicate the transitive elements.

4.4.3. Level partitioning

The hierarchical structure of enablers is established through level partitioning, where the “reachability set” (RS) and “antecedent set” (AS) for each sub-enabler are determined based on the final reachability matrix. The RS comprises the sub-enabler and other elements it can lead to (in the row direction). The AS includes the sub-enabler itself and the group of elements that contribute to achieving it (in the column direction). The “intersection set” (IS) is derived for each sub-enabler by comparing the RS and AS. Sub-enablers with common RS and IS are assigned to the first level. This process is repeated for all sub-enablers, ensuring that each sub-enabler attains its individual level (Baliga et al., 2021). The same approach is applied to assigning all elements in the final reachability matrix. This entire procedure is carried out for all sub-enablers, resulting in their assigned levels (see Table A4).

4.4.4. Formation of ISM digraph

The ISM digraph includes a seven-level hierarchy of enablers, depicted in Fig. 7. The formation of the ISM digraph presents a visual representation of the relationships between the enablers in a “multi-level structure,” as shown in Table A4. The mutual relationship among the enablers is derived from the FRM in Table A3. A unidirectional arrow from the node of an enabler (i) to the node of another enabler (j) signifies that enabler (i) leads to an enabler (j). A bidirectional arrow between nodes, one enabler (i) and the other enabler (j), symbolizes their mutual relationship (Baliga et al., 2021).

5. Total interpretive structural model (TISM) development

The developed digraph is converted into a binary interaction matrix where all depicted interactions are represented as 1, while the remaining cells are left empty (Mathivathanan et al., 2022). Based on the interaction matrix and the entries in the enablers, we developed an interpretive matrix with 19 enablers. The identified transitive links were subjected to further verification by experts. Experts were asked to rate these links on a five-point Likert scale, as shown in Table 2. Only scores greater than or equal to 3.5 were taken into account, with the remainder being disregarded. Although some research (Baliga et al., 2021) proposes a cut-off of 3, we used a harsher cut-off to achieve a more concise representation in our final digraph. It is important to note that the discarded items should not be interpreted as indicating that the links are non-transitive. The aim of this procedure was to include only the most important transitive relationships in the final digraph, which can be found in Table 6 and Fig. 8.

Table 4
List of top enablers based on Pareto analysis.

Serial no	Sub enablers	Enablers reference code
1	Top management and organizational coordination (EOF2)	EN1
2	Having technology infrastructure for cleaner and sustainable production (ETF1)	EN2
3	Having subsidized funds (EEFF4)	EN3
4	Having proper WM and recycling facility (ETF3)	EN4
5	Dynamic capabilities of companies and digitalization advances in the CE (EOF4)	EN5
6	Public demand for green products (ESF1)	EN6
7	Financing for CE and WM (EEEF1)	EN7
8	Knowledge of the green entrepreneurs (EPF2)	EN8
9	Strategic Alliances for Innovation (EOF3)	EN9
10	Low initial investment (EEEF2)	EN10
11	Government funding for green technology development initiatives (EPRF2)	EN11
12	Developing green manufacturing capabilities (ETF5)	EN12
13	Leadership of a green entrepreneur (EPF4)	EN13
14	Social impact and long-term consumer behavior (ESF4)	EN14
15	Technical know-how and training of entrepreneurs (EOF1)	EN15
16	Clean development attitudes and vision for environmental management (EEF2)	EN16
17	Technological collaboration between the firm and subcontracting firm as well as with academia (ETF2)	EN17
18	Certainty about return on investment (EEEF3)	EN18
19	Adequate, flexible, and simple regulatory framework (EPRF4)	EN19

Table 5
Explanation of symbol used in TISM.

Symbol	i→j	j→i
"V"	1 (✓)	0 (×)
"A"	0 (×)	1 (✓)
"X"	1 (✓)	1 (✓)
"O"	0 (×)	0 (×)

Stage IV: fuzzy MICMAC analysis

Further fuzzy MICMAC analysis is a method used to cluster enablers based on DEP and DRP. It outperforms existing strategies by evaluating the breadth of each enabler while taking into consideration the intensity of relationships between other enablers (Patel et al., 2021). Fuzzy MICMAC analysis enhances sensitivity by resolving "binary relationships" into a range of 0–1. To determine the DRP and DEP of each enabler, the summation value of numerical values along the row for DEP and the column for DEP. The steps in fuzzy MICMAC include the development of a "binary direct relationship matrix" (BDRM) and then a "fuzzy direct relationship matrix" (FDRM) after this "fuzzy stabilized matrix" is calculated. In fuzzy MICMAC analysis, fuzzy scales are used for data collection. The following section outlines the step-by-step process of fuzzy MICMAC analysis.

5.2.6.1. BDRM matrix

The first step is to create a BDRM by looking at the direct relationships between the enablers in the ISM and taking the diagonal element zero into account.

5.2.6.2. FDRM matrix

The experts initially involved in identifying the enablers and developing their relationships (Table 2) were again asked to reassess the relationships using a linguistic scale, assigning a numerical value between 0 and 1 to indicate the level of reachability between enablers. This assessment is presented in Table 7 (Patel et al., 2021). The suggested values for reachability were incorporated into the previously established BDRM using transitivity, resulting in the formation of the FDRM.

5.2.6.3. Fuzzy MICMAC-stabilized matrix (FMSM)

In order to determine the DRP and DEP of enablers, the approach of fuzzy matrix multiplication is utilized. In line with FST ("Fuzzy Set Theory"), when two fuzzy matrices are multiplied, the resulting matrix is also a fuzzy matrix, as described by equation (6). This process of matrix multiplication is iteratively performed until the DRP and DEP for enablers reach a stable state. In this particular study, the FMSM is presented in Table A5.

$$Z = X,\ Y = \max k\{\min(x_{ik}, y_{kj})\},\ \text{where, } X = [x_{ik}] \text{ and } Y = [y_{kj}] \tag{6}$$

The categorization of cluster performance for enablers is determined using fuzzy MICMAC analysis, considering the values of DRP and DEP. A diagram illustrating this categorization is presented in Fig. 9.

6. Discussion of results

This research focuses on identifying critical enablers that help manufacture MSMEs and develop proper CE and WM. This study helps industrial decision-makers, entrepreneurs, and academics use green practices and digitalization for waste management and CE strategies to promote sustainability.

6.1. Discussion of Best-Worst Method result

The output of the BWM analysis (Figs. 4 and 5) shows that among the seven main categories of enablers, technologically related enablers (criteria weight 0.196) are ranked first. Within the main category, technology-based enablers play a significant role in helping green entrepreneurs adopt digitalization for CE and WM practices in India and other countries, especially for MSMEs in the manufacturing sector (Maiurova et al., 2022; Mondal et al., 2023). Incorporating this factor can significantly enhance the efficiency and effectiveness of MSMEs while minimizing their environmental impact. These enablers may help MSMEs reduce waste, maximize resources, source sustainably, recycle and recover, comply with laws and regulations, and promote ethical and sustainable practices. Organizational-based enablers rank second-highest among the main category enablers (criteria weight of 0.193). These enablers play a crucial role in supporting green entrepreneurs working towards promoting sustainable practices such as CE and WM in MSMEs. The noteworthy observation suggests that organizational enabling factors like top management and organizational coordination, strategic alliances, dynamic capabilities for digitalization, and training play a significant role in the development of CE and WM (Hussain and Malik, 2020). These enablers can benefit MSMEs in several ways, like increased innovation, efficiency, competitiveness, regulatory compliance, and improved reputation. Economic and financial-related enablers (criteria weight: 0.170) are ranked third among the main category enablers. These enablers are critical for green entrepreneurs looking to incorporate digitalization in the CE and WM in India and other countries (Rizos and Bryhn, 2022). Financial enablers such as venture capitalist funds and government subsidies may assist green entrepreneurs in developing technology, infrastructure, and R&D for sustainable businesses. Economic enablers such as tax advantages for investing in environmentally friendly technology or low-interest financing for green ventures allow businesses to develop creative solutions and build a more sustainable future. Here, societal enablers ranked fourth through BWM analysis (with a criteria weight of 0.127), and they also play a vital role in promoting CE and WM (Mondal et al., 2023). Societal enablers, including public demand, increased acceptability, employee collaboration, and social effect, may maximize resource usage, manufacturing efficiency, and waste reduction. By combining digitization with societal enablers, MSMEs may adopt sustainable practices, increase their competitiveness, contribute to environmental

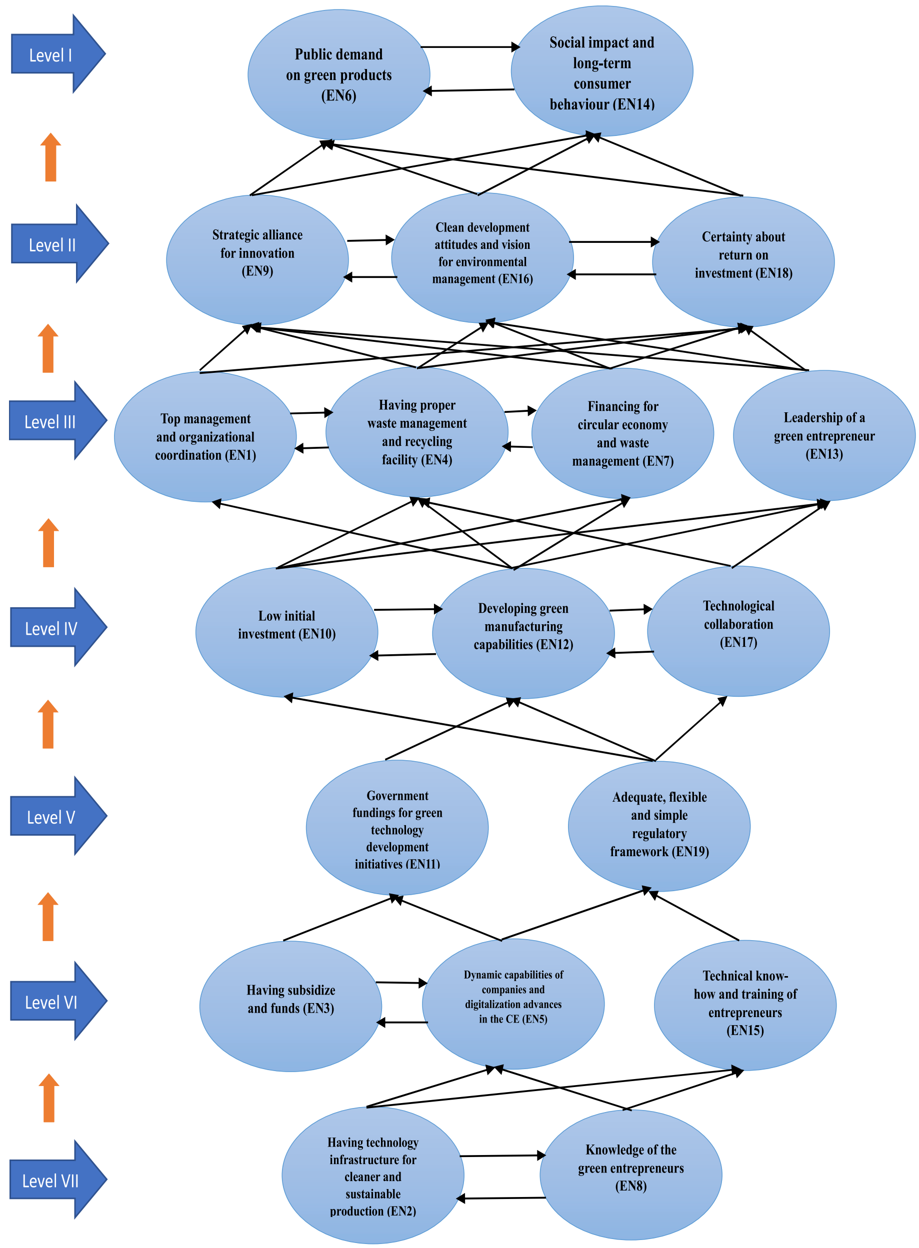

Fig. 7. Structural model.

and social well-being, and expedite the transition to a sustainable CE economy (Kumar et al., 2022). Next, psychologically related green entrepreneurial and digitalization enablers obtained the fifth position through BWM analysis (criteria weight 0.119). These enablers are critical for green entrepreneurs who are incorporating digitalization to promote CE and WM in manufacturing MSMEs in India. Psychological enablers like digitalization attitude, green entrepreneur knowledge, and leadership skills can help green entrepreneurs develop the mindset and skills to create innovative solutions that enable sustainable development and positively impact society and the environment (Agrawal et al., 2022). Further, political and regulatory-based enablers obtained the sixth rank (a criteria weight of 0.105). Political and regulatory-based enablers are crucial for green entrepreneurs who are incorporating digitalization to promote CE and WM in manufacturing MSMEs in India and other countries. Political and regulatory enablers include environmental legislation, government financing for green technology development, corporate and social responsibility policies, and flexible regulatory frameworks that encourage MSMEs to invest in sustainable solutions (Kunanuntakij et al., 2017; Kumar et al., 2022). Lastly, environmental-related enablers ranked seventh among the main category enablers, with a criteria weight of 0.090. These enablers can provide the necessary infrastructure, technology, and expertise that can enable MSMEs to reduce their environmental impact and adopt sustainable practices. Environmental-related enablers can include environmental monitoring and control, clean development attitudes, green operational practices, and safe disposal of hazardous waste that can help MSMEs reduce their carbon footprint, conserve natural resources, and promote social and environmental responsibility (Mondal et al., 2023).

Among the sub-category enablers, top management and organizational coordination obtained the first rank through BWM analysis (criteria weight 0.071). Top management and organizational coordination-related enablers ensure that MSMEs have the necessary leadership, resources, and coordination mechanisms to effectively implement sustainable practices and technologies (Fatimah et al., 2020). Next, having technology infrastructure for cleaner and more sustainable production is obtained in the second position through BWM analysis

Table 6
Validation of transitivity in the TISM model.

Sr. no.	Relation link and interpretation	Average score from an expert	Accept/reject
1	EN1 will enhance/influence EN6	4.20	Accept
2	EN1 will enhance/influence EN7	2.87	Reject
3	EN1 will enhance/influence EN14	4.07	Accept
4	EN1 will enhance/influence EN16	4.40	Accept
5	EN2 will enhance/influence EN3	2.73	Reject
6	EN2 will enhance/influence EN19	3.93	Accept
7	EN3 will enhance/influence EN12	4.33	Accept
8	EN3 will enhance/influence EN19	2.93	Reject
9	EN4 will enhance/influence EN6	4.13	Accept
10	EN4 will enhance/influence EN14	4.27	Accept
11	EN5 will enhance/influence EN10	2.80	Reject
12	EN5 will enhance/influence EN12	4.60	Accept
13	EN5 will enhance/influence EN17	4.40	Accept
14	EN7 will enhance/influence EN1	2.87	Reject
15	EN7 will enhance/influence EN6	4.47	Accept
16	EN7 will enhance/influence EN14	4.13	Accept
17	EN8 will enhance/influence EN3	2.87	Reject
18	EN8 will enhance/influence EN11	2.87	Reject
19	EN8 will enhance/influence EN19	4.33	Accept
20	EN9 will enhance/influence EN18	2.87	Reject
21	EN10 will enhance/influence EN1	2.80	Reject
22	EN10 will enhance/influence EN9	4.00	Accept
23	EN10 will enhance/influence EN16	4.07	Accept
24	EN10 will enhance/influence EN17	2.33	Reject
25	EN10 will enhance/influence EN18	4.20	Accept
26	EN11 will enhance/influence EN1	3.93	Accept
27	EN11 will enhance/influence EN4	4.13	Accept
28	EN11 will enhance/influence EN7	4.13	Accept
29	EN11 will enhance/influence EN10	4.47	Accept
30	EN11 will enhance/influence EN13	2.80	Reject
31	EN11 will enhance/influence EN17	4.13	Accept
32	EN12 will enhance/influence EN9	4.20	Accept
33	EN12 will enhance/influence EN16	4.27	Accept
34	EN12 will enhance/influence EN18	3.93	Accept
35	EN13 will enhance/influence EN6	4.33	Accept
36	EN13 will enhance/influence EN14	4.53	Accept
37	EN15 will enhance/influence EN10	3.00	Reject
38	EN15 will enhance/influence EN12	4.40	Accept
39	EN15 will enhance/influence EN17	4.27	Accept
40	EN17 will enhance/influence EN1	4.33	Accept
41	EN17 will enhance/influence EN7	4.27	Accept
42	EN17 will enhance/influence EN9	4.20	Accept
43	EN17 will enhance/influence EN10	2.60	Reject
44	EN17 will enhance/influence EN16	4.53	Accept
45	EN17 will enhance/influence EN18	3.87	Accept
46	EN18 will enhance/influence EN9	2.87	Reject
47	EN19 will enhance/influence EN1	4.27	Accept
48	EN19 will enhance/influence EN4	4.33	Accept
49	EN19 will enhance/influence EN7	2.80	Reject
50	EN19 will enhance/influence EN13	4.27	Accept

(criteria weight 0.060). Technology infrastructure is essential for cleaner and more sustainable production in today's world. With growing concern for the environment, businesses need to adopt eco-friendly practices to reduce their carbon footprint (Agrawal et al., 2022). Green entrepreneurs, particularly in manufacturing MSMEs, need to focus on CE principles, and WM can help reduce waste, increase efficiency, and enhance overall productivity (Nuringsih and Nuryasman, 2022). A study by Rizos et al. (2016) and Wilts et al. (2021) shows that technologies such as automation, artificial intelligence, and the IoT can streamline operations and optimize resource usage. This can help them reduce their environmental impact and enhance their competitiveness in the market. Ultimately, it can contribute to developing a greener and more sustainable economy. Next, subsidies and funds are the third critical enabler in this study (criteria weight 0.059). Access to subsidies and funds can play a vital role in enabling green entrepreneurs, particularly MSMEs, to adopt sustainable manufacturing practices (Awan et al., 2021; Mondal et al., 2023). Guo et al. (2018) show that subsidies can help reduce the cost of implementing environmentally friendly technologies, while funds can provide financial support for research and the development of innovative solutions. A lack of these enablers creates barriers to the circular economy and further SDGs (Grafström and Aasma, 2021). Nascimento et al. (2019) show that incorporating digitalization into CE and WM practices can further enhance the effectiveness of these initiatives. In India and other countries, providing subsidized and funded enablers for MSMEs can promote sustainable development and create new opportunities for economic growth and job creation (Kuo et al., 2021). Such investments can also contribute to mitigating the impact of climate change and the development of environmental sustainability. Here is the ranking of the remaining sub-enablers based on the BWM analysis: EOF2>ETF1>EEEF4>ETF3 >EOF4>ESF1>EEEF1>EPF2>EOF3>EEEF2>EPRF2> ETF5>EPF4> ESF4> EOF1>EEF2>ETF2>EEEF3>EPRF4>ESF2>EPF1>EEF4>EPRF1>EEF3>ESF3>EPF3>ETF4>EPRF3>EEF1.

6.2. *Discussions of TISM result*

The global weight computed for sub-enablers applying the BWM helps their global ranking (Fig. 5). The top nineteen ranked sub-enablers

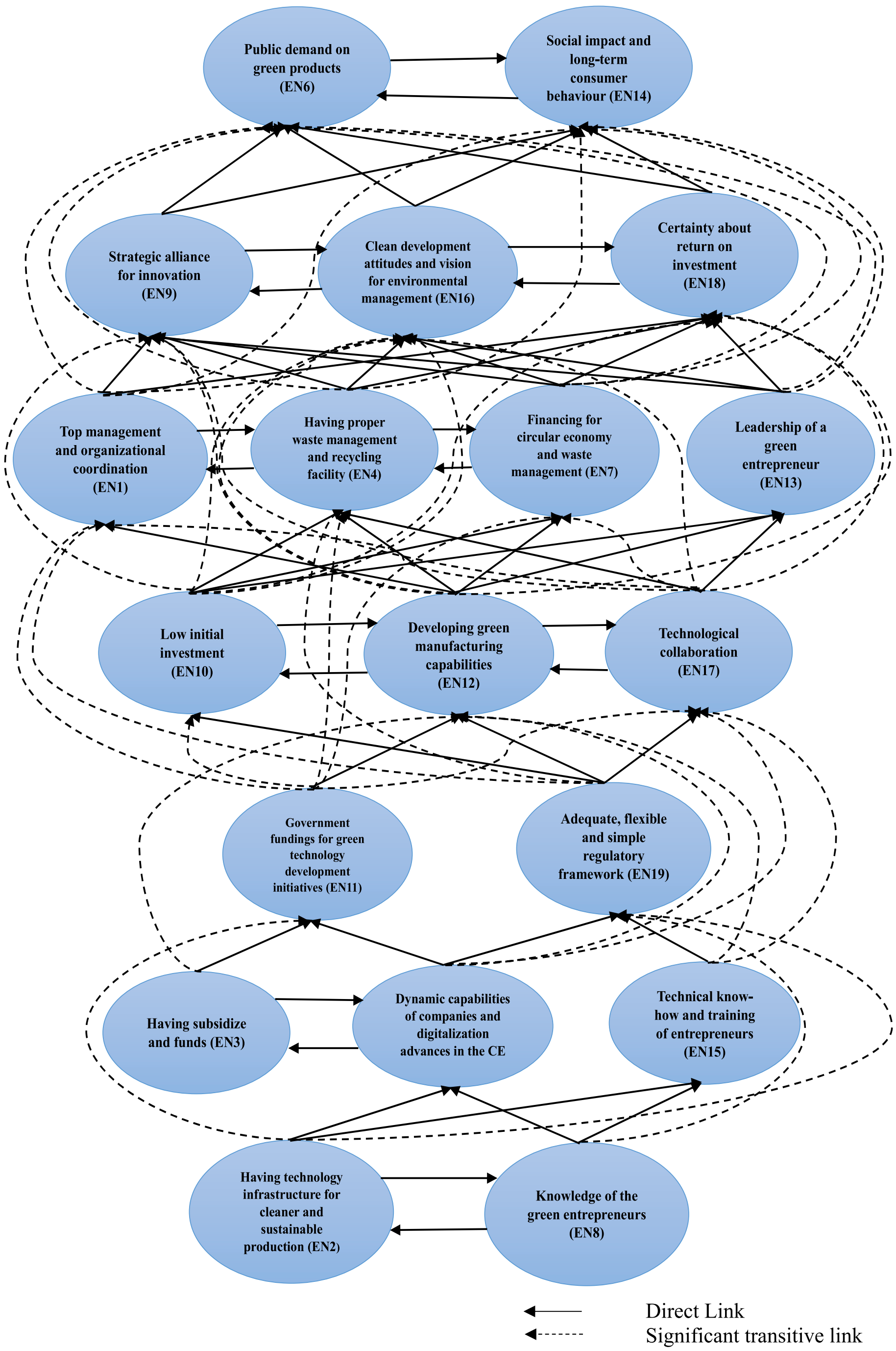

Fig. 8. Final TISM digraph.

Table 7
Possible linguistic and numerical value between enablers.

Possibility of reachability	No	Very Low	Low	Medium	High	Very High	Complete
Values	0	0.1	0.3	0.5	0.7	0.9	1

are assigned from EN1 to EN19 based on global weight. EN1 holds the highest ranking, followed by EN2, EN3, and so on until EN19 (Table 4), with a cumulative weight representation of 80%. A seven-level structure was established based on the identified nineteen sub-enablers from the BWM and TISM models. For level partitioning, level 7 indicates the highest driving power, and level 1 indicates the highest dependence power of sub-enablers (Fig. 8). The enablers, EN6 (public demand for green products) and EN14 (social impact and long-term consumer behavior) are listed in the level 1 hierarchy. This enabler has the least influence over other enablers and is least capable of affecting the development of the circular economy and waste management. Generally, this enabler depends on the other enablers (Mathivathanan et al., 2022). For instance, Luo et al. (2020) and Rainville (2021) argued that public demand for green products helps develop the circular economy. Further, Heath & Cotton (2022) show that a circular economy solves the waste problem, which further helps businesses have a social impact and influence long-term consumer behavior. This was further discussed with the experts, and they confirmed that in the given scenario, this factor helps and promotes waste management and circular economy

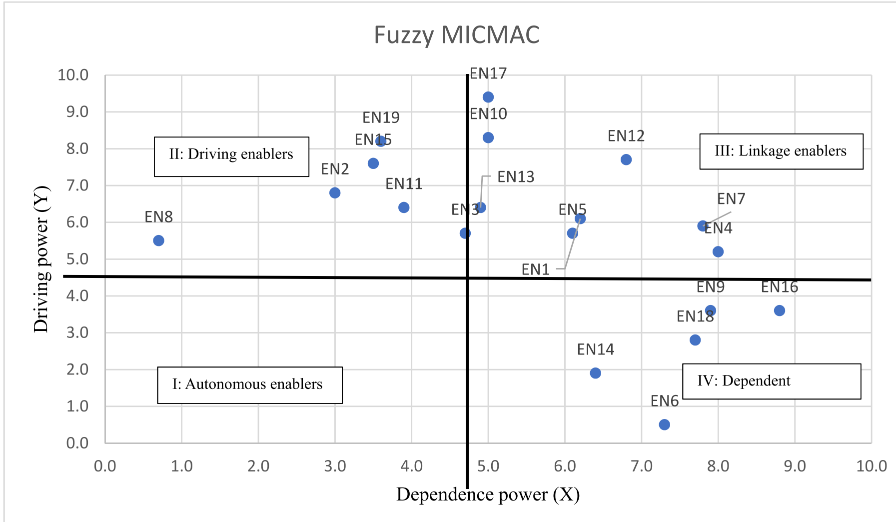

Fig. 9. Cluster of fuzzy MICMAC analysis (Author's compilations).

development.

Level 2 consists of three enablers, namely EN9 (strategic alliance for innovation), EN16 (clean development attitudes and vision for environmental management), and EN18 (certainty about return on investment), which are the dependent enablers. Fatimah et al. (2020) and Shayganmehr et al. (2021) argued that Industry 4.0 plays an essential role in cleaner production and CE development. As these are the top-level enablers, we also found dependent enablers and lower driving power in our analysis. It is important that these enablers (EN9, EN16, EN18, EN14, and EN6) have an effect on the circular economy and waste management development (Yu et al., 2022; Suchek et al., 2022; Khan et al., 2022).

Next, level 3 consists of EN1 (top management and organizational coordination), EN4 (having proper WM and recycling facilities), EN7 (financing for CE and WM), and EN13 (leadership of a green entrepreneur). These green entrepreneurship and digitalization enablers also play an essential role in the development of the circular economy and waste management. Proper EN4, backed by EN1, and finance for circular economy and waste management activities are necessary for Indian MSMEs to prosper in sustainable practices (Mondal et al., 2023; Sharma et al., 2020). Moreover, the leadership of green entrepreneurs plays a crucial role in fostering growth in the circular economy, allowing MSMEs to embrace environmentally friendly practices and contribute to a more sustainable future in India.

Level 4 consists of EN10 (low initial investment), EN12 (developing green manufacturing capabilities), and EN17 (a technological collaboration between the firm and subcontracting firm as well as with academia). Further, another important finding of our research shows that EN10, EN17, EN13, EN5, EN12, EN7, and EN4 link green enterprise and digitalization enablers that help in the development of the circular economy and waste management in manufacturing MSMEs. This is also supported by the previous study (Moktadir et al., 2020; Mondal et al., 2023; Kurniawan et al., 2022a; Suchek et al., 2022). A study by Fatimah et al. (2020), Moktadir et al. (2020), and Suchek et al. (2022) shows that financial as well as top management coordination act as strategic factors that play a strategic role in the circular economy and waste management. The lower hierarchical driving elements at Level 5 consist of EN11 (government funding for green technology development initiatives) and EN19 (adequate, flexible, and simple regulatory framework).

In addition, level 6 consists of EN3 (having subsidies and funds), EN15 (technical know-how and training of entrepreneurs), and EN5 (dynamic capabilities of companies and digitalization advances in the CE). The discussion with experts also confirmed that linkage enablers influence other enablers at multiple levels. Having subsidized funds, technical training for entrepreneurs, and capabilities also plays a significant role in the development of the circular economy and waste management (Awan et al., 2021; Khan et al., 2022; Suchek et al., 2022; Moktadir et al., 2020). These enablers further empower entrepreneurs by increasing their capabilities, fostering innovation and competence in the circular economy and waste management methods, driving sustainable solutions, and increasing resource efficiency.

Furthermore, level 7 consists of EN2 (having technology infrastructure for cleaner and more sustainable production) and EN8 (knowledge of green entrepreneurs). These enablers are the driving enablers (Fig. 9) and influence other higher-level enablers. The enablers at the bottom level of the hierarchy are capable of being positive enablers of the entire system by pushing the other enablers to achieve the research objectives. Hence, the lower-level enablers are important and influential and can be a vital force in achieving the other enablers. Thus, management and entrepreneurs should give priority to lower-level enablers or developing proper CE and WM development to achieve sustainable development objectives. As these enablers have the highest "driving power," they require urgent attention from entrepreneurs, managers, and decision-makers. Further, this is driving green entrepreneurial enablers and digitalization enablers that help circular businesses and waste management in businesses. Additionally, management experts and businesspeople who engage in green business, waste management, or the circular economy, as well as earlier research (Gupta et al., 2021; Govindan and Hasanagic, 2018; Sharma et al., 2020), support these findings.

According to Mathivathanan et al. (2022), the enablers at the bottom of the hierarchy have the potential to positively impact the entire system by motivating the other enablers to accomplish the overall goals. As a result, these enablers hold significant influence and can serve as a crucial force in achieving the other enablers. Given this importance, green entrepreneurs should prioritize these enablers when implementing digitization for the circular economy (CE) and waste management in MSMEs.

6.3. Discussion about the fuzzy MICMAC analysis result

The findings of the enablers are categorized into four clusters with the help of the "fuzzy MICMAC" analysis. Fuzzy MICMAC is an extension of the MICMAC analysis method that incorporates fuzzy logic to handle uncertainty and imprecision in the input data (Mondal et al., 2023; Patel et al., 2021). Based on the DEP and DRP values from the fuzzy MICMAC analysis, the enablers have been grouped together, as shown in Fig. 9. Here, the "driving power" or driving factors (DRP) is how this enabler affects or influences other enablers. Whereas "dependent power" (DEP) is based on how other enablers influence them.

6.3.1. Cluster I: autonomous enablers

In the fuzzy MICMAC analysis, the autonomous enablers are those enablers who have the lowest "dependency power" (DEP) as well as "driving power" (DRP). And this enabler has not influenced or been influenced by other enablers. It means that enablers in this category have no significant role or effect on other enablers. From our findings, it is evident in our research that no such enablers exist in this study. As a result, all nineteen enablers used in this study significantly influence overall relationships.

6.3.2. Cluster II: driving enablers

The cluster with the greatest "driving power" (DRP) and lowest "dependency power" (DEP). As a result, the enablers in this cluster have the highest driving power and influence other enablers; hence, they are regarded as independent variables. In this cluster six enablers belong to this group: EN11 (government funding for green technology development initiatives) and EN19 (adequate, flexible, and simple regulatory framework); EN3 (having subsidies and funds); EN15 (technical know-how and training of entrepreneurs); EN2 (having technology infrastructure for cleaner and more sustainable production); and EN8 (knowledge of green entrepreneurs). These enablers are the driving enablers (Fig. 9) and influence other higher-level enablers. Government funding, such as financial support, research grants, and incentives, enables entrepreneurs to develop green technology development initiatives (Mondal et al., 2023). This further helps to develop green or sustainable solutions for waste management practices (i.e., recycling) and the circular economy model (Demirel and Danisman, 2019). Kurniawan et al. (2022b) show that this enabler helps in the integration of digitalization in these initiatives to enhance data-driven decision-making, manage and reduce waste generation, and increase transparency and overall efficiency of circular economy strategies. As this factor is important to the development of sustainability activities, the government and management should allocate and invest funds for it. Adequate, flexible frameworks provide a clear guideline for developing sustainable business practices. It further enables entrepreneurs to adopt innovation solutions (i.e., digital technologies) for optimal use of resources, reduce waste generation, and promote recycling and circular economy development in manufacturing MSMEs (Mondal et al., 2023). Another study by Ye et al. (2020) shows that regulation plays an important role in green and other sustainability activities. Further, Trapp & Kanbach (2021) show that subsidies and funds play an essential role in green enterprise and driving green technology business model development. On the other side, Suchek et al. (2022) show that this factor is significantly responsible for green enterprise, digital transformation, improved efficiency, and proper waste management, which further help in the development of the circular economy. Compared to the previous research by Ersoy et al. (2022) and Ye et al. (2020), the training helps businesses equip entrepreneurs with the necessary technical skills to promote innovativeness and sustainable practices. This will further drive and enable the effective use of technology for waste management, i.e., waste recovery and recycling, and further contribute to a circular economy and sustainable development in MSMEs. Ersoy et al. (2022) show the impact of technology and technological infrastructure on green and sustainable business development. Further, Yazdani et al. (2021), Ramadani et al. (2022), and Agrawal et al. (2022) show that the knowledge of entrepreneurs provides expertise and an innovative mindset to develop a sustainable business model. It serves as a catalyst for expertise in managing digitalization in MSMEs to optimize waste management and resource efficiency and foster circular economy practices by driving data-driven solutions that create new opportunities.

6.3.3. Cluster III: linkage enablers

These enablers have a higher DEP as well as a higher DRP. In this cluster, these studies find that EN1 (top management and organizational coordination), EN4 (having proper WM and recycling facilities), EN7 (financing for CE and WM), EN13 (leadership of a green entrepreneur), EN10 (low initial investment), EN5 (dynamic capabilities of companies and digitalization advances in the CE), EN12 (developing green manufacturing capabilities), and EN17 (technological collaboration between firm and subcontracting firm as well as with academia) belong to this cluster. This enabler is the linkage enabler and plays a crucial role in holding the entire system together, and these enablers make a linkage between the driving and dependent enablers (Fig. 9) (Patel et al., 2021). The linkage enablers have influenced other enablers at multiple levels. These linkage enablers serve as both moderators and mediators in facilitating the relationship. According to previous research by Auh and Menguc (2005), Moktadir et al. (2020), Ye et al. (2020), and Mondal et al. (2023) emphasize the efficient coordination of top management, supporting the optimal use of digital technology with green practices for waste monitoring in a manufacturing MSME. This collaboration improves management, improves recycling processes, and promotes circular and sustainable development. In another study by Fatimah et al. (2020), green entrepreneurial initiatives and digitalization in waste management and recycling improve resource utilization and waste reduction. This further helps reduce the extraction of new raw materials and promotes a circular economy in MSMEs (Sarc et al., 2019). Moreover, financing for the circular economy and waste management can help green companies and innovative technologies (digital technologies) create sustainable solutions for resource usage, waste reduction, and recycling in a manufacturing MSME (Kurniawan et al., 2022a; Suchek et al., 2022). Yet, green entrepreneurs' leadership enables the implementation of innovative (i.e., digital technologies) and sustainable (waste management) circular economy practices, contributing to the business's sustainability (Agrawal et al., 2022). A small initial investment significantly strengthens the circular economy by improving waste management operations and increasing resource efficiency, especially in adapting to changing market needs and establishing competitive advantages (Kowalski and Makara, 2021). The dynamic capabilities and advancements in digitalization play a critical role in enabling green entrepreneurs to incorporate digitalization for waste management and circular economy practices in manufacturing MSMEs (Khan et al., 2022). In addition, incorporating digitalization and green manufacturing practices further supports the transition toward a circular economy by fostering resource conservation, product reuse, and sustainable production processes (Gupta and Dharwal, 2022). Furthermore, collaboration among MSMEs, subcontracting enterprises, and academics is vital to promoting green entrepreneurs' adoption of digitalization, waste management, and circular economy practices in manufacturing MSMEs. This relationship boosts sustainability, improves environmental performance, and enhances the competitiveness of manufacturing MSMEs (Rizos et al., 2016; Fatimah et al., 2020).

6.3.4. Cluster IV: dependent enablers

The enablers in this cluster have the highest DEP and the lowest DRP (see Fig. 9). The enablers, namely EN6 (public demand for green products) and EN14 (social impact and long-term consumer behavior), EN9 (strategic alliance for innovation), EN16 (clean development attitudes and vision for environmental management), and EN18 (certainty about return on investment), are the dependent enablers and fall into this cluster. The aforementioned enablers retain the highest place in the established hierarchy and are therefore seen as critical variables for boosting waste management and the development of a circular economy in manufacturing MSMEs. Furthermore, the interconnectedness of these enablers demonstrates that they rely on one another and play a very effective role in promoting the progress of waste management and circular economy practices inside a manufacturing MSME organization. Shah et al. (2019) and Suchek et al. (2022) show that green entrepreneurship causes innovation and the development of environmentally friendly products and services. This boosts public demand for environmentally friendly products and pushes firms to use circular economy principles such as recycling, reuse, and waste reduction to meet market demand (Govindan and Hasanagic, 2018; Sharma et al., 2021a, 2021b). Digitalization improves waste management in the circular economy by enabling real-time data collection, analysis, and resource allocation. Another study by Ye et al. (2020) and Khan et al. (2022) shows that promoting sustainable practices and eco-friendly initiatives leads to a long-term positive social impact on consumer behavior, thereby promoting green enterprise, the circular economy, and sustainable development. In addition, strategic alliances for innovation help develop and incorporate innovative technologies (i.e., digital technologies). This further enables MSMEs to promote efficient use of resources and better management of waste to contribute to a more sustainable circular economy (Suchek et al., 2022; De Angelis et al., 2018). Gupta et al. (2021) and Bonilla et al. (2013) show that clean development attitudes and vision for environmental management help minimize and manage waste generation, reduce pollution, and develop a circular economy and sustainable development. Further development of a green enterprise or waste management, as well as the development of the circular economy in a business, helps in certainty about return on investment as well as sustainable development (Jiang et al., 2018).

All nineteen enablers have been categorized as "independent," "linkage," or "dependent" in the literature. The interdependence of these enablers supports the validity of theories such as "stakeholder theory," "dynamic capability theory," "resource-based view," "met expectation theory," and "upper echelons theory." Furthermore, it shows that the driving enablers can act as essential enablers, influencing dependent enablers or business performance in the circular economy and waste management via linkage-enabling factors. These findings highlight a research gap in understanding the enablers of green entrepreneurship as well as how digitization could support CE and waste management for achieving the SDGs. This study intends to address these gaps by performing a thorough, in-depth analysis of the enablers of the circular economy and waste management.

7. Conclusions, implications, limitations, and scope for future research

7.1. Conclusion

In the present competitive business environment, GE, digitalization, and the circular economy are emerging and key research areas. The pursuit of eco-efficiency and resource optimization is a common goal for businesses across various industries. In line with this trend, GE and the adoption of digitalization practices in the CE have become increasingly prominent subjects of research. The objective of this study is to provide guidance for MSMEs on effectively implementing GE and digitalization practices within their CE and WM practices. To achieve the research objective, a hybrid four-phase method was used to arrive at a result. In the first phase of the literature review, a theoretical framework (stakeholder theory, dynamic capability theory, resource-based view, met expectation theory, upper echelons theory) and "expert opinions" were used to identify and categorize enablers. Here, seven main category enablers and twenty-nine sub-category enablers were identified. In the second phase of the methodology, the BWM is used to rank enablers and sub-enablers. In the third phase, the TISM method is used to establish relationships among the identified enablers. Further, to cluster the enablers based on "driving power" and "dependence power," fuzzy MICMAC analysis is used. From a conceptual point of view, the research identifies the enablers of GE and digitalization practices. The findings of the BWM analysis show that among the main categories, "technology-related enablers," "organizational-related enablers," and "economic and financial-related enablers" are the top three enablers. Among the sub-categories "top management and organizational coordination," "attitudes towards digitalization and the circular economy," and "having technology infrastructure for cleaner and sustainable production," CE and WM practices play an important role. Further, we perform a Pareto analysis and consider twenty percent of enablers, which contribute eighty percent among the identified enablers. Further, we consider the top twenty percent enablers for further analysis. From the TISM analysis, it is shown that "having technology infrastructure for cleaner and sustainable production" and "knowledge of the green entrepreneurs" have strong driving power, whereas "public demand on green products" and "social impact and long-term consumer behavior" have strong dependent power.

Furthermore, the study's results aid future development in many ways. Identifying and ranking key enablers and their contextual and interdependent relationships helps green entrepreneurship and digitalization practices within the circular economy provide valuable guidance for MSMEs, enabling them to implement sustainable and resource-efficient strategies effectively. By concentrating on technological infrastructure, organizational coordination, attitudes towards digitization, and understanding customer behavior, organizations may drive innovation, satisfy market needs, and create long-term environmental and economic sustainability as well as a competitive advantage.

7.2. Implications

Green entrepreneurship and digitalization have become buzzwords in today's business world. The circular economy and waste management practices have gained immense popularity due to their potential to address pressing environmental issues such as resource depletion, pollution, and climate change. While MSMEs significantly impact any country's economy, they are also responsible for a significant portion of environmental degradation. The adoption of enablers can help Indian manufacturing MSMEs transition towards sustainable business practices. This research can guide MSME managers, entrepreneurs, regulators, policymakers, and practitioners in prioritizing their efforts to implement green and digital practices in the circular economy and waste management. It enables businesses to contribute to sustainable development and environmental well-being.

7.2.1. Theoretical implications

This research makes unique theoretical contributions by focusing on the enablers within the context of the circular economy and waste management. Previous literature has overlooked these aspects, and this study confirms their significance through a literature review. Existing studies have mostly examined individual concepts like green entrepreneurship, digitalization, or the circular economy in isolation or within other industries. Therefore, this study's theoretical contribution lies in its comprehensive exploration of these enablers, which has not been done before. The research employs a combined methodology, including BWM, TISM, and fuzzy MICMAC, to determine the importance of enablers and their interrelationships. The study incorporates qualitative feedback for decision-making, enabling the identification of the most critical enablers and their contextual relationships. The study's novelty lies in its unique methodology, which incorporates industry-academician-employee feedback in the BWM-TISM-Fuzzy MICMAC process. These identified enablers are based on the principles of sustainability, the circular economy, and entrepreneurship. The adoption of these enablers can contribute to the development of new theoretical frameworks and models for sustainable business practices. Further, this study uses five theoretical frameworks that emphasize the uniqueness and novel contribution of this literature. This theory enables stakeholder engagement, leverages organizational dynamics and resources for sustainability, emphasizes meeting expectations, and illustrates the impact of leadership characteristics on decision-making. It offers a unique framework for promoting green entrepreneurship, digitalization, and sustainable waste management in this research field.

7.2.2. Managerial implications

The adoption of enablers in the circular economy and waste management has significant managerial implications for Indian manufacturing MSMEs. The managers of these enterprises need to recognize the importance of these enablers and develop strategies to integrate them into their business models. The implementation of these enablers can help MSMEs reduce their operational costs, enhance their brand image, and access new markets. The adoption of circular business models can enable MSMEs to reduce their environmental impact by promoting the efficient use of resources and reducing waste. The adoption of enablers can also enhance the brand image of Indian manufacturing MSMEs. This also helps reduce waste and enhance resource utilization. This can lead to cost savings for the enterprise, which can be invested in further research and development, enhancing competitiveness. Consumers are increasingly concerned about the environmental impact of the products and services they purchase. By adopting sustainable business practices, MSMEs can differentiate themselves from their competitors and appeal to environmentally conscious consumers. This can also lead to increased customer loyalty, higher revenues, and access to new markets. The international market for sustainable products and services is growing rapidly. By adopting sustainable business practices, MSMEs can enter new markets and compete with established players. This can lead to increased revenues and market share for the enterprise. The practical implications indicate that by adopting digital technologies, enterprises reduce their resource consumption, increase resource efficiency, and enhance their overall sustainability. This can enable them to identify areas where they can reduce their environmental footprint and increase resource efficiency. For instance, they can use data to optimize their production processes, reduce material waste, and improve energy efficiency. Moreover, studies help to find out factors that help in the development of circular business models, access to new markets, and competition with established businesses. Which further helps in increasing revenues and market share for the enterprise.

7.3. Limitation and future research avenue

There are several limitations to consider in this study. Firstly, the generalizability of the findings is restricted as the study only focused on manufacturing MSMEs in India. Secondly, specific case studies and limited experts were considered for the data collection, which may limit the diversity of perspectives. Thirdly, the study investigated only a limited number of enablers, overlooking other potential factors that could impact the circular economy (CE) and waste management. To address these limitations, a potential solution would be to conduct a cross-country study. This broader approach would help to gather data from multiple countries, allowing for more generalized insights on the enablers of GE and digitalization in relation to CE and waste management. Moreover, the study could explore additional enablers that were not considered in the current research, as they could have significant effects on CE and waste management outcomes. Furthermore, future studies could employ different methodologies to investigate the impact of these proposed enablers through other methodologies (i.e., "structural equation modeling"). This would provide a comprehensive understanding of how these enablers contribute to the overall sustainability of MSMEs. Additionally, researchers should explore the different other factors that facilitate the successful implementation of GE and digitalization across different industries. By considering other factors, future research can shed light on how public-private collaborations can drive the transition toward a more sustainable and circular economy.

CRediT authorship contribution statement

Sourav Mondal: Writing – original draft, Conceptualization, Methodology, Data collection, Formal analysis, Writing – review & editing. **Saumya Singh:** Supervision, Conceptualization, Writing – review & editing. **Himanshu Gupta:** Supervision, Conceptualization, Methodology, Writing – review & editing.

Declaration of competing interest

- ✓ We wish to confirm that there are no known conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome.
- ✓ We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed.
- ✓ We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, concerning intellectual property. In so doing, we confirm that we have followed the regulations of our institutions concerning intellectual property.

Data availability

Data will be made available on request.

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Appendix A

Table A1
Discussions of identified enablers

Main Enablers	Sub-category Enablers	Description	Code	References
Technology-related enablers (ETF)	Having technology infrastructure for cleaner and sustainable production	Technological infrastructure lets green enterprises utilize digital technology to more effectively manage WM, recycling, and reuse, resulting in cleaner and more sustainable production. It improves resource usage, operational efficiency, production, CE, and WM.	ETF1	Ersoy et al. (2022); Mondal et al. (2023)
	Technological collaboration between firm and subcontracting firm as well as with academia	This helps GE by facilitating the sharing of knowledge, technology, and expertise on the most efficient and effective uses of digital technology in WM, and this promotes the growth of a CE inside an organization.	ETF2	Rizos et al. (2016); Fatimah et al. (2020)

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Table A1 (*continued*)

Main Enablers	Sub-category Enablers	Description	Code	References
	Having a proper WM and recycling facility	Green entrepreneurs employ digitalization to maximize the utilization of recycling and WM facilities, reduce waste, and create ecologically sustainable systems.	ETF3	Mondal et al. (2023); Yazdani et al. (2021); Fatimah et al. (2020)
	Having R&D facilities	A green entrepreneur may use big data and Industry 4.0 with an emphasis on research and development. For sustainable development, this increases efficiency, resource consumption, and CE growth.	ETF4	Yazdani et al. (2021); Suchek et al. (2022); Mondal et al. (2023)
	Developing green manufacturing capabilities	GE's emphasis on sustainability and digital technologies like the "Internet of Things" and Industry 4.0 improves industrial waste recycling. It helps avoid, manage, and produce eco-friendly goods.	ETF5	Gupta and Barua (2016); Gupta and Dharwal (2022)
Psychological-related factors (EPF)	Attitudes towards digitalization and CE	Green entrepreneurs' favorable attitude toward the use of digitization in MSMEs aids in the appropriate handling and management of waste, which aids in CE and WM.	EPF1	Shah et al. (2019); Agrawal et al. (2022); Mondal et al. (2023)
	Knowledge of the green entrepreneurs	WM knowledge enables green entrepreneurs to efficiently utilize digital technologies to reuse, regenerate, recycle, and decrease waste for CE and WM.	EPF2	Yazdani et al. (2021); Agrawal et al. (2022)
	Entrepreneurs out of the box thinking	Together with technology, these factors help WM green entrepreneurs think and act productively, creatively, and differently to achieve CE and WM.	EPF3	Suchek et al. (2022); Sehnem et al. (2022); Mondal et al. (2023)
	Leadership of a green entrepreneur	Green entrepreneurs must have leadership skills, problem-solving skills, the ability to think outside the box, proper use of digitalization, the ability to work hard and be determined for WM, and the desire and passion for achieving CE and WM for the SDGs.	EPF4	Agrawal et al. (2022); Khan et al. (2022); Soni et al. (2023)
Organizational-related factors (EOF)	Technical know-how and training of entrepreneurs	These factors facilitate the growth and development of green entrepreneurs, who are thus better equipped to apply digital technology for strategic WM and the advancement of the CE.	EOF1	Mondal et al. (2023); Rizos et al. (2016); Moktadir et al. (2020)
	Top management and organizational coordination	Top management is responsible for creating WM policies, guidelines, and strategic objectives and leading quality management. Thus, green firms' higher echelons may efficiently apply digitalization for CE and WM development.	EOF2	Auh & Menguc (2005); Moktadir et al. (2020); Mondal et al. (2023)
	Strategic alliance for innovation	This factor enables green entrepreneurs to utilize digitization to efficiently leverage information, talents, and creative solutions to create new ideas and plans that can be transformed into appropriate WM and value generation, hence developing the CE.	EOF3	Suchek et al. (2022); De Angelis et al. (2018)
	Dynamic capabilities of companies and digitalization advances in the CE	Dynamic capability considers green entrepreneurs' ability to integrate digital technology to create and reconfigure internal and external WM competencies, skills, and attitudes for CE development in response to rapidly changing environments.	EOF4	Suchek et al. (2022); van de Wetering et al. (2020); Khan et al. (2022)
Societal-related factor (ESF)	Public demand for green products	Green and sustainable items are in high demand in a changing world. It encourages green enterprises to digitize WM for efficient waste reuse and recycling, supporting CE and WM.	ESF1	Shah et al. (2019); Suchek et al. (2022)
	Having higher social acceptance and a good public image	Green items are eco-friendly, so buyers think they're good for society and the environment. This pushes green businesses to reuse and recycle solutions for society. Digitalization improves WM, demand forecasting, and market targeting, which helps create a CE.	ESF2	Shah et al. (2019); Hasan et al. (2019)
	Employee cooperation and needed competence	Employee competence and cooperation assist green entrepreneurs in effective WM, which further supports and contributes to CE development.	ESF3	Rizos et al. (2016); Govindan and Hasanagic (2018)
	Social Impact and long-term consumer Behavior	This enabler enables green businesses to use digitization, which improves WM, produces a positive social impact, excellent buying habits, and long-term customer attitudes toward green and sustainable products.	ESF4	Ye et al. (2020); Khan et al. (2022)
Political and regulatory related factors (EPRF)	Environmentally supported policy	This deals with developing policies that are clean and environment-friendly.	EPRF1	Kunanuntakij et al. (2017); Su et al. (2013)
	Government funding for green technology development initiatives	This aspect helps green entrepreneurs finance digitalization and key activities that support and need WM for CE development, environmental management, and pollution reduction.	EPRF2	Rizos et al. (2016); Nandi et al. (2021)
	Policies of Corporate and social responsibility	This enabler assists GE in incorporating digitization for successful WM implementation for CE development, promoting socioeconomic growth and sustainability, and maximizing shareholder value.	EPRF3	Kumar et al. (2022); Korhonen et al. (2018)
	Adequate, flexible, and simple regulatory framework	A simple, flexible, and sufficient legal mechanism encourages green entrepreneurs or manufacturing firms to easily implement a framework of production and consumption that reuses, refurbishes, and recycles waste for CE development and sustainability.	EPRF4	Gupta and Barua (2016); Gupta et al. (2021)
Environmental-related factors (EEF)	Environmental monitoring and control	This factor is concerned with waste monitoring in conjunction with other environmentally friendly factors that encourage GE and digitization in order to control waste for CE and WM.	EEF1	Kumar et al. (2020); Kurniawan et al. (2022a, 2022b)
	Clean development attitudes and Vision for environmental management	This is concerned with fostering attitudes that are clear about the environmental aims of green entrepreneurs and organizations, as well as WM. Furthermore, the organization's vision statement	EEF2	Gupta et al. (2021); Bonilla et al. (2013)

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Table A1 (*continued*)

Main Enablers	Sub-category Enablers	Description	Code	References
		should incorporate environmental objectives that contribute to CE and WM.		
	Green operational practices	This enabler focuses on incorporating environmental management practices into industrial and operational processes to improve WM practices in CE and WM.	EEF3	Gupta and Barua (2016); Sarc et al. (2019)
	Ecological conservation and safe disposal of hazardous waste	This enabler promotes GE and digitalization in order to minimize, reuse, and recycle waste, therefore saving landfill space, conserving natural resources, improving societal health, and advancing CE in business.	EEF4	Kumar et al. (2020); Maiurova et al. (2022)
Economic and Financial related factors (EEEF)	Financing for CE and WM	This factor encourages GE and other businesses to embrace digitalization, develop infrastructure, share information, and engage in WM activities for CE and ecologically responsible development.	EEEF1	Kurniawan et al. (2022a); Suchek et al. (2022)
	Low initial investment	GE in WM is concerned with the utilization of waste as a resource, i.e., recycling, regeneration, and reproduction. As a result, modest investment is required to build a CE and ensure sustainability.	EEEF2	Kowalski and Makara (2021); Mondal et al. (2023)
	Certainty about return on investment	Investments in WM related to technical improvements provide a significant return on investment for green entrepreneurs and organizations as the demand for green and sustainable products increases, boosting the CE's development.	EEEF3	Jiang et al. (2018)
	Having subsidized funds	This enabler encourages green businesses to use digitalization to establish technological foundations, innovate, support CE and WM, and help achieve sustainable development goals.	EEEF4	Awan et al. (2021); Mondal et al. (2023)

Table A2
Structural self-interaction matrix

	EN19	EN18	EN17	EN16	EN15	EN14	EN13	EN12	EN11	EN10	EN9	EN8	EN7	EN6	EN5	EN4	EN3	EN2	EN1
EN1	O	V	O	O	O	O	O	A	O	O	V	O	O	O	O	X	O	O	
EN2	O	O	O	O	V	O	O	O	O	O	O	X	O	O	V	O	O		
EN3	O	O	O	O	O	O	O	O	V	O	O	O	O	O	X	O			
EN4	O	V	A	V	O	O	O	A	O	A	V	O	X	O	O				
EN5	V	O	O	O	O	O	O	O	V	O	O	A	O	O					
EN6	O	A	O	A	O	X	O	O	O	O	A	O	O						
EN7	O	V	O	V	O	O	O	A	O	A	V	O							
EN8	O	O	O	O	V	O	O	O	O	O	O								
EN9	O	O	O	X	O	V	A	O	O	O									
EN10	A	O	O	O	O	O	V	X	O										
EN11	O	O	O	O	O	O	O	V											
EN12	A	O	X	O	O	O	V												
EN13	O	V	A	V	O	O													
EN14	O	A	O	A	O														
EN15	V	O	O	O															
EN16	O	X	O																
EN17	A	O																	
EN18	O																		
EN19																			

Table A3
Final reachability matrix

	EN1	EN2	EN3	EN4	EN5	EN 6	EN 7	EN 8	EN 9	EN 10	EN 11	EN 12	EN 13	EN 14	EN 15	EN 16	EN 17	EN 18	EN 19
EN1	1	0	0	1	0	1*	1*	0	1	0	0	0	0	1*	0	1*	0	1	0
EN2	0	1	1*	0	1	0	0	1	0	0	1*	0	0	0	1	0	0	0	1*
EN3	0	0	1	0	1	0	0	0	0	0	1	1*	0	0	0	0	0	0	1*
EN4	1	0	0	1	0	1*	1	0	1	0	0	0	0	1*	0	1	0	1	0
EN5	0	0	1	0	1	0	0	0	0	1*	1	1*	0	0	0	0	1*	0	1
EN6	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
EN7	1*	0	0	1	0	1*	1	0	1	0	0	0	0	1*	0	1	0	1	0
EN8	0	1	1*	0	1	0	0	1	0	0	1*	0	0	0	1	0	0	0	1*
EN9	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	1	0	1*	0
EN10	1*	0	0	1	0	0	1	0	1*	1	0	1	1	0	0	1*	1*	1*	0
EN11	1*	0	0	1*	0	0	1*	0	0	1*	1	1	1*	0	0	0	1*	0	0
EN12	1	0	0	1	0	0	1	0	1*	1	0	1	1	0	0	1*	1	1*	0
EN13	0	0	0	0	0	1*	0	0	1	0	0	0	1	1*	0	1	0	1	0
EN14	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
EN15	0	0	0	0	0	0	0	0	0	1*	0	1*	0	0	1	0	1*	0	1

(*continued on next page*)

Table A3 (*continued*)

	EN1	EN2	EN3	EN4	EN5	EN 6	EN 7	EN 8	EN 9	EN 10	EN 11	EN 12	EN 13	EN 14	EN 15	EN 16	EN 17	EN 18	EN 19
EN16	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	1	0	1	0
EN17	1*	0	0	1	0	0	1*	0	1*	1*	0	1	1	0	0	1*	1	1*	0
EN18	0	0	0	0	0	1	0	0	1*	0	0	0	0	1	0	1	0	1	0
EN19	1*	0	0	1*	0	0	1*	0	0	1	0	1	1*	0	0	0	1	0	1

Table A4
Level partitioning

Factors	RS	AS	Intersection set	Level
EN1	1,4,6,7,9,14,16,18	1,4,7,10,11,12,17,19	1,4,7	III
EN2	2,3,5,8,11,15,19	2,8	2,8	VII
EN3	3,5,11,12,19	2,3,5,8	3,5	VI
EN4	1,4,6,7,9,14,16,18	1,4,7,10,11,12,17,19	1,4,7	III
EN5	3,5,10,11,12,17,19	2,3,5,8	3,5	VI
EN6	6,14	1,4,6,7,9,13,14,16,18	6,14	I
EN7	1,4,6,7,9,14,16,18	1,4,7,10,11,12,17,19	1,4,7	III
EN8	2,3,5,8,11,15,19	2,8	2,8	VII
EN9	6,9,14,16,18	1,4,7,9,10,12,13,16,17,18	9,16,18	II
EN10	1,4,7,9,10,12,13,16,17,18	5,10,11,12,15,17,19	10,12,17	IV
EN11	1,4,7,10,11,12,13,17	2,3,5,8,11	11	V
EN12	1,4,7,9,10,12,13,16,17,18	3,5,10,11,12,15,17,19	1012,17	IV
EN13	6,9,13,14,16,18	10,11,12,13,17,19	13	III
EN14	6,14	1,4,6,7,9,13,14,16,18	6,14	I
EN15	10,12,15,17,19	2,8,15	15	VI
EN16	6,9,14,16,18	1,4,7,9,10,12,13,16,17,18	9,16,18	II
EN17	1,4,7,9,10,12,13,16,17,18	5,10,11,12,15,17,19	10,12,17	IV
EN18	6,9,14,16,18	1,4,7,9,10,12,13,16,17,18	9,16,18	II
EN19	1,4,7,10,12,13,17,19	2,3,5,8,15,19	19	V

Table A5
Fuzzy MICMAC stabilized matrix (FMSM)

	EN1	EN2	EN3	EN4	EN5	EN 6	EN 7	EN 8	EN 9	EN 10	EN 11	EN 12	EN 13	EN 14	EN 15	EN 16	EN 17	EN 18	EN 19	DRP
EN1	0.9	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.9	0.0	0.0	0.0	0.0	0.7	0.0	0.9	0.0	0.9	0.0	6.1
EN2	0.0	0.5	0.5	0.5	0.9	0.0	0.9	0.0	0.0	0.0	0.7	0.5	0.9	0.0	0.5	0.0	0.0	0.0	0.9	6.8
EN3	0.0	0.0	0.5	0.9	0.9	0.7	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.9	5.7
EN4	0.0	0.0	0.0	0.9	0.0	0.9	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.9	0.0	0.9	0.0	0.7	0.0	5.2
EN5	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.9	0.7	0.9	0.0	0.0	0.5	0.9	0.9	0.0	0.0	5.7
EN6	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
EN7	0.7	0.0	0.0	0.0	0.0	0.9	0.7	0.0	0.9	0.0	0.0	0.0	0.0	0.9	0.0	0.9	0.0	0.9	0.0	5.9
EN8	0.0	0.0	0.5	0.9	0.7	0.0	0.0	0.7	0.0	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.9	5.5
EN9	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.9	0.0	3.6
EN10	0.5	0.5	0.5	0.7	0.9	0.0	0.5	0.0	0.9	0.5	0.0	0.0	0.5	0.0	0.5	0.9	0.5	0.9	0.0	8.3
EN11	0.9	0.0	0.9	0.9	0.0	0.0	0.9	0.0	0.0	0.9	0.0	0.0	0.5	0.0	0.5	0.0	0.9	0.0	0.0	6.4
EN12	0.9	0.5	0.0	0.9	0.0	0.0	0.9	0.0	0.9	0.0	0.0	0.9	0.9	0.0	0.0	0.9	0.0	0.9	0.0	7.7
EN13	0.5	0.0	0.0	0.0	0.0	0.9	0.5	0.0	0.9	0.0	0.0	0.9	0.0	0.9	0.0	0.9	0.0	0.9	0.0	6.4
EN14	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.9
EN15	0.0	0.5	0.0	0.5	0.9	0.0	0.7	0.0	0.0	0.9	0.7	0.9	0.7	0.0	0.0	0.9	0.9	0.0	0.0	7.6
EN16	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.9	0.0	0.0	0.9	3.6
EN17	0.9	0.5	0.9	0.9	0.0	0.0	0.9	0.0	0.9	0.9	0.0	0.0	0.5	0.0	0.5	0.7	0.9	0.9	0.0	9.4
EN18	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.7	0.0	2.8
EN19	0.9	0.5	0.9	0.9	0.0	0.0	0.9	0.0	0.0	0.9	0.0	0.9	0.9	0.0	0.5	0.0	0.9	0.0	0.0	8.2
DEP	6.2	3.0	4.7	8.0	6.1	7.3	7.8	0.7	7.9	5.0	3.9	6.8	4.9	6.4	3.5	8.8	5.0	7.7	3.6	

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